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Determinant of Competitiveness in Micro and Small Enterprises of the Steel-Automotive Sector in Northeastern Mexico

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Abstract: This study presents an analysis of factors influencing the competitiveness of micro and small enterprises (SMEs) in the steel-automotive sector in northeastern Mexico, specifically in the states of Coahuila and Nuevo León. Using a quantitative approach, a measurement instrument was designed, validated, and applied based on existing literature. The instrument was electronically administered to a sample of 116 entrepreneurs and managers. The study measured 12 independent variables, including the degree of technological innovation, productivity, energy efficiency, business profitability, level of Industry 4.0 adoption, strategic alliances, supply chain, staff training level, globalization, innovation capacity, market, and quality. A multiple linear regression analysis was conducted. Each construct was evaluated, and a Cronbach's alpha of 0.70 was obtained. Using the stepwise method in SPSS, six variables were selected for the final model. The adjusted R^2 of the model is 0.983 and includes X_1 = Degree of technological innovation, X_2 = Productivity, X_4 = Profitability, X_5 = Level of Industry 4.0 adoption, and X_{11} = Market. It is concluded that the non-significant variables are not yet identified or developed in this sector within the region.

Keywords: *Determinants, Competitiveness, SMEs, Steel, Automotive, Mexico.*

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I. INTRODUCTION

This study presents a global, Latin American, national, and state-level overview of the steel industry, supported by statistical data that enables reflection on its impact and relevance in improving the performance indicators of micro and small enterprises, as well as its influence on the competitiveness of the states of Coahuila and Nuevo León, Mexico (Latin American Steel Association, 2023; CANACERO, 2023; INEGI, 2022).

In the industrial sector, companies strive to overcome various challenges in competing within a dynamic and ever-changing social, economic, and business environment (INEGI, 2022; Data México, 2022; IMCO, 2023). Much of the manufacturing industry was significantly affected by the global pandemic, leading to delays, reduced production, and declining performance indicators—such was the case for the steel industry.

According to the World Steel Association (2021), steel is an alloy primarily composed of iron, with carbon added in a proportion of less than 2%, along with smaller amounts of manganese (less than 1%) and traces of other elements such as silicon, phosphorus, sulfur, and oxygen. The mechanical properties of steel—such as strength, hardness, and elasticity—can be modified depending on the type of treatment it undergoes during the manufacturing process.

Steel is the most important engineering material for the manufacturing industry. The steel industry plays a key role in economic development at the state, national, and international levels. It supplies essential inputs for industries such as construction, automotive, aerospace, metal-mechanics, and home appliances (World Steel Association, 2021). Figure 1 shows the distribution of industrial sectors consuming steel production in Latin America during 2022. The construction and automotive industries together accounted for over 65% of the steel produced in the region (Latin American Steel Association, 2022).

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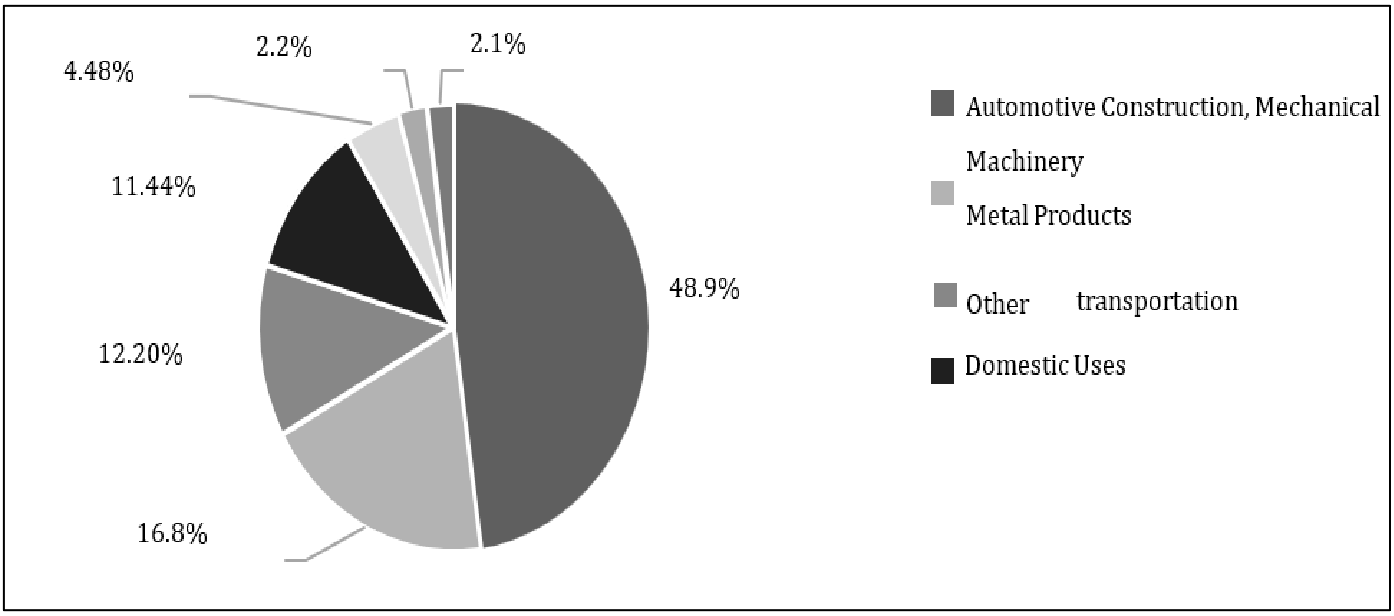

Fig 1 Distribution of Industrial Sectors Consuming Steel Production in Latin America During 2022
Source: Own Elaboration Based on Alacero (2022).

At the global level, the WSA states that the steel industry ranks second only to the oil and gas sector, with a significant socioeconomic impact on the development of any country.

According to reports published by the World Steel Association (WSA, 2022), global crude steel production in 2022 reached 1,885.4 million tons (Mt), representing a 2.8% decrease compared to the previous year.

In 2022, the Latin American Steel Association (ALACERO) reported an estimated production of 57.4 million tons of crude steel in Latin America. This industry provides direct employment to approximately 225,000 people, working in more than 160 production plants across the continent (Latin American Steel Association, 2022).

Figure 2 shows the distribution of the different countries contributing to this production and their respective percentages. Mexico ranks as the second-largest steel producer in Latin America (Latin American Steel Association, 2022).

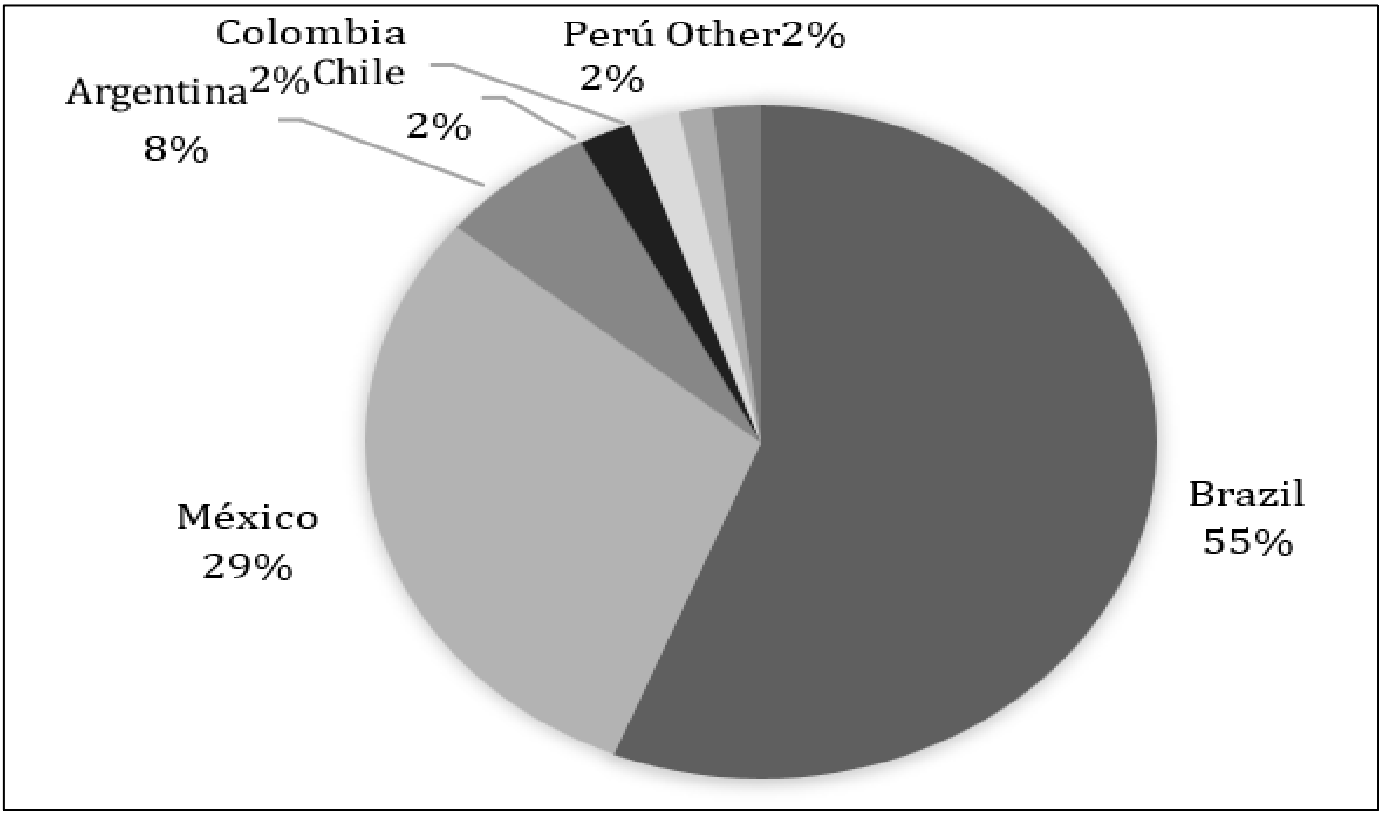

Fig 2 Distribution of Crude Steel Production in Latin America during 2022.
Source: Own Elaboration Based on Alacero (2022). *Estimate Based on the First 8 Months of 2022.

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According to data from the National Chamber of the Iron and Steel Industry (CANACERO, 2022), Mexico ranks fourteenth among the world's top steel producers. In 2022, the country produced a total of 19.7 million tons of liquid steel. The per capita steel consumption is 116 kg per year. The steel industry in Mexico generates 672,000 direct and indirect jobs (CANACERO, 2022; CANACERO, 2023).

In Mexico, 54% of steel production is based on recycled scrap, a percentage significantly higher than the global average of 25%, according to CANACERO figures (CANACERO, 2023). Mexico emits 1.18 tCO_2 per ton of steel produced, which is 38% lower than the global average of 1.88 tCO_2 per ton. Additionally, it consumes 24.3% less energy per ton of steel produced than the global average. Specifically, Mexico uses 13.3 GJ (gigajoules) per ton of steel, 38% less than the global benchmark (CANACERO, 2023).

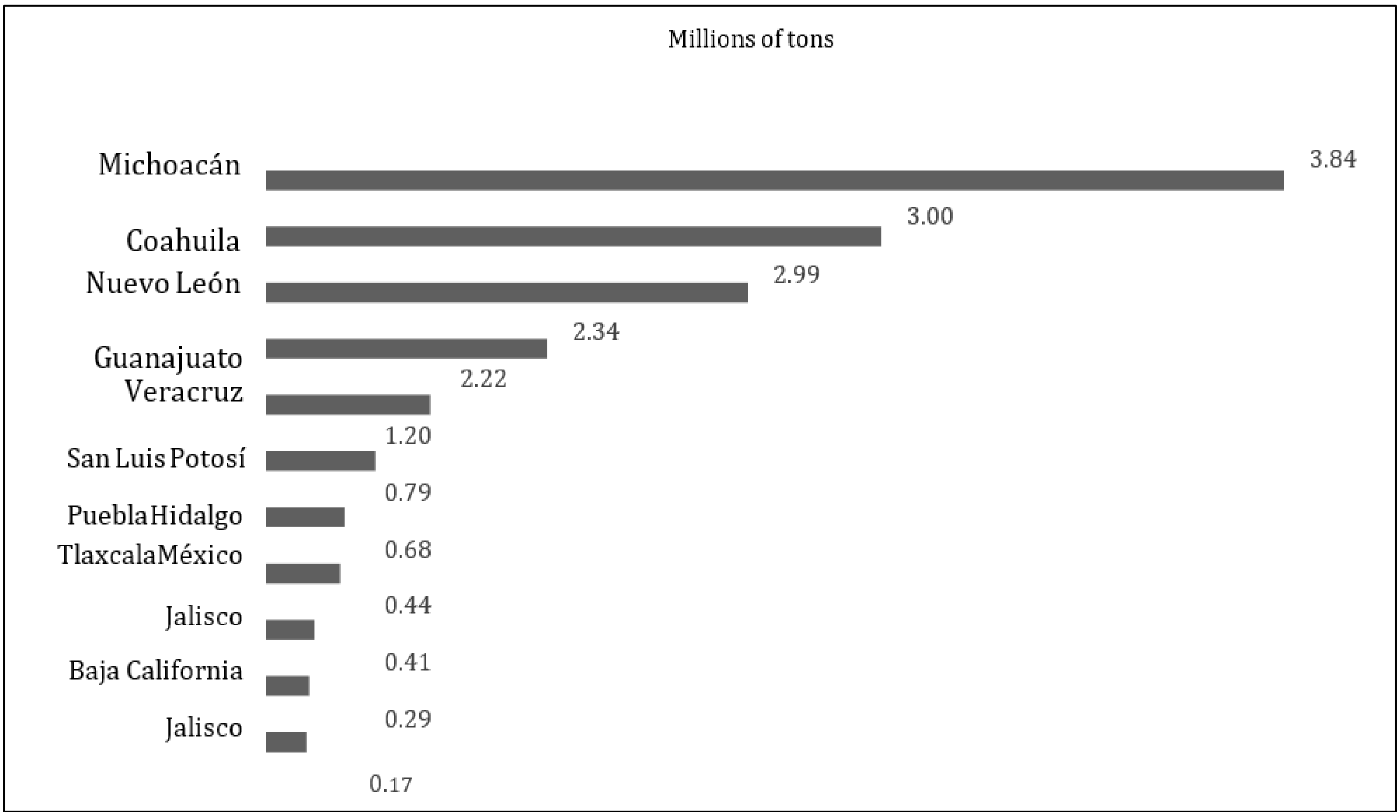

Fig 3 Presents the Distribution of Steel Production by State in Mexico During 2022.
Source: Own Elaboration Based on CANACERO (2023)

The state of Michoacán ranks as the country's leading producer, followed by Coahuila in second place and Nuevo León in third (CANACERO, 2023).

In northeastern Mexico, the country's steel industry production is concentrated, particularly in the states of Nuevo León and Coahuila (CANACERO, 2022).

In Nuevo León, there is raw material production, tube manufacturing, foundries, rolling mills, electric arc furnace production, service centers, steel distributors, and related industries (CANACERO, 2023).

In the state of Coahuila, tube production and steel manufacturing are carried out using both blast furnace and electric arc furnace methods. Additionally, this state is home to mining operations and, due to its border with the United States, has a customs facility for steel import and export activities (CANACERO, 2023).

II. THEORETICAL FRAMENWORK

Competitiveness is a key concept for understanding the economic performance of countries, industries, and companies within a dynamic global environment. Recent studies have explored this phenomenon using diverse methodologies, offering a comprehensive view of the driving forces behind it. This summary integrates five relevant investigations that examine competitiveness across different sectors and regions—from the European Union to emerging economies—with particular emphasis on the steel industry.

Benkovskis (2020) employs a quantitative approach based on Bayesian averaging to analyze the determinants of external competitiveness in 25 European Union countries. Panel models with annual data from 2003 to 2012 are used, considering 64 variables related to potential growth, as sampled by Sala-i-Martin et al. (2004). The study reveals systematic correlations between export market share growth

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and structural drivers. It identifies optimal combinations of variables that strengthen international competitiveness.

In a different context, Sekiguchi (2021) focuses on international steel trade among non-OECD countries. The study analyzes export data for approximately 190 steel products between 2001 and 2018, evaluating 88 countries using fixed-effects regression models. Although the R^2 values range from -0.040 to 0.131, relevant trends are identified, showing how emerging economies have evolved in terms of global positioning within the steel sector. The statistical analysis highlights significant relationships between changes in steel export levels and countries' structural dynamics.

Complementing these quantitative approaches, Espinoza et al. (2022) present a global literature review on competitiveness in the steel industry. Through recent publications, the study identifies key factors such as technological innovation, quality, human talent management, and energy efficiency as fundamental pillars for enhancing global competitiveness. This qualitative perspective helps bridge empirical findings with relevant theoretical frameworks.

From a financial standpoint, a study by the London School of Economics (2022) explores the strategic use of big data as a driver of competitiveness. Through semi-structured interviews and big data analysis, the study demonstrates that financial institutions adopting advanced technologies achieved significant improvements in decision-making, service personalization, and customer satisfaction—underscoring the role of digital transformation in building competitive advantage.

Finally, the University of Cape Town (2023) investigates inclusive competitiveness in South Africa. Using a mixed-methods approach, the study analyzed businesses and communities in both urban and rural areas, finding that social and economic inclusion policies increase access to opportunities and strengthen regional competitiveness. However, the study also emphasizes that persistent inequalities and infrastructure gaps still limit the full impact of these initiatives.

- *Applied Research on Variable X_1 = Degree of Technological Innovation*

Zang et al. (2020) conducted a study analyzing the impact of government effectiveness on technological innovation. The analysis included 1,844 observations related to government effectiveness and patent data in the United States, sourced from the National Bureau of Economic Research (NBER) covering the period from 1995 to 2014. The study applied the Random Forest method—a flexible and commonly used technique for feature selection—which effectively identifies the most relevant control variables. This method enhances the explanatory power of the model and provides more accurate estimations between variables. The findings demonstrate that the relationship between technological innovation and government effectiveness is not linear, but rather follows an inverted U-shaped curve.

Li et al. (2022) explored the impact of environmental regulation on technological innovation using panel data from 21 cities in the Guangdong province of China, covering the years 2005 to 2018. Through the Generalized Method of Moments (GMM) and lagged terms of the variable as instrumental variables to address endogeneity in the dynamic panel model, the study confirmed an inverted U-shaped impact of environmental regulation on technological innovation ($\alpha\_IS1 = –3.682$, $\alpha\_IS2 = 8.400$, $\alpha\_IS3 = –8.394$; $p < .05$). As the intensity of environmental regulation increased, its effect shifted from promoting to inhibiting technological innovation.

García-Lopera et al. (2022) conducted a study to analyze the influence of professionalization, risk-taking, and technological innovation on organizational performance. A total of 310 surveys were administered to SMEs in Spain. The study employed Partial Least Squares Structural Equation Modeling (PLS-SEM), a technique suited for complex relationship modeling by maximizing the explained variance of independent variables. The results showed that organizational performance is positively influenced by professionalization ($\alpha = .269$; $p < .001$), risk-taking ($\alpha = .178$; $p < .001$), and technological innovation ($\alpha = .251$; $p < .001$).

- *Applied Research on Variable X_2 = Productivity*

Parida et al. (2021) analyzed productivity differences between the public and private sectors of India's mining industry. The study utilized 906 observations to calculate Total Factor Productivity (TFP) across four mining sectors in India from 2000 to 2016. A multivariate regression model was developed with TFP as the dependent variable and lagged values of TFP, firm age, and ownership as independent variables. The results confirmed that private sector firms performed better, while public sector firms showed signs of instability over time ($\alpha = .18$; $p < .01$).

Liu et al. (2021) examined the effects and mechanisms of financing on TFP in Chinese manufacturing firms. Using a panel of 13,971 observations from 2007 to 2018, the study employed a GMM econometric model. Results indicated that deeper financial involvement significantly reduced TFP, and the magnitude of the impact varied by the type of financial asset ($\alpha = –.169$; $p < .05$).

Kumar (2021) highlighted that over the past 30 years, India has increased its steel production and consumption, leading to expanded production capacity. However, the competitiveness of the Indian steel industry does not reflect a significant break from the pre-reform decade. Real productivity of both labor and capital improved during the study period. Kumar concludes that productivity is a key factor in competitiveness and provides a time-series analysis to evaluate trends in productivity attributable to technological progress, focusing on three parameters: changes in ownership patterns, trade integration, and shifts in production technology pathways.

- *Applied Research on Variable X_3 = Energy Efficiency*

Vögele et al. (2020) analyzed the challenges faced by the steel industry in the European Union, including input price

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volatility, CO_2 emissions regulations, and trade barriers. Using a parametric metamodel, they evaluated the competitiveness of major producing countries against minimum viable costs, highlighting the need for coordinated policies that consider energy efficiency as a strategic response to these structural challenges.

From a technical perspective, Radoslaw (2020) proposed an econometric model linking energy consumption per ton of steel to investment levels and the adoption of Industry 4.0 technologies. The study emphasizes the importance of industrial cooperation networks and cyber-physical systems in increasing process flexibility and improving energy efficiency.

Stroud et al. (2020) focused their study on innovation and digitalization as tools to promote energy efficiency in the European steel industry. They pointed out that “greening” behaviors through gamification and digital management strategies can significantly contribute to the sector’s sustainability, although they also present challenges in labor relations.

Talaei et al. (2020) developed a system dynamics simulation model to assess energy efficiency alternatives in Canada’s iron and steel industry. The model integrates data on fuel types, processes, and energy intensities, and is used for long-term energy planning projections.

Fan et al. (2021) assessed green innovation efficiency in 235 cities across China using a spatial model. The results revealed significant positive spatial autocorrelation and spillover effects, indicating that energy efficiency policies can generate positive impacts in neighboring regions.

Dahir and Mahi (2021) examined the relationship between energy efficiency and environmental quality in BRICS countries using a panel ARDL model. Their findings show that a 1% increase in energy efficiency reduces carbon emissions by 1.878%, confirming its positive environmental impact.

Finally, Yan and Zhang (2021) analyzed 101 energy-intensive Chinese firms and demonstrated that both green innovation and environmental management positively influence corporate environmental performance, reaffirming the link between energy efficiency, sustainability, and competitiveness.

➢ *Applied Research on Variable X_4 = Business Profitability*

Business competitiveness is a multifactor phenomenon influenced by financial, structural, and governance elements. Recent studies have explored its determinants from different empirical perspectives, covering varied industrial sectors and geographic contexts. This summary integrates research focused on leverage, profitability, organizational structure, and market competition, highlighting their impact on corporate performance.

Apisakkul (2020) examined the factors affecting profitability in publicly listed family firms in Thailand, analyzing 164 companies from 2007 to 2017. Applying t-tests and Pearson and Spearman correlations, the findings showed that firms with female CEOs display statistically significant differences in Gross Profit Margin. Moreover, companies with women in family leadership posts exhibited better performance in Return on Assets and Return on Equity. These results underscore the importance of female leadership and board composition for business profitability.

Liu et al. (2022) investigated the impact of market competition on corporate performance in China. Using data from 1,668 firm-year observations, they employed the Generalized Method of Moments (GMM) and incorporated the Herfindahl-Hirschman Index (HHI) as a measure of market concentration. The results indicated that higher market competition is associated with significantly better business performance ($\alpha = 1.865$; $p < .01$), highlighting the positive relationship between competitive environments and organizational efficiency.

➢ *Applied Research on Variable X_5 = Level of Industry 4.0 Technology Adoption*

Kamp et al. (2021) analyzed whether the adoption of Industry 4.0 technologies influences the reshoring of production processes. The study was based on 475 surveys conducted with companies in the Basque Country participating in innovation programs. The results, obtained using the Kruskal-Wallis test, revealed a significant relationship ($p < 0.05$) between technological adoption and reshoring. However, when applying a more specific test (Dwass-Steel-Critchlow-Fligner), the significance disappeared ($p > 0.05$), suggesting that the relationship may be mediated by external factors such as uncertainty in international business environments.

In another study, Thing et al. (2021) explored the perceptions of SMEs in the halal sector in Malaysia regarding Industry 4.0. Based on 100 questionnaires and Partial Least Squares (PLS) analysis, the study found that top management perceived the technology as useful and accessible, particularly as a tool to reduce information asymmetry ($\alpha = .054$; $p < .05$), reinforcing its perceived strategic value.

Cucculelli et al. (2022) assessed the role of family leadership and institutional support in the transition to Industry 4.0 business models in 2,994 Italian manufacturing firms. Using multinomial probit regressions, the study confirmed that family ownership positively influences technological adoption ($\alpha = .028$; $p < .05$), while family management has a negative influence ($\alpha = -.017$; $p < .1$). This negative effect is offset by the intervention of the "Triple Helix" (government, university, and industry), which exerts a positive influence when acting collaboratively ($\alpha = .025$; $p < .1$), highlighting the importance of innovation ecosystems.

Finally, Xue et al. (2022) examined how digital transformation and boundary-spanning activities influence sustainable competitive advantage in 127 Chinese

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manufacturing firms. Through hierarchical regression analysis, the study confirmed that digital transformation positively impacts both boundary expansion and sustainable competitive advantage. Moreover, a mediating effect was identified, with 75% of the impact being direct and 25% explained by boundary-spanning. The "depth" of boundary-spanning was found to be more significant than its "breadth."

➢ *Applied Research on Variable X_6 = Strategic Alliances*

Tyll et al. (2020) studied the effects of strategic alliances among Czech SMEs, analyzing both the propensity of these companies to engage in alliances and the effectiveness of such collaborations in enhancing competitiveness. Surveys were designed and administered to SME representatives, specifically targeting firms with at least 250 employees. A random sample of 11,868 companies was generated using Microsoft Excel, and 1,500 firms were selected to receive the questionnaire. In absolute terms, 38 companies reported being involved in some form of strategic alliance. A similarity test was conducted to assess the correlation between cooperation and its different forms, revealing a strong relationship between cooperation and strategic alliances.

The statistical sample from this study indicates that the emergence of strategic alliances among Czech SMEs is gradually increasing. The findings also showed that partnerships with companies from the European Union were among the most strongly correlated variables with higher levels of competitiveness.

Kaihatu et al. (2020), in a quantitative study, analyzed the role of functional top management and its influence on innovation and the implementation of business strategies through strategic alliances. Data were collected from 29 four- and five-star hotels in Surabaya, Indonesia. The analysis was conducted using Structural Equation Modeling (SEM) to support the study's hypotheses. The survey took place between August and September 2019 and received a total of 87 responses. Data was processed using the General Structured Component Analysis method within SEM. The results showed that both innovation and strategic alliances had a significant influence on the organizations' performance.

Strašek et al. (2020) investigated whether companies involved in strategic business alliances demonstrate a higher level of open innovation and better outcomes. A survey was conducted among 115 companies within four industrial clusters and research and development centers in the metal processing industry. The study used various statistical methods, including the Mann-Whitney test, Chi-square test, and test-t. The questionnaire was pre-tested in a pilot study and subjected to reliability and validity checks. Conducted in Slovenia, the study found a Chi-square statistic of 8.49 with $p = 0.037$, confirming that companies engaged in strategic alliances tend to be more innovative.

➢ *Applied Research on Variable X_7 = Supply Chain*

The supply chain is a critical variable in the analysis of organizational competitiveness, especially in today's context marked by globalization, uncertainty, and the need for technological adaptation. Various empirical studies are integrated here, addressing the relationship between organizational capabilities, process integration, social responsibility, and resilience within the framework of efficient supply chain management.

Dubey et al. (2021) developed a model based on organizational information processing theory to link data analytics capability with supply chain resilience in 213 manufacturing organizations in India. Using partial least squares structural equation modeling (WarpPLS 5.0), they found that data analytics capability enhances resilience ($R^2 = 0.29$) and competitive advantage ($R^2 = 0.72$), validating all proposed hypotheses. This study highlights the importance of organizational intelligence as a catalyst for a robust supply chain.

Fontoura et al. (2021) analyzed how socially responsible behaviors within the supply chain impact the creation of shared value in the context of Portugal's largest energy provider. With a sample of 425 supply chain partners, a structured questionnaire and confirmatory factor analysis were used to validate the model. The results suggest that socially responsible practices aligned with the supply chain not only strengthen business performance but also improve the perception of shared value, thus contributing to sustainable competitive advantage.

Ma (2022) conducted an empirical analysis focused on supply chain integration—specifically internal integration—and its impact on logistics capabilities and organizational performance. Through structural equation modeling and multigroup analysis, it was confirmed that internal integration significantly enhances both logistics and supplier performance, which in turn leads to improved corporate performance. Additionally, the study found that supplier dependency can moderate these relationships.

➢ *Applied Research on Variable X_8 = Level of Staff Training*

Fanti et al. (2021) analyzed the relationship between labor productivity and skill matching in Italian companies. Using data from 2012, 2014, and 2017, they applied a new indicator that measures the alignment between the skills demanded and those offered by workers. The findings show that companies investing in adapting and developing their workforce's skills achieve higher productivity levels, validating the importance of training that is aligned with the dynamic needs of the labor market.

Finally, Noja et al. (2021) examined the drivers of competitiveness in 11 Central and Eastern European countries within the context of the knowledge economy. Applying macroeconometric models and structural equation modeling, they concluded that tertiary education and employment in knowledge-intensive sectors are decisive factors for competitive development and economic well-being. Investment in advanced training and education stands out as a key pillar for sustainable growth.

➢ *Applied Research on Variable X_9 = Globalization*

Hassan, M. S., et al. (2020) evaluated the relationship between governance and competitiveness by analyzing empirical data from developing countries, using a sample of 73 nations. The study covered a 12-year period from 2005 to 2016. The empirical analysis revealed that openness, competitiveness, and development expenditures play a significant role in shaping the competitiveness of the selected countries. The findings underscore the importance of globalization-related factors in national economic performance.

Romero-Borre, J. et al. (2022) aimed to develop a prospective model to explain how the internationalization of Venezuelan family businesses unfolds. The study began with a descriptive research phase based on theoretical and conceptual frameworks, followed by a structural analysis using the MicMac software to identify relationships among the variables in the model. The empirical data processing included a bivariate connection analysis, producing a Pearson correlation coefficient matrix to express the degree of association between the study variables. As a result, a systemic model was developed comprising 50 variables categorized as internal and external. Internal variables referred to elements within the firm that determine its competitive advantages (such as resources and capabilities under business control), while external variables represented environmental factors beyond the firm's control.

Fang, J., et al. (2022) investigated economic globalization indices and political factors through an empirical study using data from 1996 to 2016 across 142 countries. The study incorporated nine measures of economic globalization and two indicators of uncertainty: the World Uncertainty Index and the Trade Policy Uncertainty Index. Robustness checks were implemented to verify the consistency of the effects of uncertainty on economic globalization indicators. The analysis employed various alternative indicators and reported results by income-level categories. Multiple estimation procedures were used to address potential endogeneity and reverse causality issues. The study concluded that uncertainty has a detrimental impact on sustainable globalization.

➢ *Applied Research on Variable X_{10} = Innovation Capacity*

Álvarez et al. (2021) provided evidence on the complementarity between local and external knowledge sources in companies from the automotive and steel sectors in Argentina. While international networks strengthen innovation, the authors concluded that local capabilities remain essential for the absorption and adaptation of external knowledge. This finding highlights the importance of building endogenous capacities as a foundation for technological development in emerging economies.

Valenzuela-Fernández et al. (2021) conducted an empirical analysis in Chile involving 242 executives from the industrial B2B sector. Using a structured and validated questionnaire (Cronbach's alpha > 0.9, explained variance > 60%), they confirmed that organizational innovation capabilities are significantly related to innovation strategy, project management, collaborative networks, and market orientation ($p < 0.01$). Convergent and divergent validity were confirmed through exploratory factor analysis and chi-square difference tests, reinforcing the methodological robustness of the study.

➢ *Applied Research on Variable X_{11} = Market*

This section presents empirical studies that explore the relationship between market orientation and business competitiveness.

First, Stathakopoulos et al. (2022) investigated how market-driving strategies influence business outcomes, integrating both radical and incremental product innovation capabilities. The study was conducted in three phases using a mixed-methods approach.

The first sub-study was qualitative, involving interviews with 27 experts; the second was a large-scale quantitative survey with 241 valid responses; and the third involved a follow-up with 101 participants to analyze the impact of the strategy on market change. The analysis employed Partial Least Squares Structural Equation Modeling (PLS-SEM) using SmartPLS software. Although R^2 values were below 0.1, the study validated the structural model and the relationships between latent variables. The findings confirmed that a well-oriented market strategy yields strategic benefits in terms of innovation and organizational performance.

Secondly, Stocker et al. (2022) examined the impact of market orientation on the competitiveness of medium and large companies located in Central and Eastern Europe. The study used data from 119 Hungarian firms collected through surveys administered at five different points between 1996 and 2013. The surveys included four sections focused on executive perceptions in key areas such as marketing, operations, and finance. Statistical analysis included exploratory factor analysis, linear regression, and Durbin-Watson and Chi-square tests, with calculations performed in SPSS and Excel. Results indicated that market orientation, along with operational efficiency and adaptability, has a significant effect on a company's competitiveness index. Although the impact on market performance was only marginally significant ($p < 0.1$), the influence of competitive orientation on performance was confirmed.

➢ *Applied Research on Variable X_{12} = Quality*

First, the study by Aburayya et al. (2020) explores the critical success factors in the implementation of Total Quality Management (TQM) in public hospitals in Dubai. A quantitative approach was applied, using a questionnaire distributed among senior administrative and clinical staff in two public hospitals. Out of 600 distributed questionnaires, 356 valid responses were analyzed using descriptive and inferential statistics with SPSS software. Cronbach's alpha coefficients ranged from 0.724 to 0.916, indicating acceptable levels of reliability. The main finding highlights that top management commitment was the most influential factor in the effective implementation of TQM, with an average score

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of 4.8, underscoring its fundamental role in driving quality initiatives.

Valdez de la Rosa et al. (2021) analyzed the causal relationship between process quality and product innovation in relation to competitiveness in the automotive manufacturing sector, particularly among companies that use steel as a strategic input. The study demonstrated that both process quality and innovation have independent and positive causal relationships with competitiveness, emphasizing the importance of these two factors as key drivers of competitive performance in technologically demanding industrial contexts.

In a third study, Liu et al. (2022) conducted empirical research in China to assess the impact of specific quality management practices on manufacturing performance. A total of 123 valid questionnaires were collected from middle and senior managers across 210 manufacturing companies. Using SPSS 23.0, the study performed reliability tests, validity checks, and Pearson correlation analysis. The analyzed variables included employer management, customer service, supplier management, training, information analysis, and product and process design. The results revealed significant relationships between these quality management practices and manufacturing performance. The research is grounded in systems theory, viewing quality management as an interconnected set of organizational practices.

The objective is determine the factors that influence the competitiveness of micro and small enterprises in the steel industry within the automotive sector.

III. HYPOTHESIS

The factors that influence the competitiveness of micro and small enterprises in the steel industry within the automotive sector are: degree of technological innovation, productivity, energy efficiency, business profitability, level of Industry 4.0 adoption, strategic alliances, supply chain, level of staff training, globalization, innovation capacity, market, and quality.

- H_1: The degree of technological innovation (X_1) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León. H_1: βX_1
- H_2: Productivity (X_2) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León. H_2: βX_2
- H_3: Energy efficiency (X_3) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León. H_3: βX_3
- H_4: Business profitability (X_4) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León. H_4: βX_4
- H_5: The level of Industry 4.0 adoption (X_5) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León. H_5: βX_5
- H_6: Strategic alliances (X_6) are a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León. H_6: βX_6
- H_7: The supply chain (X_7) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León. H_7: βX_7
- H_8: The level of staff training (X_8) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León. H_8: βX_8
- H_9: Globalization (X_9) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León. H_9: βX_9
- H_{10}: Innovation capacity (X_{10}) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León. H_{10}: βX_{10}
- H_{11}: The market (X_{11}) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León. H_{11}: βX_{11}
- H_{12}: Quality (X_{12}) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León. H_{12}: βX_{12}

The following section presents the graphical model of the variables, illustrating the relationship between the independent variables and the dependent variable, all of which are hypothesized to have a positive impact on business competitiveness.

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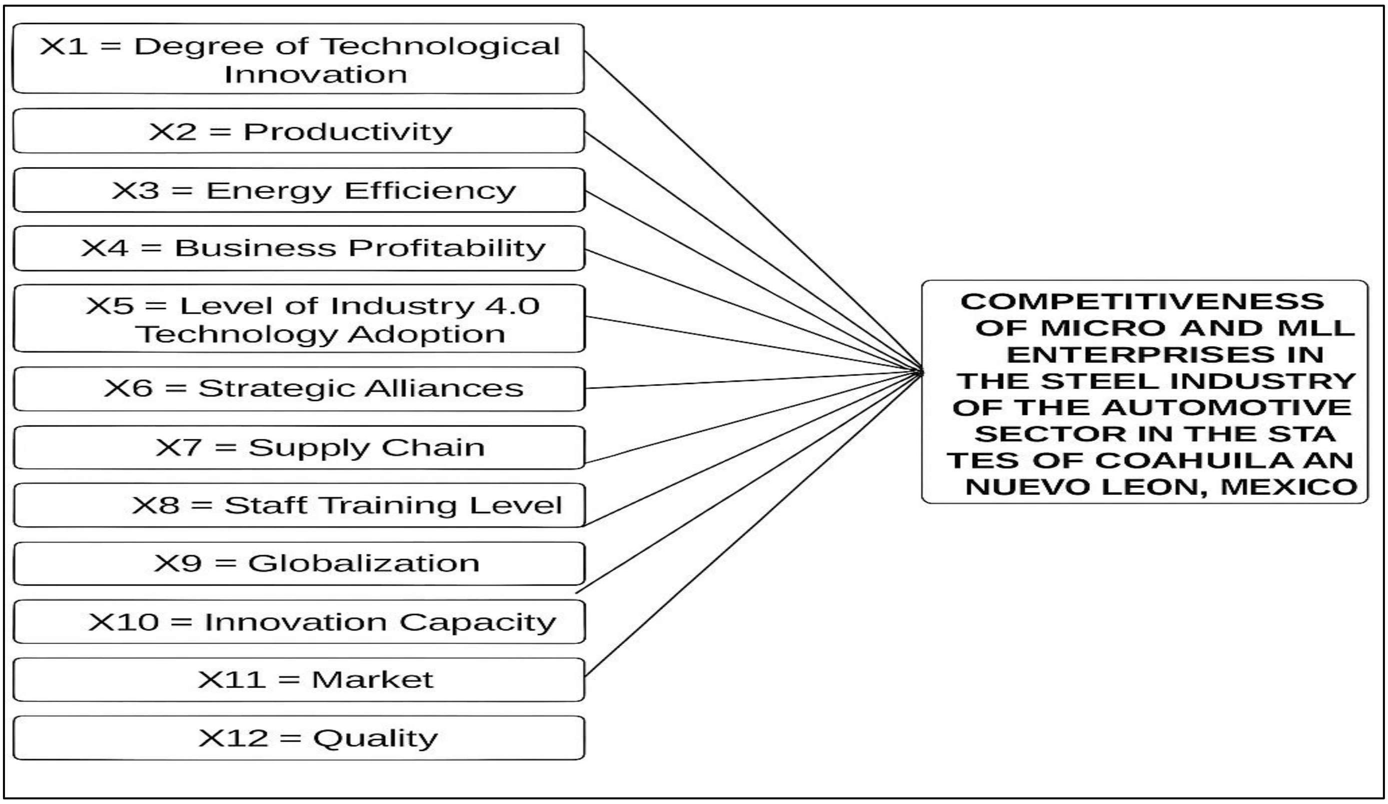

Fig 4 Graphical Model of Variables
Source: Own Elaboration

➢ *Research Question*

What are the factors that influence the competitiveness of micro and small enterprises in the steel industry within the automotive sector?

➢ *General Objective of the Research*

To analyze the factors that positively influence the competitiveness of micro and small enterprises in the steel industry within the automotive sector located in the states of Nuevo León and Coahuila.

IV. RESEARCH METHODOLOGY

This research is exploratory and descriptive in nature, aiming to identify the relationship between competitiveness and each of the independent variables. The research design is quantitative. A document analysis technique was used to present the current reality of the competitiveness problem, based on the review of documents and information sources.

The analysis was conducted through field research. A measurement instrument was designed for data collection; this is a non-experimental study. Since the data was collected at a specific point in time, the research is cross-sectional.

A target population was defined, and a representative sample of 116 micro and small enterprises in the steel industry focused on the automotive sector, located in Nuevo León and Coahuila, was obtained. The unit of analysis is micro and small enterprises in the automotive steel industry, and the sampling unit consisted of businesses in this sector located in the states of Coahuila and Nuevo León.

This study aims to test the hypotheses through a quantitative approach, using data collected with a validated measurement instrument subjected to reliability and content validity testing. The items for each variable reported a Cronbach's Alpha greater than 0.7.

The instrument was designed based on a literature review and included control questions. A pilot test was conducted before full implementation. The final instrument consists of 52 questions, including 7 demographic questions.

A probabilistic sample was determined using cluster and stratified sampling procedures to divide the population into sub-groups, and the analysis unit (micro and small enterprises) was stratified based on the geographical location of the states of Coahuila and Nuevo León.

Finally, a multiple linear regression analysis was performed to examine the relationships among the variables. The coefficient of determination was obtained to assess the validity percentage of the regression equation, along with correlation analysis and the standard error of estimation.

V. RESULTS

The target companies of this study are located in the states of Nuevo León and Coahuila. As shown in Figure 14, within the studied sample size, over 75% of the micro and

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small enterprises are from Nuevo León, while just over 23% are from Coahuila. It is important to note that there is a higher participation of companies located in the state of Nuevo León. As part of the descriptive analysis of the study subjects, it was found that all participants in this study are male. This indicates that the owners or managers of the participating companies are male, with no female participation in this study.

A multiple linear regression analysis was conducted using the stepwise method, considering the 6 variables identified as explanatory for the dependent variable, using SPSS software. As a result, the final model—Model 6—determined that 6 out of the 12 variables are statistically significant.

In Model 6, the adjusted R^2 yielded a value of 0.983. This model includes the following variables: X_1 (Degree of Technological Innovation), X_2 (Productivity), X_4 (Profitability), X_5 (Level of Industry 4.0 Adoption), and X_{11} (Market). These independent variables collectively explain 98.3% of the variance in the competitiveness variable. The Durbin-Watson coefficient, with a value of 1.532, falls within the statistically acceptable range of 1.5 to 2.5. A summary of the model is presented in Table 2.

ANOVA[a]

Modelo		Suma de cuadrados	gl	Media cuadrática	F	Sig.
1	Regresión	30.148	1	30.148	119.494	.000[b]
	Residuo	15.895	63	.252		
	Total	46.044	64			
2	Regresión	39.485	2	19.743	186.640	.000[c]
	Residuo	6.558	62	.106		
	Total	46.044	64			
3	Regresión	42.160	3	14.053	220.768	.000[d]
	Residuo	3.883	61	.064		
	Total	46.044	64			
4	Regresión	43.922	4	10.980	310.490	.000[e]
	Residuo	2.122	60	.035		
	Total	46.044	64			
5	Regresión	44.976	5	8.995	497.008	.000[f]
	Residuo	1.068	59	.018		
	Total	46.044	64			
6	Regresión	45.347	6	7.558	628.947	.000[g]
	Residuo	.697	58	.012		
	Total	46.044	64			

a. Variable dependiente: Y
b. Predictores: (Constante), X11
c. Predictores: (Constante), X11, X5
d. Predictores: (Constante), X11, X5, X1
e. Predictores: (Constante), X11, X5, X1, X10
f. Predictores: (Constante), X11, X5, X1, X10, X4
g. Predictores: (Constante), X11, X5, X1, X10, X4, X2

Fig 5 ANOVA Analysis of Model 6
Source: Own Elaboration Based on the Model Analysis

Table 1 Summary of the Selected Model

Model Summary						
Model	Variables	R	R^2	Adjusted R^2	Standard Error of the Estimate	Durbin-Watson
6	X_{11}, X_5, X_1, X_{10}, X_4, X_2	0.9920	0.9850	0.9830	0.1096	1.532

Source: Own Elaboration Based on the Model Analysis

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Table 2 Coefficient Relationship from the Linear Regression Analysis in SPSS

Hypothesis	Hypothesis	Beta Value	Significance
H_1: β X_1	H_1: The degree of technological innovation (X_1) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León.	0.325	0.000
H_2: β X_2	H_2: Productivity (X_2) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León.	0.243	0.000
H_4: β X_4	H_4: Business profitability (X_4) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León.	0.146	0.000
H_5: β X_5	H_5: The level of adoption of Industry 4.0 technologies (X_5) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises in the states of Coahuila and Nuevo León.	0.195	0.000
H_{10}: β X_{10}	H_{10}: Innovative capacity (X_{10}) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises located in the states of Coahuila and Nuevo León.	0.404	0.000
H_{11}: β X_{11}	H_{11}: The market (X_{11}) is a factor that has a positive impact on the competitiveness of the steel industry in the automotive sector among micro and small enterprises located in the states of Coahuila and Nuevo León.	0.325	0.000

Source: Own Elaboration Based on the Model Analysis

According to the information presented above, the resulting regression equation is as follows: Competitiveness = -3.064 + 0.349 Technological Innovation Degree + 0.243 Productivity + 0.146 Profitability + 0.195 Industry 4.0 Technology Adoption Level + 0.325 Market + E

VI. DISCUSSION AND CONCLUSIONS

During the analysis period, these factors did not have an impact on micro and small enterprises, the reason being that SMEs are typically associated with companies that have undergone an expansion of their internal organizational structure, which allows for greater growth aimed at enhancing competitiveness.

Regarding the variable business profitability, it was not found to be significant. This is because the companies studied lack a designated individual responsible for deeply analyzing financial factors to determine whether the business is truly profitable or not. On the other hand, the variable level of adoption of Industry 4.0 technologies did not show significance, as it involves a high budget investment that is often out of reach for micro and small enterprises. Additionally, adopting these technologies requires a cultural shift that must be embraced within the company.

As for the variable strategic alliances, due to the nature of the studied companies, most micro and small enterprises do not have partnerships, agreements, or networks with organizations or associations that promote collaboration. These companies are mainly focused on the operational aspects of their business.

The supply chain is generally considered a factor that contributes to the growth of micro and small enterprises. However, in the context of this study, it did not prove to be significant. This result is attributed to the fact that these businesses lack a structured logistics system that would allow them to measure their impact on the value chain.

Among the non-significant variables is globalization. In this case, it is believed that the companies analyzed do not currently have clear strategies for entering global markets. While some may engage in international purchasing and sales activities, during the analyzed period they did not show any plans or strategies to increase their global presence. Finally, innovation capacity, defined as a company's ability to transform its intellectual capital into innovations that meet needs and promote continuous improvement in products or processes, also proved non-significant. This may be due to the fact that micro and small enterprises are primarily focused on producing and delivering their current products. Furthermore, the study found that due to the nature of the sector, both the products and the steel production processes have remained relatively constant over time.

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