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"El saber de mis hijos hará mi grandeza"

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RESEARCH

Hierarchical ranking of the Dow Jones index using the ELECTRE-III method

Ranking jerárquico del índice Dow Jones usando el método ELECTRE-III

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Eva Luz Miranda Espinoza[1],
Manuel Muñoz Palma[2] and Pavel Anselmo Álvarez Carrillo[3]

[1] Business Consultant, Master in Financial Management from Universidad TecMilenio, certified Public Accountant from Universidad de Sonora. Member of the UADEO research group. Her research interests include fuzzy logic in the field of finance and fuzzy systems. https://orcid.org/0000-0002-0992-6956,
Email: mirandaeeva@hotmail.com, tel: (662) 127 8478

[2] Corresponding author. PhD in Administrative Sciences from Universidad de Occidente, enrolled in Portal del Consejo Nacional de Ciencia y Tecnologia (PNPC) by SEP-CONACyT. Full-time research professor in the Department of Management at Universidad de Sonora. Research areas: Finance, fuzzy logic, and intelligent models in Finance. Currently a member of the National System of Researchers (Level C). Institutional email: manuel.munoz@unison.mx , Blvd. Luis Encinas y Rosales S/N, Col. Centro Hermosillo, Sonora, Mexico . https://orcid.org/orcid-search/sear=0000-0003-2980-4814 . Tel (662)181 0280

[3] Full-time professor at Universidad Autonoma de Occidente. Currently, is a Level I of the National System of Researchers (SNI). Pavel Anselmo earned his PhD in Administrative Sciences from Universidad de Occidente, a program recognized in the National Register of Quality Graduate Programs (PNPC) by SEP-CONACyT. His research interests include web data collection, multicriteria analysis, and decision support system.
Email: pavel.alvarez@uadeo.mx. Blvd. Lola Beltran, C.P. 80020 Culiacan Rosales, Sinaloa, Mexico, http://orcid.org/0000-0003-4445-076X . Tel: (667) 759 1300

Abstract

The objective of the article is to present a multicriteria hierarchical process (MCHP) approach to decision making in the selection of stocks of the main companies of the Dow Jones index. One of the problems that investors often face is deciding which stocks should be included in an investment portfolio. The article allows investors to answer this question, through an MCHP approach and the ELECTRE III method using different criteria based on the financial relationships of profitability, liquidity, market, and efficiency. In this process, the investor generates a global ranking and a ranking of each subgroup of criteria regarding the investor's preferences.

Keywords: Hierarchical multicriteria process, ELECTRE III, Financial ratios, Dow Jones.

JEL code: C61, M40, G15

Resumen

El objetivo del artículo es presentar un enfoque de proceso jerárquico multicriterio para la toma de decisiones en la selección de acciones de las principales empresas que cotizan en el índice Dow Jones. Uno de los problemas que suelen enfrentar los inversores es decidir qué acciones deben incluirse en un portafolio de inversión. El artículo permite a los inversores dar respuesta a esa pregunta, mediante un enfoque jerárquico y el método ELECTRE III utilizando diferentes criterios basados en las ratios financieras de rentabilidad, liquidez, mercado y eficiencia. En este proceso el inversor genera un ordenamiento a un nivel global y un ordenamiento en subgrupo de criterios considerando las preferencias del inversor.

Palabras clave: Proceso jerárquico multicriterio, ELECTRE III, Ratios financieras, Dow Jones.

Código JEL: C61, M40, G15

1. Introduction

The evolution of financial theory has enabled the conceptualization of financial management from various perspectives. Its importance becomes evident when facing dilemmas such as leverage versus profitability, always seeking the timely provision of resources to support effective decision-making and ensure financial returns that drive business growth.

One of the main challenges in operating within the stock market lies in risk management. In this context, concepts such as hedging, insurance, and diversification become highly relevant. Bodie and Merton (2003) argue that diversification, by distributing capital among multiple risky assets, reduces exposure to individual asset risk. Likewise, Merton's dynamic continuous-time hedging technique serves as a bridge between Kenneth Arrow's theoretical model of complete markets and the practical needs of personal financial planning in real-world contexts (Bodie, 2019). In this sense, the investment portfolio, grounded in classical financial theory, seeks to optimize the risk-return trade-off through diversification.

Traditional models that consider only return and risk criteria—without accounting for investor preferences—may propose portfolios that do not reflect the investor's interests. In contrast, models that do incorporate such preferences, along with additional decision-making criteria, achieve a more appropriate alignment with the investor profile (Ehrgott et al., 2004). Diversification is also closely related to risk behavior according to each investor's profile (Basilio et al., 2018). However, conventional tools often fail to consider increasingly complex and multifactorial scenarios—economic, social, environmental—that involve multiple and conflicting criteria (Guerrero-Baena, Gómez-Limón, & Fruet-Cardozo, 2014).

This research adopts both quantitative and qualitative approaches and focuses on the factors influencing decision-making in the development of investment portfolio selection strategies in the context of the COVID-19 pandemic and its effects on financial ratios of companies listed on the New York Stock Exchange. Although the importance of investment portfolio selection has been addressed in various studies, current approaches often overlook investor profiles and the existence of conflicting criteria. In this regard, analytical tools are needed to meet new demands in decision-making processes

This study addresses portfolio selection as a multi-criteria ranking problem through the adaptation of the hierarchical multicriteria process proposed by Corrente et al. (2012), based on the natural hierarchy that characterizes the criteria involved in stock selection. The portfolio selection problem inherently presents a hierarchical structure of criteria. For this analysis, the ranking of stocks considers seven macro-criteria (groups of criteria): market ratios, operating results, market value ratios, financial and economic profitability, liquidity, efficiency, and dividends. The objective of the study is to generate a hierarchical ranking of companies listed on the Dow Jones Index. This entails organizing stocks by groups of criteria to analyze their performance within each group, enabling the explanation of stock behavior and investment potential.

The structure of this paper is as follows: Section 2 provides a literature review. Section 3 outlines the methodology of the hierarchical multicriteria process, incorporating the hierarchical version of the ELECTRE III method. Section 4 presents the performance analysis of the companies' stocks and the corresponding results. Section 5 contains the conclusions.

2. Literature Review

The New York Stock Exchange (NYSE) was established in 1790. The Dow Jones Industrial Average represents the top 30 industrial stocks traded on the NYSE. These companies can significantly influence overall market movements, as the index serves as a robust indicator of the U.S. economy and investor confidence in specific securities. As a global leader, the NYSE serves as a venue for investors seeking access to capital and participation in global markets. Its unique model helps minimize execution risk and stock price volatility. Chahuán (2018) noted a positive correlation between the Dow Jones Index and other markets, such as Chile's, where the index correlates more strongly with revenue than

with business outcomes. Decision-makers play a critical role in optimizing returns and minimizing investor risk when constructing a portfolio. Useche (2015) emphasized the contribution of financial institutions in providing more accurate advisory processes that cater to the personal expectations and specific interests of investor clients.

Risk, as analyzed by various authors, has a direct effect on corporate financing decisions, since the composition of a firm's capital structure and its level of financial leverage or debt ratio directly influence firm value. Milanesi (2016), in studies conducted on the Argentine stock market to evaluate the effect of volatility at varying debt levels, confirmed the consistency of the proposed model linking volatility, value, and probability of financial failure. An increase in external capital raises insolvency risk, which is reflected in a decline in stock value. López-Dumrauf (2003) argued that firms must strike the right financing mix to minimize capital costs and maximize firm value. Elselmy, Ghoneim, and Elkhodary (2019) highlighted the importance of accounting information in financial statements to identify the indicators needed for constructing business models for portfolio integration in the Egyptian stock market. Mansour et al. (2019) proposed a possibility theory and a model that allows for trade-offs between investor preferences regarding multiple incommensurable objectives in uncertain environments.

In portfolio selection under the principles of corporate social responsibility and the use of multi-objective and multi-criteria techniques, Suárez, Pimiento, and Duarte (2018) noted that such tools support socially responsible investors in identifying portfolios that meet their goals of maximizing returns while minimizing risks. Cervelló, Guijarro, and Michniuk (2014) reported a positive risk-adjusted return for the flag pattern based on Dow Jones intraday data over a time horizon of over 13 years. Ariza and Cadena (2017) applied mixed beta to assess asset risk or predict returns, which aided in capital budgeting, asset valuation, equity cost estimation, and explaining risk in the context of interest rates.

A wide range of intelligent systems has been proposed to solve the portfolio selection problem, such as reinforcement learning (Moody et al., 1998; Moody & Saffell, 2001; OJ. et al., 2002), neural networks (Kimoto et al., 1993; Dempster et al., 2001), genetic algorithms (Mahfoud & Mani, 1996; Allen & Karjalainen, 1999; Mandziuk & Jaruszewicz, 2011), decision trees (Tsang et al., 2004), support vector machines (Tay & Cao, 2002; Cao & Tay, 2003; Lu et al., 2009), and expert boosting and weighting (Creamer & Freund, 2007; Creamer, 2012). Although these studies attempt to interpret market conditions and predict future trends, such techniques are often unsuitable for small investors due to the required level of expertise. Moreover, they do not facilitate comparisons across multiple ambiguous criteria (Boonjing & Boongasame, 2016).

This study presents a multi-objective approach involving fuzzy parameters, where possibility distributions are represented by fuzzy numbers, and investor preferences are explicitly incorporated using satisfaction functions. Aldalou and Perçin (2018) proposed a financial performance evaluation model. Fuzzy AHP was used to assign weights to evaluation criteria, while Fuzzy TOPSIS ranked the alternatives. The model was applied to listed airline companies on the Istanbul Stock Exchange for the period 2012–2016. A portfolio optimization model based on Markowitz's classical mean-variance model was proposed by Ehrgott et al. (2004) and applied to the Standard & Poor's database of 1,108 mutual funds. Sánchez, Milanesi, and Rivitti (2010) studied portfolio problems using AHP on four Argentine firms and evaluated their performance through five types of financial ratios (profitability, activity, liquidity, solvency, and market value) calculated from accounting data since 2006. Mohammad et al. (2012) applied the TOPSIS method to a sample of 18 top companies from different industries listed on the Tehran Stock Exchange (TSE) over five years.

Bahloul and Abid (2013) developed combined AHP and Goal Programming (GP) methods to study the impact of investment barriers on international portfolio selection. AHP was used to identify suitable international equity portfolios based on investment barriers, while GP incorporated market weights for maximum return, minimum variance, and AHP portfolios to determine optimal international equity portfolios. Pätäri et al. (2017)

compared the effectiveness of scale median (SM), TOPSIS, AHP, and DEA in identifying future top-performing stocks in U.S. equity samples.

Altınırmak et al. (2016) applied AHP-PROMETHEE to assess the performance of nine investment trusts listed on BIST (Turkey's stock exchange). Albadvi, Chaharsooghi, and Esfahanipour (2006) noted the application of PROMETHEE to the Tehran Stock Exchange using surveys, financial reports, and expert opinions to evaluate criteria and organizations. Basilio et al. (2018) used principal component analysis and the PROMETHEE II method to compare financial performance indicators across stocks traded on the São Paulo Stock Exchange.

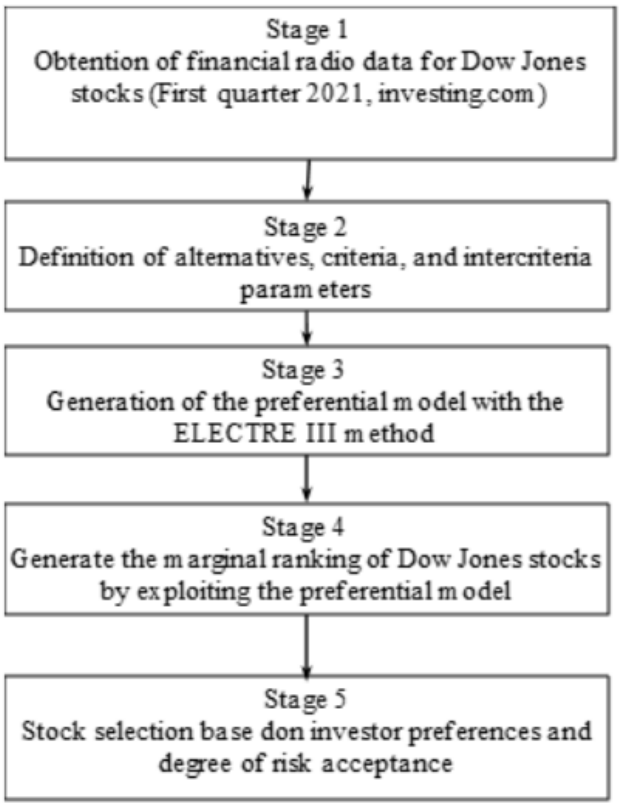
Lima and Soares (2013) applied the ELECTRE III method to select assets for a buy-and-hold strategy and to test whether the chosen assets outperformed the market as measured by the Portuguese Market Index (PSI-20TR). Vezmelai, Lashgari, and Keyghobadi (2015) used ELECTRE III to rank 20 companies listed on the Tehran Stock Exchange in 2011 and compared the results with the TSE's own rankings. Boonjing and Boongasame (2016) proposed a combinatorial portfolio selection using ELECTRE III to support small investors in making investment decisions. Xidonas et al. (2009) applied ELECTRE III to classify companies into eight sectors or industries as part of a Pareto investment portfolio. Multicriteria decision-aid (MCDA) methods have been widely used to address portfolio selection problems. The ELECTRE III method, in particular, has been employed within the MCDA framework for finance and portfolio selection problems (Spronk et al., 2016; Govindan & Jepsen, 2016).

3. Methodology

One of the basic features of multicriteria analysis is the comparison of alternatives based on a series of criteria. Therefore, multicriteria ranking methods are designed to construct a recommendation on a set of alternatives according to the preferences of the expert or decision-maker.

To generate the ranking of the main stocks, the hierarchical multicriteria process is applied to the stocks listed on the New York Stock Exchange that are part of the Dow Jones Index, considering financial ratios. The data for these stocks corresponds to the first quarter of 2021 and can be found on the financial portal www.investing.com.

Figure 1. Research model for the marginal ranking of the 30 Dow Jones stocks.



Source: Own elaboration.

Figure 1 presents the working framework of this research, which is defined in five stages. Stage 1 identifies the main data from the financial ratios of the 30 Dow Jones companies. Stage 2 corresponds to an intelligence phase in decision-making; here, the decision criteria representing the stocks must be defined, as well as the decision alternatives (the companies listed on the stock exchange), and the parameters of the multicriteria method (ELECTRE III). In Stage 3, a multicriteria analysis method is applied—in this case, the ELECTRE III method is used to generate a preference model (a valued matrix of the stocks). Stage 4 corresponds to the exploitation of the preference model; in this step, a distillation process is used to rank the stocks. In Stage 5, the ranking results and information analysis are presented to the investor for the final selection

of stocks. In this regard, the process and method consider the investor's profile and the level of risk they are willing to accept.

The following section describes the hierarchical multicriteria process and the ELECTRE III multicriteria method used to rank the stocks.

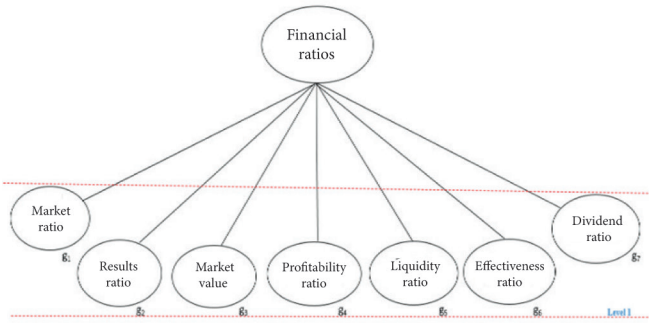
3.1 Hierarchical Multicriteria Process

In the MCDA process, a set of alternatives is defined as $A = \{a_1, a_2, .., a_m\}$, along with a coherent family of criteria $G = \{g_1, g_2, .., g_m\}$. Any MCDA method develops an overall preference method as an aggregation procedure. The method generates a recommendation in the form of a ranking of alternatives in descending order from best to worst. The first stage of the portfolio selection problem involves generating a stock evaluation ranking. For this problem, it is easy to observe the hierarchical structure of the decision criteria. Therefore, it is common for a practical application to impose a hierarchical structure (Corrente et al., 2012). For this reason, the multicriteria ranking of stocks is generated using a new method: the Multiple Criteria Hierarchy Process (MCHP).

A traditional multicriteria analysis method evaluates the stocks at the same level, assessing all the criteria at once (see Figure 2). In this way, one can identify which stocks are the best and which are the worst, but it is not possible to understand how some subcriteria (subgroups of ratios)—such as market, performance, or liquidity ratios—interact in the evaluation of a stock and influence stock selection. In this sense, a different method would be valuable to assess the stocks by subsets of criteria at different levels, following the MCHP methodology to solve the stock selection problem.

It often happens that a practical application imposes a hierarchical structure of criteria (Salvatore Corrente et al., 2012). In the stock selection problem, a large number of decision criteria are involved. In fact, evaluating stock selection requires various types of information, commonly addressed using the Dow Jones indices. Considering these characteristics, the MCHP approach allows the stock selection problem to be broken down into subproblems by using a criteria hierarchy to facilitate a deeper analysis.

Figure 2. Evaluation criteria at the same level for the stock selection problem.



Source: Own elaboration.

To address decision-making problems in which evaluation criteria are considered at the same level, a hierarchical structure is instead used to organize them within a specific segment of the problem. The basic idea of the Multiple Criteria Hierarchy Process (MCHP) is based on considering preference relations at each node of the hierarchical tree of criteria. These preference relations refer both to the phase of eliciting preference information and to the phase of analyzing a final recommendation by the decision-maker (Corrente et al., 2012).

A hierarchical structure of criteria can be seen as a criteria tree. The tree structure is of particular interest to the expert or decision-maker and clusters a subset of criteria into leaves. These leaves decompose the overall problem into smaller problems, allowing for a better understanding of the interaction among elementary criteria. Figure 2 addresses a multicriteria decision-aid problem in which all criteria are evaluated at the same level. However, the same problem can be analyzed as smaller subproblems through a hierarchical structure. In the tree structure of criteria, some leaves contain branches with additional leaves, forming a tree of subproblems. Corrente, Figueira, Greco, and Słowiński (2017) integrate the MCHP with the ELECTRE III method. To explain the ELECTRE III hierarchy, we follow the notation of Angilella et al. (2018):

G is the comprehensive set of all criteria at all levels considered in the hierarchy.

G_0 is the root of the criteria.

l_G is the set of indices of the criteria in G.

$E_G \subseteq l_G$ is the set of indices of the elementary criteria.

g is the generic criterion (where r is a vector whose length corresponds to the criterion's level).

$g_{(r,1)}, \ldots, g_{(r,n(r))}$ are the immediate subcriteria of criterion g_r (located one level below g_r).

$E(g_r)$ is the subset of indices of all elementary criteria descending from g_r.

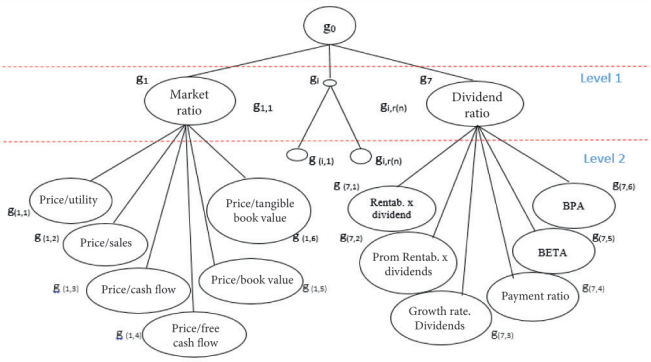
$E(F)$ is the set of indices of the elementary criteria desceding from at least one criterion in the subfamily $F \subseteq G$ (que es, $E(F) = U_{g_r \in} E(g_r)$.

G_r is the set of subcriteria of g_r located at level l in the hierarchy (below g_r).

To better understand the notation above, in a hierarchical structure, Level 1 contains the macro-criteria, and the elementary criteria descending from these macro-criteria decompose the subproblem. The complete set of elementary criteria is contained within E_G. A different approach can be implemented for the multicriteria decision-aid problem by generating a hierarchical structure with respect to the criteria of interest at a particular level of the hierarchy.

The problem of stock selection for portfolio integration can be addressed as a hierarchical problem, where some macro-criteria may encompass elementary criteria from a deeper level in the hierarchy. Figure 3 illustrates a summarized structure (two macro-criteria) of the complete hierarchical problem of stock selection within the Dow Jones index. The macro-criterion Market Ratio (g_1) integrates six Elementary criteria, Results ratio (g_2) integrates 8 elementary criteria, and so on, up to the Dividend ratio macro-criterion (g_7) which integrates six Elementary criteria. The evaluation of Dow Jones index stocks includes 47 elementary criteria structured in a two-level hierarchy: Level 1 defines seven macro-criteria (non-elementary), and Level 2 contains 47 elementary criteria that constitute the macro-criteria of Level 1.

Figure 3. Simplified MCHP structure for NYSE stock selection.



Source: Own elaboration.

3.2 Hierarchical ELECTRE III Method

The adapted version of the ELECTRE III hierarchy was first introduced by Corrente et al. (2017). The ELECTRE method is developed in two steps. The first step involves the aggregation of preferences, where informati on is processed by constructing a model based on the valued outranking relation. This process is explained with an illustrative example in the Appendix. In the second step, the valued outranking relation is exploited through the distillation process, generating either a partial or complete ranking of alternatives. For each elementary criterion $g_t, \in E_g$.

The elementary concordance index for each elementary criterion g_t is given by

$$\varphi_t(a,b) = \begin{cases} 1 & if \quad g_t(b) - g_t(a) \le q_t, (a S_t b) \\ \dfrac{p_t - [g_t(b) - g_t(a)]}{p_t - q_t} & if \quad q_t < g_t(b) - g_t(a) < p_t, (b Q_t a) \\ 0 & if \quad g_t(b) - g_t(a) \ge p_t, (b P_t a) \end{cases}$$

The elementary discordance index for each elementary criterion g_t is given by

$$d_t(a,b) = \begin{cases} 1, & if \quad g_t(b) - g_t(a) \ge v_t, \\ \dfrac{[g_t(b) - g_t(a)] - p_t}{v_t - p_t} & if \quad p_t < g_t(b) - g_t(a) < v_t, \\ 0, & if \quad g_t(b) - g_t(a) \le p_t. \end{cases}$$

The partial concordance index for each non-elementary criterion g_t

$$C_r(a,b) = \frac{\sum_{t \in E(g_r)} w_t \varphi_t(a,b)}{\sum_{t \in E(g_r)} w_t}$$

Partial credibility index

$$\sigma_r(a,b)=\begin{cases} C(a,b)x\prod_{g_t\in E(g_r)}\frac{1-d_t(a,b)}{1-C_t(a,b)} & \text{if } d_t(a,b)>C_t(a,b) \\ C(a,b) \end{cases}$$

The valued outranking relation generated in the previous step corresponds to the decision maker's preference model. The distillation method is used to exploit the preference model. Distillation is performed both in descending and ascending manners; consequently, the final preorder is obtained as the intersection of the two distillations. An overview of the distillation method is described in Giannoulis & Ishizaka (2010).

For the pair $a, b \epsilon A$ in the hierarchical process, the alternatives are ordered in a partial or complete preorder for each non-elementary criterion g_r as follows:

aP_rb:a is strictly preferred to b on the macro-criterion g_r in at least one of the orderings, a is ranked before b, and in other ordering, a is at least as good as b.

aI_rb:a is indifferent to b on the macro-criterion g_r if both actions occupy the same position in the two preorders.

aR_rb:a is incomparable to b on the macro-criterion g_r if a is ranked better than b in the ascending distillation and b is ranked better than a in the descending distillation, or viceversa.

4. Analysis of Dow Jones stocks using the hierarchical multicriteria process

The analysis is based on the financial statements from the first quarter of 2021, obtained from the financial portal Investing and collected from the NYSE, which generates a performance index reporting on Dow Jones Index companies and indicating existing capabilities for investors (see Appendix, Table A.2.1). Financial ratios are used to select the macro-criteria to evaluate each company's performance (see Table 2). These provide insights into the company's financial situation and performance prospects, as well as an evaluation of a company's position relative to others.

The data obtained from the NYSE is grouped into seven dimensions used to evaluate the stocks listed on the Dow Jones Index. Each dimension consists of a subgroup of different indicators (elementary criteria). In total, there are 47 indicators to evaluate the stocks of the 30 companies in the Dow Jones Index. The NYSE data is used in this study with a new approach—the Hierarchical Multicriteria Process (MCHP)—to analyze stock performance, considering the interaction of subgroups of criteria at different levels within a hierarchy through the ranking of Dow Jones companies, as shown in Table 1. The macro-criteria for the stock selection problem, elementary criteria, and their corresponding weights are shown in Table 2.

Table 1. Dow Jones Index Companies.

Label	Company	Label	Company
A1	3M	A16	Merck
A2	American Express	A17	Microsoft
A3	AT&T	A18	Nike
A4	Caterpillar, Inc.	A19	Pfizer
A5	Chevron Corporation	A20	Boeing
A6	Cisco	A21	Home Depot
A7	The Coca-Cola Company	A22	Procter & Gamble
A8	Dupont	A23	The Travelers Companies
A9	Exxon Mobil	A24	Walt Disney
A10	Goldman Sachs	A25	United Health Group
A11	Intel	A26	Raytheon Technologies
A12	IBM	A27	Verizon Communications
A13	Johnson & Johnson	A28	Visa
A14	JP Morgan Chase	A29	Wal-Mart
A15	McDonald's	A30	Walgreens Boots Alliance Inc.

Source: Own elaboration with data from NYSE.

Regarding the methodology proposed in Section 3.1, the HMCA (Hierarchical Multi-Criteria Analysis) is applied to solve the problem of stock selection for the construction of an investment portfolio. In the first step, the problem is structured into a multicriteria hierarchy, breaking it down into seven macro-criteria as subproblems of the stocks. As shown in the hierarchical structure in Figure 3, the stocks listed on the NYSE are organized in a hierarchy based on the seven macro-criteria and the 47 elementary criteria. The new hierarchical structure for the stock performance problem enables the analysis to align with HMCA. The approach implemented in this article evaluates each macro-criterion, allowing for analysis of the interaction between directly related, immediate sub-criteria. This is carried out by generating preferential models and rankings for each macro-criterion to understand how one stock performs relative to another, and how it influences the overall stock selection problem.

Table 2. Macro-criteria and elementary criteria for stock selection.

Index	Macro-criterion	Index	Elementary criteria	Weights
g1	Market ratios	g1,1	Price/earnings TTM ratio	0.0300
		g1,2	Price/sales TTM	0.0200
		g1,3	Price/cash flow MRQ	0.0100
		g1,4	Price/free cash flow TTM	0.0200
		g1,5	Price/book value MRQ	0.0400
		g1,6	Price/tangible book value MRQ	0.0300
g2	Results ratio	g2,1	Gross margin TTM	0.0200
		g2,2	Gross margin 5YA	0.0200
		g2,3	Operating margin TTM	0.0150
		g2,4	Operating margin 5YA	0.0150
		g2,5	Pre-tax margin TTM	0.0150
		g2,6	Pre-tax margin 5YA	0.0200
		g2,7	Net margin TTM	0.0200
		g2,8	Net margin 5YA	0.0250
g3	Market value ratios	g3,1	Earnings per share TTM	0.0250
		g3,2	Basics EPS ANN	0.0250
		g3,3	Diluted EPS ANN	0.0200
		g3,4	Book value per share MRQ	0.0200
		g3,5	Tangible book value per share MRQ	0.0200
		g3,6	Cash per share MRQ	0.0200
		g3,7	Cash flow per share TTM	0.0250
	Profitability ratios	g4,1	Return on equity TTM	0.0250
		g4,2	Return on equity 5YA	0.0300
		g4,3	Return on assets TTM	0.0300
		g4,4	Return on assets 5YA	0.0250
		g4,5	Return on equity TTM	0.0250
		g4,6	Return on investment 5YA	0.0300
		g4,7	ESP (MRQ) vs previous year quarter MRQ	0.0200
		g4,8	EPS (TTM) vs previous year TTM	0.0250
		g4,9	Sales (TTM) vs previous year TTM	0.0250
		g4,10	Sales (MRQ) vs previous year quarter MRQ	0.0300
g5	Liquidity ratios	g5,1	EPS growth in 5 years 5YA	0.0350
		g5,2	Sales growth in 5 years 5YA	0.0100
		g5,3	Capital expenditure growth in 5 years 5YA	0.0100
		g5,4	Acid-test ratio MRQ	0.0100
		g5,5	Solvency ratio MRQ	0.0100
		g5,6	Long-term debt to equity MRQ	0.0100
		g5,7	Total debt to equity MRQ	0.0100
g6	Effectiveness ratio	g6,1	Assest turnover TTM	0.0100
		g6,2	Inventory turnover TTM	0.0100
		g6,3	Profit per employee TTM	0.0100
		g6,4	Net income per employee TTM	0.0100
		g6,5	Accounts receivable turnover TTM	0.0100
g7	Dividend ratio	g7,1	Dividend yield ANN	0.0300
		g7,2	Average dividend yield over 5 years 5YA	0.0400
		g7,3	Dividend growth rate ANN	0.0400
		g7,4	Payout ratio TTM	0.0250

Source: Own elaboration.

The hierarchical ELECTRE III and distillation methods described in Section 3.2 were applied to solve each subproblem g_i (macro-criterion), and the integrated level. Table 3 presents the overall ranking, which assigns 29 positions to the analyzed companies' stocks. Microsoft (A17) ranks first and retains this position in the final ranking. Dupont (A8) and Raytheon Technologies (A26) share the 28th position, while Visa (A28) ranks second, and American Express (A2) is in 17th place—both companies belonging to the same economic sector. In the last position are Boeing (A20) and Exxon Mobil (A9), which can be explained by the fact that during the COVID-19 pandemic, the air transportation sector was among the most affected due to the economic shutdown, business closures, and reduced population mobility. Although some companies share positions, the overall ranking (g_0), assigns Microsoft (A17), Visa (A28), Home Depot (A21), Intel (A11), and Goldman Sachs (A10) the top five spots as the best-performing stocks—highlighting their status as technology and service companies. Table 4 presents the individual ranking, where macro-criteria are analyzed based on their relative importance to the decision-maker.

Table 3. Overall ranking (g_0) of the Dow Jones Index

Position	g_o	Position	g_o
1	A17	16	A4
2	A28	17	A2
3	A21	18	A16
4	A11	19	A27
5	A10	20	A14
6	A6	21	A29
7	A18	22	A23
8	A25	23	A30
9	A22	24	A5
10	A1	25	A24
11	A19	26	A3
12	A13	27	A9
13	A12	28	A8, A26
14	A15	29	A20
15	A7		

Source: Own elaboration.

Table 4. Individual ranking of company stocks.

Position	g1	g2	g3	g4	g5	g6	g7
1	A17, A18	A28	A10	A21	A17	A17	A21
2	A28	A17	A25	A1, A17	A10	A30	A19
3	A6	A10	A23	A22	A18	A25	A14
4	A15	A11	A14	A18	A11	A6	A6, A15
5	A4	A6, A7	A29	A11	A21	A29	A4
6	A2	A13	A4	A13, A28	A16	A15	A28
7	A7	A15	A21	A6	A26	A20	A12
8	A29	A16	A2	A10	A1	A24	A1
9	A21	A19	A12	A27	A25	A11, A22	A27
10	A25	A22	A5	A7	A28	A13	A13
11	A11	A27	A17	A25	A13	A8	A10
12	A19	A2	A1	A12, A19	A30	A18	A7
13	A22	A1	A11	A29	A19	A27	A25
14	A13	A12	A30	A15	A24	A26	A16
15	A14	A18	A13	A16	A29	A19	A18
16	A1	A3	A28	A4, A30	A6	A9	A3
17	A8	A21	A22	A23	A27	A16	A11, A17
18	A23	A4	A18	A2	A23	A5	A5
19	A24	A5	A6	A14	A22	A3	A9
20	A16	A24	A24	A26	A3, A15	A23	A22
21	A12	A14	A27	A24	A4	A1	A30
22	A5	A29	A16	A3, A8	A2	A28	A2
23	A10	A23	A8, A26	A5	A12	A4	A23
24	A9	A30	A15	A9	A7	A7	A29
25	A27	A25	A9	A20	A14	A14	A26
26	A3, A30	A8, A9	A7		A8	A12	A8
27	A20	A26	A19		A20	A2	A24
28	A26	A20	A3		A5, 9	A21	A20
29			A20			A10	

Source: Own elaboration.

Each macro-criterion is evaluated through a subset of sub-criteria (elementary criteria belonging to the lowest level of the hierarchy). Table 4 presents the rankings of each macro-criterion (g_1...g_{10}). The resulting rankings emerge from the interaction of elementary criteria that evaluate the corresponding macro-criteria. For the stock selection problem, the interaction of elementary criteria subsets was analyzed at the macro-criteria level (Level 2 of the hierarchy), and subsequently, the interaction of macro-criteria at the top level (Level 1) was considered to form a comprehensive stock selection model.

The relative importance of the marco-criteria is as follows: $g4 \succ g3 \succ g2 \succcurlyeq g1 \succ g7 \succ g5 \succ g6$, with the corresponding weights 0.2650, 0.1550, 0.1500, 0.1500, 0.1350, 0.0950 y 0.0400. In terms of profitability ratios (g_4) the top positions are occupied by A21 > A1 = A17 > A22. Market value ratios (g_3) rank A10 > A25 > A23 > A14 > A29. Results ratios (g_2) show A28 > A17 > A10 > A11 > A6 = A7 ; and market ratios (g_1) show A17 = A18 > A28 > A6 > A15.

Based on the multicriteria ranking, in the macro-criterion of market ratios (g_1)there is a tie for first place between Microsoft (A17) and Visa (A28), followed by Home Depot (A21). Although these companies belong to different economic sectors—information services and financial services, respectively—they exhibit superior performance in financial indicators related to market value. The third position is held by Home Depot, a company in the construction and materials sector, as reflected in the overall ranking (g_0). Therefore, each of the seven rankings allows for identifying a stock's position within its respective group. To determine the hierarchical ranking, weights were established according to the decision-maker's judgment and investor profile regarding risk tolerance, which may influence the resulting ranking (see Table 2).

Given that Microsoft (A17) and Visa (A28) appear in top positions in the performance-related macro-criteria of the individual rankings (Table 4), Microsoft stands out in sub-criteria g_1, g_5, and g_6, while Visa excels in g_2, and Home Depot in g_4. Although the profitability ratio (g_4) holds the highest weight (0.265), Home Depot performs lower in other macro-criteria, ranking 17th in g_2, 28th in g_6, and 9th in g_1. Nevertheless, its strong performance in profitability ratios places it in the 3rd position of the overall ranking (g_0). In terms of market value ratio (g_3), the stock of Goldman Sachs (A10), a financial sector company, ranks first in the individual ranking and fifth in the overall ranking (g_0).

The stocks positioned at the bottom include: 29th place, Boeing (A20); 24th place, Exxon Mobil (A9); 23rd place, Chevron Corporation (A5); 22nd place, AT&T (A3), and Dupont (A8). Specifically, the stocks of Boeing (A20), Technologies (A28), Dupont (A28), and Raytheon (A26) show low performance evaluations within the Dow Jones index. Boeing (A20) ranks among the lowest across five macro-criteria (g_2, g_3, g_4, g_5, and g_7). This is particularly attributable to its sector—aviation—which has been heavily affected by global market conditions due to the economic and financial consequences of the COVID-19 pandemic.

These variations are important to consider as they show how rankings may shift depending on the parameters applied to the same data. In this regard, rankings are not absolute; preferences and many other factors may vary depending on different quantitative parameters. Therefore, it is crucial to utilize methodologies adaptable to the decision-maker's reality for investment portfolio integration based on companies' financial indicators and the investor's profile and preferences.

5. Conclusions

This study analyzes the performance of companies listed in the Dow Jones Index and evaluates the variables affecting stock performance using seven macro-criteria and 47 elementary criteria. From a methodological perspective, a Hierarchical Multicriteria Process (MCHP) was employed to analyze the performance of NYSE-listed companies. Subgroups of elementary criteria were assessed to understand their interaction and impact on the higher-level macro-criteria. This analytical process produced a preferential model, generating individual rankings for each macro-criterion and an overall ranking for the stock selection problem, taking into account the effects of COVID-19 on financial ratios.

MCHP allows for the evaluation of interactions between sub-criteria at all levels of the hierarchy to determine their influence across the structure. In the

context of stock selection, this approach highlights business opportunities and needs, enabling more robust and reliable decision-making. Applying MCHP to evaluate Dow Jones stocks can serve as a valuable tool for formulating more assertive policies and decisions within organizations. Consequently, this would promote favorable conditions for investors. In this regard, the ELECTRE III method provides decision-making support for real-world problems using a non-compensatory approach.

However, the research presents a limitation in that it does not consider stock volatility in the analysis. This limitation could be addressed by incorporating the beta coefficient as a criterion to evaluate volatility.

For future research, stock selection could support market portfolio integration using the Markowitz model and the Capital Asset Pricing Model (CAPM) proposed by Sharpe (1964). Additionally, other areas within the social sciences and economic phenomena could be explored to help minimize uncertainty in decision-making processes within public or private organizations.

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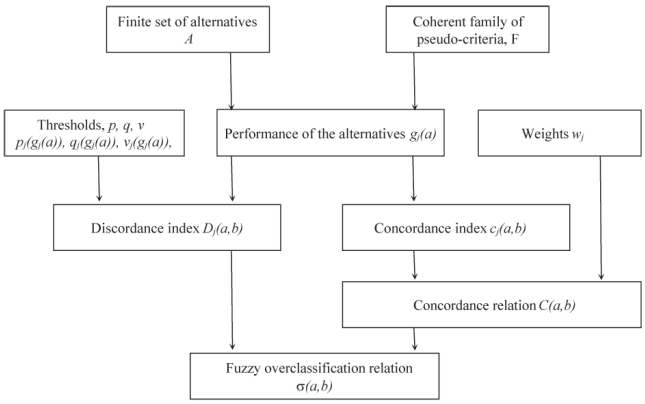
Apendix

A.1 Illustration of the Application of the ELECTRE III Method

This section presents an illustrative example of the application of the ELECTRE III method. Figure A.1.1 displays a general overview of the method's application process. For the purposes of this illustration, data from a problem presented in Macharis, Brans, and Mareschal (1998) are used. A detailed explanation of the method can be found in Almeida, Figueira, and Roy (2006). Table A.1.1 presents the evaluation matrix, while Table A.1.2 provides the parameters that will be used in the application of the ELECTRE III method.

Figure A.1.1. General structure of the ELECTRE III method



Soucre: Almeida, Figueira & Roy (2006).

Table A.1.1. Evaluation matrix of alternatives

Code	Country	g1	g2	g3	g4
A1	Italy	8	0.5	9	0
A2	Belgium	1	4	3	5
A3	Germany	4	3.5	7	65
A4	Switzerland	7	0	10	0
A5	Austria	3	4.5	2	10
A6	France	5	3.5	4	10

Table A.1.2 Parameters of the ELECTRE III Method

	g1	g2	g3	g4
	Min	*Min*	*Max*	*Min*
w	0.589	0.178	0.120	0.113
q	3.193	1.372	0.196	3.893
p	3.690	1.698	2.127	41.031
v	-	2.937	-	-

Concordance index

$$\phi_t(a,b) = \begin{cases} 1 & if \quad g_t(b) - g_t(a) \le q_t, (aS_tb) \\ \dfrac{p_t - [g_t(b) - g_t(a)]}{p_t - q_t} & if \quad q_t < g_t(b) - g_t(a) < p_t, (bQ_ta) \\ 0 & if \quad g_t(b) - g_t(a) \ge p_t, (bP_ta) \end{cases} \qquad (A.1)$$

The concordance index between the alternatives Italy (a) and Switzerland (b), considering criterion g3, is calculated using Equation A.1 as follows.

Given $\varphi_t(a,b) \rightarrow \varphi_t$(Italy, Switzerland), the following values are available for criterion 3, g_3 (Italy) = 9, g_3 (Switzerland) = 10. The difference between both cities for criterion g_3 is g_3 (Switzerland) - g_3 (Italy) = 1. This difference is neither less than or equal to q_3, (q_3 = 0.196), nor greater than p_3, (p_3 = 2.127). Therefore, the calculation corresponds to the second case of Equation A.1:

$$\frac{p_3 - [g_3(b) - g_3(a)]}{p_3 - q_3} = \frac{2.127 - [1]}{2.127 - 0.196} = 0.58$$

The concordance indices resulting from the comparison of each country with the remaining countries are presented in Table A.1.3.

Table A.1.3. Concordance indices

Italy (A1)					Switzerland (A4)				
	g1	g2	g3	g4		g1	g2	g3	g4
(A1,A2)	0	1	1	1	(A4,A1)	1	1	1	1
(A1,A3)	0	1	1	1	(A4,A2)	0	1	1	1
(A1,A4)	1	1	0.58	1	(A4,A3)	1	1	1	1
(A1,A5)	0	1	1	1	(A4,A5)	0	1	1	1
(A1,A6)	1	1	1	1	(A4,A6)	1	1	1	1
Belgium (A2)					Austria (A5)				
(A2,A1)	1	0	0	0.97	(A5,A1)	1	0	0	0.84
(A2,A3)	1	1	0	1	(A5,A2)	1	1	0.58	0.97
(A2,A4)	1	0	0	0.97	(A5,A3)	1	1	0	1
(A2,A5)	1	1	1	1	(A5,A4)	1	0	0	0.84
(A2,A6)	1	1	0.58	1	(A5,A6)	1	1	0.066	1
Germany (A3)					France (A6)				
(A3,A1)	1	0	0.066	0	(A6,A1)	1	0	0	0.84
(A3,A2)	1	1	1	0	(A6,A2)	0	1	1	0.97
(A3,A4)	1	0	0	0	(A6,A3)	1	1	0	1
(A3,A5)	1	1	1	0	(A6,A4)	1	0	0	0.84
(A3,A6)	1	1	1	0	(A6,A5)	1	1	1	1

Discordance index

$$d_t(a,b)=\begin{cases}1, & \text{if} \quad g_t(b)-g_t(a)\geq v_t,\\ \dfrac{[g_t(b)-g_t(a)]-p_t}{v_t-p_t} & \text{if} \quad p_t<g_t(b)-g_t(a)<v_t,\\ 0, & \text{if} \quad g_t(b)-g_t(a)\leq p_t.\end{cases} \qquad \text{(A.2)}$$

The discordance index between the alternatives Belgium (a) and Italy (b), considering criterion g_2, is calculated using Equation A.2 as follows.

Given $d_t(a,b) \rightarrow \quad d_t$ (Belgium, Italy), the following values are available for criterion 2,g_2 (Belgium) = 4, g_2 (Italy)= 0.5. The difference between both cities for criterion g_2 is $g_2(a)-g_2(b)=3.5$. This difference is greater than v_2, $(v_2 = 2.937)$. Therefore, the first case of Equation A.2 applies. The complete discordance index data are shown in Table A.1.4. $g_t(a)-g_t(b) \geq v_2$, then $d_t(a,b)=1$

Full concordance index

$$C_r(a,b)=\frac{\sum_{t\in E(g_r)} w_t\varphi_t(a,b)}{\sum_{t\in E(g_r)} w_t} \qquad \text{(A.3)}$$

The comprehensive concordance index corresponds to the weighted sum of each concordance index value (c_t, obtained through Equation A.1) by its corresponding importance weight (w_t).

$$C(a,b) = w_1{}^*c_1(a,b) + \ldots + w_{ll}{}^*c_{ll}(a,b)$$

Equation A.3 represents this weighted sum. An example of its application is the calculation of the comprehensive concordance index between Italy and Belgium, as follows.

C (A1, A2) → C (Italy, Belgium)

C (Italy, Belgium) = 0.589*0 + 0.178*1 + 0.12*1 + 0.113*1 = 0.41

C (Italy, Belgium) = 0.41

Table A.1.4. Discordance indices

Italy (A1)					Switzerland (A4)				
	g1	g2	g3	g4		g1	g2	g3	g4
dj(A1,A2)	0	0	0	0	dj(A4,A1)	0	0	0	0
dj(A1,A3)	0	0	0	0	dj(A4,A2)	0	0	0	0
dj(A1,A4)	0	0	0	0	dj(A4,A3)	0	0	0	0
dj(A1,A5)	0	0	0	0	dj(A4,A5)	0	0	0	0
dj(A1,A6)	0	0	0	0	dj(A4,A6)	0	0	0	0
Belgium (A2)					Austria (A5)				
dj(A2,A1)	0	1	0	0	dj(A5,A1)	0	1	0	0
dj(A2,A3)	0	0	0	0	dj(A5,A2)	0	0	0	0
dj(A2,A4)	0	1	0	0	dj(A5,A3)	0	0	0	0
dj(A2,A5)	0	0	0	0	dj(A5,A4)	0	1	0	0
dj(A2,A6)	0	0	0	0	dj(A5,A6)	0	0	0	0
Germany (A3)					France (A6)				
dj(A3,A1)	0	1	0	0	dj(A6,A1)	0	1	0	0
dj(A3,A2)	0	0	0	0	dj(A6,A2)	0	0	0	0
dj(A3,A4)	0	1	0	0	dj(A6,A3)	0	0	0	0
dj(A3,A5)	0	0	0	0	dj(A6,A4)	0	1	0	0
dj(A3,A6)	0	0	0	0	dj(A6,A5)	0	0	0	0

The complete data for the comprehensive concordance index are shown in Table A.1.5.

Table A.1.5 Full concordance index

	A1	A2	A3	A4	A5	A6
A1	1	0.41	0.41	0.95	0.41	1
A2	0.7	1	0.88	0.7	1	0.95
A3	0.6	0.89	1	0.59	0.89	0.89
A4	1	0.41	1	1	0.41	1
A5	0.68	0.95	0.88	0.68	1	0.89
A6	0.68	0.41	0.88	0.68	1	1

Credibility index

$$\sigma_r(a,b)=\begin{cases} C(a,b)\,x\prod_{g_t\in E(g_r)}\dfrac{1-d_t(a,b)}{1-C_r(a,b)} & \text{if } d_t(a,b)>C_r(a,b) \\ C(a,b) & \end{cases} \qquad \text{(A.4)}$$

The credibility index corresponds to reducing its value (credibility) for pairs of alternatives where $d_t(a, b) > C(a, b)$. Some examples of this are the pairs d_2(A2, A1) and d_2(A2, A4) (see Table A.1.4). Table A.1.6 presents the credibility index, where it can be observed how the complete concordance index is reduced to 0 for the pairs (A2, A1) and (A2, A4) due to the discordance present in these alternative pairs.

Table A.1.6 Credibility index

	A1	A2	A3	A4	A5	A6
A1	1	0.41	0.41	0.95	0.41	1
A2	0.7	1	0.88	0.7	1	0.95
A3	0.6	0.89	1	0.59	0.89	0.89
A4	1	0.41	1	1	0.41	1
A5	0.68	0.95	0.88	0.68	1	0.89
A6	0.68	0.41	0.88	0.68	1	1

A.2 Financial ratios data of companies in the Dow Jones Index

Table A.2.1 Performance of financial ratios of companies in the Dow Jones Index (Part 1, continued...)

	Market ratios (g1)						Results ratios (g2)								Market value ratios (g3)						
	g1,1	g1,2	g1,3	g1,4	g1,5	g1,6	g2,1	g2,2	g2,3	g2,4	g2,5	g2,6	g2,7	g2,8	g3,1	g3,2	g3,3	g3,4	g3,5	g3,6	g3,7
A1	21.4	3.56	35.5	35.5	8.87	0	0.4876	0.4875	0.2222	0.2223	0.2085	0.2142	0.1676	0.165	55.28	9.32	9.25	22.3	-12	8.72	12.55
A2	39.4	3.22	45.2	45.2	5.2	5.19	0.7242	0.7084	0.116	0.1839	0.116	0.1839	0.0847	0.1369	45.94	3.77	3.77	28.6	28.6	40	5.71
A3	0	1.24	17	17	1.31	0	0.5342	0.5305	0.0373	0.1245	-0.0166	0.089	-0.0222	0.0628	23.93	-0.8	-0.8	22.7	-17	1.37	3.41
A4	43.7	3.04	64.4	64.4	8.27	16.6	0.3044	0.3118	0.1091	0.1146	0.0957	0.1018	0.0697	0.0763	76.15	5.36	5.32	28.1	14	17.15	9.74
A5	0	2.12	0	0	1.51	1.57	0.4642	0.436	-0.0599	0.022	-0.0791	0.0403	-0.059	0.0297	50.37	-3	-3	68.4	66.1	2.92	7.45
A6	21.6	4.54	25.3	26.3	5.57	74.6	0.6417	0.6301	0.2593	0.2614	0.2641	0.2695	0.2109	0.2202	11.32	2.65	2.64	9.27	0.69	7.25	2.81
A7	29.8	6.96	142	68	11.9	0	0.5931	0.6096	0.2901	0.2249	0.2953	0.2397	0.2353	0.1899	7.64	1.8	1.79	4.49	-2.2	2.54	2.15
A8	41.7	2.02	20.4	20.4	1.47	0	0.3371	0.2755	-0.1129	0.0061	-0.142	0.0009	-0.1409	0.0028	27.73	-4	-4	52.4	-3.9	3.46	0.3
A9	0	1.35	0	0	1.53	1.54	0.3032	0.3083	-0.1717	0.0128	-0.1617	0.0424	-0.1303	0.0297	41.81	-5.3	-5.3	37.1	37.1	1.03	5.32
A10	8.42	1.92	0	0	1.18	1.18	0.8103	0.6918	0.3213	0.2317	0.3213	0.2317	0.2489	0.1788	168.59	25	24.7	286	286	557.01	45.81
A11	13.2	3.4	17	17	3.26	5.88	0.5601	0.5974	0.3041	0.2923	0.3221	0.3084	0.2684	0.2567	18.4	4.98	4.94	20	11.1	5.88	7.83
A12	21.2	1.61	12.9	12.9	5.75	0	0.4832	0.4737	0.063	0.1281	0.063	0.1281	0.0762	0.126	82.11	6.3	6.26	23.1	-59	15.47	13.73
A13	29.7	5.11	43.5	43.5	6.67	0	0.657	0.6711	0.1998	0.2263	0.1998	0.2263	0.1745	0.1918	30.94	5.47	5.4	24	-10	9.57	8.11
A14	12.1	3.73	0	0	1.85	2.04	0	0	0.4044	0.3533	0.4044	0.3533	0.3282	0.2756	40.11	8.89	8.88	92.7	74.7	234.9	10.23
A15	36.7	8.98	198	198	0	0	0.5077	0.4813	0.3813	0.3891	0.3197	0.3424	0.2463	0.2509	25.61	6.35	6.31	-11	-14	4.63	8.64
A16	27.6	4.04	0	0	7.66	0	0.681	0.6956	0.1647	0.1782	0.1832	0.1849	0.1476	0.1495	18.91	2.79	2.78	10	-3.8	3.19	4.22
A17	38.7	12.8	65	56.6	15	24.6	0.6835	0.6571	0.3918	0.3272	0.3962	0.3329	0.3347	0.2822	20.05	5.82	5.76	17.3	10.5	17.49	8.28
A18	63.1	5.48	0	93.9	17.7	18.5	0.4336	0.4451	0.1072	0.1179	0.104	0.1198	0.089	0.1032	24.16	1.63	1.6	7.56	7.23	7.93	2.69
A19	30.1	5	66.1	66.1	3.31	0	0	0.7895	0.1789	0.2035	0.1789	0.1886	0.1675	0.1745	7.55	1.26	1.24	11.4	-2.7	2.2	2.12
A20	0	2.5	0	0	0	0	-0.0884	0.1366	-0.2177	0.0327	-0.2468	0.0249	-0.2036	0.0234	103.16	-21	-21	-31	-49	43.94	-17.05
A21	27	2.63	35	35	105	0	0.3395	0.3411	0.1384	0.1424	0.1285	0.1327	0.0974	0.095	122.61	12	11.9	3.06	-3.6	7.33	14.28
A22	25.9	4.57	51.7	41	7.15	0	0.5191	0.5047	0.2378	0.1854	0.2316	0.1842	0.1884	0.1422	28.27	5.13	4.96	19.6	-6.9	4.85	6.35
A23	14.7	1.21	6.86	6.86	1.33	1.56	0	0	0.1116	0.1189	0.101	0.1071	0.0842	0.0867	126.04	10.6	10.5	116	98.7	2.86	13.71
A24	0	5.55	168	128	3.94	0	0.2985	0.4136	-0.0737	0.1815	-0.0711	0.1821	-0.0754	0.1276	33.52	-1.6	-1.6	47.2	-22	9.58	0.44
A25	22.2	1.4	23.7	20.1	5.32	5.32	0	0	0.0918	0.0788	0.0857	0.0725	0.0657	0.0532	273.87	16.2	16	73.3	73.3	24.24	21.05
A26	0	2.09	0	0	1.64	0	0.1578	0.2299	-0.0335	0.0877	-0.0416	0.0757	-0.0517	0.0552	38.52	-2.3	-2.3	47.5	-15	5.79	0.84
A27	13.4	1.86	21.3	21.3	3.52	0	0.6009	0.5852	0.2111	0.1973	0.1868	0.1678	0.143	0.1269	30.98	4.3	4.3	16.4	-15	5.36	8.47
A28	52.1	22.5	68.7	72.4	13.2	0	0.7904	0.8124	0.6476	0.6277	0.6315	0.6188	0.4991	0.4648	8.34	5.27	4.33	19	-3.5	9.09	4.47
A29	29.6	0.71	20.1	20.1	4.89	7.6	0.2483	0.2511	0.0253	0.0356	0.0368	0.034	0.0245	0.0237	196.64	4.77	4.75	28.7	18.4	6.29	8.74
A30	0	0.35	19.6	18.6	2.2	0	0.1995	0.2299	-0.0053	0.0375	-0.0067	0.033	-0.0067	0.0271	153.89	0.52	0.52	24.4	-2.1	1.19	1.2

Table A.2.1 Performance of financial ratios of companies in the Dow Jones Index (Part 2, continued...)

	Profability ratios (g4)										Liquidity ratios (g5)						
	g4,1	g4,2	g4,3	g4,4	g4,5	g4,6	g4,7	g4,8	g4,9	g4,10	g5,1	g5,2	g5,3	g5,4	g5,5	g5,6	g5,7
A1	0.4696	0.4854	0.1172	0.1364	0.1444	0.1702	0.4302	0.1833	0.0015	0.0582	0.0404	0.0123	0.0054	1.35	1.89	1.3981	1.4607
A2	0.1318	0.2497	0.0161	0.0299	0.0315	0.0563	-0.1392	-0.5286	-0.1792	-0.1888	-0.0569	0.0215	0.0196	0	0	1.8688	5.7303
A3	-0.031	0.0637	-0.0071	0.0222	-0.0084	0.0262	-6.9751	-1.3994	-0.0521	-0.0241	0	0.0319	-0.0399	0	0.82	0.9511	0.9726
A4	0.1951	0.2543	0.0371	0.0462	0.0558	0.0707	-0.3548	-0.4889	-0.224	-0.1452	0.0495	-0.0235	-0.083	1.09	1.53	1.6958	2.424
A5	-0.0402	0.0257	-0.0233	0.0151	-0.0261	0.017	0.9075	-3.0188	-0.3277	-0.2836	0	-0.0613	-0.2127	0.92	1.18	0.3248	0.3365
A6	0.2714	0.2137	0.1089	0.0971	0.1482	0.1279	-0.1103	-0.1329	-0.0684	-0.0037	0.086	0.0006	-0.089	1.56	1.61	0.2442	0.372
A7	0.4048	0.3501	0.0895	0.08	0.1214	0.1172	-0.288	-0.1333	-0.1141	-0.0504	0.0144	-0.0571	-0.1435	1.09	1.32	2.0791	2.2174
A8	-0.073	-0.0007	-0.041	0.0005	-0.0456	0.0007	1.3966	-2.9164	-0.0518	0.0092	0	-0.16	-0.2045	1.52	2.31	0.5663	0.5665
A9	-0.1288	0.0369	-0.0669	0.0198	-0.083	0.0243	-5.0558	-2.6506	-0.3013	-0.2743	0	-0.0573	-0.0819	0.46	0.8	0.3002	0.4304
A10	0.1619	0.1076	0.0126	0.0093	0.0297	0.0205	4.9793	1.1844	0.1287	0.5826	0.153	0.0742	0.2804	0	0	2.2347	7.7143
A11	0.2634	0.2437	0.1443	0.1401	0.1723	0.1656	-0.1003	0.0456	0.082	-0.0114	0.1618	0.0706	0.1388	1.57	1.91	0.4183	0.4492
A12	0.2709	0.5397	0.0364	0.0753	0.0487	0.1057	-0.6608	-0.4166	-0.0457	-0.0647	-0.1438	-0.0207	-0.0489	0.94	0.98	2.6388	2.9876
A13	0.2349	0.2387	0.0867	0.0991	0.1134	0.1252	-0.5662	-0.0406	0.0064	0.0833	-0.003	0.0334	-0.0068	0.99	1.21	0.5157	0.5573
A14	0.1617	0.121	0.0119	0.0113	0	0	4.738	0.4223	-0.2711	-0.2552	0.0814	0.0483	0	0	0	0.9954	2.2743
A15	0	0	0.0945	0.144	0.1047	0.1586	-0.1393	-0.211	-0.1009	-0.0211	0.0563	-0.0545	-0.0199	1	1.01	0	0
A16	0.276	0.2004	0.0805	0.0726	0.1122	0.0947	-1.8803	-0.2795	0.0246	0.0545	0.1221	0.0397	0.2956	0.79	1.02	1.0017	1.2557
A17	0.427	0.3603	0.1748	0.1304	0.2232	0.1733	0.3405	0.1693	0.1418	0.1672	0.313	0.0885	0.2104	2.55	2.58	0.5064	0.5532
A18	0.3268	0.3439	0.1099	0.1579	0.1516	0.2172	0.684	-0.2161	-0.067	0.025	-0.0292	0.041	0.0243	2.02	2.78	0.7889	0.7892
A19	0.1105	0.124	0.0436	0.0481	0.0544	0.0596	1.2513	-0.3255	0.0179	0.1182	0.0224	-0.0302	0.1328	1.04	1.35	0.5872	0.6299
A20	0	0	-0.0836	0.0175	-0.2374	0.0497	-7.2164	-16.433	-0.3084	-0.2314	0	-0.094	-0.1186	0.46	1.39	0	0
A21	140.61	9.2595	0.2112	0.217	0.3205	0.333	0.1622	0.165	0.1985	0.2513	0.1692	0.0834	0.1038	0.51	1.23	10.858	11.288
A22	0.2955	0.176	0.1202	0.0788	0.1648	0.1055	0.0427	1.9623	0.063	0.0825	0.1183	0.0006	-0.0383	0.59	0.78	0.4673	0.6455
A23	0.097	0.106	0.0238	0.0248	0	0	0.5253	0.0566	0.0143	0.0458	-0.0067	0.0358	0	0	0	0.2209	0.2243
A24	-0.0567	0.1286	-0.0227	0.0623	-0.0292	0.081	-0.9864	-1.4594	-0.1918	-0.2217	0	0.045	-0.0117	1.26	1.31	0.629	0.6932
A25	0.2674	0.2351	0.0877	0.0796	0	0	0.4451	0.2318	0.0676	0.0896	0.2167	0.1036	0.0568	0	0	0.5399	0.6674
A26	-0.0546	0.0677	-0.0194	0.0239	-0.0272	0.0332	-0.8713	-1.5028	0.2478	0.4041	0	0.0017	-0.012	0.95	1.21	0.4299	0.441
A27	0.2755	0.3557	0.0603	0.061	0.0705	0.0711	-0.1006	-0.0764	-0.0271	-0.0024	-0.0032	-0.0051	-0.0602	1.33	1.38	1.8156	1.9024
A28	0.3247	0.3117	0.1381	0.1376	0.1712	0.1634	-0.1402	-0.1844	-0.087	-0.0606	0.1093	0.095	0.122	0	2.12	0.5588	0.5588
A29	0.1737	0.1533	0.0561	0.0563	0.0899	0.0897	-1.5099	-0.087	0.0672	0.0735	0.0077	0.0301	-0.0221	0.49	0.97	0.5566	0.6039
A30	-0.0359	0.1326	-0.0099	0.0494	-0.0151	0.0712	0.0879	-1.244	0.0293	0.046	-0.3357	0.0617	0.0189	0.56	0.83	0.5687	0.8144

Table A.2.1 Financial ratios performance of companies in the Dow Jones Index (Part 3)

	Effectiveness ratio (g6)					Dividend ratio (g7)			
	g6,1	g6,2	g6,3	g6,4	g6,5	g7,1	g7,2	g7,3	g7,4
A1	0.7	3.94	338.83	56.78	6.78	0.03	0.0274	0.0775	0.6293
A2	0.19	0	0	0	0.74	0.0116	0.0141	0.095	0.4586
A3	0.32	0	746.78	-16.61	7.38	0.0699	0.0562	0.02	0
A4	0.53	2.56	429.06	29.9	5.28	0.0177	0.0246	0.0995	0.77
A5	0.39	8.76	1.97	-116.49	7.6	0.0499	0.0413	0.061	0
A6	0.52	12.34	619.69	130.7	9.76	0.0287	0.0285	0.0963	0.6009
A7	0.38	4.04	411.13	96.74	9.28	0.0315	0.031	0.0374	0.9096
A8	0.29	3.36	599.91	-84.53	5.52	0.0156	0	0.0172	0
A9	0.51	6.66	2.48	-323.28	7.51	0.0611	0.0458	0.0438	0
A10	0.05	0	1.5	372.4	0.42	0.0148	0.0154	0.1991	0.0928
A11	0.54	3.99	704.04	188.96	10.8	0.0214	0.025	0.07	0.2668
A12	0.48	22	196.17	14.96	9.53	0.0492	0.0441	0.0333	1.033
A13	0.5	3.09	614.01	107.17	5.89	0.0252	0.0259	0.0623	0.7271
A14	0	0	0	0	0	0.0237	0.0238	0.2084	0.2148
A15	0.38	186.69	96.04	23.65	8.86	0.0223	0.0242	0.0958	0.7933
A16	0.55	2.49	648.58	95.72	6.56	0.0339	0.03	0.0167	0.8925
A17	0.52	25.89	940.39	314.79	6.03	0.0086	0.015	0.0916	0.3152
A18	1.23	3.49	510.7	45.46	9.46	0.0082	0.0107	0.11	0.4504
A19	0.26	0	533.86	89.44	5.7	0.0415	0.0377	0.059	1.2271
A20	0.41	0.81	416	-84.69	5.27	0	0.0207	-0.2874	0
A21	2.17	5.6	261.71	25.49	51.8	0.0204	0.0213	0.1901	0.5014
A22	0.64	6.2	747.22	140.79	14.8	0.0254	0.0294	0.0392	0.5705
A23	0.28	0	1.05	88.14	0	0.022	0.0227	0.0631	0.323
A24	0.3	27.94	299.31	-22.56	3.9	0	0.013	-0.1737	0
A25	1.33	0	796.72	52.37	0	0.0128	0.0139	0.1888	0.2109
A26	0.38	5.16	312.64	-16.18	3.49	0.0244	0.0366	-0.074	0
A27	0.42	31.82	970.44	138.79	5.04	0.0435	0.042	0.0211	0.5777
A28	0.28	0	1.05	522.93	12.6	0.0057	0.006	0.2205	0.2603
A29	2.29	9.4	243.11	5.96	87.4	0.0157	0.0198	0.0192	0.4527
A30	1.48	11.76	599.08	-4.04	21.5	0.0348	0.0254	0.0685	0

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Employment–output elasticity and employment determinants in the Northern Region of Mexico

Elasticidad empleo-producto y determinantes del empleo en la Región Norte, México

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Joaquin Bracamontes Nevarez[1] and Mario Camberos Castro[2]

[1] PhD in Economic Sciences from the Universidad Autónoma de Baja California (UABC). Full Professor-Researcher (Level C) in the Department of Economics at the Centro de Investigación en Alimentación y Desarrollo (CIAD), joaco@ciad.mx. Research line: Economic Policy, Social Policy, and Well-being. ORCID: https://orcid.org/0000-0002-3219-9582

[2] PhD in Economic Sciences from the Universidad Autónoma de Baja California (UABC). Emeritus Professor-Researcher in the Department of Economics at the Centro de Investigación en Alimentación y Desarrollo (CIAD), mcamberos@ciad.mx. Research lines: Economic Policy, Well-being, Inequality, Poverty, Labor Markets, and Social Policy Evaluation. ORCID: https://orcid.org/0000-0002-3271-2980

Abstract

This study examines the effect of economic growth on job creation by calculating the employment–output elasticity coefficient, followed by a multiple regression model to identify the determinants of employment. The results show that employment increases by 0.75% in the region and 0.80% nationwide for every 1% increase in gross domestic product (GDP), suggesting that the crisis context does not appear to affect employment at the regional or national level. However, the sub-period analysis clearly reveals an adverse impact on job creation at the regional scale, in the states comprising the region, and at the national level. According to the econometric model, job creation is explained by economic growth, foreign investment, and public spending, but not by domestic investment.

Keywords: economic growth, employment, employment–output elasticity.

JEL code: J2,O1 y O4

Resumen

Se estudia el efecto del crecimiento económico en la creación de empleo, por ello se calcula el coeficiente de elasticidad o intensidad empleo-producto y, luego, un modelo de regresión múltiple para identificar factores determinantes del empleo. Los resultados muestran que el empleo crece 0.75% en la región y 0.80% en el país por cada 1% de aumento en el producto interno bruto (PIB), por lo que aparentemente el contexto de crisis no afecta el empleo regional ni nacional; sin embargo, el análisis por sub-periodos muestra claramente un impacto adverso en la creación de empleos a escala regional, en los estados que conforman la región y también en el país. De acuerdo al modelo econométrico, la generación de empleos se explica por el crecimiento económico, la inversión extranjera y el gasto público, pero no por la inversión doméstica.

Palabras clave: crecimiento económico, empleo, elasticidad empleo-producto.

Código JEL: J2,O1 y O4

1. Introduction

Globally, the average economic growth rate was 3.6% during the period 2011–2018, lower than the 3.9% recorded between 2001 and 2010 (IMF, 2018). In Latin America, economic growth was interrupted by the 2008 crisis, resulting in a -1.9% growth rate and an unemployment rate of 8.1% in 2009 (ILO,

2011). In Mexico, the early years of the century saw a modest annual average GDP growth of 2.8%, but in 2009 the growth rate turned negative at -6.7% (INEGI, 2010a), and the unemployment rate reached 6.4% (INEGI, 2010b).

The relationship between economic growth, employment, and productivity is increasingly relevant, as reflected in the 2030 Agenda for Sustainable Development, specifically Goal 8: Decent Work and Economic Growth (UN, 2016). In the short term, economic growth can i nfluence employment and/or unemployment; whereas long-term GDP expansion at a pace faster than employment and labor force growth may result in increased labor productivity (ILO, 2019).

Thus, the lack of employment remains a central global concern and a major challenge for governments, particularly in the context of the COVID-19 pandemic. In 2014, over 200 million people were unemployed 31 million more than before the global financial crisis and in 2015 a further increase of 3 million unemployed persons was expected worldwide (ILO, 2015). By 2018, there were 172 million unemployed people worldwide, corresponding to an unemployment rate of 5% (ILO, 2019).

Even before the emergence of COVID-19, with a global unemployment rate around 5% and a growing labor force, an annual increase of 1 million unemployed persons was projected, reaching 174 million in 2020 (ILO, 2019; Table 1.5, p. 20). In Mexico, with the arrival of the pandemic, the unemployment rate was estimated at 11.7% by the end of 2020, equating to approximately 6 million people (ILO, 2020). So far this century, the Mexican economy has shown slow growth, impacting employment levels, as job creation has not kept pace with the growth of the working-age population. In this context, the research problem involves examining the impact of economic growth on employment levels in the northern region[1] and the country before the global crisis (2005–2007), during the crisis (2008–2010), and after the crisis (2011–2013).

This study seeks to answer the following questions: What are the levels of investment, economic growth, and employment in the northern region? What effect has economic growth had on job creation in the region and the country? What other factors influence or determine job creation? The working hypothesis posits that despite the crisis, economic growth in the northern region positively affects employment, due to its proximity to the U.S. economy and the benefits from trade liberalization, which fosters productive investment not only the exchange of goods and services.

Therefore, the general objective of this research is to determine the impact of economic growth on job creation in the northern region, its constituent states, and the country as a whole. Two specific objectives are proposed: 1) To calculate the employment–output elasticity coefficient to capture the impact of economic growth on job creation; and 2) To identify the main factors that influence or determine the creation of new jobs.

Following this introduction, the second section presents the conceptual aspects of the relationship between economic growth and employment, along with recent empirical evidence. The third section details the methodology and data used. The fourth section provides a brief characterization of the study region, followed by an analysis of employment–output elasticity in the region, its states, and the country, as well as the factors promoting job creation. The final section presents the conclusions.

2. Theoretical framework and evidence on the subject

Economic theory posits a positive relationship between output variations and the level of employment; that is, an increase in output implies an increase in the number of employed persons, thereby reducing the unemployment rate (Tangarife, 2013, p. 40). Thus, economic performance is a fundamental determinant of job creation in any country, as higher output requires more labor and increases people's purchasing power.

According to Keynesian theory, the economy does not operate at full employment, and labor market equilibrium is based on effective demand. The market is quite slow to reach such equilibrium, making state intervention necessary as a regulator, promoter, and driver of investment and employment.

Keynes clarified the relationship between income–output growth and employment, showing that

[1] The Northern Region is one of the four major regions defined by the National Population Council (Conapo 2004, cited in Zúñiga and Leite, 2006), which group the federal entities based on geographic proximity and their tradition of high migration intensity: Northern Region: Baja California, Baja California Sur, Coahuila, Chihuahua, Nuevo León, Sinaloa, Sonora, and Tamaulipas; Traditional Region: Aguascalientes, Colima, Durango, Guanajuato, Jalisco, Michoacán, Nayarit, San Luis Potosí, and Zacatecas; Central Region: Mexico City, Hidalgo, State of Mexico, Morelos, Puebla, Querétaro, and Tlaxcala; Southern-Southeastern Region: Campeche, Chiapas, Guerrero, Oaxaca, Quintana Roo, Tabasco, Veracruz, and Yucatán.

changes in output (Y) are driven by changes in employment (N) through aggregate demand (Keynes, 1936) a basic production function already expressed by classical Ricardian economics as Y = f(N), with dy/dn > 0, assuming land (another factor) is constant, which led to the law of diminishing returns.

The relationship between output and employment is evident when Y is replaced by the modern concept of GDP (Dornbusch et al., 2002). Although modern growth theory identifies other factors influencing GDP growth such as physical capital investment (Solow, 1957), human capital (Mankiw et al., 1992), research and development (Romer, 1990), public spending, work environment, labor organization, and skill level these factors are ultimately absorbed into employment (OECD, 2001).

However, according to Skidelsky (2011), economic growth and existing employment levels are also the result of a combination of short-term expectations, reflected in corporate profitability, and long-term expectations, reflected in capital accumulation. Nevertheless, in times of crisis, expectations in both directions are clearly reversed.

It is worth noting that while the Keynesian approach explains economic fluctuations through effective demand in the short term, the existence of effective demand fosters optimistic investment expectations, which increase investment levels and, in turn, production. This dynamic leads to higher economic growth and consequently, job creation.

In other words, the Keynesian principle holds that productivity growth stimulates wage increases, which boost demand and employment. As demand grows, investment tends to rise, restarting the cycle of greater productivity (Camargo, 2013). This implies that employment is a function of output level, and not solely of wage levels, as assumed in the labor market framework (Kato, 2004).

The output–employment relationship is often measured using the output–employment elasticity of the economy, which quantifies the relative response of employment levels to changes in output. However, as noted earlier, other factors besides labor are involved in the production process, so employment levels may not solely depend on GDP (Tangarife, 2013).

This means that economic growth may be a necessary but not sufficient condition for job creation. Therefore, employment elasticity values should be analyzed in the context of the business cycle and other macroeconomic variables such as labor productivity, labor costs, investment, labor demand, etc. (Tangarife, 2013; Pattanaik & Nayak, 2011; Kapsos, 2005; Islam & Nazara, 2000).

Despite criticisms[2] mainly that it ignores the supply side the concept of employment output elasticity remains a convenient way to summarize the effect of economic growth on employment. It aligns with Okun's Law, which has been useful in industrialized countries to identify growth thresholds at which job creation becomes significant (Islam & Nazara, 2000).

Specifically, Okun's Law examines the empirical relationship between cyclical changes in GDP and unemployment (Dornbusch et al., 2002), supporting the idea that a 1% loss in employment corresponds to a 2-percentage-point loss in GDP. However, a simplistic market analysis often places GDP growth as the main driver of employment increases hence the common expression that economic growth is necessary for job creation.

Within this analytical framework, the key issue remains: By what percentage does employment increase for every 1% increase in GDP? This is the research question to be addressed in the following sections, focusing on the states that make up the Northern Region and the country as a whole.

Regarding international studies analyzing the effect of economic growth on employment, Morén and Wändal (2019) calculated employment elasticity of economic growth for 168 countries and found that higher elasticity corresponds to more labor-intensive growth. The results vary widely by country, with elasticity ranging from -0.32 to 2.61. At the regional level, the most employment-intensive growth was seen in the Caribbean, Central America, and Southern Europe. Elasticity was higher in developing countries compared to developed ones,

[2] For a detailed review of these criticisms, see Islam and Nazara, 2000:4–7.

and for most regions, the highest elasticity was recorded for adult women, followed by adult men. Finally, they demonstrated that labor force growth, the share of employment in services and industry, foreign direct investment (FDI), and trade all influence employment elasticity.

Meanwhile, Görg et al. (2018) studied 20 OECD countries over the period 1960–2014 and found that the long-term employment–output elasticity averaged around 0.80. They note that this indicates a significant increase in employment responsiveness to output fluctuations in recent decades, with labor market policies playing a crucial role. Flexible short-term contracts may also affect employment dynamics.

For the South African economy, Mkhize (2019) investigates the evolution of employment intensity across eight non-agricultural sectors from the first quarter of 2000 to the fourth quarter of 2012, aiming to identify key growth sectors that are labor-intensive. The empirical findings suggest that total non-agricultural employment and GDP do not move together in the long term, implying that unemployment growth occurred in South Africa during the analyzed period. This supports the idea that South Africa has become less labor-intensive and more capital-intensive. Accordingly, branches within the tertiary sector show better performance in terms of employment intensity, reflecting the changing structure of the economy, with employment shifting from the primary to the tertiary sector. Therefore, investment in the tertiary sector is necessary to promote new jobs and could help improve overall employment intensity in southern Africa.

In Latin America, Kapsos (2005) found an employment–output elasticity of 0.65 for the period 1991–1995, 0.70 for 1995–1999, and 0.45 for 1999–2003. These figures are similar to those published by ECLAC for 20 countries in the region, reporting an average employment elasticity of 0.60 for Latin America during the 1990s (ECLAC, 2000, cited in Kato, 2004:89). In both studies, the method used to estimate employment–output elasticity consisted of dividing the employment growth rate by the output growth rate. Stallings and Weller (2001) also estimated an employment–output elasticity of 0.60 for Latin America, but for the longer period of 1950–1999.

In the case of Mexico, Cruz and Ríos (2014) analyzed employment–output elasticity by occupation, highlighting the ten most dynamic and the ten least dynamic occupations. They pointed out that occupations with high elasticity are likely to involve labor-intensive or low-productivity production methods, whereas those with low elasticity may indicate high productivity and potential unemployment if productive capacity does not expand progressively. The results show that workers are concentrated in activities where earnings are low (between one and three minimum wages), and that in the main occupational groups, workers typically have only primary or secondary education. Only those with upper secondary or higher education are able to earn more than three minimum wages.

Ríos and Carrillo (2014) studied the impact of output changes on employment across Mexico's manufacturing subsectors in the aftermath of the 2009 crisis. Using data from the National Accounts System and the National Survey of Occupation and Employment (ENOE) by INEGI, they applied a fixed-effects panel model and found that the subsectors with the highest elasticity were 2 (textiles, apparel, and leather industries), 4 (paper, printing, and publishing), and 8 (metal products, machinery, and equipment). This indicates that high-tech subsectors are not the only ones with high elasticity and, therefore, may be more affected by employment reductions during economic downturns. In subsectors with a high relative demand for unskilled labor such as subsector 2 (apparel manufacturing) and subsector 8 (furniture manufacturing) layoffs are the preferred measure during periods of low product demand, with maquiladoras and traditional labor-intensive industries being the most affected.

Carbajal and Almonte (2017) analyzed, at the level of major manufacturing divisions, the performance of production and its effects on formal job creation in the Central region of Mexico. They identified the most dynamic divisions of manufacturing activity and, by estimating an employment function with panel data for each of the nine major manufacturing divisions, reported that the following divisions show high income elasticity

of employment: I. Food products, beverages, and tobacco; II. Textiles, apparel, and leather; III. Wood and wood products; and IX. Other manufacturing industries, with elasticities of 0.716, 1.035, 0.781, and 0.94, respectively. Meanwhile, divisions comprising the most technologically advanced, innovative, and export-oriented branches such as Division VIII. Metal products, machinery, and equipment showed lower elasticity.

Also focusing on the manufacturing sector and using data from the Monthly Industrial Survey, Kato (2004) found that social benefits have been more important than wages in absorbing employment in response to production changes. This may be due to average worker compensation not increasing in real terms, while social benefits have maintained a negative relationship with employment. Consequently, reducing labor costs through this component has promoted greater job creation at the expense of social benefits. These two effects enabled a higher employment–output elasticity when comparing the periods 1987–1993 and 1995–2001, which showed employment–output elasticities of 1.17 and 1.86, respectively demonstrating that elasticity is higher in the manufacturing sector than in the Mexican economy overall.

Ríos and Cruz (2019) calculated the impact of economic growth on employment for the group "transport and mobile machinery drivers" during the period 1996–2012, using data from the National Survey of Household Income and Expenditure (ENIGH) published by INEGI. For the main group "Transport and mobile machinery drivers," they found that the states with the most positive elasticities were Campeche, Jalisco, Michoacán, Morelos, Sonora, Veracruz, and Yucatán. Among the 14 unit occupational groups within group 83: transport and mobile machinery drivers, eight showed positive employment–output elasticity, particularly the following unit groups: Bicycle transport drivers (9321), Mobile machinery operators for cargo movement in factories, ports, commerce, etc. (8352), Deck officers, sailors, and pilots (8322), Mobile machinery operators for construction and mining (8351), and Drivers of buses, trucks, vans, taxis, and passenger cars (8342).

Lastly, Bracamontes and Camberos (2016) investigated the impact of growth on employment during the first decade of the 21st century for the state of Sonora and its regions. They found that by the end of the decade, the Costa region had the highest employment–output elasticity coefficient (0.421), surpassing the employment intensity observed for the state of Sonora as a whole (0.362) implying that in the Costa region, employment increased by 0.42% for every 1% increase in output, while in the state overall it only rose by 0.36% per 1% growth in GDP. The next highest were the Frontera region (0.304) and the Sierra region (0.072). The Costa region showed a clear predominance in terms of investment share, value-added generation, and employment. However, employment–output elasticity coefficients were relatively low for all three regions and for the state as a whole.

3. Methodology and data used

Employment–output elasticity helps assess the intensity of economic growth in relation to job creation. Equation (1) measures arc elasticity, which is the calculation of elasticity between two different time points. This descriptive method has been used by the ILO and ECLAC (Islam & Nazara, 2000). Where Ɛ represents employment elasticity, L is the employed population, and Y is the Gross Domestic Product (GDP) of the country, region, and constituent states.

$$Ɛ = (\Delta L / L) / (\Delta Y / Y)$$

(Ec. 1)

The numerator simply provides the percentage change in employment in an economy (L_i) between periods t_0 and t_1, while the denominator gives the corresponding percentage change in output (Y_i). In this sense, employment elasticity (Ɛ) measures the percentage change in job creation for every one percent increase in GDP.

The Economic Commission for Latin America and the Caribbean (ECLAC, 2000, cited in Cruz & Ríos, 2014) notes that it is not easy to prescribe whether high or low employment–output elasticity values are desirable. In the first case, the economy would be characterized by labor-intensive or low-productivity

production methods, while in the second case, high productivity may exist, potentially accompanied by unemployment if there is no progressive expansion of productive capacity.

Changes in employment have implications in terms of productivity, which complicates the interpretation of elasticity values. To address this challenge, and in line with Kapsos (2005), this study assumes that employment and productivity growth should be pursued jointly in order to maximize the potential for achieving economic development goals, such as poverty reduction.

Table 1. Interpretation of Employment–Output Elasticities

Employment Elasticity	GDP Growth	
	Positive GDP Growth	Negative GDP Growth
$\varepsilon<0$	(-) Employment growth (+) Productivity growth	(+) Employment growth (-) Productivity growth
$0\leq\varepsilon\leq1$	(+) Employment growth (+) Productivity growth	(-) Employment growth (-) Productivity growth
$\varepsilon>1$	(+) Employment growth (-) Productivity growth	(-) Employment growth (+) Productivity growth

Source: Adapted from Kapsos (2005:4)

To clarify the relationship between employment–output elasticities, real employment growth, and productivity increases, the author establishes a summary of this relationship under different scenarios of GDP growth. This framework is used in the present research to analyze elasticities. In Table 1, the cells can be interpreted as follows (Kapsos, 2005:4):

1. When the economic growth rate is positive and the employment elasticity is negative (less than zero), the employment growth rate is negative and the productivity growth rate is positive (labor productivity increases but employment does not).

2. When the economic growth rate is positive and employment elasticity is between zero and one, both employment and productivity growth rates are positive (both labor productivity and employment increase). This scenario is often considered ideal, as employment growth goes hand in hand with productivity gains. However, within this range, higher elasticities (0.6 to 1.0) imply greater employment intensity but lower productivity growth.

3. The lower left cell of the table shows that in economies with positive GDP growth, elasticities greater than one correspond to positive employment growth but negative productivity growth (employment increases, but productivity deteriorates).

4. The right-hand columns indicate that the interpretation of employment elasticities vis-à-vis employment and productivity growth is exactly the opposite in cases where GDP is experiencing negative growth.

Furthermore, various studies use macroeconomic variables to examine employment generation in both developed and developing countries (Sodipe & Ogunrinola, 2011; Fofana, 2001). According to data availability, to test the research hypothesis, a multiple linear regression model will be estimated in which the main determinants of employment generation are economic growth, investment, and public spending on infrastructure. The model will be estimated for average values during the study period 2005–2013, as well as for the sub-periods: 2005–2007, 2008–2010, and 2011–2013, and is specified as follows:

$$LgPOi = \beta 0 + \beta 1LgPIBi + \beta\ 2LgIEDi + \beta 3LgFBKi + \beta 4LgGP$$

(Ec. 2)

Where:

LgPO= The natural logarithm of the employed population;

LgPIB= The logarithm of Gross Domestic Product (GDP);

LgIED = The logarithm of foreign direct investment (FDI);

LgFBK= The logarithm of domestic investment;

LgGP= The logarithm of public spending on infrastructure.

The employment data are obtained from the National Survey of Occupation and Employment (ENOE), which is conducted and published annually by INEGI. Economic growth is measured using the average GDP value for the period and sub-periods, with data obtained from the National Accounts System of INEGI. Foreign direct investment data are provided by the Economic Information Bank of INEGI. Data on Gross Fixed Capital Formation are also taken from INEGI[3], as reported in the Economic Censuses, since gross fixed capital formation represents the direct investment observed in the production process in the form of means of production. These censuses are published every five years, so the values published in 2004 and 2014 are used as approximate initial and final values for the period, respectively.

Similarly, public spending on infrastructure is obtained from the INEGI website, specifically from the state and municipal public finance[4] section under Administrative Records. Public investment is used as a proxy variable for public spending on infrastructure, as it represents government expenditure that encourages third-party investment, anticipating general potentialities where applied, rather than benefiting only a specific group.

For data processing and management, the statistical software Excel version 14.0 and STATA version 12.1 are used.

4. Employment elasticities and determinants

Before analyzing the effects of economic growth on job creation, a brief characterization of the study region is presented. In 2010, the Northern Region had a population of 23.2 million people (Table 2, 2nd column), representing 20.74% of the total national population. The most populous states were Nuevo León, Chihuahua, Tamaulipas, and Baja California, followed in smaller numbers by Sinaloa, Coahuila, and Sonora. Baja California Sur was the least populated.

The Region accounted for 23.27% of the national GDP, which amounted to 12 trillion pesos in 2010. The state of Nuevo León, with 6.7%, had the largest share in generating regional wealth, followed at an intermediate level by Coahuila, Tamaulipas, Baja California, Sonora, and Chihuahua. The states of Sinaloa and Baja California Sur had the smallest shares in the wealth generation of the Northern region.

[3] It is the value of fixed assets purchased by economic units (domestic or imported, new or used), minus the value of fixed asset sales. It includes, as part of the fixed asset purchases, the value of renovations, improvements, and major overhauls made to fixed assets that extended their useful life by more than one year or increased their productivity, as well as fixed assets produced by the economic activity for its own use (INEGI, 2009).

[4] The variable Public Investment, formerly known as "Public Works and Social Actions," is divided into Public Works on Public Domain Assets and Productive Projects and Promotion Actions. Public Works on Public Domain Assets includes the construction of schools, hospitals, public buildings, roads and highways, infrastructure for the supply of water, oil, gas, electricity, and telecommunications, as well as civil engineering works such as land division and urban development projects. As for Productive Projects and Promotion Actions, these include investments in public security, agricultural development, industrial development, administrative development, tourism promotion, and educational promotion.

Table 2. Mexico and Northern Region. Population, Gross Domestic Product (GDP), Investment and GDP Per Capita, 2010.

Entities	Total Population	%	GDP1	%	Investment2	%	GDP per Capita
Mexico	112,336,538	100	12,756,947.64	100	464,390.60	100	113,560.09
Northern Region	23,299,205	20.74	2,968,513.55	23.27	108,814.70	23.27	127,408.36
Baja California	3,155,070	2.81	348,466.63	2.73	9,918.60	2.73	110,446.56
Baja California Sur	637,026	0.57	89,603.56	0.7	3,835.00	0.7	140,659.19
Chihuahua	3,406,465	3.03	326,658.13	2.56	11,784.00	2.56	95,893.58
Coahuila	2,748,391	2.45	380,884.16	2.99	12,184.60	2.99	138,584.42
Nuevo León	4,653,458	4.14	855,024.82	6.7	28,455.70	6.7	183,739.67
Sinaloa	2,767,761	2.46	255,621.38	2.0	6,825.60	2	92,356.74
Sonora	2,662,480	2.37	331,009.28	2.59	11,967.40	2.59	124,323.67
Tamaulipas	3,268,554	2.91	381,245.58	2.99	23,843.50	2.99	116,640.44

The POB figures are expressed in millions of pesos, and GDP per capita is reported in 2008 current pesos.
This represents Gross Fixed Capital Formation in millions of pesos for the year 2010.
Source: Adapted from Millán L. Christian (2017:37)

Total investment in the region amounted to 108,814.7 million pesos (Table 2, 6th column), equivalent to 23.4% of the national investment, which totaled 464,390.6 million pesos. The states of Nuevo León and Tamaulipas stood out with the highest investment levels, followed to a lesser extent by Coahuila, Sonora, Chihuahua, and Baja California. The lowest investment levels were observed in Sinaloa and Baja California Sur.

It is important to note that despite the crisis, the relative share of the Northern region in the national GDP has remained approximately stable at 23.0% during 2004-2014 (Millán, 2017:51, Table 11). However, the regional investment's share of total national investment fell from 35.05% to 18.19% during the same period; in other words, in the context of the crisis, investment amounts in the Northern region were nearly halved. This decline is observed in all states of the region, particularly in Tamaulipas, whose share dropped from 5.48% to 0.91% over the period (Millán 2017:42, Table 5).

The last column of Table 2 shows that the Northern region had a GDP per capita of 127,408 pesos, surpassing the national GDP per capita of 113,560 pesos per year. The states of Nuevo León, Baja California Sur, and Coahuila have GDP per capita figures above those observed in both the region and the country, followed by Sonora, Tamaulipas, and Baja California. Chihuahua and Sinaloa recorded the lowest GDP per capita in the Northern region.

4.1. Analysis of Employment-Output Elasticities

It is important to consider that employment-output elasticity trends only show employment's response to economic growth and, although this is an important indicator, it does not provide information regarding the number of employed persons, employment quality, or job types (Kapsos, 2005). Furthermore, while the computational estimation of arc elasticity is simple, Islam and Nazara (2000) caution that elasticity values calculated year after year using this method may exhibit considerable instability and may be unsuitable for comparative purposes. This, however, is not the case here as the analysis presented is short-term.

The last column of Table 3 shows relatively high employment-output elasticities, although these are higher nationwide than for the Northern region during the 2005–2013 period. At the national level, employment grows by 0.80%, while in the Northern region, employment grows by only 0.75% for every 1% increase in GDP. In both cases, GDP growth rates are positive (Tables A and B in Annex I), and according to Kapsos' (2005) classification, this represents the ideal scenario, as employment growth goes hand in hand with productivity increases. However, this reflects a labor-intensive economic growth that is becoming increasingly less productive, both in the Northern region and nationally[5].

In the states of Baja California (1.58%), Tamaulipas (1.38%), Baja California Sur (1.14%), and Coahuila (1.02%), the highest employment elasticities were

[5] According to Kahn (2000, cited in Kapsos 2005), developing economies should ideally have employment-output elasticities of 0.70, and as they achieve upper-middle-income status, these employment elasticities will gradually decline as a country becomes more developed and labor becomes scarce. In this way, Kahn argues that labor-abundant economies especially those with a relatively high incidence of poverty need to achieve a relatively higher employment intensity than economies that are less labor-abundant.

Table 3. Northern Region. Employment-Output Elasticity by Sub-Periods and for the Total Period, 2005–2013.

Region	Sub-period 2005-2007	Sub-period 2008-2010	Sub-period 2011-2013	Period 2005-2013
Mexico	0.79	0.6	0.65	0.8
Región norte	0.7	-0.38	0.7	0.75
Baja California	0.92	-0.24	1.06	1.58
Baja California Sur	0.82	-1.07	0.61	1.14
Chihuahua	0.7	1.43	0.72	0.44
Coahuila	1.7	-2.22	0.77	1.02
Nuevo León	0.52	4.31	0.37	0.52
Sinaloa	0.01	-3.1	0.33	0.45
Sonora	0.64	0.62	0.64	0.81
Tamaulipas	1.14	0.12	1.59	1.38

Source: Own elaboration based on Sistema de Cuentas Nacional of Mexico and the National Survey of Occupation and Employment by INEGI

recorded, exceeding both the employment elasticity of the Northern region and that of the country. Meanwhile, the state of Sonora (0.81%) shows an employment elasticity similar to that of the country. The fact that GDP growth rates are positive (see Tables C–J in Annex I), along with an employment-output elasticity greater than 1, implies that in these states employment increased, but productivity did not during the 2005–2013 period. Conversely, Nuevo León (0.52%), Sinaloa (0.45%), and Chihuahua (0.44%) had the lowest employment-output elasticities, indicating productivity increases but not employment growth in those states.

When analyzing employment elasticities by sub-periods (Table 3, columns 2, 3, and 4), it can be seen that at the national level (0.60) and in the Northern region (-0.38), employment generation declined in the context of the crisis (2008–2010). However, the drop in job creation was steeper in the Northern region, which recorded a negative employment elasticity, meaning not only was job creation halted, but previously generated jobs were also lost. Similarly, the states of Sinaloa, Coahuila, Baja California Sur, and Baja California recorded negative employment elasticities, except for Nuevo Leónand Chihuahua, where the impact of the crisis is reflected in the post-crisis period (2011–2013), with a significant decline in their employment elasticities: Nuevo León (0.37) and Chihuahua (0.72). In Sonora (0.62), there was a slight decline in elasticity, indicating the crisis had milder effects; the opposite occurred in Tamaulipas, where the employment-output elasticity fell to 0.12 during the crisis.

In the post-crisis period (2011–2013), the Northern region increased its employment elasticity (0.70), recovering the level observed before the crisis and exceeding the national employment elasticity (0.65), which also showed a slight recovery. The states of Baja California (1.06) and Tamaulipas (1.59) achieved significant recovery in employment generation during the post-crisis period, surpassing both regional and national employment elasticities. These were followed by Coahuila (0.77), Chihuahua (0.72), Sonora (0.64), and Baja California Sur (0.61). Meanwhile, Nuevo León (0.37) and Sinaloa (0.33) experienced the lowest employment elasticities in the post-crisis period.

So far, it can be confirmed that the employment-output elasticities calculated for the total period at the national, regional, and state levels are high. According to the literature, this is to be expected when comparing the employment elasticities of developed and developing economies (Morén & Wändal, 2019; Kahn, 2000). In this sense, the elasticities obtained in this study for the country and the Northern region align with the findings of Görg et al. (2018), who estimated an employment-output elasticity of 0.80 for the OECD during 1960–2014, as well as the estimates of Kapsos (2005) and ECLAC (2000), who estimated an average elasticity of 0.70 and 0.60 respectively for Latin America. However, it is important to note that the sub-period analysis clearly highlights the adverse impact of the crisis on employment creation at the national, regional, and state levels.

In terms of sectoral contribution to employment creation in the Northern region and the country (Table 4), it is evident that the primary sector presents the lowest employment-output elasticities: regional (0.40) and national (0.38), and therefore is the sector that generates the fewest jobs in both the region and the country. This result can be interpreted based on three possible arguments: a) a high capital coefficient in the sector, which leads to productivity growth but not employment growth (ILO, 2013; ECLAC 2000, cited in Cruz & Ríos, 2014), b) the ongoing rural exodus in the country, and c) a combination of both (a and b).

On the other hand, in the secondary sector, the Northern Region (0.86) shows a high employment elasticity, although lower than the country (1.11), which has a very high employment-output elasticity. In the tertiary sector, the highest employment elasticities are observed: Northern Region (2.41) and Mexico (2.36), which confirms a process of tertiarization of the regional and national economy. This means that both the region and the country base job creation on the secondary and tertiary sectors, although to a greater extent in the tertiary sector, as shown by the employment-output elasticities in 7 of the 8 states that make up the region.

In summary, when the elasticity analysis is conducted for the entire period (2005–2013), a high employment elasticity is observed in the Northern Region (0.75), although lower than the national level (0.80), which is also high. This would mean that the global crisis context apparently did not have harmful effects in terms of job creation for the Northern Region, nor for the country.

Table 4. Northern Region. Employment-Output Elasticity by Sector and in the Total Period, 2005–2013

Region	Sectoral Elasticities 2005-2013			Total period 2005-2013
	Primary	Secondary	Tertiary	
Mexico	0.38	1.11	2.36	0.80
Región norte	0.4	0.86	2.41	0.75
Baja California	-1.31	5.16	5.17	1.58
Baja California Sur	5.32	1.04	3.87	1.14
Chihuahua	0.35	1.56	0.11	0.44
Coahuila	-0.86	1.02	3.29	1.02
Nuevo León	-4.6	0.64	1.54	0.52
Sinaloa	1.9	1.86	1.52	0.45
Sonora	1.31	0.46	3.68	0.81
Tamaulipas	-0.76	1.67	3.65	1.38

Source: Own elaboration based on Sistema de Cuentas Nacional of Mexico and the National Survey of Occupation and Employment by INEGI

However, the sub-period analysis shows that in the context of the crisis (2008–2010), there was a clear drop in job creation at the national level (0.60), followed by a slight recovery in the post-crisis period (0.65), although this employment-output elasticity is still far from that observed before the crisis in the country (0.79). In other words, in the post-crisis period, the country did not manage to recover the employment levels that existed before the crisis.

On the other hand, in the context of the crisis, a negative employment elasticity is observed in the Northern Region (-0.38), which implies that not only did job creation stop, but jobs created before the crisis were lost. However, for the post-crisis period, the Northern Region (0.70) recorded an employment elasticity equal to that observed before the crisis, which means that at least in the Northern Region, the jobs lost due to the global crisis were recovered.

Among the states, during the crisis and with negative employment-output elasticities, Sinaloa, Coahuila, Baja California Sur, and Baja California were the most affected, followed by Tamaulipas, whose elasticity fell to 0.12 during the crisis. In Sonora (0.62), there was only a slight drop in elasticity, reflecting the least damage from the crisis. In contrast, in Nuevo León and Chihuahua, the impact of the crisis was reflected in the post-crisis period (2011–2013), when they recorded a noticeable drop in employment elasticity: Nuevo León (0.37) and Chihuahua (0.72). In the post-crisis period (2011–2013), the states that achieved a significant recovery in employment elasticity were Baja California (1.06) and Tamaulipas (1.59), followed by Coahuila (0.77), Chihuahua (0.72), Sonora (0.64), and Baja California Sur (0.61).

Finally, the sectoral employment-output elasticities show that in the Northern Region and in the country, job creation relies more on the secondary and tertiary sectors. Throughout the period, the Northern Region (0.86) recorded a high employment elasticity in the secondary sector, but lower than that observed in the country (1.11). In the tertiary sector, the Northern Region (2.41) also recorded a high employment elasticity, slightly higher than the country (2.36), which indicates the tertiarization of economic activity at both regional and national levels.

4.2. On the determinants of employment

Various studies use macroeconomic variables to examine job creation in both developed and developing countries (Sodipe & Ogunrinola, 2011; Fofana, 2001). In Equation 1, the factors that stimulate job creation beyond economic growth are explored. By considering the average values of annual data for the states during the period 2005–2013, a coefficient of determination of $R^2 = 0.90$ is obtained, indicating a high explanatory power of the model in terms of employment generation, due to changes in GDP growth, foreign direct investment, gross capital formation, and public infrastructure spending.

Likewise, the probability of the F-statistic being < 0.05 indicates a 95% confidence level in the model, meaning that overall the model shows statistical significance between the independent variables

and employment. However, when looking at the probabilities associated with the t-statistic, we can see that all the coefficients are statistically significant, except for gross capital formation, which does not show the expected sign[6]. This implies that domestic investment is inhibited, leading to a decline in job creation in the region and the country during the crisis context.

Equation 1. $LgPOi = \beta 0 + \beta 1 LgPIBi + \beta\ 2LgIEDi + \beta 3 LgFBKi + \beta 4 LgGP$

```
. regress lgMPO0513 lgMPIB0513 lgMIED0513 lgMFBK0513 lgMGP0513

      Source |       SS       df       MS              Number of obs =      37
-------------+------------------------------           F(  4,    32) =   72.31
       Model |  7.84265781     4  1.96066445            Prob > F      =  0.0000
    Residual |  .855892449    32  .026746639           R-squared     =  0.9016
-------------+------------------------------           Adj R-squared =  0.8893
       Total |  8.69855026    36  .241626396           Root MSE      =  .16354

------------------------------------------------------------------------------
    lgMPO0513 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
--------------+---------------------------------------------------------------
  lgMPIB0513 |   .9260183   .1152729     8.03   0.000     .6912151    1.160821
  lgMIED0513 |   .1600255   .0857338     1.87   0.071    -.0146086    .3346596
  lgMFBK0513 |  -.3849062   .1146519    -3.36   0.002    -.6184444   -.1513679
   lgMGP0513 |    .252944   .0947128     2.67   0.012     .0600203    .4458676
       _cons |   1.089508   .3305343     3.30   0.002     .4162313    1.762784
------------------------------------------------------------------------------
```

The Breusch-Pagan test is applied to check for evidence of heteroskedasticity[7], for which a null hypothesis of constant variance is established (H_0 = constant variance). A chi-squared value of 1.63 and a p-value of 0.2012 (Prob > chi^2 = 0.2012) are obtained. Since the p-value is greater than 0.05, we cannot reject the null hypothesis our model has constant variance, and therefore, there is no heteroskedasticity.

5. Conclusions

This study examines the impact of economic growth on job creation in the Northern Region, its constituent states, and the country before the global crisis (2005–2007), during the crisis (2008–2010), and after the crisis (2011–2013). To this end, the employment-output elasticity coefficient is first calculated, and then a multiple regression model is used to explore the macroeconomic factors that influence job creation.

The first finding is that for the entire period, employment elasticity is high in the Northern Region (0.75), although lower than that recorded for the country (0.80). This suggests that the crisis did not affect job creation at the regional or national level. However, the sub-period analysis shows a clear drop in job creation during the crisis in both the Northern Region and the country. This decline was more abrupt in the region, where elasticity was negative, implying that not only did job creation stop, but previously created jobs were destroyed.

A second finding is that the states most affected during the crisis were Sinaloa, Coahuila, Baja California Sur, and Baja California, since they, like the Northern Region, had negative employment-output elasticities. They were followed by Tamaulipas, whose employment elasticity suddenly dropped to 0.12 during the crisis. The state of Sonora (0.62) experienced less severe effects on job creation, with only a slight drop in employment elasticity during the crisis. In contrast, in Nuevo León and Chihuahua, the impact of the crisis was reflected in the post-crisis period.

Another finding is that in the post-crisis period, the region recorded an employment elasticity equal to that observed before the crisis. This implies that the region recovered the jobs lost due to the global crisis, something that did not occur at the national level. The states that achieved a significant recovery in elasticity after the crisis were Baja California and Tamaulipas, followed by Coahuila, Chihuahua, and Baja California Sur. Additionally, the sectoral employment elasticities in both the region and the country show that job creation relies on the secondary and tertiary sectors, as confirmed by the very high sectoral employment elasticities of the states.

Therefore, the empirical evidence confirms a clear link between economic growth and job creation. Moreover, the working hypothesis of this study must be accepted, since the results of the econometric model show that job creation is explained by GDP growth, foreign direct investment, and public spending but paradoxically, not by domestic investment.

The results reveal the labor market's insufficiency in restoring equilibrium between labor supply and demand, highlighting the indispensable role of the State in restoring business confidence and encouraging entrepreneurs to invest a greater share of the value generated, thereby stimulating labor demand. In this sense, amid the pandemic context, a partnership between the State and the business sector undoubtedly becomes imperative for the region and the country in order to reverse the undeniable damage caused by COVID-19 in terms of economic

[6] Similar results were found in the analysis by sub-periods; see Equations 2, 3, and 4 in Appendix II.

[7] Tests for normality, multicollinearity, and the functional form of the model were also verified; see Annex III.

growth, job creation, and overall well-being.

In this regard, the current approach of the Fourth Transformation (4T) government in engaging with all business groups including its critics becomes highly relevant as a strategy to promote the necessary short- and medium-term investment across all sectors and branches of the economy. This aims to boost job creation in a context where domestic investment must play an increasingly central role, which may help improve the overall employment intensity in both the country and its regions.

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Appendix I

Table A. Mexico. GDP Growth Rates, Employment, and elasticities by period, subperiods, and sector

Entity	Period	GDP Growth Rate	Employment Growth Rate	Elasticity
Mexico	2005-2007	2.57	2.02	0.79
	2008-2010	1.15	0.69	0.60
	2011-2013	1.55	1.02	0.65
	2005-2013	2.11	1.68	0.80
Primary Sector	2005-2007	4.38	0.20	0.05
	2008-2010	-2.08	1.23	-0.60
	2011-2013	3.39	0.87	0.26
	2005-2013	2.48	0.94	0.38
Secondary Sector	2005-2007	1.60	2.06	1.29
	2008-2010	0.58	-0.40	-0.69
	2011-2013	0.37	1.96	5.29
	2005-2013	0.98	1.09	1.11
Tertiary Sector	2005-2007	3.07	2.41	0.78
	2008-2010	1.69	1.08	0.64
	2011-2013	2.12	0.77	0.36
	2005-2013	2.76	6.53	2.36

Source. Own estimates based on the Sistema de Cuentas Nacionales and the Encuesta Nacional de Ocupación y Empleo (INEGI).

Table B. Northern Region. GDP Growth Rates, Employment, and elasticities by period, subperiods, and sector

Entity	Period	GDP Growth Rate	Employment Growth Rate	Elasticity
Northern Region	2005-2007	3.57	2.51	0.70
	2008-2010	-0.41	0.16	-0.38
	2011-2013	2.25	1.57	0.70
	2005-2013	2.52	1.89	0.75
Primary Sector	2005-2007	4.12	0.24	0.06
	2008-2010	0.95	3.06	3.22
	2011-2013	3.86	0.63	0.16
	2005-2013	1.25	0.50	0.40
Secondary Sector	2005-2007	3.61	1.55	0.43
	2008-2010	-1.22	-1.00	0.81
	2011-2013	1.69	4.54	2.69
	2005-2013	2.20	1.89	0.86
Tertiary Sector	2005-2007	3.51	3.24	0.92
	2008-2010	0.03	0.52	15.08
	2011-2013	2.52	0.74	0.29
	2005-2013	2.81	6.79	2.41

Source. Own estimates based on the Sistema de Cuentas Nacionales and the Encuesta Nacional de Ocupación y Empleo (INEGI).

Table C. Baja California. GDP Growth Rates, Employment, and Elasticities by Period, Subperiods, and Sector

Entity	Period	GDP Growth Rate	Employment Growth Rate	Elasticity
Baja California	2005-2007	3.12	2.87	0.92
	2008-2010	-2.11	0.52	-0.24
	2011-2013	1.63	1.73	1.06
	2005-2013	1.38	2.19	1.58
Primary Sector	2005-2007	1.89	-3.21	-1.69
	2008-2010	3.35	3.54	1.06
	2011-2013	1.42	-9.87	-6.93
	2005-2013	1.31	-1.71	-1.31
Secondary Sector	2005-2007	3.59	3.39	0.94
	2008-2010	-4.77	-3.22	0.67
	2011-2013	0.93	7.37	7.92
	2005-2013	0.33	1.69	5.16
Tertiary Sector	2005-2007	2.86	3.63	1.27
	2008-2010	-0.68	2.11	-3.10
	2011-2013	2.04	1.00	0.49
	2005-2013	2.03	10.52	5.17

Source. Own estimates based on the Sistema de Cuentas Nacionales and the Encuesta Nacional de Ocupación y Empleo (INEGI).

Table D. Sonora. GDP Growth Rates, Employment, and elasticities by period, subperiods, and sector

Entity	Period	GDP Growth Rate	Employment Growth Rate	Elasticity
Sonora	2005-2007	3.64	2.32	0.64
	2008-2010	1.04	0.65	0.62
	2011-2013	3.77	2.41	0.64
	2005-2013	3.55	2.86	0.81
Primary Sector	2005-2007	5.04	3.74	0.74
	2008-2010	1.81	2.71	1.50
	2011-2013	3.88	2.67	0.69
	2005-2013	2.63	3.46	1.31
Secondary Sector	2005-2007	4.21	1.03	0.24
	2008-2010	1.21	0.10	0.08
	2011-2013	4.80	0.70	0.15
	2005-2013	4.43	2.04	0.46
Tertiary Sector	2005-2007	2.99	3.36	1.12
	2008-2010	0.79	0.72	0.91
	2011-2013	2.87	3.65	1.27
	2005-2013	2.94	10.82	3.68

Source. Own estimates based on the Sistema de Cuentas Nacionales and the Encuesta Nacional de Ocupación y Empleo (INEGI).

Table E. Chihuahua. GDP Growth Rates, Employment, and Elasticities by Period, Subperiods, and Sector

Entity	Period	GDP Growth Rate	Employment Growth Rate	Elasticity
Chihuahua	2005-2007	3.62	2.54	0.70
	2008-2010	-1.97	-2.82	1.43
	2011-2013	3.78	2.72	0.72
	2005-2013	2.31	1.03	0.44
Primary Sector	2005-2007	4.40	3.72	0.85
	2008-2010	2.36	2.74	1.16
	2011-2013	7.64	2.92	0.38
	2005-2013	3.97	1.40	0.35
Secondary Sector	2005-2007	3.69	1.57	0.42
	2008-2010	-4.69	0.08	-0.02
	2011-2013	5.18	8.28	1.60
	2005-2013	1.68	2.62	1.56
Tertiary Sector	2005-2007	3.50	1.70	0.49
	2008-2010	-0.77	-4.48	5.80
	2011-2013	2.59	1.10	0.42
	2005-2013	2.51	0.26	0.11

Source. Own estimates based on the Sistema de Cuentas Nacionales and the Encuesta Nacional de Ocupación y Empleo (INEGI).

Table F. Coahuila. GDP Growth Rates, Employment, and Elasticities by Period, Subperiods, and Sector

Entity	Period	GDP Growth Rate	Employment Growth Rate	Elasticity
Coahuila	2005-2007	2.84	4.83	1.70
	2008-2010	-0.05	0.11	-2.22
	2011-2013	1.77	1.37	0.77
	2005-2013	2.63	2.70	1.02
Primary Sector	2005-2007	1.82	4.61	2.53
	2008-2010	0.68	3.70	5.46
	2011-2013	-0.46	-9.04	19.75
	2005-2013	0.55	-0.47	-0.86
Secondary Sector	2005-2007	2.45	1.82	0.74
	2008-2010	-0.50	-0.30	0.59
	2011-2013	1.65	4.03	2.44
	2005-2013	2.65	2.71	1.02
Tertiary Sector	2005-2007	3.32	6.09	1.84
	2008-2010	0.39	0.24	0.62
	2011-2013	2.02	0.87	0.43
	2005-2013	2.73	8.98	3.29

Source. Own estimates based on the Sistema de Cuentas Nacionales and the Encuesta Nacional de Ocupación y Empleo (INEGI).

Table G. Nuevo León. GDP Growth Rates, Employment, and Elasticities by Period, Subperiods, and Sector

Entity	Period	GDP Growth Rate	Employment Growth Rate	Elasticity
Nuevo León	2005-2007	4.87	2.56	0.52
	2008-2010	0.34	1.45	4.31
	2011-2013	2.04	0.75	0.37
	2005-2013	3.29	1.72	0.52
Primary Sector	2005-2007	4.07	-12.34	-3.04
	2008-2010	3.17	16.59	5.23
	2011-2013	-0.33	-0.96	2.93
	2005-2013	0.47	-2.18	-4.60
Secondary Sector	2005-2007	5.60	1.80	0.32
	2008-2010	0.36	-0.56	-1.54
	2011-2013	0.73	2.33	3.22
	2005-2013	2.93	1.87	0.64
Tertiary Sector	2005-2007	4.41	3.48	0.79
	2008-2010	0.29	2.04	7.09
	2011-2013	2.90	0.07	0.02
	2005-2013	3.54	5.44	1.54

Source. Own estimates based on the Sistema de Cuentas Nacionales and the Encuesta Nacional de Ocupación y Empleo (INEGI).

Table H. Tamaulipas. GDP Growth Rates, Employment, and Elasticities by Period, Subperiods, and Sector

Entity	Period	GDP Growth Rate	Employment Growth Rate	Elasticity
Tamaulipas	2005-2007	1.94	2.21	1.14
	2008-2010	-0.78	-0.09	0.12
	2011-2013	1.13	1.79	1.59
	2005-2013	1.35	1.85	1.38
Primary Sector	2005-2007	2.02	1.35	0.67
	2008-2010	1.40	5.20	3.73
	2011-2013	-2.58	3.69	-1.43
	2005-2013	-1.59	1.21	-0.76
Secondary Sector	2005-2007	1.03	-0.51	-0.49
	2008-2010	-1.46	0.21	-0.15
	2011-2013	-0.32	5.7440	-17.90
	2005-2013	0.44	0.73	1.67
Tertiary Sector	2005-2007	2.60	3.83	1.47
	2008-2010	-0.42	-0.73	1.74
	2011-2013	2.30	0.15	0.06
	2005-2013	2.15	7.85	3.65

Source. Own estimates based on the Sistema de Cuentas Nacionales and the Encuesta Nacional de Ocupación y Empleo (INEGI).

Table I. Sinaloa. GDP Growth Rates, Employment, and Elasticities by Period, Subperiods, and Sector

Entity	Period	GDP Growth Rate	Employment Growth Rate	Elasticity
Sinaloa	2005-2007	2.87	0.04	0.01
	2008-2010	-0.23	0.70	-3.10
	2011-2013	2.24	0.74	0.33
	2005-2013	1.83	0.83	0.45
Primary Sector	2005-2007	6.36	-0.85	-0.13
	2008-2010	-1.86	0.47	-0.25
	2011-2013	7.65	3.12	0.41
	2005-2013	-0.21	-0.40	1.90
Secondary Sector	2005-2007	2.01	0.15	0.08
	2008-2010	-0.83	-5.05	6.08
	2011-2013	-1.44	3.9	-2.69
	2005-2013	0.41	0.77	1.86
Tertiary Sector	2005-2007	2.48	0.39	0.16
	2008-2010	0.34	2.57	7.46
	2011-2013	2.74	-0.69	-0.25
	2005-2013	2.68	4.07	1.52

Source. Own estimates based on the Sistema de Cuentas Nacionales and the Encuesta Nacional de Ocupación y Empleo (INEGI).

Table J. Baja California Sur. GDP Growth Rates, Employment, and Elasticities by Period, Subperiods, and Sector

Entity	Period	GDP Growth Rate	Employment Growth Rate	Elasticity
BCS	2005-2007	5.60	4.60	0.82
	2008-2010	-0.52	0.56	-1.07
	2011-2013	1.95	1.20	0.61
	2005-2013	3.30	3.75	1.14
Primary Sector	2005-2007	-2.48	-2.96	1.19
	2008-2010	2.33	-0.92	-0.39
	2011-2013	1.27	1.74	1.36
	2005-2013	0.28	1.49	5.32
Secondary Sector	2005-2007	4.46	7.93	1.78
	2008-2010	-4.21	-0.97	0.23
	2011-2013	3.65	3.84	1.05
	2005-2013	4.17	4.33	1.04
Tertiary Sector	2005-2007	6.40	4.88	0.76
	2008-2010	0.65	1.40	2.17
	2011-2013	1.40	0.39	0.28
	2005-2013	3.16	12.22	3.87

Source. Own estimates based on the Sistema de Cuentas Nacionales and the Encuesta Nacional de Ocupación y Empleo (INEGI).

Appendix II

Equation 2. LgPOi = β0 + β1LgPIBi + β 2LgIEDi + β3LgFBKi + β4LgGP

```
. regress lgMPO0507 lgMPIB0507 lgMIED0507 lgMFBK0409 lgMGP0507
```

Source	SS	df	MS	Number of obs =	37
				F(4, 32) =	54.61
Model	7.70205829	4	1.92551457	Prob > F =	0.0000
Residual	1.12839218	32	.035262256	R-squared =	0.8722
				Adj R-squared =	0.8562
Total	8.83045047	36	.245290291	Root MSE =	.18778

lgMPO0507	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lgMPIB0507	.9476868	.1390216	6.82	0.000	.664509	1.230865
lgMIED0507	.1551452	.0991617	1.56	0.128	-.0468405	.3571309
lgMFBK0409	-.4381021	.1794236	-2.44	0.020	-.803576	-.0726282
lgMGP0507	.2624237	.0991625	2.65	0.013	.0604363	.4644112

Equation 3. LgPOi = β0 + β1LgPIBi + β 2LgIEDi + β3LgFBKi + β4LgGP

```
. regress lgMPO0810 lgMPIB0810 lgMIED0810 lgMFBK09 lgMGP0810
```

Source	SS	df	MS	Number of obs =	37
				F(4, 32) =	64.12
Model	7.71195099	4	1.92798775	Prob > F =	0.0000
Residual	.962205304	32	.030068916	R-squared =	0.8891
				Adj R-squared =	0.8752
Total	8.67415629	36	.240948786	Root MSE =	.1734

lgMPO0810	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lgMPIB0810	.9622479	.1277972	7.53	0.000	.7019335	1.222562
lgMIED0810	.1207066	.0805372	1.50	0.144	-.0433424	.2847555
lgMFBK09	-.3559651	.1223212	-2.91	0.007	-.6051253	-.1068049
lgMGP0810	.2068423	.0818103	2.53	0.017	.0402001	.3734845
_cons	.8619368	.3629113	2.38	0.024	.1227107	1.601163

Equation 4. LgPOi = β0 + β1LgPIBi + β 2LgIEDi + β3LgFBKi + β4LgGP

```
. regress lgMPO1113 lgMPIB1113 lgMIED1113 lgMFBK0914 lgMGP1113
```

Source	SS	df	MS	Number of obs =	37
				F(4, 32) =	85.27
Model	7.87767942	4	1.96941986	Prob > F =	0.0000
Residual	.739064609	32	.023095769	R-squared =	0.9142
				Adj R-squared =	0.9035
Total	8.61674403	36	.239354001	Root MSE =	.15197

lgMPO1113	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lgMPIB1113	.9169663	.1057687	8.67	0.000	.7015226	1.13241
lgMIED1113	.2302106	.0757837	3.04	0.005	.0758442	.3845769
lgMFBK0914	-.3076541	.0865426	-3.55	0.001	-.4839356	-.1313727
lgMGP1113	.1215058	.0727158	1.67	0.104	-.0266116	.2696231
_cons	.7615838	.3152752	2.42	0.022	.1193892	1.403778

Appendix III

*Model Specification: Ramsey Test (ovtest)

```
Ramsey RESET test using powers of the fitted values of lgMPO0513
       Ho:  model has no omitted variables
                  F(3, 29) =      0.08
                  Prob > F =      0.9718
```

The null hypothesis (H_0) is that there are no omitted variables. The p-value is greater than 0.05 (Prob > F = 0.9718). Therefore, the null hypothesis is not rejected. This means that there are no omitted variables in the model.

*Heteroscedasticity in the model: Breusch-Pagan Test (estat hettest)

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of lgMPO0513

         chi2(1)      =     1.54
         Prob > chi2  =   0.2149
```

The null hypothesis (H_0) is that the variance is constant. The p-value is greater than 0.05 (Prob > F = 0.2149). Therefore, the null hypothesis is not rejected. The model does not present heteroscedasticity.

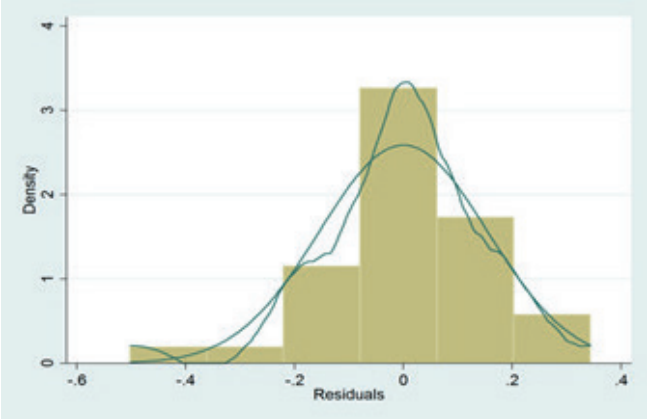
*Normality in the model: Jarque-Bera normality test (predict resid, residuals; then: jb resid)

```
. jb resid
Jarque-Bera normality test:  .9788 Chi(2)    .613
Jarque-Bera test for Ho: normality:
```

The null hypothesis (H_0) is that the residuals are normally distributed. The p-value is greater than 0.05 (Prob = 0.613).

The null hypothesis is not rejected. In the model, the residuals follow a normal distribution, as also shown by the graphical method:

Histogram of the residuals:



*Multicollinearity in the model: Variance Inflation Factor (VIF)

Variable	VIF	1/VIF
lgMFBK0513	6.40	0.156305
lgMPIB0513	5.04	0.198370
lgMIED0513	3.48	0.287703
lgMGP0513	3.22	0.310878
Mean VIF	4.53	

*There are two metrics to determine whether a variable shows correlation:

1st: VIF > 5 = Correlation; VIF > 10 = Strong correlation

2nd: VIF > 4 = Correlation; VIF > 8 = Strong correlation

The second is stricter than the first. The average of the VIF values and the highest of these factors are both below 10; therefore, the variables are significant at the 10% level and can be jointly included in the model specification, as they do not generate multicollinearity.

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Interdisciplinary Faculty of Economic and Administrative Sciences

RESEARCH

Concurrence in the public bid of projects PPP, 2018

Concurrencia en la Licitación de Proyectos APP, 2018

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Eva Grissel Castro Coria[1] and
Rodrigo Gómez Monge[2]

[1] Corresponding author: PhD student in Public Policy, Master's degree in Law with a specialization in Humanities, Universidad Michoacana de San Nicolas de Hidalgo (UMSNH).
Email: eva072001@hotmail.com ORCID: https://orcid.org/0000-0001-6106-5631

[2] PhD in Applied Economics from Universidad de Santiago de Compostela and PhD in Administrative Sciences from Instituto Politécnico Nacional, SNI Level I, professor at the Faculty of Economics "Vasco de Quiroga" at Universidad Michoacana de San Nicolas de Hidalgo.
Email: rmonge@umich.mx, ORCID: https://orcid.org/0000-0001-8393-2855

Abstract

The object of the investigation is to identify the percentage of concurrence in the bidding process of the Strategy Program to Promote PPP Projects, block II, for this purpose, data mining is used as a methodology, intending to examine data public, identify patterns and answer the research question: What is the percentage of concurrence in the tender of the Strategy Program to Promote PPP Projects, Block II? Then, the results are presented, the findings are highlighted and as a conclusion, it is proposed to implement a previous stage called: prequalification, of a mandatory nature, to ensure the participation of a more significant number of bids, verify the capacity of potential bidders, gather complete proposals for technical and economic evaluation, and consider negotiation, as an alternate element. The limitation of the research is limited to the amount of data to be analyzed within block II, and as future lines of research, it is suggested to compare the processes of similar sectors within block I.

Keywords: PPP, Concurrence, Public Bid, México, Data Mining.

Resumen

El objeto de la investigación es identificar cual es el porcentaje de concurrencia en el proceso de licitación del Programa de Estrategia de Impulso a los Proyectos APP, bloque II, para ello, se utiliza la minería de datos como metodología, con la intención de examinar datos públicos, identificar patrones y dar respuesta a la pregunta de investigación: ¿Cuál es el porcentaje de concurrencia en la licitación del Programa de Estrategia de Impulso a los Proyectos APP, Bloque II?, luego entonces, se presentan los resultados, se resaltan los hallazgos y como conclusión se propone implementar una etapa previa denominada: precalificación, de naturaleza obligatoria, para asegurar la participación de un mayor número de ofertas, verificar la capacidad de los posibles licitantes, reunir propuestas completas para la evaluación técnica y económica, y considerar la negociación, como elemento alterno. La limitación de la investigación se circunscribe a la cantidad de datos a analizar dentro del bloque II, y como futuras líneas de investigación se sugiere comparar los procesos de los sectores similares dentro del bloque I.

Palabras Clave: APP, Concurrencia, Licitación, México, Minería de datos.

Introduction

This study introduces the reader to a specific concept underpinning the research: What should be understood by Public-Private Partnerships (PPPs)? This question is addressed from academic, regulatory, and international best practices perspectives. To this end, three key characteristics are identified: 1) the contractual term, 2) the financing or payment method, and 3) the social benefit. These characteristics develop within a cycle that begins with the preparation phase and ends with the implementation phase, during which the bidding stage arises. Among other principles, this stage must safeguard competitiveness and participation, as these are indispensable elements for fostering a genuine contest.

Building on the above, the second section develops the importance of participation (concurrence), followed by the justification for analyzing the PPP Project Promotion Strategy Program, Block II. It is important to clarify that the 2013-2018 National Development Plan, published in the Official Federal Gazette (DOF), was implemented during the administration of President Enrique Peña Nieto. This plan established in its fourth axis, second section, the need to eliminate barriers limiting the country's productive potential and to foster infrastructure projects through PPPs. Consequently, in 2017, the Comprehensive Strategy Program to Promote PPP Projects was launched for investment projects planned during 2017 and 2018, known as Block I and Block II.

Focusing on 2018 is justified by the fact that the projects tendered that year belonged to the same sector — the road sector — and their bidding documents allow for identifying patterns to compare levels of participation.

The methodology used is data mining, aimed at obtaining public data, identifying patterns, and answering the research question: What is the percentage of participation in the public bidding of the PPP Project Promotion Strategy Program, Block II? After developing the methodology, results are presented, findings highlighted, and a conclusion is proposed to implement a preliminary stage called prequalification.

The importance of Public-Private partnerships

PPPs have been defined as "private initiatives to finance projects" (Vicher, 2020, p. 69), aimed at delivering new or maintained goods, services, and infrastructure to society by the State (Sorace, Domenico et al., 2006). They materialize through a "long-term contract between a private entity and a government body to provide an asset or public service, where the private entity assumes significant risk, is responsible for management, and remuneration is linked to performance" (World Bank Group, 2015, p. 5). Consequently, decision-making shifts from horizontal, general relationships to more specialized, hierarchical ones (Castro Coria, 2020). This change implies that the government moves from ordering to a more parallel, almost horizontal relationship, as PPPs involve granting concessions for infrastructure, goods, and services, transferring decision-making capacity (Vicher, 2020, p. 76), especially when financing and performance-based payments are involved.

One key characteristic of PPPs is that they are long-term contracts, which require coordinated decision-making, since the Inter-American Development Bank (IDB) points out that long-term contracts become complex as initial conditions may change due to unforeseen future requirements and rules (IDB, 2020a).

The second characteristic is the payment mechanism, which must be linked to performance. Several mechanisms exist: first, the private entity may receive payment through user fees; second, periodic government payments; and third, a mixed mechanism combining both (World Bank Group, 2015, p. 21).

PPPs are especially characterized by financing projects when the government lacks resources but has obligations to fulfill — goods or services to deliver to citizens — or when resources exist but are allocated to other projects (Gómez Monge & Castro Coria, 2020). Private financing arises from scarcity of public funds. Although initial financing costs may be higher compared to fully public financing, the transfer of risk from taxpayers to the private sector's performance is critical (Garcia-Kilroy & P. Rudolph, 2017, p. 14). Accordingly, the private sector commits to maintaining service quality and efficient resource management (Engel et al., 2014).

The third characteristic is the complexity of a PPP project because its goal is to increase social welfare and investment levels in the country (LAPP, 2018, art. 2) through infrastructure and service execution. The PPP project cycle is complex, involving several phases that establish regulatory, administrative, and technical bases for preparation and implementation. The IDB emphasizes the importance of defining processes, responsibilities, and institutional coordination mechanisms (IDB, 2020, p. 6).

The importance of participation as a mechanism for involvement

The objective of any public tender is to open doors to competitiveness. A key element to achieve this competitiveness is participation, as it is essential to generate enough competitors (Fernández Ruiz, 2015). Therefore, the World Bank in its PPP project reference guide (2015, pp. 170-174) recommends:

1. Making project information available to all interested parties both in person and online
2. Providing information and clarifying doubts about the procedure
3. Establishing clear evaluation criteria depending on the project's nature
4. Setting criteria for managing problems, especially when only one or no suitable offers are received

Competitiveness together with participation are guiding principles for the bidding stage because they ensure transparency and that the public sector receives the highest number of quality offers (IDB, 2020b). International best practices recommend implementing a preliminary stage called prequalification to verify the capacity of potential bidders before the tender begins. This stage aims to limit non-competitive participants and ensure complete proposals (IDB, 2020b; Kerf et al., 1998).

In Mexico, PPPs are regulated by the Public-Private Partnerships Law (LAPP), published in the DOF on January 16, 2012, and its Regulation (RLAPP), published November 5, 2012. These binding instruments govern tender procedures and stipulate that competitions must be conducted according to the principles of legality, free participation and competition, objectivity and impartiality, transparency and publicity, and equal conditions for all participants (LAPP, 2018, art. 38).

This is highly relevant because the Political Constitution of the United Mexican States (CPEUM) establishes that concessions in their various forms are vital for the country's economic and social development (CPEUM, 2019, arts. 25, 27, 28). Therefore, decisions by authorities in this area require more rigorous analysis than usual (SJF, 2016). The LAPP aims to regulate PPP project development under the principles of Articles 25 and 134 of the CPEUM, protecting the national economy through strong, dynamic, permanent, and equitable democratic planning actions that promote economic growth and free competition in all fields (SJF, 2016). Consequently, the administrative bidding procedure must adhere to these essential principles:

> "Participation, which ensures the public administration receives a larger number of offers, thereby increasing the possibility of selection and obtaining better conditions regarding price, quality, financing, and timeliness; 2) Equality, referring to the status of bidders relative to the administration and each other; 3) Publicity, allowing interested parties access to all information from the call for offers to the final stages; and 4) Opposition or contradiction, derived from due process, enabling interested parties to engage in disputes over competing interests, challenge others' proposals, and defend their own" (SJF, 2007)

Thus, ensuring participation—and consequently the greatest number of bidders and viable proposals—is of vital importance. Therefore, authorities' decisions when preparing tender documents must be based and justified on this principle (CPEUM, 2019, art. 16). By guaranteeing participation, the aim is to increase social welfare and investment levels (LAPP, 2018, art. 2). Hence, requirements that limit competition and free participation should not be imposed (LAPP, 2018, art. 47). This essentially involves applying game theory to determine which procedural modality, given a certain information structure, can stimulate the best competition by encouraging the most rational decisions (Amster & Pinasco, 2015).

The PPP tender procedure in the PPP project promotion strategy program, Block II

For the case study, the implementation phase is analyzed specifically the bidding stage, as this stage

will select the private entity responsible for project execution. The bidding stage begins with preparing at least the following documents: the call for bids, bidding rules, the PPP contract model, annexes, technical project studies, and feasibility analyses (IDB, 2020, p. 14). Activities include publishing the call, information or clarification meetings, submission and evaluation of technical and economic proposals; the latter is split into two parts — legal and technical proposals are submitted first and evaluated by the contracting authority, followed by economic proposals (RLAPP, 2017). Finally, the award is announced, and the contract signed (IDB, 2020, p. 14).

The case study analyzed the PPP Project Promotion Strategy Program, which aimed to promote APPs (Secretariat of Finance and Public Credit, 2017) during 2017 (Block I) and 2018 (Block II). The budgeted PPP projects for 2018 (Block II) numbered eighteen (see annex 1); however, only four projects were tendered (see table 1), all within the same sector—the road sector. Additionally, one project was directly awarded and is currently in operation/execution, while the others did not proceed with the registration process.

Table 1. PPP projects 2018 (Block II) in operation/execution stage

Illicit number	Description
Secretariat of Communications and Transportation	
APP-009000959-E456-2017	Rehabilitation and maintenance of the Campeche – Merida road section, in Campeche and Yucatan.
APP-009000959-E455-2017	Rehabilitation and maintenance of the Arriaga – Tapachula road section, in Chiapas.
APP-009000959-E12-2017	Rehabilitation and maintenance of the San Luis Potosi – Matehuala road section, in San Luis Potosi.
APP-009000959-E454-2017	Rehabilitation and maintenance of the Tampico (Altamira) – Cd. Victoria road section, in Tamaulipas.
Governorship	
Direct award	Expansion and equipment of the penitentiary complex in Papantla, Veracruz.

Source: Information from the National Transparency and Access to Information Platform

The projects tendered in 2018, known as Block II, are identified by a unique, non-repetitive tender number. The four tendering processes are consistent, as they were carried out by the same sector, allowing for the identification of patterns to compare levels of competition. A key feature of the bidding phase in a Public-Private Partnership (PPP) project is negotiation. The World Bank has stated that negotiation, as a tool, should be adopted by each country based on its political and social circumstances, as it may reduce the transparency of the tendering process. Nevertheless, it considers it relevant to assess the possibility of negotiating with bidders regarding their proposals (World Bank Group, 2015, p. 165).

Methodology

This research is presented as a non-experimental, descriptive, and quantitative study. It employs data mining (DM) to transform data, facilitating its processing and interpretation (Riquelme et al., 2006, p. 2). DM has been recognized as an appropriate methodology for identifying potential risks in government procurement (Organization for Economic Co-operation and Development, 2017). It aims to prioritize results to support decision-making processes (Lorenzo Martínez Luna, 2011). Accordingly, the procedure seeks to collect data, identify patterns, and interpret the resulting knowledge (Asencios, 2004).

This research is focused on answering a specific research question and achieving the stated objective.

Research question:

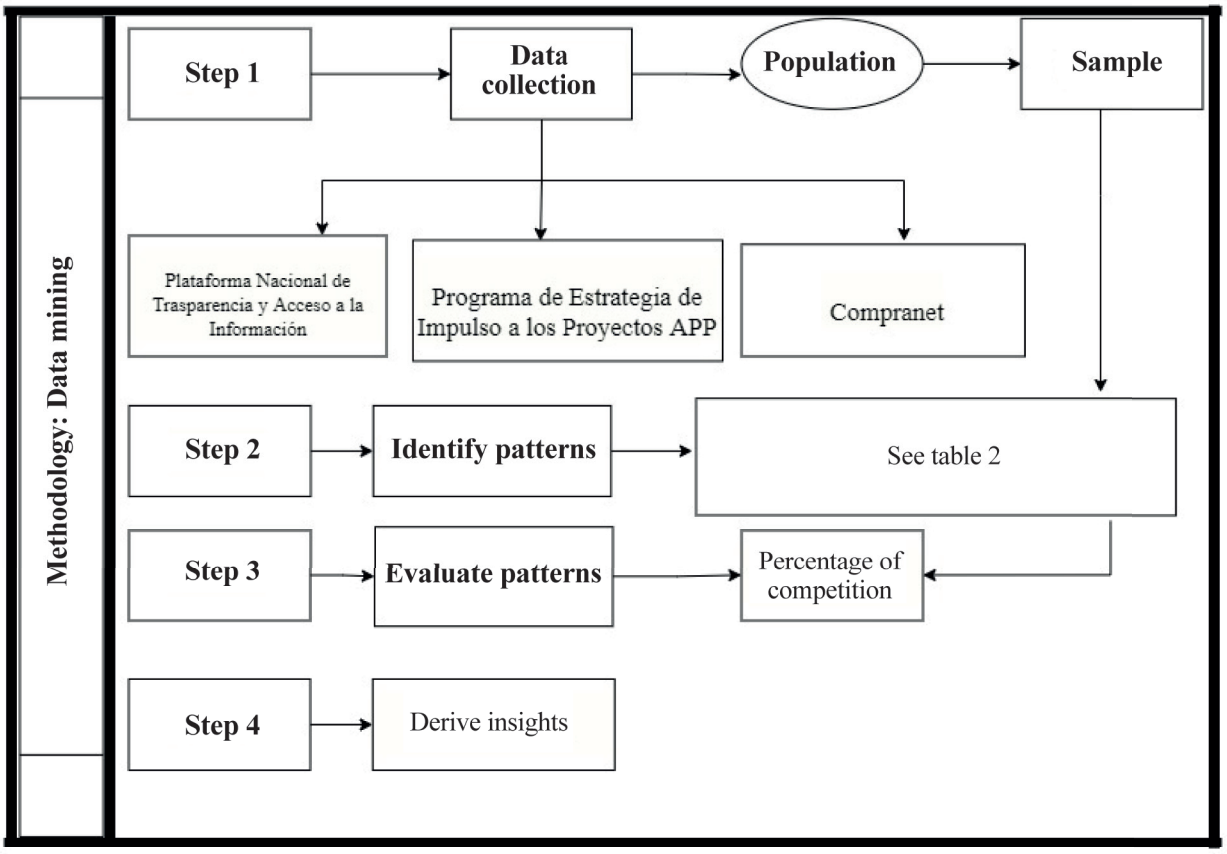
What is the level of competition in the tendering process of the PPP Project Promotion Strategy Program, Block II?

Objective:

To identify the level of competition in the tendering process of the PPP Project Promotion Strategy Program, Block II.

To answer the research question, the following steps are followed:

Figure 1. Methodological design



Source: Own elaboration based on information from Hernandez Sampieri et al., 2014; Torres Hernandez & Navarro Chavez, 2014; Vilalta J., 2016.

To obtain the data, we relied on three sources:

1. Programa de Estrategia de Impulso a los Proyectos PPP (Secretaría de Hacienda y Crédito Público, 2017) focusing on the information from block II;
2. Plataforma Nacional de Transparencia y Acceso a la Información (PNT)
3. Plataforma de contrataciones gubernamentales Compranet (Compranet), which contains a large amount of data for analysis in accordance with the LAPP(Cámara de Diputados del H. Congreso de la Unión, 2018, art. 11)

The objective was to identify the number of projects scheduled for the 2018 fiscal year (Block II). Once this was done, the national transparency platform was used to request the bidding number for each project under execution/operation, and finally, the official information regarding the bidding processes was downloaded.

To identify the patterns:

From the four PPP projects of 2018 (block II) in the operation/executation stage, as described in Table 1, and tendered by Secretaría de Comunicaciones y Transportes, the following information was extracted and analyzed:

1. Bidding documents: Execution period, evaluation type, disqualification criteria (Secretaría de Comunicaciones y Transportes, 2018n, 2018m, 2018o, 2018p)
2. Contract model: Payment and financing method (Secretaría de Comunicaciones y Transportes, 2018s, 2018r, 2018q, 2018t)
3. Technical proposal opening minutes: General participation percentage and by consortium (Secretaría de Comunicaciones y Transportes, 2018a, 2018b, 2018c, 2018d)

4. Technical proposal evaluation and financial proposal opening minutes: Disqualification criteria of technical proposals (Secretaría de Comunicaciones y Transportes, 2018e, 2018f, 2018g, 2018h)

5. Tender decision: Percentage of awards by consortium, project winners without competitor breakdown, winners with competitor breakdown, contractual amount data per winning consortium including VAT, and final participation rate (Secretaría de Comunicaciones y Transportes, 2018i, 2018j, 2018k, 2018l)

To assess or measure the patterns:

They are assessed as follows:

Table 2. PPP contracting patterns

Element	Pattern
Private actors	General participation percentage Participation percentage by consortium Participation rate per procedure Final participation rate Winners per project
Contracting form Payment method and financing	Contract amount data per winning consortium with and without VAT
Public actors	Decision criteria Disqualification criteria of technical proposal

Information from: Secretaría de Comunicaciones y Transportes, 2018c, 2018n, 2018m, 2018d, 2018e, 2018f, 2018g, 2018h, 2018i, 2018j, 2018k, 2018l, 20180, 2018p, 2018t, 2018q, 2018r, 2018s, 2018a, 2018b.

To interpret the knowledge:

The interpretation of knowledge is closely related to the objective of our research: To analyze competition in public procurement for the PPP Programa de Estragia de Impulso, Block II.

Results

As general information, prior to the specific patterns required by the methodology, it is important to note the following: the four procedures analyzed in this study have a 10-year execution term, are fully privately financed, required the presence of a social witness, and used the evaluation criterion known as points and percentages, as defined in the tender documents. All four procedures were carried out by the same contracting authority or purchasing unit—SCT-General Directorate for Road Maintenance—and overseen by the same public official: the Director of Planning and Evaluation. From the four procedures analyzed, a total of 17 concessionaires participated, submitting 24 bids in total, meaning that several concessionaires submitted bids for more than one procedure (see Table 3).

Table 3. Overall participation rate

Procedure tender number	Number of bidding consortia	Participation rate
APP-009000959-E12-2017	8	33.33%
APP-009000959-E454-2017	4	16.67%
APP-009000959-E455-2017	5	
APP-009000959-E456-2017	7	29.17%
Grand total	24	100.00%

Own elaboration based on Secretaría de Comunicaciones y Transportes, 2018a, 2018b, 2018c, 2018d

From table 3, we can deduce the following:

1. The procedure for the rehabilitation and maintenance of Tampico (Altamira) - Cd. Victoria highway section in Tamaulipas (APP-009000959-E454-2017), received the fewest technical proposals––only four.

2. Next is Arriaga – Tapachula highway section in Chiapas (APP-009000959-E455-2017) with five proposals,

3. Followed by the Campeche – Merida highway section in Campeche and Yucatan (APP-009000959-E456-2017) with seven proposals,

4. The procedure with the highest number of bidders and proposals was the San Luis Potosi – Matehuala highway section in San Luis Potosi (APP-009000959-E12-2017).

Regarding the consortia, two strategic alliances were identified: E and E.1, and F and F.1, meaning the leading consortia partnered with other companies (see Table 4). In Table 4, it is also noted

that Consortium A participated in three procedures and won one, with an individual success rate of 33.33%. Consortia D, I, and M each participated only once and won their respective bids, resulting in an individual success rate of 100%. The overall success rate for the four awarded consortia—based on the number of times they participated—is 83.33%.

Table 4. Participation rate by consortium

Consortium ID	Number of bids submitted	General participation	Winner/ Loser	Individual success rate
A	3	12.50%	Winner	33.33%
B	3	12.50%	Loser	0%
C	2	8.33%	Loser	0%
D	1	4.17%	Winner	100%
E	1	4.17%	Loser	0%
E.1	1	4.17%	Loser	0%
F	1	4.17%	Loser	0%
F.1	1	4.17%	Loser	0%
G	2	8.33%	Loser	0%
H	1	4.17%	Loser	0%
I	1	4.17%	Winner	100%
J	2	8.33%	Loser	0%
K	1	4.17%	Loser	0%
L	1	4.17%	Loser	0%
M	1	4.17%	Winner	100%
N	1	4.17%	Loser	0%
O	1	4.17%	Loser	0%
Grand total	**24**	**100%**	**4 winners**	

Own elaboration based on Secretaría de Comunicaciones y Transportes, 2018a, 2018b, 2018c, 2018d, 2018i, 2018j, 2018k, 2018l

Now, analyzing the bidding participation per procedure, and considering the full evaluation process (1. Legal and technical documentation review, 2. Financial proposal evaluation), we observe the following:

Table 5 shows that four consortia submitted their technical proposals, and only two consortia proceeded to the analysis of the financial proposal, resulting in an initial participation reduction of 50% compared to the final proposals evaluated in their economic aspect.

Table 6 shows that five consortia submitted their technical proposals, all five met the legal documentation requirements, but only two consortia proceeded to the analysis of the financial proposal, resulting in an initial participation reduction of 60% compared to the final proposals evaluated in their economic aspect, since only two were considered for evaluation.

Table 7 identifies seven consortia participating at the beginning of the procedure; however, of the seven initial consortia, only one proposal is viable for economic analysis, so the initial competition decreases by -85.71% compared to the final proposals evaluated economically. Additionally, one proposal is discarded at the stage of legal documentation submission.

Table 8 shows the process with the highest number of consortia at the beginning of the procedure; however, of the eight initial consortia, only one proposal is viable for economic analysis, reducing the initial competition by -87.5% compared to the final proposals economically evaluated.

Therefore, in general terms, the final concurrence is presented in Table 9.

Table 5. Participation rate – procedure APP-009000959-E454-2017

APP-009000959-E454-2017 Rehabilitation and Maintenance of the Tampico (Altamira) - Cd. Victoria highway, in Tamaulipas								
Consortium ID	**Technical score**	**Financial score**	**Total score**	**Amount without IVA**	**Amount with IVA**	**Legal documentation**	**Thecnical documentation**	**Financial documentation**
M	52.6	40	92.6	4,477,902,538.28	5,194,366,944.40	Compliant	Compliant	Compliant
B	0	0	0	$0	$0	Compliant	Non-compliant*	Not evaluated
N	50.6	39.71	90.31	4,512,810,220.00	5,234,859,855.20	Compliant	Compliant	Compliant
O	0	0	0	$ 0	$ 0	Compliant	Non-compliant **	Not evaluated

Source: Secretaría de Comunicaciones y Transportes, 2018d, 2018l, 2018h
Note (*) Did not meet the required coverage index (>1.10) for 2015
(**) Did not submit audited financial statements for 2015 and 2016

Table 6. Participation rate - procedure APP-009000959-E455-2017

APP-009000959-E455-2017 Rehabilitation and Maintenance of the Arriaga – Tapachula highway, in Chiapas								
Consortium ID	**Technical score**	**Financial score**	**Total**	**Amount without IVA**	**Amount with IVA**	**Legal documentation**	**Thecnical documentation**	**Financial documentation**
H	48.5	38.95	87.45	9,899,926,369.00	11,483,914,588.04	Compliant	Compliant	Compliant
F.1	0	0	0	$0	$0	Compliant	Non-compliant (*)	Not evaluated
A	0	0	0	$0	$0	Compliant	Non-compliant(**)	Not evaluated
I	47.5	40	87.5	9,639,923,130.00	11,182,310,830.80	Compliant	Compliant	Compliant
J	0	0	0	$0	$0	Compliant	Non-compliant (***)	Not evaluated

Source: Secretaría de Comunicaciones y Transportes, 2018e, 2018i, 2018a

Note: (*) Grupo Emprendedor Caltia did not provide the payment receipt for the November 2017 declaration. Sociedad Anonima de Obras y Servicios Copasa did not provide commercial background information nor the list of suppliers who have granted them commercial credits for the financing of similar projects

(**) Did not provide the written statement confirming knowledge of the work site and its conditions

(***) Constructora Marko did not submit the monthly tax declarations nor the corresponding payments for the months of February, July, and September 2017, and did not provide a copy of the certified public accountant who issued the financial statements. Servicios Mexicanos de Ingenieria Civil did not submit the payments corresponding to the 2017 tax declarations, nor a copy of the accountant's certification who issued the reports. Magnamaq did not provide a copy of the accountant's certification who issued the reports. Groupo Concesionario de Mexico did not submit the payments corresponding to the tax declarations for the months of May, June, July, August, September, October, and December 2017, nor a copy of the accountant who issued the reports.

Table 7. Competition percentage for procedure APP-009000959-E456-2017

APP-009000959-E456-2017 Rehabilitation and Maintenance of the Campeche – Merida highway, in Campeche and Yucatan								
Consortium ID	**Technical score**	**Financial score**	**Total**	**Amount without IVA**	**Amount with IVA**	**Legal documentation**	**Thecnical documentation**	**Financial documentation**
A	51.6	0	51.6	5,145,843,806.85	5,969,178,815.95	Compliant	Compliant	Non-compliant(*)
B	0	0	0	$	$	Compliant	Non-compliant (**)	Not evaluated
C	0	0	0	$0	$0	Non-compliant(***)	Not evaluated	Not evaluated
D	53	40	93	4,389,740,148.45	5,092,098,572.20	Compliant	Compliant	Compliant
E	52.2	0	52.2	6,548,885,196.67	7,596,706,828.14	Compliant	Compliant	Non-compliant (****)
F	0	0	0	$0	$0	Compliant	Non-compliant (*****)	Not evaluated
G	0	0	0	$0	$0	Compliant	Non-compliant (******)	Not evaluated

Source: Secretaría de Comunicaciones y Transportes, 2018f, 2018j, 2018b

Note: (*) Proposes standard monthly unit prices that are not applicable; the economic offer amount is affected because if the monthly unit prices are cancelled, the proposal amount is affected; there are errors related to the financial model integration

(**) (i) Does not meet financial ratios, (ii) does not include the bid bond guarantee in documentation, (iv) fails the bases and affects the validity and solvency.

(***) ICA Infraestructura omitted to include a copy of the public deed showing powers of legal representatives

(****) Monthly Unit Prices were not used to determine the "Scheduled Program of Monthly Unit Prices for 2018-2028"; (2) amounts listed for the Supervisor Manager payment do not correspond; there is an error in the financial model form date

(*****) Does not submit tax declaration payments nor commercial background and supplier's situation. Grupo Emprendedor Caltia did not present the November 2017 complementary declaration payment receipt. Sociedad Anonima de Obras y Servicios does not present commercial background nor suppliers lists that granted commercial credits for similar projects.

(******) Promotora y Desarrolladora Mexicana did not present payment receipts for complementary declarations for January, March, April, and June 2017; Desarrollo de Terracerias did not present lists of banks and/or suppliers granting banking or commercial credits for similar projetcs

Table 8. Competition percentage for procedure APP-009000959-E12-2017

APP-009000959-E12-2017 Rehabilitación y Conservación del tramo carretero San Luis Potosí - Matehuala, en San Luis Potosí								
Consortium ID	**Technical score**	**Financial score**	**Total**	**Amount without IVA**	**Amount with IVA**	**Legal documentation**	**Thecnical documentation**	**Financial documentation**
B	0	0	0	$0	$0	Compliant	Non-compliant (*)	Not evaluated
E.1	49.9	0	49.9	5,585,933,795.41	6,479,683,202.68	Compliant	Compliant	Non-compliant (**)
C	0	0	0	$0	$0	Compliant	Non-compliant (***)	Not evaluated
A	53.3	40	93.3	5,530,007,272.30	6,414,808,435.87	Compliant	Compliant	Compliant
K	0	0	0	$0	$0	Compliant	Non-compliant (****)	Not evaluated
L	0	0	0	$0	$0	Non-compliant (*****)		Not evaluated
J	45.9	0	45.9	7,021,256,159.99	8,144,657,145.59	Compliant	Compliant	Non-compliant (******)
G	0	0	0	$0	$0	Compliant	Non-compliant (********)	Not evaluated

Source: Secretaría de Comunicaciones y Transportes, 2018g, 2018k, 2018c

Note: (*) Does not comply with coverage indices for years 2015 and 2016

(**) Data regarding the monthly unit price is inconsistent with the monthly unit price catalog; there is an error in the scheduled program

(***) Does not present 2017 annual declarations before SAT

(****) Api Movilidad did not present financial statements for 2015, professional license of the accountant, nor commercial backgrounds or supplier lists; Avianza Soluciones y Movilidad did not present internal financial statements for 2017 nor the sworn statement legend; Constructora Garza Ponce did not present commercial backgrounds nor supplier credit lists; no banking or commercial backgrounds presented

(*****) Does not present power of attorney of the consortium representative elevated to public deed

(******) Inconsistencies in initial rehabilitation program, financial model; starts work on the same segment in the same month; balance sheet does not include requested social capital

(********) Does not present financial statements or cash flow for 2015 and 2016

Table 9. Final competition percentage

Procedure tender number	Number of consortia bidding per procedure	Number of consortia bidding per procedure	Reduction percentage
APP-009000959-E12-2017	8	1	-87.500%
APP-009000959-E454-2017	4	2	-50.000%
APP-009000959-E455-2017	5	2	-60.000%
APP-009000959-E456-2017	7	1	-85.714%

Source: Secretaría de Comunicaciones y Transportes, 2018a, 2018b, 2018c, 2018d, 2018e, 2018f, 2018g, 2018h, 2018i, 2018j, 2018k, 2018l

Finally, regarding the most common reasons for discarding proposals, the following stand out:

1. In the legal section, two consortia omitted to present a copy of the public deed showing powers of legal representatives, and the consortium representative's power of attorney was not elevated to a public deed.
2. In the technical section, nine consortia were disqualified for failing to submit payments of tax declarations, commercial background information, supplier lists granting commercial credits for similar projects, and the public accountant's copy who issued the reports.
3. Three consortia failed to meet coverage indices, and one did not submit a written statement acknowledging knowledge of the work site and conditions.
4. In the economic section, four consortia had inconsistencies in unit prices and scheduled programs.

In summary, the winning consortia are broken down in Table 10:

Table 10. Winners by project

Tender number	Description	Participant	Amount without IVA	Amount with IVA
APP-009000959-E456-2020	Rehabilitation and Maintenance of the Campeche – Merida highway, in Campeche and Yucatan	Consortium: Calzada Construcciones S.A. de C.V.; Construcciones y Dragados del Sureste S.A. de C.V.; Construcciones Urales S.A. de C.V; Cointer Concesiones México S.A. de C.V., and Icapsa Infraestructura y Desarrollo S.A. de C.V.	$4,389,740,148.45	$5,092,098,572.20
APP-009000959-E455-2020	Rehabilitation and Maintenance of the Arriaga – Tapachula highway, in Chiapas	Consortium: Impulsora de Desarrollo Integral S. A de C.V., Gami Ingeniería e Instalaciones S. A de C.V. Supra Constructores S. A de C.V, and Constructora y Arrendadora Cañeros S. A de C.V.	$9,639,923,130.00	$11,182,310,830.80
APP-009000959-E12-2020	Rehabilitation and Maintenance of the San Luis Potosi – Matehuala highway, in San Luis Potosi	Consortium: Omega Construcciones Industriales S. A de C.V	$5,530,007,272.30	$ 6,414,808,435.87
APP-009000959-E454-2017	Rehabilitation and Maintenance of the Tampico (Altamira) - Cd. Victoria highway, in Tamaulipas	Consortium: Mota-Engil México S.A.P.I; Construcciones y Mantenimiento Roca S. A. de C. V; Desarrollo y Construcciones Urbanas S. A. de C. V; Grupo Rio San Juan S. A. de C. V; and Grupo R Exploración Marina S. A. de C. V.	$4,477,902,538.28	$5,194,366,944.40

Based on information by Secretaría de Comunicaciones y Transportes, 2018l, 2018k, 2018j, 2018i.

Findings

It is noteworthy that since PPPs are long-term contractual relationships, in the case study, the project execution period for the evaluated projects is 10 years. Another feature studied was financing, which should be performance-related, as well as the financing method for the bidding processes. In this case study, all projects are of the pure modality, meaning that the resources for the payment of service provision, as well as investment, operation, maintenance, and infrastructure preservation costs, come entirely from federal budgetary resources, or from the National Infrastructure Fund or other non-budgetary federal public funds (Chamber of Deputies of the Congress of the Union, 2017, Art. 3).

Regarding the elements necessary for competitiveness and participation to materialize, the findings show that:

1. The PPP project information for bidding is made available virtually to all interested parties through the government procurement platform Compranet (Cámara de Diputados del H. Congreso de la Union, 2018, art. 11; *Compranet*).
2. Information is provided, and questions about the procedure are clarified.
3. There are no established criteria for handling issues, specifically when only one economic proposal is received.

Additionally, there is no prequalification stage, which, according to international recommendations, could have been used to verify the capacity of potential bidders before the procedure, ensuring that the bidders submit complete proposals for evaluation (Inter-American Development Bank, 2020b; Kerf et al., 1998).

Conclusions

PPPs have been defined as long-term contracts between a private entity and a public entity, in which the financing or payment mechanism is performance-based. Given the scarcity of public resources, the risk is transferred from taxpayers to the performance of the private sector, encouraging the private sector to maintain service quality and efficiently manage available resources with the intention of increasing social welfare and investment levels in the country.

From the development of the research, the objective was met to identify the level of competition in four PPP projects related to the 2018 PPP Project Promotion Strategy (Block II), from which the following conclusions were drawn:

1. A total of 17 bidders participated 24 times,
2. Consortium A participated in three procedures and won one of them, with an individual success rate of 33.33%.
3. Consortia D, I, and M each participated only once, and each won in that single participation, indicating a 100% individual success rate.
4. The total success rate of the four awarded consortia, considering the number of times they participated, is 83.33%.
5. Final participation was reduced by the following percentages:
   - Procedure No. APP-009000959-E454-2017 began with 4 proposals but only 2 were evaluated economically, reducing the number of competitors by -50%. In this procedure, competitor M won.
   - Procedure No. APP-009000959-E455-2017 began with 5 proposals and only 2 were economically evaluated, reducing competitors by -60%. Competitor I won.
   - Procedure No. APP-009000959-E456-2017 started with 7 proposals, but only 1 was economically evaluated, reducing competitors by -85.71%. Competitor D won, as the only bidder with an economic proposal evaluated.
   - Procedure No. APP-009000959-E12-2017 began with 8 proposals, but only 1 was economically evaluated, reducing competitors by -87.50%. Competitor A won, as the only bidder with an economic proposal evaluated.

Finally, the disqualification criteria that contributed to the reduction in participation are related to disqualification for lack of information in the technical and legal sections, and inconsistencies in the economic section.

Theoretical and practical references highlighted in this research helped identify the PPP cycle and the implementation phase during the bidding stage, as this is the stage in which the awarded private entity responsible for project execution is selected. This phase must create the necessary mechanisms to foster competitiveness alongside participation, meaning that the public sector should receive the highest number of quality offers. To achieve this, it is recommended—following best practices—that governments implement a prior stage called prequalification and consider negotiation, especially when evaluating bidders' proposals.

In line with this, the study of the four PPP projects related to the 2018 PPP Project Promotion Strategy (Block II) reveals that the authority, in its role as the contracting entity or responsible public official, must implement adequate measures to ensure that the bidding process enables greater participation, thereby allowing for a broader range of options and better conditions in terms of price, quality, financing, and timeliness, among others.

Thus, it is proposed to implement a mandatory prequalification stage to ensure greater participation, during which the capacity of potential bidders would be verified, ensuring complete proposals for economic evaluation, and to consider negotiation when evaluating bidders' proposals.

Finally, the strength of this research lies in the use of data mining as a methodology to identify patterns in public procurement and, therefore, in the delivery of goods and services. As for limitations, the research is restricted to the amount of data analyzed within Block II. As future lines of research, it is proposed to compare the processes of similar sectors within Block I to refine the pattern analysis and improve the robustness of the results.

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Appendix I

The APP projects related to the 2018 APP Project Promotion Strategy (Block II) that were budgeted include:

1. Rehabilitation and Maintenance of the Tulum - Cancún highway segment, in Quintana Roo
2. Rehabilitation and Maintenance of the Las Brisas - Los Mochis highway segment, in Sinaloa
3. Rehabilitation and Maintenance of the Campeche - Mérida highway segment, in Campeche and Yucatán
4. Rehabilitation and Maintenance of the Arriaga - Tapachula highway segment, in Chiapas
5. Rehabilitation and Maintenance of the San Luis Potosí - Matehuala highway segment, in San Luis Potosí
6. Rehabilitation and Maintenance of the Tampico (Altamira) - Cd. Victoria highway segment, in Tamaulipas
7. General Hospital "Dr. Santiago Ramón y Cajal" in Durango, Durango
8. General Hospital in Tampico, Tamaulipas
9. General Hospital "Dr. Francisco Galindo Chávez" in Torreón, Coahuila
10. General Hospital in the Northern Zone of Mexico City
11. General Hospital in the Eastern Zone of Mexico City and the State of Mexico
12. General Hospital in Acapulco, Guerrero
13. Regulation Lagoons for the Eastern Rivers of the Valley of Mexico (NAICM)
14. Wastewater Treatment Plants in the River Basins of the Eastern Lake of Texcoco
15. Proyecto de Modernización del Servicio Metereológico Nacional
16. Modernization, improvement, and efficiency enhancement of the Los Berros Water Treatment Plant of the Cutzamala System
17. Rehabilitation, Modernization, and Maintenance of physical infrastructure for basic education in Mexico
18. Expansion and equipment of the Penitentiary Complex in Papantla, Veracruz

Apendix II

ID	Participant
A	Consortium: Omega Construcciones Industriales S. A de C.V.; Impulsora de soluciones de Infraestructura S. A de C.V.
B	Consortium: Coconal SAPI de C.V. y Operadora de Autopistas S. A. de C. V
C	Consortium: ICA Infraestructura S.A. de C.V.; ICA Constructora de Infraestructura S.A. de C.V. y Constructora el Cajón S.A. de C.V.
D	Consortium: Calzada Construcciones S.A. de C.V.; Construcciones y Dragados del Sureste S.A. de C.V.; Construcciones Urales S.A. de C.V.; Cointer Concesiones México S.A. de C.V. e Icapsa Infraestructura y Desarrollo S.A. de C.V.
E	Consortium: La Peninsular Compañía Constructora S. A de C.V.; Constructora y Edificadora GIA+A S. A de C.V.; y Operadora y Administradora Técnica S.A. de C.V.
E.1	Consortium: La Peninsular Compañía Constructora S.A. de C.V.; Constructora y Pavimentadora Vise S.A. de C.V.; Operación y Administración Técnica S.A. de C.V.;
F	Consortium: Grupo emprendedor Caltia, SAPI de C.V.; Caltia Concesiones S. A de C.V.; Sociedad Anónima de Obras y Servicios Copasa Asesorías Proser, S.A. de C.V.
F.1	Consortium: Grupo emprendedor Caltia, SAPI de C.V.; Caltia Concesiones S. A de C.V.; Sociedad Anónima de Obras y Servicios Copasa Asesorías Proser, S.A. de C.V. y Jagual Ingenieros Constructores S.A. de C.V.
G	Consortium: Promotora y Desarrolladora Mexicana de Infraestructura, S.A. de C.V.; Promotora y Desarrolladora Mexicana S.A. de C.V.; Desarrollo de Terracerías S.A. de C.V. y Prodemex Construcciones S.A. de C.V.
H	Consortium: Construcciones Urales S. A de C.V.; Infineo S. A de C.V.; Cointer Concesiones México S. A de C.V.; Compañía Constructora Mas S. A de C.V.; Icapsa Infraestructura de Desarrollo S. A de C.V.; GC Grupo Cimarrón S. A de C.V.; Técnicos Especializados de Chiapas S. A de C.V.;
I	Consortium: Impulsora de Desarrollo Integral S. A de C.V., Gami Ingeniería e Instalaciones S. A de C.V. Supra Constructores S. A de C.V. y Constructora y Arrendadora Cañeros S. A de C.V.
J	Consortium: Constructora Makro S. A de C.V. Servicios Mexicanos de Ingeniería Civil S. A de C.V. Magnamaq S. A de C.V. Proyextra S. A de C.V. y Grupo Concesionario de México S. A de C.V.
K	Consortium; Api Movilidad S.A. de C.V. Constructora Garza Ponce S.A. de C.V.; Avanzia Soluciones y movilidad S.A. de C.V.;
L	Consortium: Construcciones Rubau S.A. de C.V.; Grupo Valoran S.A. de C.V.;
M	Consortium: Mota-Engil México S.A.P.I; Construcciones y Mantenimiento Roca S. A. de C. V; Desarrollo y Construcciones Urbanas S. A. de C. V; Grupo Rio San Juan S. A. de C. V; y Grupo R Exploración Marina S. A. de C. V;
N	Consortium: Gami Ingeniería e Instalaciones S. A. de C. V; Impulsora de Desarrollo Integral S. A. de C. V; Supra Construcciones S. A. de C. V; y Constructora y Arrendadora Cañeros S. A. de C. V;
O	Consortium: Integradora Latinoamericana de Infraestructura Contructiva S.A.P.I de C.V. Grupo Edificador Baesgo S. A. de C. V; Constructora Eunice S. A. de C. V; Constructora Feluxa S. A. de C. V; Servicios de Consultoría en Infraestructura Vial S. A. de C. V; y Herrera Garnica José Félix

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Interdisciplinary Faculty of Economic and Administrative Sciences

RESEARCH

Customs management and its modernization: an analysis using structural equations at the Lázaro Cárdenas customs office, Mexico

Gestión aduanera y su modernización: un análisis con ecuaciones estructurales en la aduana Lázaro Cárdenas, México

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Oscar Bernardo Reyes Real [1],
Cristian Omar Alcantar López [2] and Ana María Del Rosario Alvarado Oregón[3]

[1] Corresponding Author: PhD in Fiscal Studies, Full-time Professor and Researcher, Faculty of Foreign Trade, Universidad de Colima, Mexico; member of the National System of Researchers, Candidate level. Member of the academic group UCOL-CA-114 "Management in Innovation for Sustainable Development."
Email: oscarreal@ucol.mx ORCID: https://orcid.org//0000-0001-7631-1946

[2] PhD in Fiscal Studies with a specialization in Public Finance. Full-time Professor at Universidad de Guadalajara, Mexico. Member of the National System of Researchers, Candidate level. Member of the academic group UDG-CA-483 "Accounting, Finance, and Competitive and Sustainable Enterprises."
Email: cristian_alcantar@hotmail.com ORCID: https://orcid.org/0000-0002-1436-6711

[3] Master in Corporate Development of International Trade, Universidad de Colima, Mexico. Undergraduate professor at various universities and independent researcher, collaborator of the academic group UCOL-CA-114 "Management in Innovation for Sustainable Development."
Email: oregon.ana@gmail.com ORCID: https://orcid.org//0000-0001-7631-1946

Abstract

This research study examines the relationships between best practices in modern customs operations and their effect on customs functions in the case of the Lázaro Cárdenas customs office, Michoacán. The measurable model of customs modernization, with validated observed variables from the case of the Manzanillo customs office by Reyes (2021), is applied. The aim is to determine how much of the improvements in customs functions can be attributed to public service reforms, technological and infrastructure changes, and, consequently, to analyze the effects on the efficiency of customs management related to revenue collection, trade facilitation, and oversight. The method employed is the structural equation modeling technique, as recommended by Coyle et al. (2015), for analyzing customs modernization constructs. The results clearly show positive and significant effects on the core functions of customs management as a result of best modernization practices. This work is expected to contribute to improving customs management by recognizing the relevance of best practices and identifying which dimensions of modernization generate the greatest impact in achieving efficient, transparent, and competitive performance, thus leading to actionable propositions and recommendations for administrators and officials.

Keywords: customs modernization, revenue collection, oversight, trade facilitation.

JEL code: C10, H30, F23

Resumen

En este trabajo de investigación se estudian las relaciones entre las mejores prácticas de la aduana moderna y su efecto en las funciones aduaneras en el caso de la aduana Lázaro Cárdenas, Michoacán. Se aplica el modelo medible de modernización aduanera con variables observadas validado en el caso de la aduana de Manzanillo por Reyes (2021). El objetivo de dilucidar cuánto de las mejoras en las

funciones de la aduana son atribuible a las reformas en la función pública, los cambios tecnológicos y de infraestructura y en consecuencia analizar los efectos en la eficiencia de la gestión aduanera relacionada con la recaudación, facilitación comercial y fiscalización. La técnica empleada es el modelo de ecuaciones estructurales mediante recomendado por Coyle et al. (2015) para el análisis de constructos de modernización aduanera. Los resultados obtenidos dejan de manifiesto los efectos positivos y significativos sobre las funciones sustantivas de la gestión aduanera producto de las mejores prácticas de su modernización. Se considera que este trabajo contribuirá a mejorar la gestión aduanera reconociendo la relevancia que tienen las mejores prácticas y desde cuáles dimensiones de la modernización se producen mayores efectos para lograr una actuación eficiente, trasparente y competitiva y se deriven consecuentemente proposiciones y recomendaciones para administradores y funcionarios.

Palabras Claves: modernización aduanera, recaudación, fiscalización, facilitación comercial.

Código JEL: C10, H30, F23

1. Introduction

The reforms to Mexican customs legislation (Administración General de Aduanas, 2007) and the introduction of mechanisms and systems supported by technological changes and new Information and Communication Technologies (ICTs) have produced significant effects, particularly in trade facilitation and the efficient service to foreign trade. At the same time, customs management has maintained and improved revenue collection levels by combating tax evasion and smuggling, ensuring control over imports and exports. These developments have led to important changes in the auditing and tax collection functions (Reyes, 2021).

Recent studies (Horta, 2006; Trejo, 2007; Reyes, 2021) have shown that Mexico is transitioning toward more effective, transparent, and competitive customs management. Nevertheless, research on modernization has focused on describing reforms by examining customs functions individually, without adopting a comprehensive approach to adapt the theory of the World-Class Customs Model proposed by Coyle et al. (2015).

However, studies such as the one by Reyes (2021), which analyzes customs modernization through a case study of the Manzanillo customs office in Colima, Mexico, have made it possible to determine the extent to which best practices impact auditing, tax collection, and trade facilitation key functions of modern customs. The study also assesses the degree to which these functions respond to public service reforms, technological changes, and infrastructure improvements. To do this, the author used a measurable model of customs modernization with observed variables collected via surveys, employing Structural Equation Modeling (SEM) as outlined by Hair et al. (1999).

Although the most significant advances in customs modernization in Mexico have occurred at the Manzanillo customs office, notable developments have also taken place at the Lázaro Cárdenas customs office, following the implementation of the Customs Modernization Plan 2007–2012 (PMA), which aimed to boost the efficiency and productivity of the national and international logistics chain (Reyes et al., 2020).

This has led to increased capacity at this customs office, solidifying its position as the second most important port in terms of container handling, with connectivity to 138 ports in 41 countries (Administracion Portuaria Integral de Lázaro Cárdenas, 2018) ranking 14th in Latin America and the Caribbean according to the Comisión Económica para América Latina y el Caribe (CEPAL) (Comisión Economica para América Latina y el Caribe, 2018).

t is also important to note that cutting-edge technological systems and mechanisms have been introduced at this customs office, indicating technological advancements. It is even part of the Customs Technological Integration Program (PITA) (Servicio de Administración Tributaria, 2016). It plays a key role as a link between Asia and North America, reaching the main consumer centers. The physical and geographical characteristics of the port make it a viable alternative for cargo movement and a strategic logistics hub to serve this growing market (Administracion Portuaria Integral de Lázaro Cárdenas, 2018).

However, while the relevance of the Lázaro Cárdenas customs office for customs management studies is acknowledged, it is necessary to verify the effect of modernization reforms to determine whether they actively contribute to the efficiency of its management and administration related to the functions of auditing, trade facilitation, and tax collection. Given the importance of foreign trade to Mexico and the key role of this customs office, it is essential to address questions such as:

How much of the improvements in customs functions can be attributed to reforms in public service, technological changes, and infrastructure at the Lázaro Cárdenas customs office? Is there a balance between the role of customs management in facilitating trade and the need for control in the context of increasing reduction of international trade barriers, regional integration mechanisms, and free trade agreements?

The aim of this study is to apply the measurable model of customs modernization with observed variables through surveys (Reyes, 2021) at the Lázaro Cárdenas customs office in Michoacán to study the best practices of modernization and their effect on the core functions of its management.

2. Theoretical-conceptual development

Customs modernization and substantive functions of customs management

By their nature, public customs administrations are not exempt from the principles of New Public Management (NPM). On the contrary, the World Trade Organization (WTO) and the World Customs Organization (WCO) regard the management and functions of customs worldwide as a crucial link in the global supply chain due to customs' determining role in foreign policy, economic development, international trade flows, and national security (Reyes, 2021).

The main strategic factors currently influencing customs administrations are related to the increase in international trade volume, trade liberalization, new international standards, the proliferation of regional trade agreements, significant changes in traditional trade patterns, and the rise in the number of participants. Additionally, the emergence of new logistics and supply chain models, the rise of transnational organized crime networks, borderless security threats, and growing concerns about public health and the environment also play a role (Gordhan, 2017).

As a result of these factors, customs administrations have implemented various responses to different degrees ranging from comprehensive reforms to more minor adjustments, as noted by Gordhan (2017).

Indeed, the priorities arising from foreign trade in Mexico have led to a shift from a revenue-oriented auditing approach to a facilitative approach with a stronger focus on the protection of other collective legal goods safeguarded by the state, such as national security, public health, animal and plant health, and the environment.

As stated by Shujie and Shilu (2009), the most important milestones that have driven customs modernization are the Revised Kyoto Convention and the SAFE Framework of Standards to Secure and Facilitate Global Trade from the World Customs Organization (WCO), from which the so-called best customs practices can be identified. These are defined as: "...simple and effective procedures designed to provide the highest level of facilitation for customs operations involving goods and passengers, as well as various special procedures" (Trejo, 2007).

Authors such as Coyle, Cruthirds, Naranjo, and Nobel (2014), Gwardzińska (2012), and the World Bank (2017) conclude that best practices in customs matters can be summarized through six constructs: infrastructure, procedures, technology, time orientation, cost, and mission. These constructs enable the development of a theoretical model for world-class customs, incorporating the best practices that customs administrations should follow in pursuit of modernization to enhance their core functions.

However, based on the research conducted by Reyes (2021) to develop the construct of customs modernization, it is considered that the components of mission, time orientation, and cost, together with simplified, efficient, and risk-based procedures, constitute the "public function" dimension. This dimension is understood, as expressed by Rozas and Hantke-Domas (2013), as:

> ...an essential function of the state, exercised through norms established in the legal system, referring to specific activities related to the legislative process, administration of justice, management of the state apparatus, national defense, law enforcement, fiscal and tax administration, and certification, among other similar essential and mandatory functions (p. 46).

The public function, by ensuring more efficient use of available resources and greater agility in operations, impacts both trade facilitation and auditing functions. Additionally, it significantly affects auditing and revenue collection functions by improving compliance with tax obligations

related to non-tariff regulations and restrictions and enhancing the capacity to detect acts leading to infractions and crimes committed by traders.

Regarding technological changes, Barahona (2002) states that the most advanced customs administrations have automated the majority of their processes, thus reducing paper usage through the digitalization of operations. The use of the internet to receive declarations and disseminate information enables intense electronic communication among customs offices and the application of computerized data analysis models (p. 305).

On this basis, Reyes (2021) argues that technological changes also have a significant effect on customs functions. By allowing for the processing of larger volumes of information, they enable the effective development of risk management, and consequently, the streamlining and increased efficiency of customs procedures, resulting in better overall management. He also acknowledges a relationship between technological changes and the public function.

Finally, the aforementioned author considers that technological changes, together with the customs public function, will affect both auditing and trade facilitation. He supports this claim by referencing Widdowson (2007), who states that the use of technology and risk management will allow customs administrations to focus on high-risk areas and, as a result, ensure more efficient use of available resources, improve the ability to detect infractions and crimes committed by traders and travelers who fail to comply with their obligations, and provide faster processing for users who comply with tax regulations.

The position assumed by Reyes (2021) is that customs modernization is represented through three interrelated dimensions: public function, technological changes, and infrastructure, which significantly impact the essential functions of the modern customs system: control, revenue collection, and trade facilitation an approach adopted in this study.

In studies on the effects of customs modernization, including those by Barahona (2002), Basaldúa (2007), Trejo (2007), Grainger (2008), Cipoletta, Pérez, and Sánchez (2010), Zake (2011), Coyle et al. (2014), Davaa and Namsrai (2015), Morini (2015), and Reyes (2021), the relationship between modernization and the substantive functions of customs management reveals several benefits, such as: improved voluntary compliance; increased speed and quality of service; access to new sets of skills, tools, and methods; simplified processes and procedures; enhanced management discipline; measurement and transparency; capital investment instead of spending; increased revenue; greater institutional efficiency; reduced transaction costs; economic growth; and the ability to handle the growing volume of goods, which is also a driver of economic development.

However, it is necessary to distinguish the specific case of customs in Mexico particularly in Lázaro Cárdenas, due to its importance to the country by identifying from which modernization dimension the impact on customs functions originates, and the resulting benefits. This distinction can help in the pursuit of greater efficiency in customs management, which improves as international trade transactions become easier, while maintaining strict fiscal and security controls required by international trade, and facilitating the commercial flow for the benefit of both the country and the global trading community (Cantens, Ireland, and Raballand, 2013).

3. Methodology: mesurable model of customs modernization with variables observed through surveys

In the case of the Lázaro Cárdenas customs office, a structural model is applied, following the recommendations of Coyle et al. (2014, p. 13) and Reyes (2021). The essential functions of the modern customs system are assumed as dependent (latent) variables: Oversight of foreign trade operations (FTO), Tax revenue collection from foreign trade (RCET), and Trade facilitation (FTF). The explanatory variables are: Public Function (PF), Technological Changes (TC), and Infrastructure (INF) (Reyes, 2021).

The relationships between dependent and explanatory variables in the model are based on the matrix of relationships between best customs practices and the essential functions of Mexican customs, systematized by Reyes (2021) (Appendix 1).

According to Hair et al. (1999), the development of this technique involves seven fundamental

steps, which are repeated interactively until the model achieves the best fit according to the chosen strategy. These steps are followed in the present study:

I. Develop a theoretically grounded model.

II. Construct a sequence diagram of casual relationships.

III. Convert the sequence diagram into a set of models and structural relationships.

IV. Choose the input matrix and estimate the proposed model.

V. Evaluate model identification.

VI. Evaluate fit quality criteria.

VII. Interpret and make possible modifications to the proposed initial model.

Dependent variables and explanatory or independent variables

Dependent variables refer to the customs functions listed below:

Oversight of foreign trade operations (FA): A function of customs management that includes control of international traffic. It involves activities related to international trade agreements and treaties, such as rules of origin, preferential tariffs, intellectual property rights, and enforcement of tax provisions that trigger contributions other than customs taxes. It also includes intelligent auditing, which requires reliable, accessible, and prudent information for building a data repository useful to all foreign trade actors. This oversight covers not only non-tariff or prohibited issues but also tariff and tax matters (Reyes, 2021).

Tax revenue from foreign trade (RCEA): Not limited to collecting foreign trade taxes, but also includes other state contributions and revenues such as the customs processing fee and compensatory fees (Reyes, 2021).

Trade facilitation (FCEA): Involves actions aimed at easing the flow of goods and reducing the costs of foreign trade operations and customs procedures in general (Reyes, 2021).

Independent or explanatory variables are:

Public Function (PF): Customs administration processes based on a reliable and accessible information system. This includes organizational schemes and anticipatory legal frameworks, new managerial tools and techniques, risk management, and procedures ensuring more effective use of available resources, greater capacity to detect violations and crimes, increased operational agility, and enforcement of tax obligations, regulations, and non-tariff restrictions (Reyes, 2021).

Technological Changes (CTN): Represents a practice of customs modernization involving automation of processes, use of the internet for submitting claims and sharing information, computer-based data analysis models, electronic communication with foreign customs offices, and new information systems to control goods and combat tax evasion. Its implementation in risk management reduces corruption and illegal practices by operators, improves information generation and reception, and rationalizes, simplifies, and enhances the effectiveness of customs administrative procedures (Reyes, 2021).

Infrastructure (INF): Encompasses modernization of buildings for commercial operations, ports, airports, roads, security infrastructure, improved working conditions, communication systems between customs offices, IT infrastructure, telephone and electricity services. Its implementation reduces cargo volume bottlenecks, improves global cargo movement efficiency, organizes infrastructure and equipment, and enhances information transmission capacity interrelated with technological changes (Reyes, 2021).

PF, TC, and INF are the constructs of customs modernization and are represented as latent variables with interdependent relationships among them, as well as varying levels of effect on the dependent variables AFT, FTTC, and TFC.

It is important to note that multiple relationships exist between customs modernization and the essential functions of modern customs (Reyes, 2021), which can be summarized as follows:

1. Oversight of foreign trade depends on administrative procedures, the use of information and communication technologies (ICTs), and infrastructure investments that facilitate management processes.
2. Revenue collection is influenced by the quality of public management and the ability to estimate

the cost of imported godos even in contexts of tariff reductions as well as technological changes that not only impact the public function but also ease revenue processes and support infrastructure modernization at ports, airports, warehouses, roads, and buildings involved in trade operations.

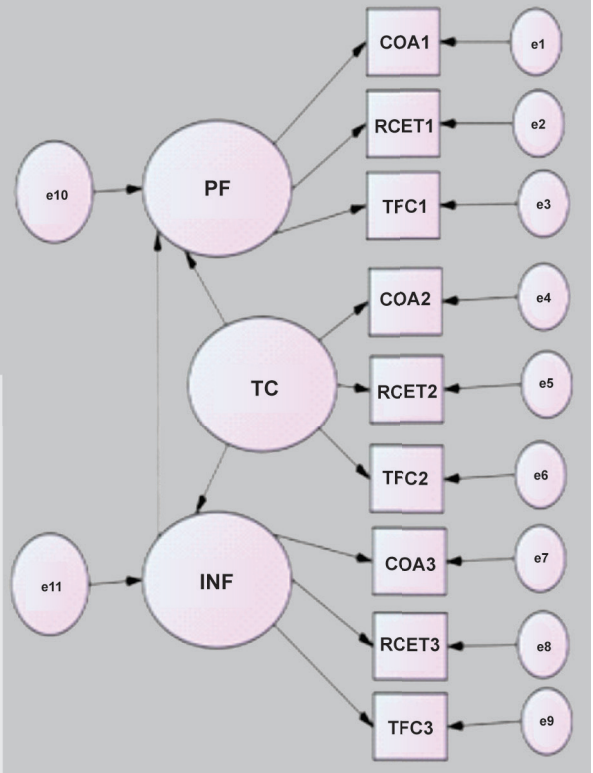
3. Trade facilitation depends on the public function in terms of compliance with commercial regulations, but this should not hinder technological and infrastructural reforms that allow the flow of goods while minimizing logistics costs.

This model aims to relate the components of the customs modernization construct instead of treating them individually, evaluating them in terms of "best-in-class" performance (Coyle et al., 2015), and studying their impact on the core functions of customs management at Lázaro Cárdenas through a perception-based analysis that links both theoretical constructs.

Associating essential customs management functions with reforms that led to best modernization practices is not trivial. Attempting to explain these relationships helps not only to understand how much improvement in customs functions can be attributed to best practices, but also to estimate the effect of reforms introduced in order to propose actions that strike a balance between trade facilitation and control and oversight.

Table 1 presents the variables, hypotheses, and sequence diagram of causal relationships for the structural model of customs modernization using latent variables. The hypotheses correspond to the analysis of customs modernization practices in Mexico and the association between modernization constructs and the essential functions of modern customs.

Table 1. Variables, hypotheses and sequence diagram of casual relationships

Variables	Hypotheses	Sequence Diagram of Casual Relationships
Structural model of customs modernization with latent variables		
Explanatory and simultaneously intervening variables: Public function (PF) Technological changes (TC) Infrastructure (INF)	H1: Public function, technological changes, and infrastructure are interrelated factors that have a positive and significant effect on the essential functions of customs management. H2: Public function is a factor that positively and significantly influences the auditing of foreign trade operations, and to a lesser extent, the foreign trade tax collection and trade facilitation by customs.	
Dependent variables: Auditing of foreign trade operations (AFT) Foreign trade tax collection (FTTC) Trade facilitation by customs (TFC)	H3: Technological changes are a factor that positively and significantly influences the auditing of foreign trade operations, and to a lesser extent, foreign trade tax collection and trade facilitation by customs. H4: Infrastructure is a factor that positively and significantly influences trade facilitation, and to a lesser extent, the auditing of foreign trade operations and foreign trade tax collection.	

Source: Own elaboration based on Reyes (2018).

Once the theoretical model was developed and expressed in the form of a diagram, it was formally specified through equations (Hair et al., 1999). The data for the model were obtained from a sample of 254 individuals based on a survey administered to people involved in various foreign trade operations at the Lázaro Cárdenas customs office, following the sampling criteria proposed by Palacios and Vargas (2012).

The sample was determined using the criteria established by Palacios and Vargas (2012), who recommend the use of the tables published by Cohen (1998) and Green (1991). According to these authors, given the number of parameters to be estimated (ranging from 25 to 30), the sample should consist of at least 250 to 300 observations or completed questionnaires.

The survey used was structured, and the instrument consisted of a questionnaire in which the items were rated on a Likert-type scale from 1 to 5 (1 = "very low perceived importance" to 5 = "very high perceived importance"), adapted from the proposal by León (2012).

The subjects comprising the sample were former customs officials at the chief or sub-administrative level involved in customs auditing and merchandise clearance processes at the Lázaro Cárdenas customs office, as well as authorized agents from customs brokerage firms directly involved in the customs operational procedures under study, following the recommendations of Reyes (2021).

Based on the questionnaire responses, the sample was characterized by variables such as gender, age, educational level, employing institution, level of government, and years of experience in the public customs sector.

4. Discussion and argumentation: results of the measurable customs modernization model with observed variables through surveys

In this study, the AMOS (Analysis of Moment Structures) software (Arbuckle, 1994), version 21.0, integrated with SPSS of the same version, was used.

Data entry was conducted using tabulated or properly coded data in a spreadsheet within the SPSS statistical package. When used for this purpose, SPSS generates variance-covariance and correlation matrices for all indicators included in the model.

Since all items in the survey questionnaire were answered, there were no missing data, resulting in a total of 254 valid completed questionnaires.

Because the observed variables are ordinal as in this study, which employed a Likert scale and cannot be treated as continuous variables, the covariance matrix cannot be calculated as a measure of association, as it would not accurately estimate the relationships among the variables. Thus, alternative yet robust methods must be employed (Díez, 1992).

Consequently, the Generalized Least Squares (GLS) estimation method was used in this model, based on Díez's (1992) criteria, as it is appropriate for the analysis of dichotomous or ordinal variables. The variances of the latent variables were fixed at 1.0.

Once the valid questionnaires were entered into the model, and in pursuit of a better model fit given the small effect of the infrastructure construct on Public Function that relationship was removed from the causal relationship sequence diagram presented in Table 1.

Normality was analyzed, and the distributional characteristics of individual variables were assessed (Hair et al., 1999). A fundamental assumption of multivariate analysis is data normality. Thus, skewness and kurtosis analyses were conducted, along with statistical normality tests. The skewness values were below 2 and kurtosis values below 10 (Kline, 2015), indicating that the data are normally distributed.

There were no signs of negative error variances; the variances explained by the observed variables fell within permissible ranges, as did the standardized parameter estimates and their corresponding standard errors. No coefficients close to or exceeding 1 were observed[1].

Simultaneously, model fit criteria were analyzed based on degrees of freedom, which are defined as the difference between the number of correlations or covariances and the effective number of coefficients in the proposed model (Hair et al., 1999).

The model has 24 degrees of freedom. Additionally, the ratio of Chi-square to degrees of freedom (χ^2/

[1] During the estimation process, illogical results may occur that represent identification problems in the structural model, known as offensive estimates, such as standardized beta coefficients with values very close to or greater than one.

df), known as the normed chi-square, had a value of 2.76, which falls within the acceptable range according to recommendations ranging from as high as 5.0 (Wheaton et al., 1977) to as low as 2.0 (Hooper et al., 2008). The statistical significance level is 0.00, indicating an adequate model fit.

If there is a good fit, it indicates empirical evidence in favor of the theoretical model. The most commonly used and basic fit indices considered were the Comparative Fit I ndex (CFI), the Goodness of Fit Index (GFI), and the Root Mean Square Error of Approximation (RMSEA).

In practice, an RMSEA value close to 0 indicates an excellent fit; a value between 0.05 and 0.08 indicates a satisfactory fit; and a value above 0.10 indicates a poor fit. For GFI, CFI, and the Adjusted Goodness of Fit Index (AGFI), values close to 1 indicate a good fit, while values below 0.85 indicate a poor fit (Palacios and Vargas, 2012).

In this model, the RMSEA value was 0.08 with a significance level (P-close) of 0.01 (RMSEA values ≤ 0.1 indicate an acceptable fit) (Romero and Babativa, 2016). The Root Mean Square Residual (RMR), used to measure how well the model estimates the covariance matrix, had a value of 0.03, indicating a good fit (Byrne, 1998; Diamantopoulos and Siguaw, 2000).

The index results were: GFI = 0.94 (this goodness-of-fit index, when approaching 1, indicates a perfect fit), and AGFI = 0.90. These results confirm a satisfactory fit, and thus the proposed model is considered acceptable (Kenny, 2015).

Effects among modernization components at the Lázaro Cárdenas customs office

Table 2 presents the standardized direct and total coefficients between the components of customs modernization, obtained from the results using the AMOS software. In all cases, the relationships are significant, with p-values less than 0.05 (Kenny, 2015).

Table 2. Total standardized coefficients among components of customs modernization

Customs modernization components	Total effects	
	PF	INF
Technological changes	0.42	0.58

Source: Own elaboration based on AMOS results.

The first result observed is that the direct effect of Technological Changes on Infrastructure and Public Function is positive. In the first case, the standardized coefficient of 0.42 ($p < 0.05$) indicates a medium positive effect of Technological Changes on Public Function. In contrast, the total effect (0.58, p-value 0.00) of Technological Changes on the Infrastructure construct is classified as large (Kline, 2015).

The results show that the innovative and modernization drive in customs management, together with technological changes, despite structural adjustments in both systems and procedures, tends to impact infrastructure.

To explain this behavior from a theoretical perspective, it is important to consider that technological changes represent a practice of customs modernization that integrates into the public function of customs through process automation, the use of the internet to receive claims and disseminate information, the application of computerized data analysis models, among othersfactors which in turn affect IT, technological, transport, and operational equipment infrastructure.

Despite the absence of a theoretical stance regarding which relationship produces a greater effect in the cases mentioned above, the study conducted at the Manzanillo customs office reported coefficients of 0.37 and 0.73, respectively (Reyes, 2021), which shows a behavior similar to that obtained in Table 2 for the customs office under study.

One argument to explain this behavior at the Lázaro Cárdenas customs office is that the technological changes implemented during the period 2003–2021, although they have contributed to the streamlining and simplification of management procedures, have had a significant effect on infrastructure optimization through the Comprehensive Model Customs Infrastructure project applied as part of the Customs Modernization Plan (General Customs Administration, 2008).

In this same vein, the adoption of foreign trade information systems and mechanisms introduced at the customs office through the[2] employed technologies that offer ease of operation, data integrity, and information security. In this way, they

[2] Currently, the Proyecto de Integración Tecnología Aduanera (PITA) is being implemented, which integrates the Sistema Automatizado Aduanero Integral (SAAI) and the Módulo de Administración Tributaria del Comercio Exterior (MATCE).

influence Public Function as mediated by reforms in security infrastructure, information technology, and communications, progressively increasing the capacity for information transmission and reception, as well as the streamlining and simplification of procedures.

These effects highlight the transparency of customs operations, expressed in the maximum amount of information available to all users and intermediaries regarding current tariffs and duties, valuation procedures, tariff classification criteria, restrictions and prohibitions applicable to the import and export of goods, potential sanctions, and available remedies, among others.

Effects of modernization on the functions of customs management at the Lázaro Cárdenas

The second result is related to the effects of best modernization practices at the Lázaro Cárdenas Customs Office on its core functions, as shown through the standardized total coefficients presented in Table 3.

The results show the following effects:

1. Reforms in the Public Function positively influence the three core functions of customs. This is expressed in standardized regression coefficients that, being greater than 0.5, indicate large effects.

The Public Function influences the auditing function through a more professional organization that makes intensive use of information technology, new procedures and management tools, agile, modern and flat structures, intensive use and distribution of information and international exchanges, automation of customs declaration processes, and strengthening of human capital.

An analysis from the perspective of management carried out by the Lázaro Cárdenas customs and port, as part of modernization and with the aim of adapting to the needs of international trade without neglecting its auditing authority, shows important actions and results, as detailed below.

First, the introduction of more effective procedures, increased capacity to detect violations and crimes committed by traders, more skilled human resources with appropriate profiles, improvements in risk management to focus inspections on potentially non-compliant operations (and thus violating the legal framework), among others.

Table 3. Standardized total coefficients between components of customs modernization and functions.

Indicators	Total effects	Total effects on customs functions mediated by other modernization components		
		TC	INF	PF
As an effect of Public Function reforms (PF)				
Customs operations auditing (COA1)	0.64	0.27	0.077	
Tax collection from foreign trade (RCET)	0.66	0.27	0.077	
Trade facilitation by customs (TFC1)	0.65	0.26	0.075	
As an effect of Technological Reforms (TC)				
Customs operations auditing (COA2)	0.70		0.00	0.00
Tax collection from foreign trade (RCET2)	0.68		0.00	0.00
Trade facilitation by customs (TFC2)	0.73		0.00	0.00
As an effect of Infrastructure Reforms (TC)				
Customs operations auditing (COA3)	0.75	0.43		0.00
Tax collection from foreign trade (RCET)	0.85	0.49		0.00
Trade facilitation by customs (TFC3)	0.65	0.37		0.00

Source: Own elaboration based on AMOS results.

According to the Ministry of Communications and Transport (Secretaría de Comunicaciones y Transportes, 2018), the customs modernization project carried out between 2014 and 2018 enabled the auditing, monitoring, and control of the entry and exit of goods, as well as the means of their transportation, ensuring compliance with

foreign trade regulations. It featured the following additional characteristics:

- Docks to achieve 90 inspection positions for foreign trade cargo.
- A maneuvering yard with a 11,033.00 m² hydraulic concrete area.
- A forklift platform with a 2,245 m² area.
- Hydro-sanitary and electrical installations.
- Emergency stations.
- A 2,245.00 m² metal structure supported by 24 round hydraulic concrete columns, 60 cm in diameter.
- Installation of gamma-ray inspection equipment.

The most significant results were that with the new inspection positions for foreign trade cargo, 1,115,452 TEUs[3] were processed in 2016 and 1,149,079 in 2017. Additionally, a capacity was created to handle up to four million TEUs.

As a result of these measures, the port recorded a 31% growth in automotive cargo handling, managing 460,959 units by December 2021, surpassing the 351,993 units handled during the same period in 2020. Of the total handled, 49% were export vehicles, 48% were import vehicles, and 3% were transshipment vehicles.

In the same report, the National Port System Administration reported that exports increased by 23% and imports exceeded 35%. The port became the first specialized terminal for vehicle handling in Mexico and achieved a 96% share of total new vehicle operations in Mexican Pacific ports, maintaining global competitiveness.

In this line of analysis, the effect on trade facilitation is attributed, according to the theoretical arguments of Reyes (2021), to changes in fraud risk analysis, random and selective inspections, post-clearance audits that do not hinder trade flows, clear and transparent procedures made available to all, a drastic reduction in inspections, a harmonized classification system, and simplification of declarations all of which are part of current customs practices.

This is confirmed in practice by the fact that in 2021, the port opened a fourth service module to expedite container transportation. This measure represents a 33% increase in inspection capacity with the aim of facilitating ground freight transport operations within the port facilities, simplifying the reception and dispatch of goods, promoting space availability at the terminals, and ensuring a constant flow of freight transportation for dispatch (Administración del Sistema Portuario Nacional Lázaro Cárdenas, 2022).

The effect of Public Function on revenue collection stems from new methods of collecting non-customs taxes due to the gradual reduction of tariffs and the implementation of administrative regulations in favor of importers and exporters for goods clearance procedures, which reduce import and export costs.

These methods have simplified the payment of tariffs, taxes, and fees and customs operations at the Lázaro Cárdenas customs office. This explains the effect of the Public Function on revenue collection, which is evidenced by the trend in the revenue flow shown in Graph 2 of this study.

> I. The direct and positive effects of technological reforms, mainly resulting from advances in digital technologies and the reduced cost of communications, have a favorable influence greater than that of changes in the Public Function and with no significant differences across the three core customs functions. Regression coefficients of 0.70, 0.68, and 0.73 for auditing, revenue collection, and trade facilitation, respectively, indicate that technology has significantly contributed to the effective administration of customs and its operations, as it has been widely integrated into modernization efforts.

From a theoretical perspective, Reyes (2021) links technological changes to the auditing of foreign trade operations through electronic systems and mechanisms such as the SAAI (Automated Customs System), the Electronic Customs System (SEA), the Single Window for Foreign Trade (VUCE)[4], the MATCE, the Single Customs Clearance Document (DUNIC), the FAST and Express lanes, process reengineering, and the paperless customs system due to automation processes. These changes, in turn, have created new customs facilities, resumption of activities, partnerships for secure

[3] A twenty-foot equivalent unit, meaning this unit represents the length of a container which is equivalent to 6 meters, and it is the unit used internationally for cross-border trade.

[4] They began in 2012 at all customs offices in Mexico.

trade, harmonization of criteria, and extended service hours.

The main technological changes at the Lázaro Cárdenas customs office to audit and facilitate foreign trade include:

- MATCE was launched in 2016 with the purpose of providing and maintaining IT solutions to help reduce taxpayer service times, ensure the operational continuity of systems supporting tax collection, foreign trade, and internal operations; evolve operational continuity services to increase productivity and handle more services at lower costs and in less time; and implement quality assurance in internal and provider services.
- The PITA program is an expression of the technological changes aimed at trade facilitation and, consequently, revenue collection (Reyes, 2021). In the case of the Lázaro Cárdenas customs office, a pilot program was launched considering that it was not only about introducing technology into the customs process, but also about conducting a deep review of it to automate and make it transparent, thereby facilitating trade. In this regard, DODA-PITA tests began in 2020 (Gomsa Logística, 2020). Combined with the previously mentioned technological changes, these tests have significantly increased import and export operations, as shown in Graph 1 analyzing the indicators.

In summary, the technological reforms implemented have produced changes in the information system to control goods and combat tax evasion, with a consequent effect on auditing and trade facilitation through (Servicio de Administración Tributaria, 2020):

- Automated procedures for on-site and post-clearance control.
- Use of non-intrusive inspection mechanisms.
- Automation of tax obligation procedures.

II. Lastly, reforms in technological, communication, and physical infrastructure have a direct and positive effect first on revenue collection, second on auditing, and finally, although still significant, on trade facilitation. This is reflected in the high observed regression coefficients of 0.85, 0.75, and 0.65, respectively. The indirect influence of technological changes on these functions occurs in the same order, as a medium effect (0.49, 0.43, 0.37).

From a theoretical standpoint, the relationship between infrastructure as one of the best modernization practices and the main customs functions is discussed from a broad perspective by Reyes (2021). First, the link with auditing is evident in management infrastructure, such as equipment, operational buildings, service and administrative infrastructure, and IT systems. Second, the connection with trade facilitation includes, in general, IT and technological infrastructure. Lastly, transportation infrastructure aimed at increasing the volume of international cargo and reducing operational costs including ports, airports, warehouses, road systems, among others is directly related to the revenue collection function.

This is evidenced in the case of the Lázaro Cárdenas customs office and port, where significant changes in infrastructure have taken place. On this matter, the General Customs Administration, through its Central Administration for Customs Equipment and Infrastructure, reported that for the period 2007–2012, modernization efforts related to infrastructure produced the following outcomes (Servicio de Administración Tributaria, 2020):

- The customs office was equipped with an infrastructure project located in the northern area of the Lázaro Cárdenas port, which has been completed.
- During the period, new customs facilities were inaugurated, including operational and administrative areas, inspection facilities, and inspection equipment for foreign trade goods, allowing foreign trade companies to carry out import and export procedures at a single location. Among the improvements:
  - The capacity of the inspection platform was expanded,
  - new operational and administrative facilities were built,
  - new control booths, as well as access and exit lanes for road transportation and inspection equipment, were installed,
  - the customs office was enabled to carry out foreign trade clearance procedures more efficiently,

- due to its location (entry and exit point of the Lázaro Cárdenas port), it allows foreign trade companies to conduct import and export procedures at a single site.

For the years 2018 and 2019, there are records of public works investments in the customs office and the port in real estate, infrastructure, and ongoing construction projects, amounting to 236,668,733 and 421,323,673 pesos, respectively (Administración Portuaria Integral de Lázaro Cárdenas, 2019).

In 2021, the customs office opened a fourth service module to streamline the transportation of full import containers. This measure represented a 33% increase in inspection capacity and was implemented to facilitate ground freight operations within the port facilities. It aimed to simplify the reception and dispatch of goods, improve the availability of space at the terminals and customs office, and ensure a constant flow of cargo transportation for clearance.

From the perspective of the performance of the indicators related to the customs trade facilitation function (FCEA) and foreign trade tax revenue collection function (RCEA) proposed by Reyes (2021), there is evidence of real improvements as a result of the reforms and the set of best customs practices analyzed.

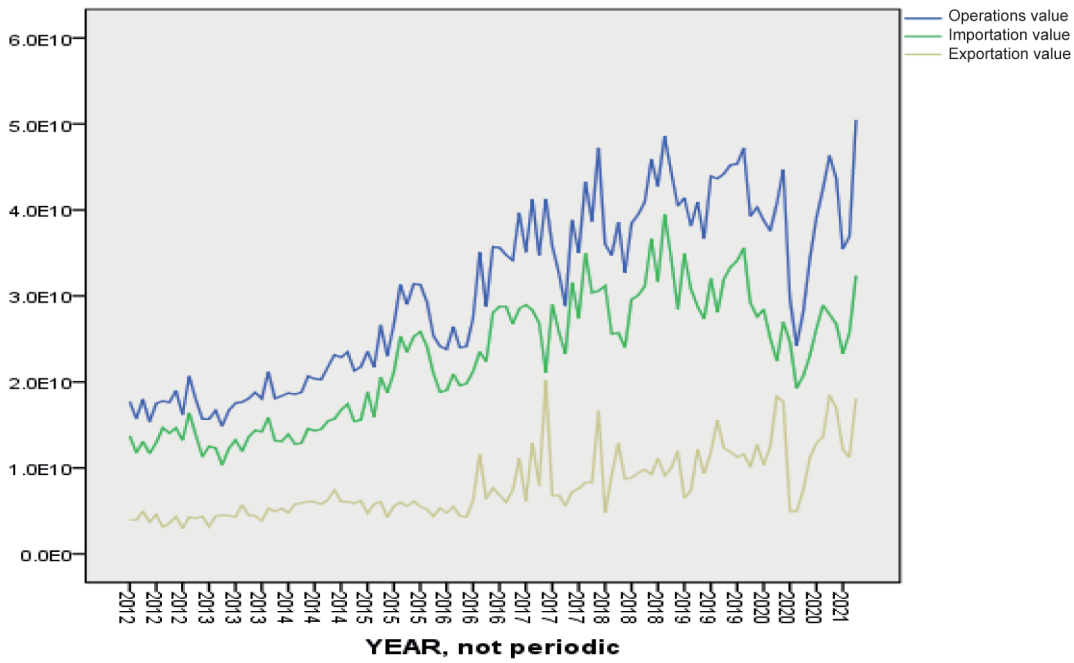
Data regarding the total value of operations for the period 2012–2021 which includes both imports and exports are presented in Graph 1. This represents one of the main indicators of FCEA.

The graph shows growth in the total value of operations over the period; however, due to the economic crisis resulting from the health emergency caused by COVID-19, there was a significant decrease in December 2020, mainly due to the decline in export value.

In 2021, a renewed increase in this indicator can already be observed.

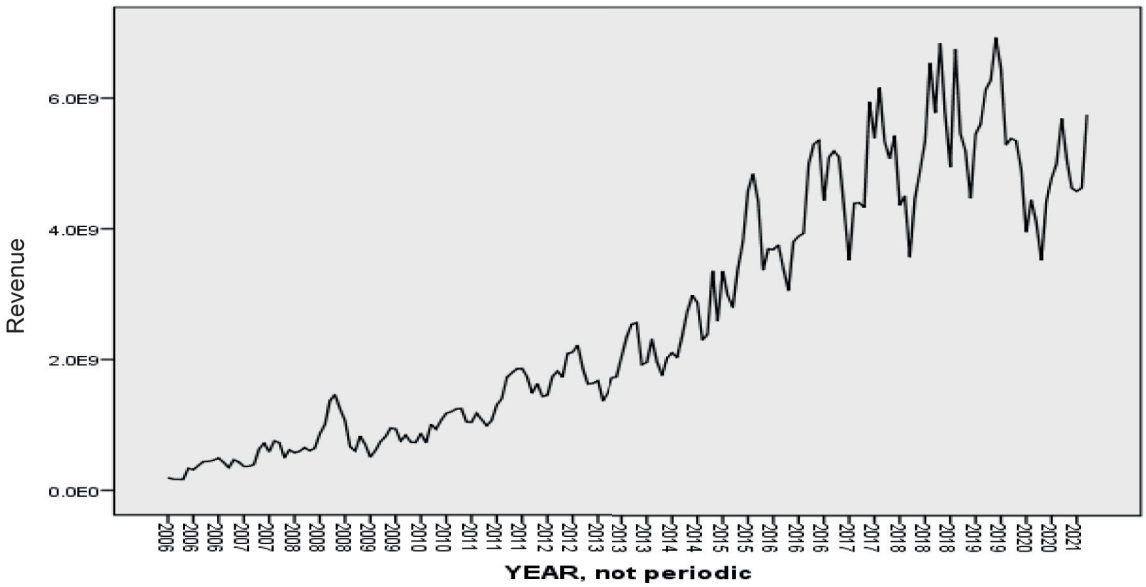
Regarding the cash flow revenue from foreign trade at customs, which represents the main indicator of RCEA, its behavior is shown in Graph 2.

Graph 1. Total value of operations at the Lázaro Cárdenas customs office, 2012–2021 (monthly) (Millions of pesos).



Source: SPSS v. 22 output based on data from the Ministry of Finance and Public Credit (2022).
Note: The value of imports refers to the customs value of the goods, whereas the value of exports corresponds to the commercial value of the goods.

Graph 2. Cash flow revenue at Lázaro Cárdenas Customs Office, 2006–2021 (monthly, in millions of pesos).



Source: SPSS v. 22 output based on data from the Ministry of Finance and Public Credit (2022).

During the analyzed period, revenue shows growth despite a decline in 2020 caused by a reduction in operations and their value, as previously mentioned. In March 2021, revenue began to increase again within the context of the country's economic recovery.

5. Conclusions

Customs modernization, conceived as a public function involving technological and infrastructure changes, aims to establish a balance between the customs functions of control and collection of fiscal revenues and the facilitation of foreign trade.

The "model customs" program and the customs modernization plan 2007-2012, along with port development programs and the electronic systems and mechanisms applied in Mexico, have been the main avenues contributing to the facilitation, simplification, and automation of foreign trade, as well as to the efficiency of customs administration control and oversight tasks.

According to the master plan (Secretariat of Communications and Transport, 2018), the Integral Port Administration of Lázaro Cárdenas has been empowered to promote comprehensive development, aiming to become one of the most important ports in Latin America, both industrially and commercially.

As a result of the program, the necessary conditions were established for a dynamic and efficient flow of cargo handling, which in turn contributes to the high and sustained growth of the regional and national economy. This reflects the changes in customs modernization, particularly in administrative processes, automation, technological changes, and infrastructure.

The study of best practices in the modernization of the Lázaro Cárdenas Customs and their effect on its management functions through SEM corroborates that:

a) Customs is no longer limited to collecting taxes at borders but has become the manager of all state functions related to border crossings, such as trade facilitation, control, and oversight.

b) There is a positive and significant effect of best practices in customs modernization on the three essential functions recognized by the theoretical

model applied. The behavior of foreign trade operations and revenue indicators during 2006-2021 confirms this.

c) Although there are no significant differences in the effects of customs modernization reforms on its functions, results suggest that the impact on oversight of foreign trade operations mainly comes from infrastructure and technological reforms.

d) Public function reforms act directly on revenue, then on trade facilitation and oversight. In contrast, technological and infrastructure changes have a greater impact on facilitation, oversight, and lastly revenue. Infrastructure's effect is the opposite, impacting revenue collection most strongly, followed by oversight and trade facilitation.

The behavior of the Trade Facilitation and Tax Revenue indicators at Lázaro Cárdenas confirms the changes in modernization and their effects on the essential functions of modern customs in the context of Mexico.

The results express efficiency in customs management, which will continue to make Lázaro Cárdenas a competitive port that generates better services and immediate comprehensive solutions for the economic growth of the sector.

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Appendix

Appendix 1. Relationship between best customs practices and essential customs functions in the context of Mexico

Customs Functions and Practices	Oversight of Foreign Trade Operations	Tax Revenue Collection from Foreign Trade	Customs Trade Facilitate
Public function	• More professional organization that makes intensive use of information technology, new procedures, and managerial tools. • ISO 9002 standard. • High proportion of officials with university education and agile, modern, flat structures. • Intensive use and distribution of information and international exchanges. • Automation of customs declaration processes. • Strengthening of human capital.	• New methods for collecting non-customs taxes due to the gradual reduction of tariffs. • International trade agreements to increase revenue collection. • Administrative regulations favoring importers and exporters in customs clearance procedures, reducing import and export costs.	• Risk analysis of fraud, random and selective inspections, and post-clearance controls that do not hinder trade. • Clear, transparent, and available procedures. • Drastic reduction of inspections (aforos). • Introduction of specific criteria for inspections. • Harmonized classification system. • Simplified declarations. • Facilities for prior inspections. • Clear, transparent, and automated procedures for in situ and post-clearance control. • Use of non-intrusive inspection mechanisms, such as Gamma-ray machines.
Technological changes	• Electronic systems and mechanisms (SAAI, SEA, VUCE, MATCE, DUNIC, automated selection mechanism). • Process reengineering. • Paperless customs. • FAST and Express lanes. • Customs facilitations. • Resumption of activities. • Partnership for Secure Trade. • Harmonization of criteria and extended hours.	• Electronic systems and mechanisms (SAAI, SEA, VUCE, MATCE). • Customs Technological Integration Program (PITA).	• Simplified export Project. • Customs confinement. • Phazir • Secure Wireless communication. • Automated procedures for tax compliance (SAAI, SEA, VUCE, MATCE, DUNIC). • Customs Technological Integration Program (PITA).
Infrastructure	• Management infrastructure: equipment, commercial operations buildings. • Proximity of service and administrative infrastructure. • IT infrastructure.	• IT infrastructure. • Technological infrastructure.	• Infrastructure in transportation means to increase international cargo volume and reduce operational costs. • Improvements in port, airport, warehouse, and road system infrastructure.

Source: own elaboration based on Reyes (2021).

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Interdisciplinary Faculty of Economic and Administrative Sciences

RESEARCH

Quantitative analysis of tourism competitiveness in Bahía de Kino, Sonora

Análisis Cuantitativo de la Competitividad Turística en Bahía de Kino, Sonora

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Aaron Chavez Valdez [1],
Jesús Ángel Enríquez Acosta [2] and María Elena Robles Baldenegro[3]

[1] PhD in Social Sciences from Universidad de Sonora, he holds a Master's degree in Administration from Universidad de Sonora, a specialization in Sustainable Development from the same institution, and a Bachelor's degree in Economics from Universidad de Sonora. He is currently a candidate-level member of the National System of Researchers (SNI), and a full-time professor in the Department of Economics at Universidad de Sonora.
Email: aaron.chavez@unison.mx, https://orcid.org/0000-0003-1904-4794

[2] PhD in Political and Social Sciences from Universidad Nacional Autónoma de México, Master's in Social Sciences from El Colegio de Sonora (COLSON), and Bachelor's degree in Sociology from Universidad de Sonora (UNISON). He is a research professor in the Department of Sociology and Public Administration at Universidad de Sonora. He is a member of Cuerpo Académico, Multiculturalidad, Identidad y Cambio Social, and president of Academica Globalización y Procesos Locales in Northwestern Mexico. He is also a Level I member of the National System of Researchers (SNI).
Email: thejesus.enriquez@unison.mx, https://orcid.org/0000-0002-0931-8491

[3] Research professor affiliated with the Department of Accounting at Universidad de Sonora, and a graduate of El Colegio de Sonora. She holds a PhD in Social Sciences with a specialization in Regional Development. She completed her Master's degree at Universidad Nacional Autónoma de México (UNAM), within the Faculty of Sciences. She is a research professor recognized with a PRODEP profile and is a member of the National System of Researchers. Her academic work has been published both nationally and internationally.
Email: maria.robles@unison.mx, https://orcid.org/0000-0003-3358-1342

Abstract

The article aims to explore and build a quantitative analysis of tourism competitiveness for Bahía de Kino Sonora, based on the perceptions of local actors involved in tourism. In recent years, this police station became one of the tourist destinations in Sonora with the highest influx of visitors due to its proximity to Hermosillo, the capital of the State and the United States, the natural attractions and the real estate development built on second homes. To obtain the index, a quantitative instrument was designed that consisted of 60 items, most of them on a Likert scale, a convenience sample was applied to 120 people dedicated to the tourism industry: service providers, hotel employees, shops, restaurants, promoters, tourism students, public officials, among others. The variables used in the different analyzes include: tourism supply, tourism promotion, human resource training and tourism in general. The data was processed using the SPSS version 21, EQS 6.1 software in order to carry out reliability tests, and to carry out the exploratory and confirmatory quantitative analysis for the validation of the instrument. Finally, the corresponding correlations were made to average the tourism competitiveness index.

Keywords: Quantitative analysis, Tourism, Competitiveness

Resumen

El artículo tiene por objetivo, explorar y construir un análisis cuantitativo de la competitividad turística para Bahía de Kino Sonora, a partir de las percepciones de los actores locales que participan del turismo. Esta localidad se constituyó en años

recientes en uno de los destinos turísticos de Sonora con mayor afluencia de visitantes debido a su cercanía con Hermosillo la capital del Estado y los Estados Unidos, los atractivos naturales y el desarrollo inmobiliario fincado en las segundas residencias. Para la obtención del índice se diseñó un instrumento cuantitativo que constó de 60 preguntas, la mayor parte de ellos en escala de Likert, se aplicó un muestreo a conveniencia a 120 personas dedicadas al ramo turístico: prestadores de servicios, empleados de hotel, comercios, restaurantes, promotores, estudiantes de turismo, funcionarios públicos, entre otros. Las variables utilizadas en los diferentes análisis abarcan: oferta turística, promoción turística, formación de recursos humanos y el turismo de forma general. Los datos se procesaron utilizando el software SPSS versión 21, EQS 6.1 con la finalidad de realizar pruebas de confiabilidad, y hacer el análisis cuantitativo exploratorio y confirmatorio para la validación del instrumento. Por último, se hicieron las correlaciones correspondientes para promediar el índice de competitividad turística.

Palabras Clave: Análisis cuantitativo, Turismo, Competitividad

1. Introduction

Globally, tourism is one of the most increasingly relevant sectors of economic activity at the international, national, and regional levels. In this context, it is important to analyze the tourism competitiveness of local tourist centers. Based on this premise, it is necessary to determine how competitive local environments linked to tourism actually are. Conceptually, tourism competitiveness is understood as the ability of a tourist destination to generate the necessary attractions for tourists to enjoy a high-quality tourism offer. This, in turn, creates significant economic spillovers, which refers to the quantification of the total average monetary value, according to Secretaría de Fomento al Turismo (SEFOTUR, 2012–2018). These benefits manifest in terms of revenues for tourism-related economic units and expenditures by tourists, ultimately fostering a sense of belonging among visitors. The competitiveness of a tourist destination contributes to greater growth across different economic variables associated with tourism (Siles, 2016).

Moreover, it is necessary to analyze competitiveness at the local level due to its implications for the design of public policies from within the destinations themselves. This type of analysis can contribute to the reduction of negative social impacts generated by tourism and, conversely, promote the development of infrastructure and the improvement of tourism services. Additionally, competitiveness entails attracting and encouraging private and foreign investments that generate employment, foster a tourism-oriented identity, and offer diverse and appealing services for visitors—thereby strengthening tourism as a sector of economic activity.

Tourism competitiveness, as defined by Ritchie and Crouch (2000:137–152), refers to "the ability of a location to generate greater economic capacity and achieve sustained growth; in this way, the well-being of a place or region is achieved through the management of advantages and processes, attractions, aggressiveness, and proximity, integrating the relationships among these elements within an economic and social model." Tourism competitiveness is thus linked to the concept of a tourist destination. In this regard, González and Mendieta (2009:111–128) note that a tourist destination is "a geographical area with distinctive characteristics such as climate, culture, attractions, infrastructure, services, facilities, pricing, image, and management, all of which are positioned in the minds of consumers in market terms." The attributes of a tourist destination, in connection with competitiveness, are based on the natural and built resources it possesses, as well as the range of amenities and services intended to meet the needs of tourists or potential visitors. Ultimately, competitiveness is associated with the destination's attractiveness factors (Montaño, Pérez, & De la O, 2014).

Considering the above, the purpose of this study is to analyze the local competitiveness of a tourist destination undergoing development. It stems from the premise that empirical evidence on this topic exists mainly at the national or regional level, while studies at the local level remain limited.

Accordingly, this study poses two research questions: What factors could make Bahía de Kino, Sonora, a competitive destination at the regional level? And, what are the strongest and weakest factors that either hinder or facilitate the local tourism competitiveness? To answer these questions,

a research study was carried out, employing correlation coefficients as a basis for testing the hypothesis. The strength of the correlations was assessed as follows: very high 0.81–1.00, high 0.61–0.80, moderate 0.41–0.60, low 0.21–0.40, and very low 0.00–0.20. The hypothesis is accepted when the correlation value is at least 0.61, with a significance level of at least 95%. The study adopts a quantitative theoretical and methodological approach, which involved administering a survey to local stakeholders engaged in tourism promotion, tourism services, business owners and managers of hotels and restaurants, public officials, tourism students, among others. In the quantitative analysis phase aimed at measuring the competitiveness index, a correlation analysis was conducted on tourism-related variables such as infrastructure, tourism promotion, human capital development, and complementary services.

The objective of this article is to explore and develop a tourism competitiveness index for Bahía de Kino, Sonora, based on the perceptions of those involved in tourism activities. Bahía de Kino is considered one of the main tourist destinations in the state of Sonora. This study seeks to contribute to knowledge on tourism competitiveness by addressing existing gaps on the subject at the local level in Mexico.

2. Tourism in the global, national and local context

The Organizacion Mundial del Turismo (OMT) reported that Mexico rose from eighth to sixth place in international tourist arrivals, recording 39.3 million tourists in 2017. This positioned the country ahead of destinations such as the United Kingdom, Turkey, and Germany. According to the OMT Tourism Highlights 2018 Edition, these figures also reflect a 12% increase in the flow of international travelers (OMT, 2019).

These data highlight the growing significance of tourism as a global economic activity. Currently, tourism is estimated to contribute 10% of the global Gross Domestic Product (GDP), generate 1 in every 11 jobs, account for 1.5 trillion dollars in exports, represent 7% of global exports, and contribute 30% of services exports (OMT, 2019). In Mexico, tourism represented 8.7% of national GDP in 2015 (Sectur, 2016).

Given such promising data, countries with a strong tourism orientation increasingly develop tourism development plans to attract more visitors each year. Mexico is an example of this, as it has implemented a series of plans, programs, regulations, and standards aimed at leveraging its tourism potential. These efforts have enabled the country to rank among the top 10 tourist destinations worldwide and to occupy the 22nd position in the Global Competitiveness Index for tourism, according to Foro Economico Mundial (FEM, 2017).

Understanding the social and economic context of Bahía de Kino is crucial due to its nature as a fishing village or *comisaría*, which, according to Article 197 of the Ley Orgánica de los Municipios (LOM), represents a decentralized administrative entity of municipal governments—in this case, the municipality of Hermosillo. One of the most evident issues is the scarcity of resources, which, when operating in a competitive and environmentally sustainable tourism framework, often neglects the aesthetic aspects of the locality.

Most economic activities in Bahía de Kino—whether through extraction, exploitation, or direct use—are dependent on coastal and marine natural resources. Fishing accounts for 46.35% of the total local economic output, followed by trade and services at 43.54%. Although the industrial and artisan sector only contributes 9.59%, it plays a crucial role as these activities are widely practiced throughout the town. The remaining 0.52% comes from other productive activities, including livestock and family orchards (INEGI, 2010).

3. Tourism competitiveness

Hassan (2000:239) defines tourism destination competitiveness as "the ability of a destination to create value-added products that sustain its resources while maintaining market position relative to its competitors". Similarly, D'Hauteserre (2000:23) describes destination competitiveness as "a destination's ability to maintain its market position and share or enhance it over time".

Within this framework, growing interest in identifying the key factors that determine the competitiveness of tourism destinations—particularly the incorporation of sustainability as a strategic condition—has led to the development of various conceptual models (Mazaro & Varzin,

2008:790).

Scientific contributions indicate that interest in tourism competitiveness has evolved over time, as evidenced by the work of (Bravo, 2004; Crouch and Ritchie, 1999; Daskalopoulou and Petrou, 2009; De Keyser and Vanhove, 1994; D'Hauteserre 2000, Dwyer and Kim, 2003; Dwyer et al. 2000, 2004; Enright and Newton, 2004; Faulkner et al., 1999; Flores and Barroso, 2009; Garau, 2006; Go and Govers, 2000; Gooroochurn and Sugiyarto, 2005; Hassan, 2000; Hong, 2009; Kim and Dwyer, 2003; Kozak and Rimmington, 1999; Mihalič, 2000; Monfort, 1999; Navickas and Malakauskaite, 2009; Pearce, 1997; Poon, 1993; Ritchie and Crouch, 2000, 2003; and Sánchez 2006).

Building upon these theoretical foundations, the key contributions of major tourism competitiveness models have been analyzed, outlining their strengths and limitations. As Ritchie and Crouch (2000:5) assert, competitiveness is "illusory without sustainability".

In this regard, Ritchie and Crouch (2003) argue that a competitive destination is one that promotes the highest possible level of well-being for its residents in a sustainable manner. Furthermore, they emphasize that a destination must be economically, ecologically, socially, culturally, and politically sustainable to be genuinely competitive (Ritchie & Crouch, 2003:49).

4. Methodology

The proposed model (see Figure 1) draws from the theoretical contributions of the most influential literature and authors associated with the concept of tourism competitiveness. It is presented as a perception-based model that assesses highly specific aspects, incorporating various constructs and variables with a degree of validity across different types of results. In this context, authors such as Crouch and Ritchie (1999) and Dwyer and Kim (2003) have developed leading global models of tourism competitiveness. Their frameworks include variables similar to those utilized in this study, which is why they are referenced as primary sources for their significant theoretical contributions to the global understanding of tourism competitiveness, particularly in Europe and the United States.

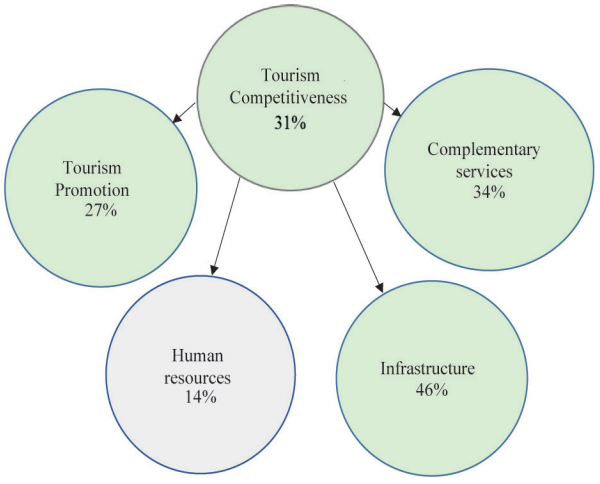
Fundamentally, the models proposed by these authors are based on four key variables: infrastructure, tourism promotion, human resource development, and complementary services. These variables were included as indicators in the instrument applied to residents involved in tourism-related activities in Bahía de Kino.

According to Miguel et al. (2014), the conceptualization of tourism competitiveness in their model has a more regional focus, as their research and model for Mexico used regional indicators by state.

Based on the theoretical framework established by these authors, the core of the problem statement and general objective is to correlate tourism competitiveness with the defined variables. This raises the question of why, in terms of tourism competitiveness, the locality of Bahía de Kino, Sonora, has undergone new forms of economic organization over time, driven by economic crises in Mexico. These crises have caused severe economic and social disruptions worldwide, and tourist destinations like Bahía de Kino have not been exempt. The impact of these economic crises persists today, and their effects remain evident in the locality.

Although there is extensive literature on tourism competitiveness, most approaches are grounded in diverse and heterogeneous contexts. In contrast, the model proposed in this article has been scarcely researched and theorized—especially considering its focus on a specific tourism locality in the state of Sonora.

Figure 1. Methodological model of tourism competitiveness in Bahía de Kino



Source: Own elaboration based on the tourism competitiveness and local sustainability survey of Bahía de Kino, analyzed using SPSS and EQS 6.1 software.

The model proposed for obtaining the tourism competitiveness index was designed based on variables and indicators. To measure competitiveness, four variables were considered: tourism promotion, human resources, tourism infrastructure, and tourism and complementary services. These were broken down as follows:

Tourism promotion: Includes indicators related to promotional efforts by different levels of government, the private sector, service companies, travel agencies, among others.

Human resources and training: Includes indicators related to educational institutions that train personnel for the tourism sector, employee training in tourism services, job creation linked to tourism, among others.

Infrastructure: Includes indicators related to roads, airports, marinas—elements that generally facilitate the mobility of tourists and local residents. This also includes foreign direct investment, national private investment, among others.

Tourism and complementary services: Includes indicators on the sufficiency of hotels, motels, bars, restaurants, among others.

A survey-based instrument was designed consisting of 60 items. Each variable evaluated contained various indicators, which are detailed in (table 4) where most items were quantified using a Likert scale. The survey was conducted in the tourist locality during 2018 with a sample of 120 individuals. The instrument was administered to individuals involved in tourism and commerce, those responsible for tourism promotion in the public sector, and tourism students. Overall, the sample was selected to ensure participants had direct involvement with the tourism sector. A convenience sampling approach was used, aiming to reflect the professionalization of human resources involved in tourism, as well as participation in the dimensions of infrastructure, mobility, and complementary tourism services.

The main assumption is that tourism competitiveness must exhibit a positive level of concordance among the variables that comprise it. Tourism competitiveness includes: the number of tourism-related businesses, human resources and their professionalization, the complementary services associated with tourism, tourism promotion, and the level of infrastructure. A comparison was conducted among the correlation results of the aforementioned variables to determine their interrelations and the degree of correlation among them, which was used to derive the tourism competitiveness index for Bahía de Kino. From the proposed methodological model for measuring tourism competitiveness, exploratory and confirmatory analyses were derived based on the data obtained through the quantitative instrument. The variables with the greatest impact on tourism competitiveness were identified, and coefficients obtained through SPSS version 21 were used to conduct reliability tests, exploratory analysis, and confirmatory analysis to validate the quantitative instrument. Finally, the relevant correlations were carried out to obtain Pearson correlation coefficients. These correlations are assumed to represent the tourism competitiveness index. This study has a correlational scope, as it was structured as a structural equation model. The instrument used was Encuesta Competitividad Turística en las Localidades Turísticas en el Norte de México, applied to 120 participants linked to the tourism sector. The survey was developed out of the need to measure the tourism competitiveness index at the local level based on the perceptions of stakeholders involved in tourism activities.

This case also incorporates the concept of benchmarking applied to the tourism destination. As proposed by Kozak (2004), this approach involves sensitivity to the identification of political, social, environmental, and technological opportunities. In the case of Bahía de Kino, the measurement of customer satisfaction falls outside the scope of this article. However, the social or sociodemographic variables of the respondents are presented in table 1. Other variables—such as the political dimension, explained through tourism promotion from the perspective of local and state governments (see table 4), and the technological and environmental dimensions—are excluded from the research scope.

The sociodemographic characteristics of the Bahía de Kino residents who participated in the survey conducted in November 2018 are as follows:

Table 1. Survey participant structure in Bahía de Kino.

Sex		Marital status	
Male	54%	Single	67%
Female	46%	Married	43%
Age		**Occupation**	
18-23	20%	Commerce	24%
24-29	36%	Fishing	9%
30-35	32%	Employee	55%
36-40	12%	Students	12%
Place of birth		**Income (Mexican pesos)**	
Bahía de Kino locality	59%	2294-4598	48%
Other locality in Sonora	31%	4998-6882	34%
Other Mexican state	6%	6882 or more	18%
Another country	4%	more	0%

Source: Own elaboration using the survey on tourism competitiveness and local sustainability in Bahía de Kino, analyzed with SPSS software.

4.1 Exploratory factor analysis: Bahía de Kino Case

In exploratory factor analysis, the primary goal is often to test the reliability of a statistical model through constructs and dimensions. In this case, the model of tourism competitiveness and local sustainability presents four constructs that, to some extent, demonstrate reliability; additional relevant values are also shown.

Table 2. Exploratory factor analysis of tourism competitiveness and local sustainability in Bahía de Kino

Factors or constructors	Eigen value	% of cumulative variance explained	Cron bach's Alpha	Number of items	Kmo	Bartlett's sphericity
Tourism	2.273	53.44	0.604	4	0.752	276.774
Supply	2.615	50.919	0.722	4	0.798	289.733
Tourism promotion	1.613	60.323	0.710	4	0.629	239.409
Human resources	1.929	37.189	0.676	3	0.644	54.64

Source: Own elaboration using the survey on tourism competitiveness and local sustainability in Bahía de Kino, analyzed with SPSS software.

In general, the tourism construct presents a Cronbach's Alpha of 60.4%, indicating that the construct or dimension is reliable. To reinforce this reliability, eigenvalues greater than one are considered; in this case, there are three such values, explaining 53.44% of the variance. Additionally, the KMO value is 0.75; the closer to one, the stronger the reliability, and Bartlett's Sphericity is 276, which is acceptable.

The supply and infrastructure construct shows a Cronbach's Alpha of 72%, indicating reliability. Eigenvalues greater than one are considered, in this case two, explaining 50.93% of the variance. The KMO value is 0.79, and Bartlett's Sphericity is 289, also acceptable.

The tourism promotion construct presents a Cronbach's Alpha of 71%, confirming its reliability. One eigenvalue greater than one is considered, explaining 65.32% of the variance. The KMO is 0.629, and Bartlett's Sphericity is 239, considered acceptable.

The human resources training construct has a Cronbach's Alpha of 67%, also indicating reliability. Two eigenvalues greater than one are considered, explaining 54.18% of the variance. The KMO value is 0.64, and Bartlett's Sphericity is 44, considered acceptable (see table 2).

4.2 Confirmatory factor analysis: Bahía de Kino Case

In the confirmatory factor analysis of tourism competitiveness and local sustainability, it is confirmed that the measurement instrument indeed measures what it is intended to measure through six dimensions. In this case, the general model of tourism competitiveness provides the following results: the Mardia coefficient is 9.62%, which is greater than the cutoff point of 7; therefore, the robust method is used. The Satorra-Bentler chi-square is 70.666 with 44 degrees of freedom and a probability of 0.018%, yielding acceptable goodness-of-fit indices: NNFI at 90% (the closer to one, the better), CFI at 93%, RMSEA at 6% (the closer to zero, the better), and Cronbach's Alpha at 96%.

For the tourism variable in the general model, the following results were obtained: the Mardia coefficient is 3.04%, below the cutoff point of 7, so the maximum likelihood method is used. The

normalized chi-square is 1.884 with 3 degrees of freedom and a probability of 5.3%, with acceptable goodness-of-fit indices: NNFI at 99%, CFI at 100%, RMSEA at 0%, and Cronbach's Alpha at 82%.

The supply and infrastructure variable in the general model presents the following: the Mardia coefficient is 4.44%, below the cutoff of 7, and thus the maximum likelihood method is used. The normalized chi-square is 0.401 with a probability of 7.6%, with acceptable goodness-of-fit indices: NNFI at 100%, CFI at 100%, RMSEA at 0%, and Cronbach's Alpha at 81%.

Tourism promotion, as presented in a general model, shows the following results: the Mardia coefficient is 3.88%, which is below the cut-off point of 7; therefore, the maximum likelihood method is applied. In this way, the regular chi-square value is 0.0050 with 1 degree of freedom and a probability of 7.5%. The model exhibits acceptable goodness-of-fit indices, including an NNFI of 100% (the closer to one, the better), a CFI of 100% (the closer to one, the better), and an RMSEA of 0% (the closer to zero, the better). Cronbach's alpha is 89%.

In the case of the variable "human resources training," as presented in a general model, the results are as follows: the Mardia coefficient is 1.62%, also below the cut-off point of 7; thus, the maximum likelihood method is applied. The chi-square value is 1.64 with 2 degrees of freedom and a probability of 2.1%. The model also presents acceptable goodness-of-fit indices: NNFI at 100% (the closer to one, the better), CFI at 100% (the closer to one, the better), and RMSEA at 0% (the closer to zero, the better). Cronbach's alpha is 71%.

The model of local sustainability presents the following results: the Mardia coefficient is -3.5%, which remains below the cut-off point of 7. Consequently, the maximum likelihood method is applied. The chi-square value is 6.75 with 5 degrees of freedom and a probability of 2.2%. The model demonstrates acceptable fit indices: NNFI at 98% (the closer to one, the better), CFI at 97% (the closer to one, the better), and RMSEA at 3.8% (the closer to zero, the better). Cronbach's alpha is 48%. This variable was not included in table 4, as its confirmatory analysis showed a negative incidence (see table 3).

5. Analysis and discussion of results in Bahía de Kino

Based on the exploratory and confirmatory analysis of the dimensions established in the measurement instrument, bivariate correlations were carried out to obtain Pearson's determination coefficient. According to theory, Pearson's coefficient is useful for determining the tourism competitiveness index at the local level. This index is crucial for this study as it allows for the hypothesis to be tested.

Table 3. Confirmatory factor analysis of tourism competitiveness and local sustainability in Bahía de Kino.

Factors or constructors	Mardia	Chi-square (or Chi square of Satorra-Bentler)	Degrees of freedom	p	NNFI	CFI	RMSEA	Cronbach's alpha	Number of items
Competitiveness	9.6283	66.466	44	0.0172	0.901	0.937	0.068	0.965	12
Tourism	3.0417	1.814	3	0.5531	0.911	1	0	0.821	5
Supply	4.4938	0.401	2	0.7601	1	1	0	0.811	4
Tourism promotion	3.8653	0.005	1	0.7563	1	1	0	0.892	4
Human resources	1.0328	1.646	2	0.2177	1	1	0	0.715	4

Source: Own elaboration using the survey on tourism competitiveness and local sustainability in Bahía de Kino, analyzed with SPSS and EQS 6.1 software.

The coefficient presents results for the various dimensions analyzed, and the index is derived from an average of the obtained correlations.

In summary, the variables that make up the index include:1) tourism promotion, which involves federal, state, and municipal governments, as well as travel agencies and tour operators; 2) human resources training, encompassing all institutions providing education related to tourism; 3) infrastructure, referring broadly to all facilities and equipment available to tourists from arrival to departure; and, 4) complementary services; which are central to lodging, gastronomy, and retail services.

The study of tourism competitiveness is a tool for evaluating the main variables that comprise it. It also provides information useful for decision-making, especially for improving public policies aimed at tourism, and for identifying strengths and weaknesses to act accordingly.

In this case, the evaluation of tourism competitiveness in Bahía de Kino displays the various correlations achieved by the variables when the model was run. This analysis serves as a basis to understand the development level of the destination and its current and potential economic capabilities.

The research conducted is based on the analysis and weighting of four competitiveness factors defined by regional tourism competitiveness models, as outlined by authors such as Miguel et al. (2014). The hypothesis testing is performed through the correlation coefficients, evaluated as follows: Very high 0.81–1.00, high 0.61–0.80, moderate 0.41–0.60, low 0.21–0.40, and very low 0.00–0.20. The hypothesis is accepted if the correlation is 0.61 or higher, with at least 95% significance.

In table 4, a breakdown of variables, indicators, and associated values that constitute the tourism competitiveness index of Bahía de Kino is presented. It highlights the highest values where the destination is strongest and the lowest values where weaknesses remain. The weakest components of the index are the complementary services, including lodging, gastronomy, and entertainment, which reflect a questionable quality of the tourism offer. In the human resources variable, issues are evident regarding the lack of training and the low wages of staff working in tourism services.

Table 4. Correlation of variable in the tourism competitiveness index of Bahía de Kino.

Variables or constructors	Indicators	Values (Pearson correlation)
Tourism Promotion	State government promotion	.23
	Municipal government promotion	.27
	Travel agency promotion	.32
	Tours	.27
Human Resources Training	Employment	.10
	Salaries	.12
	University-based training	.19
	Professional training	.16
Infrastructure	Roads	.49
	Airports	.38
	Foreign Direct Investment	.46
	Private Investment	.52
Complementary Services	Hotels	.48
	Motels	.28
	Bars	.18
	Restaurants	.45

Source: Own elaboration with preliminary results from the tourism competitiveness and local sustainability survey applied in Bahía de Kino.

Based on the specific results shown in table 4, the first variable, tourism promotion, consists of four indicators with the following Pearson correlations: .23 for state government promotion, .27 for municipal government, .32 for travel agencies, and .27 for tour operators.

Likewise, the variable human resources training presents correlations of .10 for employment, .12 for salaries, .16 for training, and only .19 for university-provided education.

The infrastructure variable shows the highest correlation, with .49 for roads. Regarding airports, Hermosillo's airport is used as a reference, with a correlation of .38. Private and foreign direct investment displays moderate correlations, one slightly below and one slightly above .50, indicating an acceptable but still insufficient investment level.

Finally, the complementary services variable presents the most substantial indicators: .48 for hotels, .45 for restaurants, .28 for motels, and .18 for bars—representing the lowest values in this category.

Based on general aspects of tourism—economic, social, environmental, and local experience—it is ultimately suggested that Bahía de Kino holds a privileged position due to its tourism potential. However, the variable and indicator values do not sufficiently explain the potential scope of Pearson's correlation, as they fall well below the average required for establishing moderate and satisfactory results. Nevertheless, obtaining this type of result is advantageous because it clearly identifies areas of opportunity for tourism development in Bahía de Kino. Likewise, these findings offer a new perspective for redirecting public policy strategies for this destination, which currently presents a tourism competitiveness index averaging 30% (see table 4), a preliminary result close to the numerical mean. Its greatest strengths lie in complementary services focused on tourist care and in tourism infrastructure.

Although there are studies related to tourism in Bahía de Kino, the lack of research specifically focused on tourism competitiveness in this location limits opportunities for scholarly dialogue with other authors. Therefore, this type of study may be considered pioneering within this area of inquiry.

6. Conclusions

As a result of the interaction of the different components of the quantitative model, it is shown that Bahía de Kino, Sonora is a tourist destination with a low competitive structure. This is due to multiple factors, including the scarcity of hotel and restaurant complexes, which are insufficient during high season or weekends, resulting in an economic spillover limited mainly to weekend tourism. On the other hand, the road infrastructure provides easy access for local, national, and international tourists, especially from the southwestern United States.

Moreover, tourism promotion is insufficient. However, being one of the most important and closest sun-and-beach tourist locations to the United States and other states bordering Sonora gives it an added value compared to other destinations in the same region. Another important variable, complementary services, is one of the most impactful factors based on the correlation coefficients. In the specific case of Bahía de Kino, Sonora, survey respondents highlighted the role of local universities in tourism training. These institutions provide quality education for students in the tourism field, which is reflected in the increasing qualification of workers in the tourism sector and the good customer service offered in restaurants, hotels, rental homes, and local businesses—encouraging local, regional, and international tourists to return.

However, the weakest component in the correlation coefficients indicates that the most visible sectors of tourism—such as hotels and restaurants—require more investment and involvement at different levels to improve the destination's image and the services provided to tourists.

According to the research questions posed and the objective aimed at measuring competitiveness, Bahía de Kino, Sonora is a developing tourist destination. The challenges and opportunities arising from its natural features (such as sun and beach) serve as key attractions for a growing number of visitors. The components of the correlations, based on the perceptions of the stakeholders who participated in the study, show that the locality is developing, demonstrating strong potential in several variables. The combination of these correlation components for Bahía de Kino, Sonora, allows us to envision the level of competitiveness the destination could achieve and to predict which factors need improvement through a reorientation of public policies applied to different tourist destinations.

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RESEARCH

Knowledge transfer networks on COVID-19 in aquaculture organizations of the Northern Pacific Region of Mexico

Redes de transferencia del conocimiento COVID-19 en organizaciones acuícolas del pacífico norte de México

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José Crisóforo Carrazco Escalante [1],
Eduardo Leyva León [2] and Nissa Yaing Torres Soto Baldenegro[3]

[1] PhD in Science, adjunct professor at Universidad Autonoma de Sinaloa.
Email: jcrisoforo.carrazco@gmail.com, ORCID:http://orcid.org//0000-0002-9979-4079

[2] PhD in Regional Development, researcher at Instituto de Desarrollo y Gestión Empresarial, candidate for the Sistema Nacional de Investigadores (SIN).
Email: lelehim@gmail.com, ORCID:https://orcid.org/0000-0003-0455-218X

[3] PhD in Social sciences, professor-researcher at Universidad de Quintana Roo.
Email: yaing.torres@gmail.com, ORCID:https://orcid: 0000-0003-3646-6649

Abstract

The objective of this study was to analize the knowledge transfer networks on COVID-19 in shrimp aquaculture production groups in the northern Pacific region of Mexico. Method. A cross-sectional, descriptive and correlational study was carried out, which allowed acquiring information from a survey of 102 aquaculture producers in the northern Pacific region of the state of Sinaloa. Social Network Analysis (SNA) was used for the analysis of results. Results. Four sources of information are reported - Health Sector, Private Sources, Governmental Sector and Media - to which the producers turn to acquire information on Covid-19 and its effects on the aquaculture activity.

Key words: Social Network Analysis (SNA) - Knowledge Transfer Networks - COVID-19 - Aquaculture Organizations

JEL code: Z13, D83, D2

Resumen

El presente trabajo tuvo como objetivo analizar las redes de transferencia del conocimiento sobre el COVID-19, en los conjuntos acuícolas productores de camarón de la región pacifico norte de México. Método. Se realizó un estudio de corte transversal, descriptivo y correlacional, el cual permitió adquirir información de una encuesta de 102 acuacultores de la región del pacifico norte, del estado de Sinaloa. Para el análisis de resultados se probó el Análisis de Redes Sociales (ARS). Resultados. Se reportan 4 fuentes de información -Sector Salud, Fuentes Privadas, Sector Gubernamental y Medios de Comunicación- a las cuales los productores acuden para adquirir información sobre el Covid-19 y sus efectos en la actividad acuícola.

Palabras clave: Análisis de Redes Sociales (ARS) - Redes de Transferencia de conocimiento - COVID-19 - Organizaciones Acuícolas.

Código JEL: Z13, D83, D2

1. Introduction

The disease known as Coronavirus disease 2019 (COVID-19) spread rapidly throughout communities worldwide, affecting over 6.7 million people due to the Sars-Cov-2/COVID-19 pandemic (Silva-Sobrinho et al., 2021). The various interconnections of the Coronavirus pandemic led to the collapse of the global capitalist economy—or at least

triggered an unprecedented recession and potential depression not seen since World War II (Waitzkin, 2021). Public health policies, as governmental tactics, were based on social isolation, social segregation, and the limitation of work-related activities. This economic impact of COVID-19 affected all activities performed by human capital.

Under the adverse conditions brought about especially by COVID-19, companies and entrepreneurs faced complex decision-making and had to rapidly adapt to the use and management of technology and innovation. León, López, & Sandoval (2009) highlight the importance of managing technical knowledge through business networks or the interconnectivity among different entities that provide information—such as research centers, universities, competitors, suppliers, and others—who contribute valuable resources like knowledge and information spillovers to organizations. Similarly, academic producers of scientific-technological knowledge form external networks to transmit this intangible resource—knowledge—to society (Carrazco & León, 2017; Vázquez, 2017).

Knowledge transfer networks among agents/actors are key to generating valuable resources within their areas of specialization. These transfer methods can create innovations that are promoted within knowledge networks or sub-networks composed of different branches or innovation nodes (Arias & Aristizábal, 2011; Vázquez, 2017). In the knowledge era, the capacity to generate valua ble knowledge primarily stems from universities, research centers, government institutions, and productive sectors. These actors play an important role in the scientific and technological development of companies and in both regional and local economic and social development (León, Gutiérrez & Carrazco, 2019). Like other productive activities, aquaculture is affected by internal and external factors that influence decision-making, reduce productivity, and consequently, impact profitability and competitive positioning (Araiza et al., 2020).

This research identified a set of institutional agents, both public and private, whose purpose is to meet the demands and needs of the shrimp aquaculture sector by generating, transferring, and communicating knowledge throughout production processes during the coronavirus pandemic. For this study, we identified four main sources of information (health, media, individuals, and government institutions). The objective of this study was to compare COVID-19 knowledge networks within shrimp-producing organizations in the Northwestern region of Mexico.

Based on the above, the following research question is posed:

What are the knowledge networks related to COVID-19 among shrimp aquaculture groups in the northern Pacific region of Mexico, particularly in the state of Sinaloa?

This article is structured as follows. The first section presents a literature review on the importance of scientific-technological knowledge transfer networks. The second section addresses the methodological procedure, and the analytical framework used in our analysis. The third section presents the results and discussion. The fourth section contains the conclusions of the research. Finally, the references that supported the work are listed.

2. Literature review

2.1. Knowledge Transfer Networks (KTN)

The study of knowledge and innovation transfer networks is considered a source of competitive advantage for companies, as it increases the stock of valuable knowledge that drives the creation of value through the transformation of manufactured goods and services. Thus, technology transfer consolidates innovation and serves as an important channel for cohesion among scientific-technological actors, universities/academics, the government sector, suppliers, and competitors.

Bergman (2009) notes that studies on knowledge and innovation transfer networks are not new. However, they emphasize the relevance for companies of managing technological innovation networks to support knowledge growth and development, helping improve competitive positioning in increasingly dynamic and turbulent local and international markets. In this sense, innovations can arise through complex social interactions among a group of actors committed to generating and transferring knowledge within the network (Hermans et al., 2017). Social networks act as catalysts in learning mechanisms to mitigate

problems and foster new ideas. Clearly, in business innovation, social networks are indispensable as effective tools for research and for transforming commercial products and services offered to local and international markets (Kolleck, 2013).

Pérez & Harwith (2008) argue that networks with greater link capacity exhibit higher average rates of adoption for profitable knowledge. This is crucial for companies, as contact networks facilitate access to information and the ability to transform knowledge into service improvements. Furthermore, the strategic positioning and quality of actors within the network allow them to acquire key information from external sources, thereby boosting productivity and competitiveness (Aguilar et al., 2016). Strong and direct business relationships help establish a favorable position relative to competitors. In other words, strategic positioning within a knowledge transfer network acts as a source of competitive advantage for the company (Galán, Casanueva & Castro-Abancéns, 2010).

2.2. Social Network Analysis (SNA) as an approach to business studies

The RS is based on the study of the impact of multiple interactions among heterogeneous and homogeneous agents by classifying their structures. Structural analysis of social networks studies the behavior of individuals at the micro level (network structure), at the macro level, and the interaction between the two levels (Sanz, 2003). That is, ARS supports the analysis of interactions among individuals and organizations within the social network, reflecting both the quantity and quality of knowledge and information flows. León, Gutiérrez & Carrazco (2019) point out that ARS, as a social approach, addresses various aspects where data richness is a relevant factor, along with the variables or characteristics of the unit of analysis, based on questions such as: Who do you learn from and/or consult to acquire technical and productive knowledge related to your production unit? Additionally, ARS establishes a fundamental principle: Who are your contacts/relationships or immediate neighbors?

In this way, ARS holds a relevant position in studying organizational impacts and innovation networks, making it a suitable analysis method for these fields. However, innovation networks or collaborative networks among actors help facilitate the development of new products; though, they do not guarantee productivity and successful growth (Van der Valk & Gijsbers, 2010; Van der Valk, Chappin & Gijsbers, 2011; Landsperger & Spieth, 2011).

Thus, ARS facilitates the analysis of interactions between actors and their social and institutional environment. In this study involving agricultural producers (aquaculturists), measures of Degree, Betweenness, Authority, and Hub were used. According to social network theory and analysis (SNA theory), these indicators allow identifying reciprocal and non-reciprocal ties, which acknowledge that knowledge and information are transferred along these links.

Leyva, Borbón & Pérez (2018) point out that the structure formed by a set of companies within the same homogeneous sector and distributed within the same geographic area or locality results in a virtuous collaboration network. In ARS, actors in a social network may have different roles depending on their degree, highlighting their power of betweenness in relation to others and their closeness. Betweenness plays a key role for network members, as they benefit from the spillover of information arising from the interconnectivity of groups, thus gaining a more advantageous position due to their specific placement in the network.

Meanwhile, Pérez, Ureña & Rodríguez (2015) define betweenness degree as the extent to which other actors must pass through a focal actor to communicate with the rest of the actors. This metric provides an idea of the control each actor holds over relational flows within the network. Núñez-Espinoza, Figueroa-Rodríguez & Jiménez-Sánchez (2014) state that betweenness is the centrality measure indicating how frequently a node appears as a potential connection between otherwise disconnected nodes. These authors suggest that through betweenness in the network, actors connected to a group of actors through linking mechanisms positively influence either the opening or closure of cohesion processes in the social network or community (Colina et al., 2013).

For social network analysis, the position of edges can be studied through centrality measures. That is, the node with the highest number of links within the network has a greater capacity to absorb learning and innovation from participation with other actors who provide a spillover of valuable knowledge or control key information (Reinholt, Pedersen & Foss, 2011).

Table 1. Metrics of social netowork analysis

Concept	Definition	Authors
Degree	a) The number of actors to which an actor is directly connected. b) The number of adjacent nodes. c) It expresses the percentage of ties an actor has. The higher the degree, the greater the number of people a node connects with, thus representing the quantity of links but not their quality. d) Degree is a simple centrality measure that counts how may neighbors a node has.	Borgatti et al. (2002); Sanz (2003).
Betweenness	a) The position of a node in the network in terms of its capacity to connect pairs of nodes in the network, "it is the sum of the combinations of all pairs of nodes in the network that communicate via the shortest path". b) The ability of a node to mediate communication between pairs of nodes. These nodes are also known as bridge actors. c) This indicator measures the extent to which a point is located between other points in the network. "Its importance lies in measuring the capacity of nodes to connect different groups and act as intermediaries, and they are usually associated with individuals who have greater innovation capability".	Freeman et al. (1991)
Authority	a) A node that provides relevant content in a network and selects, groups, and disseminates information within the network. b) Provides a measure of how valuable the information provided by a node is to its linked actors; calculated using the PageRank algorithm, which computes the authority of node i based on the authority of its neighbors according to their relationships.	Marcelino, Pinto & Marqués (2020); De la Rosa et al. (2005).
Hub	a) An actor/node that concentrates the largest number of links in the network, "dynamically managing organizational boundaries by connecting external resources with those inside". b) The capacity of a hub is measured by the maximum incoming or outgoing information per period, assessing the quality and quantity of the information (it is a space where diverse actors interact).	Cruz (2014); Roldán-Suárez et al. (2018).

Source: Own elaboration.

Marcelino, Pinto & Marqués (2020) determine that authority in a social network is considered a node that provides valuable information to actors interconnected in diverse ways with others. De la Rosa et al. (2005) identify authority in social network analysis as the node author with the highest hierarchy concerning the edges forming the graph. Building effective and efficient authority networks is associated with the mediating role played by the best-positioned actor in the network, acting as a bridge or direct link to social capital to exploit their skills, information exchange, accessibility, and connections with other actors (Yeniterzi & Callan, 2014).

Hubbell (1965), Kleinberg (1999), and Arcos (2017) clearly explain the relevance of authority distribution by measuring how valuable the information of an actor is to its linked nodes, whereas the Hub measures the quality of the nodes connected to the actor with the highest authority. Hubbell (1965) explains that each node has a priori internal weight from the beginning, accompanied by the strength of connection between each pair of nodes. The interaction of diverse actors through a similar notion of influence weights, scaled by connection strength, captures its most prominent and central members with a large volume of information in a more manageable representation. In other words, the hub maintains value with environmental agents and acts as a key information source for the organization. Therefore, the quantity and quality of interconnectivity among actors determine the level of technological and competitive innovation

compared to competitors.

According to social network analysis, Roldán-Suárez et al. (2018) argue that the Hub increases the content and type of knowledge flows in the network, promoting improvement of relational capital and the structure of regional networks. Arias and Alarcón (2019) maintain that agri-food innovation systems feedback knowledge to achieve technological change with collective benefits and must possess synergies between actors and productive systems, where relational capital seeds ties intraorganizationally and extraorganizationally, in regions that form Hubs based on their diversity of relations and closeness in the network with other actors.

3. Methodology

3.1. Participants

This study was conducted using a quantitative approach based on ARS. A sample was taken consisting of aquaculture farms located in the northwestern region (Sinaloa) of Mexico, during the period from April to August 2020. According to Leskovec & Faloutsos (2006), the type of sampling used in ARS differs from conventional analysis and can be done in three ways: a) random selection of nodes, b) random selection of links, and c) an exploration technique that simulates random steps. For this study, the first type was used, as it establishes a sub-network that represents the total connections of the original network (León et al., 2019).

3.2. Sample characteristics

This study is presented as a cross-sectional, descriptive, and correlational study (Field, 2013), with a randomly selected total of 102 shrimp-producing aquaculture units along the Sinaloa coast. Of these, 79.1% (n=81) were male and 20.9% (n=21) were female. The aquaculture producers surveyed were between 29 and 58 years old. Their educational background showed that 73.5% had completed university studies, 10.7% had finished upper secondary education (high school), and 15.6% had a technical degree.

According to the statistical description, the sample consisted mainly of small enterprises (74.50%), followed by medium-sized ones (23.52%), and to a lesser extent, large enterprises, which accounted for only 1.96%. Additionally, it was reported that some aquaculture units had an average operational history of 10 years (50%), followed by those with 11–15 years of operation, which represented 19.60% of the sample. Enterprises with 16–20 years of experience accounted for 8.82%, and those operating for over 20 years represented 21.56%. Regarding the economic sector (social or private) to which these aquaculture units belong, 94.11% were in the private sector, and 5.88% were in the social sector. The human experience of aquaculture producers in this region showed that 50% of respondents were aged between 39 and 50 years. A portion of the population reported being between 29 and 40 years old, representing 26.47%, while a group aged over 51 years made up 23.52%, where their experience in the field is key for future generations of aquaculture producers in Sinaloa.

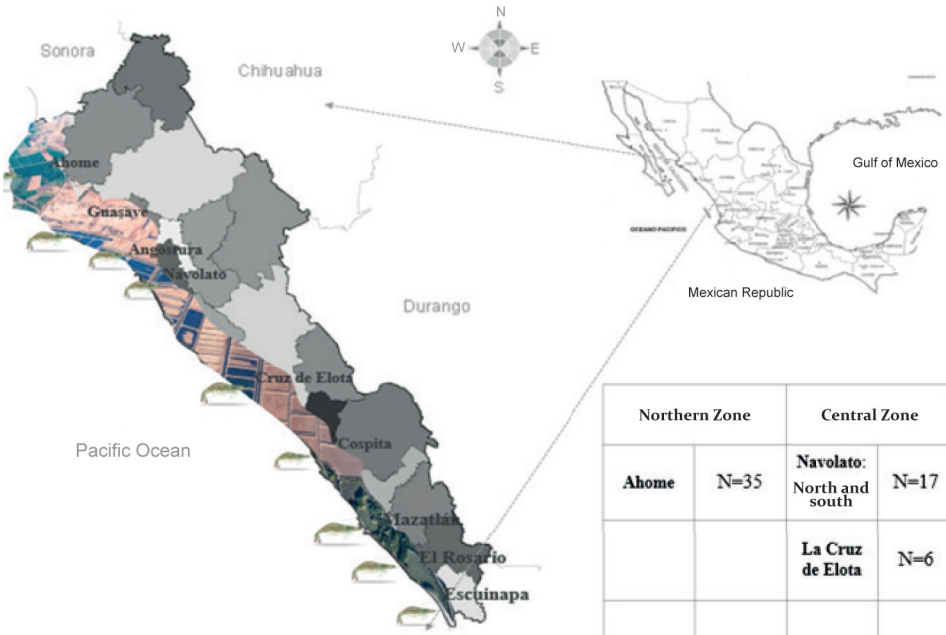
3.3. Research context

According to the regional diagnosis and planning for fisheries and aquaculture in Mexico, the Secretariat of Livestock and Rural Development (SADER) states that Region 1 of the northern Pacific, where the State of Sinaloa is located, is considered a significant corridor in the agri-food industry through shrimp production by aquaculture (SAGARPA, 2008). Geographically, Image 1 illustrates the regions that provided valuable information on knowledge networks during COVID-19 times.

3.4. Instruments

A questionnaire divided into three sections was applied: a) organizational variables; including company age, company size, and sector affiliation; b) productive variables related to COVID-19: including items about production before and during the pandemic, and the effects of COVID-19 on the production processes; and, c) social network variable: where organizations listed the contacts they turned to for information about COVID-19 and its relationship with the productive sector (see table 2).

Image 1. Location of the aquaculture units in Sinaloa.



Northern Zone		Central Zone		North Central Zone		Southrn Zone	
Ahome	N=35	**Navolato:** North and south	N=17	**Angostura**	N=3	**Mazatlán**	N=10
		La Cruz de Elota	N=6	**Guasave:** North and south	N=6	**El Rosario**	N=2
				Cospita	N=17	**Escuinapa**	N=6
TOTAL= 102							

Source: Own elaboration.

Table 2. Instrument structure

Variable	Item
Organizational	a. Company size; b. Years in operation; c. Education level of the aquaculture producer (decision-maker); d. Age; e. Sector to which the farm belongs
Productive (COVID-19)	a. Production before COVID-19 (Kgs); b. Production during COVID; c. Was production affected by COVID-19?, d. Were biosafety measures increased?, e. Is there a plan to mitigate a prolonged COVID-19 outbreak?
Social Network	Provide a list of your main contacts whom you reached out to for information during COVID-19 contingency, in order to protect your employees and act responsibly under good practices.

Source: Own elaboration.

It is important to mention that the social network variable is visualized through a graph, and the following measures were considered:

- Degree: This measure is expressed by the following formula:

$$CD\ (ni)=jxij$$

- Betweenness: This is represented by the following formula:

$$CB\ (ni)=j<kgjk(ni)/gjk$$

Where gjk is the number of shortest paths from node j to node k, y gjik is the shortest path from j to k that passes through node i.

- Authority: This measure is expressed as:

$$ai=jB(i)hj$$

Where ai represents the authority of node i, and B(i) is the set of reference nodes foor node i.

- Hub: Represented by the following expression:

$$hi=jF(i)aj$$

Where hi represents the Hub weight of node i, and F(i) is the set of nodes referenced by node i.

3.5. Data Analysis

Data analysis was conducted using the statistical software STATA 14 for descriptive statistics. Meanwhile, for the construction of the networks (graph) and the calculation of network indicators (degree, betweenness, authority, and hub), the software Gephi 0.9.2 was used.

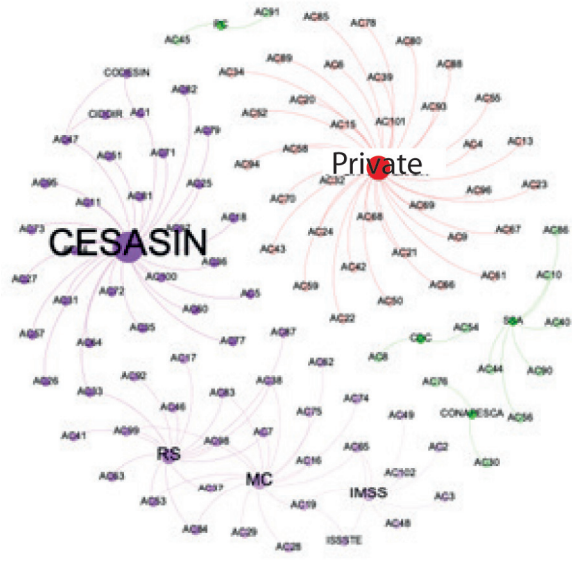
4. Results

4.1. Characteristics of the COVID-19 Knowledge Transfer Networks in aquaculture clusters in the state of Sinaloa

Based on a sample of 102 aquaculture clusters (farms) engaged in shrimp farming, four main sources were identified: 1. Health Sector, 2. Private Sources 3. Government Sector; and, 4. Media, to which producers turned for information about COVID-19 and its effects on shrimp farming in the northern Pacific region. Figure 1 shows a graphical representation of these sources as factors in the COVID-19 knowledge transfer process, in relation to the different sets of information sources linked to aquaculture farms.

The graph reveals that the sectors with the greatest weight in the network are the Health Sector (CESASIN, IMSS, ISSSTE, and SSA) and the Private Sector. Regarding the Health Sector, its significant impact on the aquaculture industry is understandable, as it encompasses the main official sources of health information. This finding aligns with Mohamad et al. (2020), who found that in Malaysia, the primary source of information for the population was the Ministry of Health, with 95% acceptance. On the other hand, the Private Sector is somewhat ambiguous, as the sources of information may include healthcare professionals but also individuals unrelated to the field, potentially leading to misinformation. This concern is also raised by Salaverría et al. (2020).

Figure 1. COVID-19 RTC in aquaculture farms of Sinaloa.



Source: Own elaboration
Note: The nodes starting with AC represent the aquaculture farms.

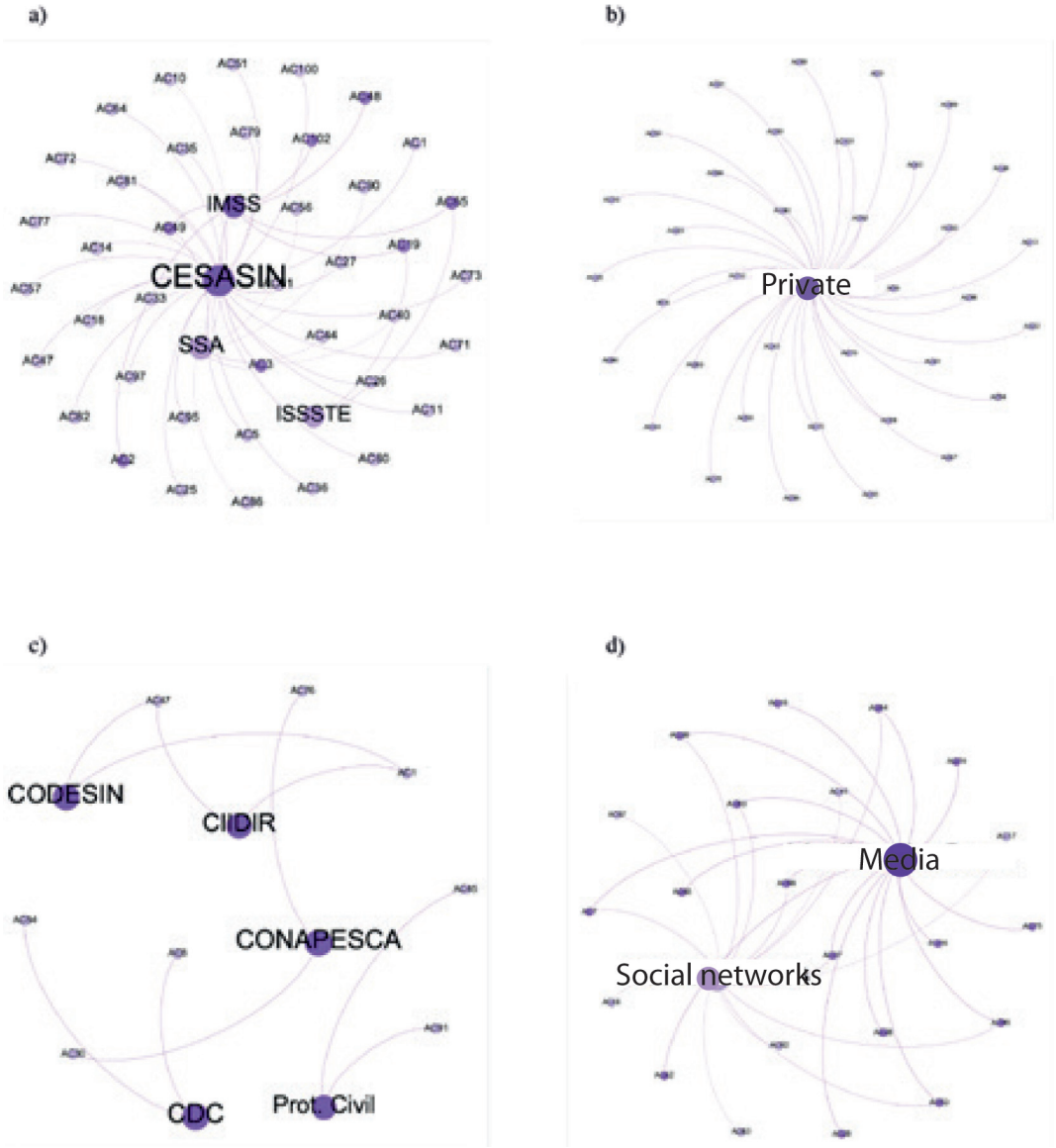
Figure 2 groups the network of the Health Sector. It shows that the network is highly centralized around CESASIN, which functions as the main source of knowledge transfer from the health sector to aquaculture enterprises. Secondary sources include IMSS, SSA, and ISSSTE. The number of aquaculture clusters belonging to this network is 40, and within it, 44 connections are generated. This network concentrates 39.2% of the aquaculture farms that make up the sample.

The figure also shows the links between aquaculture farms and private actors who provided information about COVID-19. Private sources refer to independent biologists, family members, friends, and other aquaculture producers in the studied region. The network is completely centralized, as the sources mentioned are grouped into a single node. Similar to Wang et al. (2020), personal networks played a significant role, with 46.1% of participants stating they turned to private sources for COVID-19 information.

In Table 3, the measures of the network presented in Figure 3a are shown. It can be observed that CESASIN is the main source of information within the Health sector, concentrating 27 links with producers (aquaculture farmers), making it the main actor acting as an intermediary (351.0) for the rest of the aquaculture farmers in the network. Regarding the authority measure, CESASIN provides highly valuable information to its linked actors (0.981); however, the nodes surrounding CESASIN do not provide high-quality information (0.188). This is natural since CESASIN, as the main actor within the network, concentrates the greatest information transfer, which represents higher quality. These results are consistent with those of Carrazco, Leyva, and León (2020), where the Sinaloa Aquaculture Cluster showed similar levels of intermediation (114.85), authority (0.29), and hub (0.15), considering CESASIN as a common denominator in the knowledge networks of both studies.

Table 4 presents the characteristics of the network shown in Figure 3b. This table highlights the value of influence and information quality provided by private sources. The intermediation of this node (Private) is high, as it is the only node that connects the rest of the network, with a value of 630.0. Likewise, the information it manages for the network members is highly valuable (0.986).

Figure 2. COVID-19 RTC in aquaculture clusters of Sinaloa.



Note: The nodes that start with AC are aquaculture farms.

Table 3. Measures of the Knowledge Network between Aquaculture Groups and the Health Sector

Actors	Degree	Betweenness	Authority	Hub
**CESASIN*	27	351.0	0.981	0.188
***IMSS*	7	67.0	0.0	0.0
****ISSSTE*	2	0.5	0.0	0.0
*****SSA*	8	69.5	0.0	0.0
Aquaculture average	1.1	1.55	0.02	0.12

Source: Own elaboration
*CESASIN. Comité Estatal de Sanidad Acuícola de Sinaloa
**IMSS. Instituto Mexicano del Seguro Social
***ISSSTE. Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado
****SSA. Secretaría de Salud

Table 4. Network Measures between Aquaculture Groups and Private Sources

Actors	Degree	Betweenness	Authority	Hub
Private	36	630.0	0.986	0.164
Aquaculture average	1	0.0	0.027	0.164

Source: Own elaboration.

Figure 3 shows the network between farms and the government sector. Unlike the previous networks, this one has only 13 actors, but is more distributed. However, it can be inferred that producers consulted the government sector to a lesser extent for COVID-19 information. In Thomas et al. (2021), there were no

similar participation patterns to those in the present study; however, the government ranked the lowest (31%) among the sources consulted by the Australian population, similar to the knowledge network of the government sector regarding aquaculture farms.

Although all government actors have a degree of 2, CONAPESCA, CDC, and Protección Civil have higher intermediation (1) because they act as the only links between two aquaculture producers, hence their higher intermediation. On the other hand, CIIDIR and CODESIN have an intermediation of 0.5, as they share the same four aquaculture farms, which divides the connection. However, in terms of authority and hub, the latter two score 0.5 in both measures, as the information they transfer to these four farms is more influential (see Table 5).

Table 5. Network measures between aquaculture groups and the government sector

Actors	Degree	Betweenness	Authority	Hub
**CONAPESCA*	2	1	0.0	0.0
***CIIDIR*	2	0.5	0.5	0.5
***CODESIN	2	0.5	0.5	0.5
*****CDC*	2	1	0.0	0.0
Prot. Civil	2	1	0.0	0.0
Aquaculture average	1.25	0.12	0.12	0.12

Source: Own elaboration.
*CONAPESCA. Comisión Nacional de Acuacultura y Pesca.
**CIIDIR. Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional. Unidad Sinaloa.
***CODESIN. Consejo para el Desarrollo Económico de Sinaloa.
****CDC. Centros para el Control y la Prevención de Enfermedades.

The knowledge network in Figure 3d represents the relationship between farms and the media. This is a bifurcated network between social media (SM) and traditional media (TM). What stands out in this network is that aquaculture producers largely alternated between both sources.

Both TM and SM have very similar measures, as reflected in the values in Table 6. However, TM has slightly higher values, as it connects with 16 aquaculture farms, has an intermediation of 162, and provides highly valuable information (0.714). In contrast, SM has an intermediation of 131, an authority score of 0.630, and a hub score of 0.201. Despite appearing to be a polarized network, it is actually very homogeneous, as there are eight aquaculture producers who are interconnected with both types of sources. It is important to note that this network ranks third in terms of degree, just six nodes below the private network. This shows that the media and social networks play a very important role within aquaculture farms. This result aligns with various studies showing that, globally, social media (internet) was the predominant source of information among the population (Wang et al., 2020; Mohamad et al., 2020; Aweke et al., 2020); however, these are also the sources most prone to misinformation and fake news (Salaverría et al., 2020).

Table 6. Network Measures between Aquaculture Groups and Media

Actors	Degree	Betweenness	Authority	Hub
Media	16	162	0.714	0.227
Social networks	14	131	0.630	0.201
Aquaculture average	1.3	2.86	0.061	0.191

Source: Own elaboration.

4.2. Relationship between organizational, productive, and social network variables

Table 7 presents a description of the aquaculture groups' production variable and the COVID-19 knowledge networks. In Table 8, it is shown that the producers linked with the knowledge networks in the Health sector, Private sources, and Media reduced their production during the confinement period (April–August 2020) compared to the pre-COVID-19 period. However, the network most affected was the Private one, with the largest drop in production compared to other networks. On the other hand, the farms that slightly increased their production during confinement were those in the government network.

Regarding the remaining variables (Productive Impact, Increase in Safety Measures, and Mitigation Plan), there is a similarity across all knowledge networks. However, the Private network stands out, as despite experiencing a considerable decline in productivity, only 57% of the aquaculture groups within this network reported having a backup plan to face a prolonged outbreak. This could indicate

Table 7. Descriptive statistics of the productive variable in relation to COVID-19

Variables	Health Network	Private Network	Government Network	Media Network
Network Variables				
Betweenness	122 (155.9)	630	.8 (.273)	146.5 (21.9)
Maximum Authority	.981	.986	.5	.714
Maximum Hub	.188	.164	.5	.227
Productive Variables				
Production before COVID-19 (Kgs)	59,805 (71,745)	92,040.17 (117,339.39)	64,243.75 (77,780.90)	74,413.63 (71,833.51)
Production during COVID-19 (Kgs)	53,171.09 (54,189.83)	84,789.14 (105,891.85)	64,510.12 (70,437.55)	71,095.21 (68,401.77)
COVID-19 affected production =1	.80 (.40)	.71 (.45)	.87 (.35)	.72 (.45)
Increased biosecurity measures since COVID-19 =1	.82 (.38)	.85 (.35)	.62 (.51)	.72 (.45)
Has plan for extended outbreak=1	.77 (.42)	.57 (.50)	.75 (.46)	.59 (.50)

Source: Own elaboration
Note: Table shows the mean of each variable and the standard deviation in parentheses.

that the private network, despite its levels of intermediation, authority, and hub status, did not provide sufficient knowledge to the farms connected to it to sustain production during the COVID-19 lockdown period.

5. Conclusions

Globally, Mexico ranks seventh in food production from the agricultural sector. In the fishing and aquaculture field, it has the potential to expand the national food supply, contribute to food security, generate foreign exchange through exports, and serve as a source of direct and indirect employment, thereby contributing to the region's social well-being.

The objective of this study was to analyze the knowledge transfer networks related to COVID-19 among shrimp-producing aquaculture groups in the northern Pacific region of Mexico, with a special focus on the state of Sinaloa, and to understand how these networks contributed to mitigating the effects of COVID-19 at the organizational and productive levels.

Collective efforts among aquaculture farmers and the capacity to manage knowledge through business networks or interconnectivity among the different entities that provide information—as well as the producers of scientific-technological knowledge who strengthen cooperation ties to transmit resources to society—substantially contribute to the competitive performance of companies and help mitigate the turbulent impacts produced by the market.

This research provides an empirical contribution to the literature on the COVID-19 pandemic within the agricultural system, especially in aquatic sectors such as Pacific white shrimp aquaculture. Furthermore, it allows researchers and producers to understand the structure of networks and knowledge flows for the benefit of aquaculture farmers and companies.

Based on the results, it is reported that through Social Network Analysis (SNA), there are different sources of information that aquaculture farmers turn to in order to acquire knowledge about COVID-19 and its effects on shrimp farming. This information enabled a comparative analysis of the different knowledge transfer networks present in the northern Pacific region of the state of Sinaloa.

Through SNA, four networks were identified as knowledge transfer channels (health sector, private sources, government sector, and media), which producers use to obtain information about COVID-19 and its impact on the studied agricultural activity. One of the main limitations of the study lies in the sample size, which limits the ability to generalize the large-scale impact. However, specific data can still be retrieved for the aquaculture groups in the state of Sinaloa. Originality. This study provides an analysis of the topology of COVID-19 knowledge networks for an aquaculture sector that has been little studied to date.

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RESEARCH

Use of conjoint analysis to estimate consumer preferences for goat milk powder in the Coquimbo Region, Chile

Uso del análisis conjunto para estimar preferencias de consumo de leche de cabra en polvo en la Región de Coquimbo Chile

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Matías Arancibia Flores [1],
Nicolás Jorquera Reyes [2] and Marcelo Chacana Ojeda [3]

[1] Master's in Business Innovation Management, Universidad Santo Tomás, Chile. Researcher at Centro de Innovación y Modelación de Negocios, Universidad Santo Tomás, Chile, Ruta Norte 5 Nº 1068 La Serena, Chile.
E-mail: marancibia11@santotomas.cl ORCID: https://orcid.org/0000-0001-7010-8947

[2] Master's in Innovation and Design, Universidad Adolfo Ibáñez, Chile. Researcher at Centro de Innovación y Modelación de Negocios, Universidad Santo Tomás, Chile. Faculty member at Escuela de Diseño Design Lab Universidad Adolfo Ibáñez Chile, Diagonal las torres 2640 Peñalolén Santiago Chile.
E-mail: njorquera4@santotomas.cl ORCID: https://orcid.org/0000-0003-4717-1854

[3] Corresponding autor. PhD candidate in Economics and Business, Universitat Jaume I, Spain. Executive director of Centro de Innovación y Modelación de Negocios, Universidad Santo Tomás, Chile, Ruta Norte 5 Nº 1068 La Serena, Chile.
E-mail: mchacana@santotomas.cl ORCID: https://orcid.org/0000-0002-2303-8509

Abstract

Traditional foods can use consumer science approaches to define market segments and consumer attributes, the present research analyzes the relative importance of consumer determinants for goat milk powder (origin, fat content, format, price), using the multivalent conjoint analysis methodology on a sample of 188 subjects from the Coquimbo Region (Chile). The results show that the most valued attribute in relative importance by the surveyed consumers is the origin of the product 26.7 %, preferring a national product to an international one, followed by fat content 26.4 %, distinguishing skim milk over whole milk, then product format 24.2 %, a small format, and finally price 22,8 %, as the least significant attribute, opting for the lowest cost ($15,000 CLP). Consumers preferred the skim variant, which is suitable for children and adults, as well as the small package size (450 g) because it is easier to measure and consume.

Keywords: Goat milk powder, consumer preferences, conjoint analysis, Traditional food products.

Resumen

Los alimentos tradicionales pueden utilizar enfoques de la ciencia del consumidor para definir segmentos de mercado y atributos de consumo, la presente investigación analiza la importancia relativa de los determinantes del consumidor para leche de cabra en polvo (origen, contenido de grasa, formato, precio), mediante la metodología multivalente de análisis conjunto (conjoint analysis) sobre una muestra 188 sujetos de la Región de Coquimbo Chile. Los resultados evidencian que el atributo más valorado en importancia relativa por los consumidores encuestados es el origen del producto 26.7 %, prefiriendo un producto nacional al internacional, seguido del contenido de grasa 26.4 %, distinguiendo la leche descremada sobre la leche entera, luego el formato del producto 24.2 %, un formato pequeño, y finalmente el precio 22.8 %, como atributo menos significativo optando al de menor costo ($15.000 CLP). Los consumidores prefirieron la variante nacional, descremada que se adapta a niños y adultos, también el tamaño de envases pequeño (450 gr) ya que es más fácil de medir y consumir.

Palabras Claves: Leche de cabra en polvo, preferencia del consumidor, análisis conjunto, productos agroalimentarios tradicionales

1. Introduction

Chile shares, along with many other Latin American countries, a rich heritage of traditional and typical foods with unique sensory and nutritional properties—products that reflect the history, culture, and way of life of each country and region. Traditional foods resemble functional foods in that they have proven physiological benefits, helping to improve public health and reduce the risk of diseases (Al-Sheraji et al., 2013). Consequently, consumer demand for these products has increased in recent years, with the dairy industry having the potential to become one of the main sources of traditional products.

Dairy products have been recognized as an important part of the human diet in both developed and developing countries. Goat milk (Capra hircus) contains water, proteins, fats, sugars, minerals, and vitamins, all of which are essential for maintaining good health (Pineda et al., 2017).

Goat milk is produced by female goats after giving birth. Within 0–3 days, their colostrum contains many nutrients and is considered one of the best sources of protein, almost equivalent to human breast milk (Ranadheera et al., 2019).

Fluid goat milk and its processed products are useful as functional foods for maintaining nutrition and health in both young and elderly people, especially for those with cow milk allergies (Bytyqi et al., 2020; Sánchez et al., 2020). Goat milk can be used to produce a wide variety of dairy products such as cheese, yogurt, ice cream, condensed milk, butter, and powdered milk.

Powdered milk is prepared by removing water from the liquid milk (Pineda et al., 2017). It offers better qualities for maintaining its quality, requires less storage space, and incurs lower transportation costs (Pineda et al., 2017).

El proceso de obtención de leche de cabra en polvo ha sido estudiado por diferentes autores. En este sentido, Reddy et al. (2017) optimizaron las condiciones de procesamiento para la fabricación de leche de cabra en polvo, tomando en cuenta como variables independientes la concentración de la leche (25, 40, 45%) y la temperatura del aire de entrada (160, 170, 180 ºC), obteniéndose una composición aproximada de humedad (4,08%), grasas (26.85%), proteínas (25.48%), carbohidratos (36,99%) y cenizas (6.60%) (Getaneh et al, 2016).

In the Coquimbo Region (Chile), goat farming is highly important due to its historical and territorial ties. This region holds over 54% of the country's goat population (Yañez, 2022), with 80% being local breeds from crosses between goats originating from Spain and other European countries, resulting in high genetic variability. Production is mainly aimed at obtaining milk for cheese production, for both self-consumption and informal sales in nearby urban centers. To a lesser extent, goat meat is produced for sale. The production system is extensive and characterized by low herd productivity, where goats must forage over large areas for low-quality shrubs and grasses. Goats are milked once per day with low yields, and natural weaning is practiced (Venegas, 2017).

The profits obtained by small-scale goat producers (locally known as crianceros) through cheese production are low and highly dependent on climatic conditions—particularly given the region's and the country's ongoing water scarcity. Production is largely informal, with little to no implementation of food safety systems, traceability, or tax/health formalization by the producers. To reverse this situation, the Instituto de Desarrollo Agropecuario (INDAP), an agency under Chile's Ministry of Agriculture, has implemented a series of technical and commercial support programs for goat producers. These include the Programa de Desarrollo Local (PRODESAL), the Programa Agropecuario para el Desarrollo Integral de los Pequeños Campesinos del Secano de la Región de Coquimbo (PADIS), and the Programa de Alianzas Productivas (PAP).

Regarding goat milk product consumption, research exists on consumer behavior and preferences for dairy products, as well as the factors influencing such preferences toward goat milk (Bytyqi et al., 2020; Shunekeyeva, 2020; Güney & Sangün, 2019; Šugrová, 2018).

The price of goat milk is higher than that of cow milk, making it a promising commercial prospect in the long term (Tarigan et al., 2020). Moreover, studies show that consumers assume that all types

of goat dairy products—both fluid milk and its derivatives—share the same nutritional quality. Thus, it is important to study consumer preferences for a traditional product like powdered goat milk, given its high biological value, long shelf life, and ease of commercialization. It represents a significant innovation alternative for goat milk produced by crianceros in the Coquimbo Region.

Based on these considerations, it can be stated that there is limited information in the literature regarding consumer preferences for powdered goat milk in developing countries and regions with permanent water shortages. Therefore, the main objective of this study is to examine the relative importance of consumer preferences for powdered goat milk using a multivariate approach such as Conjoint Analysis. This approach assumes that a product's value (utility) is the sum of its constituent attributes (origin, fat content, format, price), which in turn determine consumer preferences for powdered goat milk in the Coquimbo Region of Chile.

2. Theoretical framework

2.1. Market Studies and Food Products

At times, market research may not be realistic or practical. Even asking respondents about preferred prices and attributes can be risky, potentially yielding impractical results. To complicate matters, it may be difficult for respondents to react to food products with which they are unfamiliar (Giacalone et al., 2015).

There is extensive literature on methodologies for evaluating consumer preferences: attribute ranking, the Zaltman technique, Kelly's repertory grid, semantic differential, preference maps, empathic design, laddering, group analysis, category appraisal, free elicitation, information acceleration, and comparisons that elicit character traits (Prada, 2013). However, the most commonly used method for assessing consumer preferences for a set of attributes is conjoint analysis (Eversheim, 2009).

Conjoint analysis is widely used in the food industry to develop experiments that examine the interaction between the various components and characteristics of food products (Calegari et al., 2018; Decloedt, Van Landchot & Vanhaecke, 2016; Qian et al., 2022). It is used to identify and understand consumer behavior toward attributes and stimuli, as well as to study how consumers perceive different combinations of attributes that make up food product offerings (Jensen et al., 2019; Lee & Hwang, 2016; Krystallis & Ness, 2005).

In food products, intrinsic properties such as flavor, texture, and aroma affect customers' perceived value (Reis et al., 2017; Calegari et al., 2018). However, several studies also highlight the importance of extrinsic attributes—such as brand, price, and packaging—in the purchasing decisions of food products (Ahmad & Anders, 2012; Annunziata & Scarpato, 2014; Bronnmann & Asche, 2016). It is important to note that product attributes are elements that consumers consider important and that serve as the basis for decision-making (Hidayat et al., 2012; Tekea, 2021).

In the global food market, the demand for animal-origin products is expected to grow in the coming years due to increasing urbanization, population growth, and rising incomes. The average growth rate of milk production was 2.1% over the last decade, and it is projected to increase by 22% by 2027 compared to the base period of 2015–2017 (OECD/FAO, 2018). Milk and dairy products fall under the category of frequently purchased food items, which makes the factors influencing their consumption even more important (Kurajdováa et al., 2015).

In recent years, there has been a growing trend in the consumption and awareness of goat milk and its products, based on their nutritional value and high digestibility compared to other types of milk (Popescu, 2019).

2.2. Traditional Agri-food Products

Traditional agri-food products (TAPs) are usually linked to the history and culture of a specific region (Cavicchi & Santini, 2018). TAPs can command a premium price because they are perceived as authentic, which in Europe often includes certification (Balogh et al., 2016). Although traditional foods may be considered more time-consuming, consumers are often willing to make this trade-off for health reasons (Almli et al., 2011; Balogh et al., 2016). Essentially, consumers prefer to

purchase typical and traditional foods that provide them with a sense of trust, familiarity, and tradition (Espejel, Camarena & Sandoval, 2014).

Traditional channels clearly have an opportunity to attract highly involved consumers who display price inelasticity. Applying consumer science can help bring innovation to traditional agricultural products (Torquati et al., 2018). Studies such as Nazzaro et al. (2019) have shown consumer acceptance of purchasing a traditional yet innovative product. However, consumers also tend to look for foods that are easy to transport, prepare, and store—that is, they seek convenience when it comes to preparing and cooking food (Botonaki, Natos & Mattas, 2009).

All of the above leads us to the following general research questions: (1) What are the most highly valuable attributes by consumers of powdered goat milk from the Coquimbo Region of Chile?, (2) What is the best combination of attribute utilities for powdered goat milk preferred by consumers in the Coquimbo Region of Chile? (3) What is the most relevant relative attribute for consumers of powdered goat milk in the Coquimbo Region of Chile?

3. Methodology

The research employed a quantitative, explanatory, and cross-sectional approach, measuring consumer preferences by calculating marginal utility indices for the different attributes valued by consumers in powdered goat milk. A field study was conducted in the main municipalities of the Coquimbo Region of Chile: La Serena, Coquimbo, Ovalle, Illapel, and Salamanca, using a convenience sample of 188 subjects, both men and women, who were adults and consumers of traditional goat milk products (target segment).

Data collection for the study was carried out in three stages: 1º a literature review to identify the main attributes considered important when choosing traditional goat milk products and their derivatives; 2º interviews with experts (8 professionals specializing in agri-food product development) and one focus group (10 participants from the target segment) define the purchase decision characteristics, resulting in four attributes and eight proposed levels; 3º a questionnaire was applied, composed of three sections: (i) respondent characterization questions, including gender, age, family income, place of residence, education level, among others; (ii) questions regarding the purchasing behavior of traditional goat milk products, especially powdered goat milk; (iii) an experiment with 8 product alternatives that respondents had to rank based on their consumption preferences (ordinal scale from 1 to 8), using the full-profile method (Naous & Legner, 2017). Respondents assigned a value of 1 to the most desired profile and 8 to the least desired, which was necessary for conducting the conjoint analysis. The product card is shown in Figure 1.

Table 1. Proposed attributes and levels for the purchase decision experiment of powdered goat milk in the Coqimbo Region, Chile.

Experiment	Product origin	Price	Fat content	Format
Product 1	National	$19.900	Skimmed	900 gr
Product 2	International	$15.900	Skimmed	450 gr
Product 3	National	$19.900	Skimmed	450 gr
Product 4	International	$19.900	Whole	450 gr
Product 5	International	$15.900	Skimmed	900 gr
Product 6	National	$15.900	Whole	450 gr
Product 7	International	$19.900	Whole	900 gr
Product 8	National	$15.900	Whole	900 gr

Source: Own elaboration.

Figure 1. Proposed card with the 8-product alternative (experiments)

Source: Own elaboration.

For the analysis of preferences, the product valuation

formula was used, which provides an estimate of the relative importance weights of the attributes. It is based on the premise that the different levels of attributes make a partial contribution to the total utility (Naous & Legner, 2017)).

$$Valuation = \beta_0 + \sum_{i=1}^{n} \beta_{1i} D_{1i} + \sum_{j=1}^{m} \beta_{2j} D_{2j} + \sum_{k=1}^{p} \beta_{3k} D_{3k} + \sum_{l=1}^{q} \beta_{4l} D_{4l}$$

Where $\beta_{1i}, \beta_{2j}, \beta_{3k}, \beta_{4l}$ are the values associated with levels i (i=1, 2, ..., n); j (j=1,2,.....,m), k (k=1,2,....., p) and l (l=1,2,...., q), corresponding respectively to the attributes: (1) product origin, fat content (2), format (3), and, price (4). The dummy variables $D_{1i}, D_{2j}, D_{3k}, D_{4l}$ take a value of 1 if the corresponding attribute level is present, and 0 otherwise (Malhotra, 2019).

Partial utilities may reach zero contribution, indicating the lowest preference for certain levels and, therefore, the minimum contribution to the total expected utility. They may also obtain the highest score, indicating the highest level of preference (Choi et al., 2013). The estimation of the partial utility values was carried out under an additive conjoint model, whose mathematical structure is expressed through the following equation of U(*Total*):

$$U_{(Total)} = U_{(Origin)i} + U_{(fat\ content)j} + U_{(Format)k} + U_{(Price)l} + constant$$

4. Results and discussion

There is evidence that factors such as gender, age, and educational level are linked to the preference for health-beneficial foods. Table 2 shows the demographic characteristics of consumers (survey respondents) of powdered goat milk in the Coquimbo Region of Chile. 64% are female, while male consumers make up 36%. This is consistent with the findings of Nugroho et al. (2020) and Agustina et al. (2021), which suggest that women tend to have a higher consumption-oriented nature. In particular, housewives play a fundamental role in determining and deciding the food consumed by their family members. Most respondents are between 31–40 years old (46%), and the highest level of education reported is technical-professional training (44%).

Table 2. Characteristics of goat milk consumers

N.º	Characteristics	Number of respondents	Percentage (%)
1	**Gender**		
	Female	125	66
	Male	63	34
	Total	**188**	**100**
2	**Age range**		
	18-30	44	23
	31-40	87	46
	41-50	46	24
	>50	11	6
	Total	**188**	**100**
3	**Educational level**		
	High school	38	20
	Technical-professional	46	25
	University degree	84	44
	Graduate studies	20	11
	Total	188	100

Source: Own elaboration based on primary data.

4.1. Research Data Correlation Test

This correlation test aimed to determine the relationship between the research data, i.e., the combination of attributes and consumer preferences for goat milk products in the Coquimbo Region. Table 3 shows the statistical correlation of the proposed model, identifying a strong relationship between attribute combinations and consumer preferences. The Pearson correlation coefficient was 0.897, indicating that consumer preference influences up to 91.8%. This reflects a very strong correlation, supported by a significance level of 0.001. Similarly, Kendall's Tau confirmed the correlation of the proposed variables with a coefficient of 0.786.

Table 3. Statistical correlation of the proposed model

	Value	Sig.
Pearson's R	0.897	0.001
Kendall's Tau	0.786	0.003

Source: Own elaboration.

4.2. Utility Value for Each Attribute Level Based on Consumer Preferences

The utility value expresses each respondent's opinion in numerical form as a basis for determining satisfaction levels (Shingh et al., 2020; Velcovská & Larsen, 2021). The utility value reflects consumer evaluation of each attribute level using positive and negative numbers. Larger positive values indicate higher acceptance of the attribute level, while negative values indicate lower acceptance. Table 4 shows the utility values for each attribute level based on consumer preferences. The most important attribute in goat milk from the Coquimbo Region is product origin, with an importance value of 26.7%. This aligns with findings from Hoffmann et al. (2020) and Achabou et al. (2022), which emphasize the relevance of extrinsic product attributes such as the country or region of origin. This is followed by fat content (26.4%), product format (24.2%), and finally, price (22.8%).

These results suggest that consumers perceive the origin of a product as a differentiating and health-promoting image, which could be leveraged as a commercial differentiation strategy. This would enable producers to maintain and enhance competitiveness and profitability in the market (Bentivoglio et al., 2019; Toledo-Macas et al., 2021).

Table 4. Utility value by preference for each attribute level

Attribute	Level	Utility estimate	Importance value (%)
Product origin	National	0.197	26.7
	International	-0.197	
Fat content	Whole	-0.265	26.4
	Skimmed	0.265	
Product format	450 gr	0.382	24.2
	900 gr	-0.382	
Price	$15.900 CLP	0.034	22.8
	$19.900 CLP	-0.034	

Source: Own elaboration.

5. Conclusions

This study aimed to examine the relative importance of consumer preferences for powdered goat milk in the Coquimbo Region, Chile, through the application of Conjoint Analysis methodology. The results reveal that the most accepted preferences for establishing a product were: product origin, fat content, packaging format, and price.

The most highly valued attribute by surveyed consumers was product origin (26.7%), with a preference for domestic over international products. This was followed by fat content (26.4%), where skimmed milk was favored over whole milk; product format (24.2%), with a preference for smaller packages; and finally, price (22.8%), where the lower price ($15,900 CLP) was the least significant attribute. Consumers preferred the skimmed variant, which is suitable for both children and adults. They also favored the smaller package size (450 g) due to its ease of use and consumption.

The results also highlight potential alternatives for adding value and innovating in traditional agri-food products—specifically, powdered goat milk—by identifying factors for differentiation and repositioning. These findings can guide local producers in developing strategies based on product origin.

Future research could apply Conjoint Analysis to gain deeper insight into the value attributes influencing product choice and estimate willingness to pay for features like a specific origin label. This study presents limitations related to its geographic scope; therefore, it is recommended to replicate it in other regions of the country (central and southern) to validate the findings.

Ultimately, the study's results offer valuable insights for professionals and decision-makers responsible for designing and implementing targeted strategies and policies to promote the differentiation and consumer acceptance of traditional agri-food products.

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