Encouragement Policies and Productivity Indicators for Colombian SMEs Using Data Envelopment Analysis and Malmquist Indexes*

Políticas de fomento e indicadores de productividad de las pymes colombianas mediante análisis envolvente de datos e índices de Malmquist

Manuel Eduardo García Camacho
MGC Yield Consulting,
Bogotá – Colombia, manuelh57@hotmail.com

José Daniel Anido R.
Universidad de Los Andes-ULA,
Mérida – Venezuela, anidoriv@gmail.com

How to cite

García Camacho, M. E., y Anido R., J. D. (2024). Encouragement Policies and Productivity Indicators for Colombian SMEs Using Data Envelopment Analysis and Malmquist Indexes. *Revista CEA*, *10*(22), e2708. https://doi.org/10.22430/24223182.2708

Received: 9 de mayo de 2023
Accepted: 20 de diciembre de 2023

Abstract

Purpose: This study aimed to characterize the performance of Colombian Micro, Small, and Medium-sized Enterprises (MSMEs) in recent years, along with the legal framework and central public policies governing and promoting this business segment. In addition, it sought to design, validate, and implement a dynamic system of productivity indicators to help these companies improve their efficiency and competitiveness in the short, medium, and long terms. MSMEs represent approximately 99% of the business sector in Colombia, accounting for nearly 80% of national employment.

Design/Methodology: In the initial descriptive–analytical phase, using secondary sources, an analysis was conducted on the performance and current situation of Colombian MSMEs, as well as the main

* The article is derived from the research project entitled "Diseño de un sistema de indicadores de productividad para gestión empresarial de las Pymes de Colombia", carried out jointly by the first author of the article, under the direction/tutoring of the second author. The article therefore contains partial results of this Project, mostly unpublished.

legal provisions regulating and contributing to their development. The subsequent phase (of an applied nature) involved estimating and validating a dynamic system of productivity indicators using Data Envelopment Analysis (DEA) and Malmquist indexes for 2 samples of SMEs.

Findings: After conducting the DEA, a significant decrease was observed in the productivity of the MSMEs, particularly in terms of technical efficiency in both the Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) models. This means that, evaluated both under the CRS and VRS modes, these enterprises use more inputs than necessary for the amount of goods produced. In addition, the Malmquist indexes showed that, during the period under analysis, technical efficiency related to changes in innovation exhibited a positive behavior, attributed to the incorporation of technological changes for improving their productivity.

Conclusions: Despite the development of public initiatives and institutional support in recent decades, Colombian SMEs still face adverse conditions that affect their competitiveness and limit their potential in the national economy. The proposed system of indicators, which is based on DEA techniques and Malmquist indexes, holds promise in helping these businesses to improve their productivity.

Originality: This study makes a significant contribution to the fields of economics and business management in the region by providing a critical and updated evaluation of the efficiency of MSMEs in Colombia. Additionally, it examines their performance and current situation and summarizes the main legal provisions regulating and contributing to their development in the country.

Keywords: productivity, DEA, Malmquist indexes, public policies, Colombia.

JEL classification: C14, C44, D24, L25, M11, O32

Highlights

- MSMEs usually face more limitations than large companies in implementing major changes in production processes.
- Despite the development of public initiatives and institutional support, Colombian MSMEs still face conditions that limit their potential for dynamizing the national economy.
- According to the estimated DEA models, the productivity of the Colombian MSMEs decreased during the period spanning from 2016 to 2019.
- Employing productivity indicators derived from DEA and Malmquist Indexes may help Colombian MSMEs to improve their competitiveness.
- These tools may allow Colombian MSMEs to identify opportunities for improvement, whether in reducing inputs or increasing outputs.

Resumen

Objetivo: Este estudio tuvo como objetivo caracterizar el desempeño reciente de las micro, pequeñas y medianas empresas (mipymes) en Colombia, junto con el marco legal y las principales políticas públicas implementadas en el país para la regulación y promoción de este segmento empresarial. Además, buscó diseñar, validar e implementar un sistema dinámico de indicadores de productividad/eficiencia técnica para mejorar la operatividad y competitividad de estas empresas en el corto, mediano y largo plazo. Este análisis se justifica en la importancia que tienen las mipymes en

Colombia, donde representan aproximadamente el 99% del tejido empresarial y son responsables de cerca del 80% del empleo.
Diseño/metodología: En la primera fase, del tipo descriptivo-analítica y a partir de fuentes secundarias, se examinaron y sintetizaron publicaciones, datos e indicadores sobre el desempeño y situación reciente de las mipymes colombianas, así como los principales dispositivos legales que regulan y coadyuvan al desarrollo de estas empresas. En la segunda fase, de naturaleza aplicada, se estimó y validó un sistema dinámico de indicadores de productividad mediante la técnica de análisis envolvente de datos (DEA, por sus siglas en inglés) y los índices de Malmquist para dos muestras de pymes.
Resultados: Tras aplicar el DEA, se evidenció una disminución significativa en la productividad de las mipymes colombianas, particularmente en la eficiencia técnica en los modelos CRS y VRS. Ello indica que este tipo de empresas utilizan más insumos que los necesarios para la cuantía de bienes que producen, evaluados ambos en las modalidades CRS y VRS. Por su parte, los índices de Malmquist permiten concluir que, para el periodo analizado, la eficiencia técnica relacionada con los cambios en la innovación mostró un comportamiento positivo, atribuido a la incorporación de cambios tecnológicos para mejorar la productividad.
Conclusiones: A pesar de los esfuerzos públicos y el desarrollo institucional de las últimas décadas, las mipymes colombianas aún enfrentan condiciones y entornos que disminuyen su competitividad y les impiden ser dinamizadores de la economía de acuerdo con su potencial. La aplicación de indicadores de productividad basados en técnicas DEA o índices de Malmquist, como los propuestos en esta investigación, podrían ayudar a las mipymes colombianas a mejorar su competitividad.
Originalidad: Este estudio ofrece una evaluación crítica y actualizada de la eficiencia de las mipymes en Colombia, siendo relevante para los ámbitos de la economía y la gestión empresarial. Además, examina el desempeño y la situación actual de las mipymes colombianas y resume los principales dispositivos legales que regulan y coadyuvan al desarrollo de estas empresas de pequeña escala en el país.

Palabras clave: productividad, DEA, índices de Malmquist, políticas públicas, Colombia.

Clasificación JEL: C14, C44, D24, L25, M11, O32

Highlights

- Las mipymes suelen enfrentarse a más obstáculos que las grandes empresas al momento de implementar cambios significativos en sus procesos de producción.
- A pesar de los esfuerzos públicos y del reciente desarrollo institucional, las mipymes colombianas todavía se ven afectadas por condiciones que limitan su capacidad para dinamizar la economía nacional.
- Según los modelos DEA estimados, la productividad de las mipymes colombianas experimentó una disminución entre 2016 y 2019.
- La aplicación de indicadores de productividad basados en el DEA y los índices de Malmquist podría ayudar a que las mipymes colombianas mejoren su competitividad.
- Estos indicadores de productividad les ofrecerían a las mipymes colombianas la posibilidad de identificar oportunidades de mejora, ya sea reduciendo insumos o aumentando la producción.

1. INTRODUCTION

In the economic literature, there has been an increasing emphasis on the fundamental role of Micro, Small, and Medium-sized Enterprises (MSMEs), particularly since the 1980s (Gesellschaft für Technische Zusammenarbeit-Comisión Económica para América Latina-Centro Regional de Promoción de la MIPYME [GTZ-CEPAL-CENPROMYPE], 2009; García-Martinez et al., 2023; Habibi et al., 2023). These enterprises are recognized for their contribution to employment and as drivers of economic growth and development, both locally and regionally (Romero Luna, 2006; Chauca Malásquez, 2014; Aldeanueva Fernández & Cervantes Rosas, 2019; Franco-Ángel & Urbano, 2019). In addition, they play a pivotal role in the path to sustainable development (Lisi et al., 2023). Due to the growing importance of these enterprises in the industrial production of countries (Glonti et al., 2021), different levels of government are paying more attention to them and implementing targeted policies (Chauca Malásquez, 2014; Leckel et al., 2020). In Latin America, 99% of formal enterprises fall into the MSME category, accounting for about 61% of formal employment in the region (Dini & Stumpo, 2020). However, a lack of uniform criteria for their definition or classification at the international level (GTZ-ECLAC-CENPROMYPE, 2009) poses severe limitations for comparative studies due to the varying criteria employed by different countries.

Due to the complexity of their conceptualization, diverse criteria and approaches have been historically used, such as the type of activity, technology, productive intensity, investment levels, sales volume, and employment capacity (Cardozo et al., 2012). In general, three factors—the number of employees, total assets, and annual sales—are the most commonly used to characterize any establishment or firm as an MSME. In the European Union (EU), the definition of an MSME suggests a relationship between assets and gross sales, with the company required to comply with at least the more convenient of the two (GTZ-CEPAL-CENPROMYPE, 2009). As in the United Kingdom (UK), the recurring criterion in the EU is up to 250 employees and a turnover of less than €50 million (European Commission [EC], 2015, 2022). In the United States (US), from a government perspective, an MSME is defined as a for-profit, independently owned and operated, nationally non-dominant business within its industry and located within the US, which must also meet industry size standards based on its number of employees or average annual revenue (Small Business Administration [SBA], 2019). Although this volume varies depending on each of the 19 industry branches or sectors established in the North American Industry Classification System (NAICS), they generally have fewer than 500 workers. In Colombia, the current legislation (Ley 590 de 2000; Ley 905 de 2004) establishes as criteria a value of assets less than or equal to 30,000 legal monthly minimum wages[†] and a number of employees less than or equal to 200.

In the US, there were approximately 28 million MSMEs in 2014, accounting for almost two-thirds of net new private sector jobs in recent decades. Moreover, 98% of US exporters were small businesses (Office of the United States Trade Representative [USTR], 2019). By 2021, the number had increased to 32.5 million firms, constituting 99.9% of the national total and employing 61.2 million people,

[†] The legal monthly minimum wage for 2022 was set at COP 1,117,172 (consisting of a salary of COP 1 million and a transportation allowance of COP 117,172). At the exchange rate on June 30, 2022 (Banco de la República Representative Market Rate of COP 4,127.47/USD), this amount approximately equated to USD 8,120,025 (Source: *El Empleo*; available at https://www.elempleo.com/co/noticias/noticias-laborales/definido-el-salario-minimo-en-colombia-para-2022-en-cuanto-quedo-la-cifra-6584).

which translates to 46.8% of the total workforce (SBA, 2021). In Spain, Small and Medium-sized Enterprises (SMEs)—defined as those with 0 to 249 employees—made up 99.8% of the total number of companies in 2022 and contributed to 64.3% of total employment (Gobierno de España. Ministerio de Industria, Comercio y Turismo, 2022). Across the EU, MSMEs represent, on average, 99% of all businesses, generate two-thirds of private sector employment, and contribute more than half of the total value added by EU companies (EC, 2022).

Similar to what is happening in Europe and the US, MSMEs are a fundamental component of the business sector in Latin America. In 2019, SMEs contributed about 60% of formal productive employment in Latin America and the Caribbean and accounted for 99.5% of the total number of companies in the region (Organización para la Cooperación y el Desarrollo Económico-Corporación Andina de Fomento [OECD-CAF], 2019). Specific country data reveals that 98.7% of the 1 074 040 companies in Chile in 2016 were MSMEs, contributing more than 59% of total employment (Tharawat Magazine & INE-Chile, cited by Taborda Ocampo et al., 2018). In Argentina, MSMEs represented 99.8% of the business universe in 2019, covering 76.9% of formal private employment (Secretaría de Transformación Productiva, as cited in Belacín & Arnoletto, 2019). In Mexico, there are about 4.2 million MSMEs, contributing about 52% of the country's Gross Domestic Product (GDP) and responsible for 72% of formal employment (Forbes Mexico, by Zamora Guzmán, 2022). Another notable example from Latin America is Ecuador, where this industry represents over 96% of the national productive sector and employs 70% of the economically active population (INEC, as cited in Confirmado.net, 2021).

Colombia is no exception to this worldwide trend. In 2005, SMEs[‡] accounted for 96.4% of the total number of companies in the country and contributed 63% of national employment (Departamento Administrativo Nacional de Estadística [DANE], cited by Barrios-Hernández et al., 2019). A decade later, they comprised 99.5% of the national business landscape (Confederación Colombiana de Cámaras de Comercio [Confecámaras], cited by Murillo Lozano & Restrepo Sánchez, 2016). By 2021, they represented 99.6% of the national total, generating 79.1% of employment and contributing approximately 40% of the GDP (Asociación Nacional de Instituciones Financieras [ANIF], 2021). Despite the adverse effects of the COVID-19 pandemic, 307 679 new companies were established in the country in that year, marking a 10.6% increase with respect to 2020. Most of these companies were micro-enterprises (306 140 companies, constituting 99.5% of the total), followed by small (1449 companies, constituting 0.4% of the total) and medium-sized (69 companies) and large companies (21 companies), with these latter making up the remaining 0.03% (Confecámaras, 2022). By the end of 2021, there were 5 780 623 micro-businesses in Colombia, employing 7 769 303 workers (DANE, 2022), which is equivalent to more than 36% of the total national workforce.

Despite the significant contribution of MSMEs to employment (both in Latin America in general and in Colombia in particular), their relatively low contribution to production underscores productivity gaps among production units of different sizes in the region (Dini & Stumpo, 2020). This paradox in small-sized companies in Colombia reflects the constant challenges they face, such as conditions and environments that diminish their competitiveness and prevent them from fully realizing their potential as economic drivers, especially during economic recessions (Escandón Barbosa & Hurtado

[‡] In Colombia, given the high number of registered formal micro-enterprises, the proportion and weight of SMEs in the total number of firms/enterprises is lower than in other countries (Ferraro & Stumpo, 2010).

Ayala, 2014; Niebles-Nuñez et al., 2022). As early as the mid-2000s, Amézquita Zárate (2007) wa rned that Colombian MSMEs were oriented towards the domestic market, and barely around 30% focused on exports. This behavior, coupled with the absence of government support and financing channels, together with their low productivity, low production volume, and non-tariff barriers can be attributed to structural factors.

Furthermore, the ever-increasing demands for productivity and competitiveness (both in domestic and international markets) have compelled companies to compete for new market niches, one way of doing this being by creating high-productivity sustainable industries (Padilla Martínez et al., 2018). For companies, particularly smaller ones, the main challenges revolve around survival and growth, in addition to significant tax burdens, high labor costs, and a lack of labor flexibility (Jiménez, as cited in Niebles-Nuñez et al., 2022).

Despite their key role in poverty reduction (Nursini, 2020), economic growth, and the development dynamics of different countries (Absah et al., 2023; Singh et al., 2021), MSMEs face increasing challenges for their long-term sustainability. This is further exacerbated by the ongoing new post-COVID-19 reality, along with the growing competitiveness of markets. Although there is no clear trend in terms of business continuity/discontinuity in Colombia (with a closure rate ranging between 5.1% and 8.9% from 2008 to 2017, according to Asociación de Emprendedores de Latinoamérica-Laboratorio de Innovación del Banco Interamericano de Desarrollo ([ASELA-IDB Lab], 2018), MSMEs have a high failure rate, as is the case across the rest of Latin America. In Colombia particularly, these businesses confront additional major problems and challenges, largely due to their low productivity. Hence, it becomes imperative for organizations to enhance their productivity and management practices to thrive in these changing markets, boost profitability, and experience sustained growth.

In light of the above, this article aims to characterize the current situation and recent performance of MSMEs in Colombia, as well as the legal framework governing their operations and the main public policies specifically targeting this business segment. In addition, it seeks to design, validate, and implement a dynamic system of productivity indicators, which will provide dynamic information and improve the short-, medium-, and long-term operability and competitiveness of Colombian MSMEs. For that purpose, in the initial phase of our analysis (conducted through a descriptive-analytical approach and relying on secondary sources), we briefly examine data and indicators regarding the performance and recent status of Colombian MSMEs. In the second phase (of an empirical nature), we design, estimate, and validate a dynamic system of productivity indicators using Data Envelopment Analysis (DEA) and Malmquist indexes for Colombian SMEs. Drawing on data from 2016 to 2019, Stata v 16 was employed to measure their total and marginal productivity in real-time. In both phases, we consulted secondary sources of information. The estimated DEA models adhere to the principle of universality, which means they can be replicated in other contexts or sectors. They also adhere to the principles of comparison, validation, and peer verification (Lakatos, 1987), as well as of socialization, emphasizing the potential of scientific knowledge to provide solutions to specific problems (Padrón Guillén, 1994).

2. THEORETICAL FRAMEWORK

Business productivity, recent performance, and policies to promote the MSME sector in Colombia

Productivity, defined as the ratio of production to inputs (Samuelson & Nordhaus, 2010), also serves as an indicator of how well resources or production factors have been combined and used to meet specific objectives (Bain, 1985)[§]. In other words, it reflects the output (physical quantity of a good or service) per unit of input or factor used, making it one of the most important economic performance measures (Samuelson & Nordhaus, 2010). In manufacturing organizations, productivity means efficiency, quality, quantity, the ratio of quality to quantity, goal attainment, improvement possibilities, and value added (Clampitt & Downs, 1993). In strategic terms, productivity involves producing above average and fully satisfying consumers by making the best use of all available resources (Muñoz Hernández, 2012).

In Latin American economies, the structural heterogeneity that characterizes them can, at least in part, be explained by the low competitiveness and productivity of small enterprises compared to their larger counterparts (Ferraro & Stumpo, 2010). In the specific case of Colombia, this low productivity can also be attributed to the downward trend in the country's competitiveness across different economic activities and products, particularly those with more complex manufacturing processes and an export-oriented focus (Franco-Ángel & Urbano, 2019). In addition, Colombia exhibits low levels of innovation and technology, which places it below the Latin American average and barely above the primary goods subsector (Blyde, cited by Franco-Ángel & Urbano, 2019). Specifically, small-sized companies in the country face limited progress in terms of knowledge management, organizational development, and the adoption of Information and Communication Technologies (ICTs) (Hernández et al., 2014).

Regarding the importance of MSMEs, studies point out that, by the mid-2010s, over 97% of municipalities in Colombia were politically, socially, and economically dependent on small-sized companies (Muñoz Cardona & Mayor López, 2015). Another important aspect, at least in the mid-2010s, was that the majority of the country's businesses was concentrated in mountainous areas and plateaus (Granda & Hamann, 2015), with little development occurring in coastal cities (Muñoz Cardona & Mayor López, 2015). In 2018, a new national study brought to light other relevant characteristics of the small business segment. The main shortcomings observed in this segment included (i) a very short-term planning, (ii) prioritization of everyday issues over those that can make a difference in the markets (e.g., the creation of added value and low market diversification), (iii) low internationalization (i.e., export-oriented activity), and (iv) insufficient training and financial knowledge among owners (ANIF, 2018). In addition to these shortcomings, difficulties in terms of available information and information systems were identified, which hinders an accurate understanding of the company's actual and current situation and the orientation of its commercial

[§] According to the authors, productivity increases when the same amount of inputs produces more output. Samuelson & Nordhaus (2010) point out that, specifically, in the context of labor, productivity is increased through improved technology, improvements in personnel training, or capital deepening (Samuelson & Nordhaus, 2010). For its part, Total Factor Productivity (TFP) serves as an indicator of total output per unit of total inputs. The numerator is the total output, while the denominator is a weighted average of capital, labor, and resource inputs. The growth of TFP is often considered an indicator of technological progress.

strategy (Franco et al., 2014; Niebles-Nuñez et al., 2022). More specific research, such as that conducted by Jaimes et al. (2018) in the apparel subsector in Bucaramanga, pinpointed group behavior, the social work environment, process management, and training/control as the main determinants of productivity in SMEs.

In addition to the previously discussed aspects, a relevant input for evaluating business performance (in this case, calculated exclusively for the SME sector) is the SME indicator of ANIF, abbreviated as IPA in Spanish. This indicator aims to synthesize in a single value the overall climate or environment in which this business sector operates, considering various variables to determine the economic cycle. These variables include: (i) the current economic situation with respect to that in the previous period (assessed semi-annually), (ii) the current sales volume with respect to that in the previous period, (iii) the company's performance expectations for the upcoming period; and (iv) the company's sales expectations for the upcoming period (ANIF, 2018; Clavijo, 2018). From the second semester of 2011 (when the results of the IPA assessment started to be published) until the second semester of 2019, the IPA exhibited great variability. Initially, it showed a growth trend from the second semester of 2011 to the second semester of 2014, when it reached its highest value (averaging 72 points for SMEs). Then, it steadily decreased until the second semester of 2017 (averaging 54). Between 2018 and 2019, it showed a slight recovery, although it barely reached an average of 59 points. In terms of the different regions, in 2018, Bogotá, Bucaramanga, and Medellín witnessed a reduction in their IPA, with the first and third maintaining a "good" economic performance (ranging from 55 to 73 points) (ANIF, 2018, 2020). The most recent available study, corresponding to the second half of 2020 (ANIF, 2021), revealed, as anticipated, a contraction in employment within the business segment, with the main causes being restrictions due to COVID-19 and a decrease in activity levels.

Another crucial indicator (estimated at the regional level and associated with competitiveness) is the Regional Competitiveness Index, abbreviated as IDC in Spanish) (Consejo Privado de Competitividad [CPC], 2016). This index adheres to the methodology of the World Economic Forum's Global Competitiveness Index[**]. Originally, the goal was for Colombia to be among the three most competitive economies in Latin America by 2030, although it was already in the fourth position in 2019, according to the Global Competitiveness Report (CPC, 2022). Based on the 2013 IDC, Bogotá (the capital city) was the most competitive region in Colombia, with scores of 6.49 (out of 10 potential points) in the basic conditions factor, 7.42 in the efficiency factor, and 9.40 in the sophistication and diversification factor (CPC, 2014). It was followed by Antioquia (with a weighted IDC of 6.93) and Santander (with a weighted IDC of 5.21). One year later, Bogotá retained its lead in this indicator, with a score of 7.82, followed by Antioquia (with 5.94) and Caldas (with 5.77) (CPC, 2014). Five years later, in the 2020–2021 report, the ranking was led by Bogotá (with 8.33), Antioquia (with 6.80), and Valle del Cauca (6.36) (CPC-UR-SCORE, 2021). According to the most recent ranking available (in 2022), Bogotá again leads the national ranking (with 8.59 points), followed by Antioquia (with 6.93) and Santander (with 6.33). An additional noteworthy aspect was the observed deterioration in the

[**] This indicator was calculated for 26 departments in Colombia. The overall ranking is derived from the identification and computation of 94 hard variables, which are grouped into the following three competitiveness factors: (i) basic conditions, (ii) efficiency, and (iii) sophistication and innovation (Consejo Privado de Competitividad, 2022). By 2022, its coverage will encompass all 32 departments of the country and the city of Bogotá.

competitive performance of fundamental pillars for productivity, particularly the institutional pillar, which saw a decrease in score in 70% of the studied regions) (CPC-UR-SCORE, 2022).

Concerning the factors affecting the productivity of companies in Colombia in general, Gómez and Steiner (2015) highlight the historical tendency of the tax system to impose a heavier burden on companies than on individuals. This translates into a high tax burden for firms, which leads to a significant reduction in their competitiveness at the international level. Both income tax and other taxes impact the sustainability and growth of the equity of small companies (Fernández Bustamante & Meza Muñoz, 2019). Likewise, these firms exhibit a low export propensity, as indicated by the empirical evidence organized to study export propensity, coupled with a high outflow dynamic (Mesa & Torres, 2019). Besides low productivity, the revaluation of the Colombian peso against the US dollar has made the domestic market more profitable than the international market, especially during periods of expansion of the Colombian economy. In the 2000–2012 period, sectors such as the leather and footwear, basic metallurgy, radio and television equipment, and transportation equipment industries showed the highest number of companies participating in exports. Conversely, the food, beverage, and tobacco industries were the largest exporters in terms of value (Mesa & Torres, 2019). In other scenarios, these types of businesses face severe difficulties in formalizing a new business, along with enormous threats to their survival (Hernández et al., 2014; Niebles-Nuñez et al., 2022).

Also, in Colombia, factors like communication can significantly boost the productivity of SMEs (Alfonso-Orjuela et al., 2022), at least from the perspective of their managers and workers (Muñoz Hernández, 2012). In addition, administrative management emerges as a key factor in improving productivity and competitiveness, particularly for micro-enterprises (Soledispa Rodríguez et al., 2022). Other factors include product and process innovation, especially when aimed at enhancing labor productivity (Griffith et al., and Hall et al., cited by Classen et al. (2014)). Innovation, serving as a foundation for transformation and rapid market growth (Mosquera Palacio & Díaz Córdoba, 2022), is also fundamental for both the survival and profitability of small firms. It drives sales growth and is a key source of competitive advantage, particularly in the absence of economies of scale (Soledispa Rodríguez et al., 2022).

Despite their heterogeneity in terms of size, economic sector, and regional contexts, the Colombian government has long recognized the importance of MSMEs in the economy. One of the first regulatory instruments specifically designed for them was Law 78 of 1988 (repealed on 07/10/2000). This law aimed at promoting the creation and development of micro, small, and medium-sized industries, serving as catalysts for job creation and reducing inequality. Eventually, these industries were to be scaled up to become large industries that would support the Colombian economy in the future (Ley 78 de 1988). Later, in 2000, Law 590[††] was enacted (Ley 590 de 2000), with its primary

[††] Some sources, such as the MSME Information Center of Colombia, regard the enactment of Law 67 of 1979 as a milestone in the context of the legal framework governing MSMEs. This law provides a set of measures to promote Colombian exports (and foreign trade, in general), specifically through "international marketing companies." However, the primary instrument that explicitly regulates them is Law 590, which has been permanently amended through, for instance, Law 905 of 2004 (Diario Oficial No. 45.628, dated August 2, 2004) and Law 1151 of 2007 (dated July 24, 2007). The most recent amendment, as of June 21, 2022, was published in the Diario Oficial No. 52,052 (dated June 1, 2022). Other legal provisions that regulate or are linked to MSME activity in Colombia include Law 1753 of 2015 (Diario Oficial No. 49,538, dated June 9, 2015); Ley

objective centered around creating jobs, fostering regional development, integrating different economic sectors, making efficient use of small capitals, and taking into account the entrepreneurial potential of Colombians. Over time, the secondary objective of this law has undergone several modifications, and now aims to stimulate the development and establishment of highly competitive markets by constantly encouraging the creation and operation of the largest number of MSMEs.

According to this, the Colombian government acknowledges, in addition to their role as driving forces of the country's economy, development, and competitiveness, that fostering the creation of MSMEs should be an ongoing practice. Law 590 also established the following three criteria for classifying businesses into micro, small, medium-sized, and large companies: (i) total number of employees, (ii) gross annual sales, and (iii) total assets (Art. 2). Other regulatory frameworks include the 2010–2014 National Development Plan or Law 1450 of 2011 (Ley 1450 de 2011) and Law 1753 of 2015 or the 2014–2018 National Development Plan (Ley 1753 de 2015). These regulations set forth the main objectives to achieve sustainable development and sustained growth, increase formal employment, reduce poverty, and promote greater prosperity for the country's population.

Based on the above review and the recommendations of the Consejo Privado de Competitividad (Private Competitiveness Council [CPC], 2022), a preliminary conclusion can be drawn. In the context of the challenges faced by the Colombian economy in the years 2021 and 2022—characterized by business closures, an increase in unemployment (especially among the youth), and an inactive population, coupled with the pandemic sequelae that permanently threaten both social cohesion and the nation's growth potential—MSMEs must become a means to improve the lives of as many citizens as possible. In light of this, productivity management should be aligned with the organizational strategy, serving as an instrument to enhance performance and contribute to the growth of companies, particularly MSMEs. This article aims to address this through the design, estimation, and evaluation of a dynamic system of productivity indicators in Colombian MSMEs. The ultimate goal is to take advantage of the available information, improve the monitoring and control systems of these organizations, and contribute to the improvement of their operations and competitiveness in the

1819 de 2016 (Diario Oficial No. 50,101, dated December 29, 2019); Resolution No. 3205 of 2008 (dated November 28, 2008), which regulates the functions of the Regional Council of MSMEs and set guidelines for their organization and operation; Decree No. 2706 of December 27, 2012, which governs Law 1314 of 2009 on the technical regulatory framework for financial information for micro-enterprises (Presidencia de la República de Colombia, 2012); Decree No. 489 of March 14, 2013, which partially regulated Law 1429 of 2010 (Presidencia de la República de Colombia, 2013); Decree No. 1875 of November 17, 2017, which added a chapter to Title 2 of Part 2 of Book 2 regarding the creation of the *Ventanilla Única Empresarial* (a strategy aimed at enhancing the environment for the development of entrepreneurial activities in Colombia and abbreviated as VUE in Spanish) (Ministerio de Comercio, Industria y Turismo, 2017); and Decree 1357 of 2018, which modified Decree 2555 of 2010 concerning crowdfunding (Presidencia de la República de Colombia, 2018). Additionally, decisions made by the Organization of American States (OAS-OEA, 2011a), particularly Decision 748 (Creation of the Andean Committee of Micro, Small, and Medium-sized Enterprises —CAMIPYE—) and Decision 749 (Creation and Implementation of the Andean Observatory of MSMEs —OBAPYME—), both dated May 27, 2011 (OAS-OAS, 2011b) also played a crucial role. Finally, a noteworthy precedent is the 1991–1994 National Plan for the Development of Micro-enterprises, a study conducted in collaboration with the United Nations (PNUD, 1991, p. 3), which established strategies and programs to increase the productivity of micro-enterprises within the framework of the national development plan, with a special emphasis on the opening and modernization of the economy.

short, medium, and long terms. The methodology employed in this applied phase of the research is further detailed below.

3. METHODOLOGY

Population, sample, and quantitative variables

Using data from the Registro Único Empresarial y Social (Business and Social Single Registry) of Confecámaras (2018), which reported a population of 1 613 549 SMEs, an initial random sample of 384 companies was selected. Subsequently, a DEA model was designed and estimated to analyze their productivity in 2016, 2017, 2018, and 2019. These particular years were chosen because they were the only ones with homogeneous and comparable figures, following the mandatory adoption of the International Financial Reporting Standards (IFRS) in Colombia starting from 2016. This analytical approach was also applied to a medium-sized company, identified as LSF DMU in this study, which has six production plants across three different production centers in the country.

The financial secondary information of the selected SMEs was obtained from the Superintendence of Companies (2020), the government agency in charge of regulating and overseeing companies in the country. Additionally, government officials were consulted to clarify any doubts about the content obtained from the Integrated Corporate Information System (Superintendencia de Sociedades, 2023). Finally, information concerning the LSF DMU was directly supplied by the company's management.

For the analysis, the *total tangible production inputs* (adjusted by adding income from ordinary activities + other income + current inventories) of each j-th Colombian SME was used as the output variable. The input variables were (i) *tangible production inputs* (equivalent to the cost of sales, as no separate information for human resources, materials, and energy was available), (ii) *other expenditures inputs* (comprising sales expenses + administrative expenses + other expenses), and (iii) *capital inputs*, which included fixed capital (total non-current assets) and working capital input (total current assets) (Figure 1). In the case of the six plants owned by the LSF company, input variables included (i) *raw materials*, (ii) *labor*, (iii) *maintenance*, (iv) *coal (energy)*, (v) *natural gas (energy)*, (vi) *liquid fuels (energy)*, (vii) *electrical energy (energy)*, (viii) *depreciation (assets)*, (vii) *packaging*, and (ix) *indirect expenses* (Figure 2). The output variable, for its part, was the *total sales* of each j-th plant of the LSF company. In both cases, all input and output variables were expressed in Colombian pesos (COP) using values as of December 31 of each year.

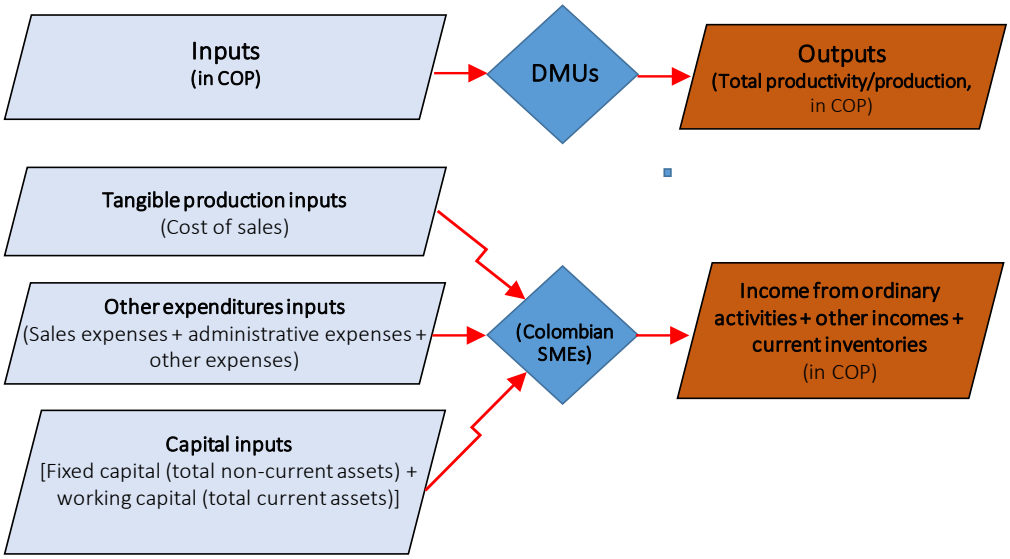

Figure 1. DEA model for the Colombian SMEs (inputs and outputs)

Figura 1. Diagrama del modelo DEA para las pymes colombianas (entradas y salidas)

Source: Own work.

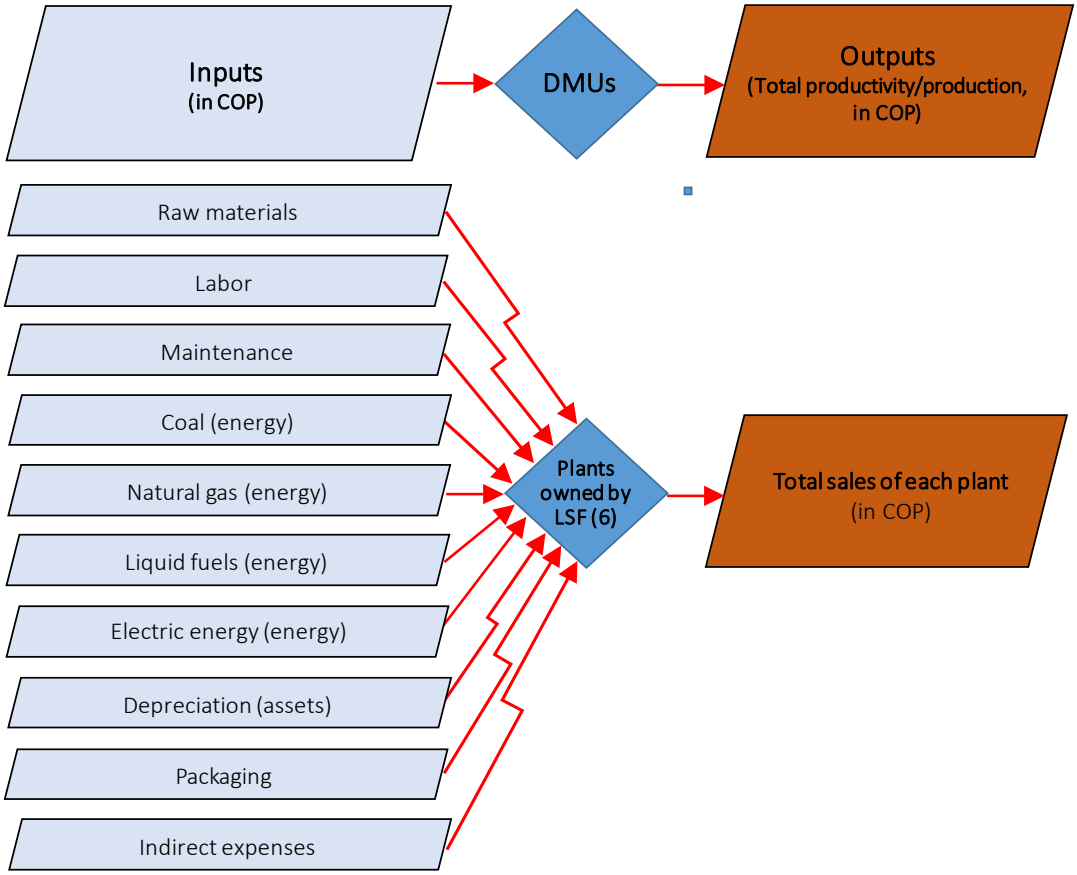

Figure 2. DEA model for the production plants of the LSF company (inputs and outputs)

Figura 2. Diagrama del modelo DEA para las plantas de producción de la LSF (entradas y salidas)

Source: Own work.

Productivity estimation

Data Envelopment Analysis (DEA) has shown to be a very useful tool for evaluating the efficiency of diverse organizations or productive units, as it allows capturing their different performances (Abdella et al., 2021). It is based on the seminal work research conducted by Charnes, Cooper, and Rhodes in 1978, as well as on Farrell's groundbreaking research from 1957 (as cited in Guzmán et al., 2006). Achieving technical or productive efficiency within a given productive unit involves attaining the maximum possible level of output from a predetermined combination of inputs, while price efficiency is defined as the best combination of inputs capable of achieving a given level of output at the lowest cost (Guzmán et al., 2006).

DEA models are generally used in almost any economic sector or geographical area, with numerous applications in the financial/banking, health, and education industries (e.g., Suin Guaraca et al., 2021; Al-Khasawneh et al., 2020; Sanmartín-Durango et al., 2019; Buitrago Suescún et al., 2017). Regarding the literature in the field, a growing body of research focuses on assessing efficiency in SMEs (Ahmadi et al., 2020; Jácome Riera, 2018) and studying the effects of specific public policies on the productivity of this type of businesses (Sarria-Pedroza & Fernández-Guadaño, 2022). Recent research trends involve measuring eco-efficiency and/or environmental sustainability (Abdella et al., 2021) and examining the social performance/corporate social responsibility of companies (Montalbán-Domingo et al., 2022). In some cases, DEA is employed as a sole tool, but it is also combined with other techniques when the purpose is to evaluate and predict efficiency (Fontalvo et al., 2018) or to measure and compare competitiveness in developing countries (Medeiros et al., 2019).

DEA, a non-parametric deterministic approach (Acevedo Villalobos & Ramírez Vallejo, 2005), employs mathematical models of linear programming. These models establish restrictions and conditions for evaluating a set of Decision-Making Units (DMUs), such as companies or units that use inputs to produce outputs, for which an efficient production frontier is estimated (Acevedo Villalobos & Ramírez Vallejo, 2005). This estimation is done using either the Constant Returns to Scale (CRS) or Variable Returns to Scale (VRS) mode or technology, either from an input- or output-oriented approach. When a DMU is situated on the frontier, the estimated value is equal to unity (1). A value less than one indicates that the DMU is inefficient compared to the set of DMUs on the frontier. Prior to estimating this value, the original sample was filtered to remove any DMUs with zero values in the inputs and/or outputs. As a result, the final samples for the set of Colombian SMEs (sample subset 1) comprised 116 DMUs in 2016, 208 in 2017, 159 in 2018, and 210 in 2019. This process was repeated for the DMUs of the LSF company (sample subset 2) for the same years.

Malmquist Productivity Indexes (MPIs), for their part, serve as a tool for estimating Total Factor Productivity (TFP) variations between two periods, offering a comparative temporal measure of productivity (Coelli et al., 1998; Medeiros et al., 2019). These indexes are based on the developments of Caves et al. (1982) and the index numbers proposed by Malmquist in 1953. In this study, MPIs were calculated to dynamically assess productivity between two consecutive years for the national sample of companies (sample subset 1) and the plants of the LSF company (sample subset 2). These indexes use a Bayesian frontier approximation approach based on distance functions (distance of a productive unit in two given periods) (Delfín Ortega & Navarro Chávez, 2015). Their usefulness and relevance lie, in part, in the fact that they do not require price data or assumptions about whether the objective of the entrepreneur/DMU is to maximize profits or minimize costs.

The primary objective of MPIs is to determine the total factor productivity of a DMU. This involves evaluating changes in both the productivity of the employed set of productive factors and total productivity, i.e., its evolution over time, from one period (t) to the next (t + 1). Moreover, MPIs make it possible to separate productive change owing to improvements in technical efficiency from that attributable to technological change. In addition, they enable the description of any multi-input and multi-product technology without having to specify any behavioral objective such as cost minimization or profit maximization (Coelli et al., 1998). In practice, the aim is to assess a DMU's productive efficiency and its evolution or improvements in the employed technology in relation to the set of DMUs under analysis (Pumisacho Álvaro & Alvarado Ramírez, 2018, for SMEs in different productive sectors). One variation in its applications involves comparing efficiency between countries, as demonstrated in the study by Medeiros et al. (2019).

The following are the indicators that can be obtained using MPIs:

- *Total factor productivity change* (*TFPCH*), which is evaluated between periods t and t + 1. In this case, the value of this indicator must be > 1 to denote an improvement.
- *Allocative efficiency change* (*TECH*), which measures the capacity to optimally use inputs based on their respective prices and is evaluated between periods t and t + 1. In this case, TECH > 1 indicates progress; otherwise, it indicates a reduction in efficiency in that same period.
- *Technical efficiency change* (*TECHCH*), which also evaluates efficiency between periods t and t + 1. In this case, *TECHCH* > 1 (frontier displacement) suggests improvements in technology.
- *Scale efficiency change* (*SECH*), which evaluates changes in scale efficiency (scale utilization) between periods t and t + 1. In this case, SECH > 1 indicates improvement.

Finally, by combining the results of DEA and MPIs, a system of dynamic indicators for measuring productivity in small companies was designed, estimated, and validated. The steps involved are summarized as follows: (i) calculation of productivity ratios for sample subsets 1 and 2; (ii) estimation of the DEA model to obtain the efficiency parameters for both cases (sample subsets 1 and 2); and (iii) estimation of Malmquist indexes, also performed for both cases (sample subsets 1 and 2). Importantly, these indicators facilitate the effective analysis of an organization's improvements in terms of total factor productivity. Simultaneously, they allow the measurement of improvements in efficiency, technical efficiency, and scale efficiency for the analyzed DMUs. The software used for calculating and estimating the DEA model and MPIs was Stata/SE v16.

4. RESULTS

Table 1 summarizes the main results of the DEA model estimation for the final sample of MSMEs in Colombia (sample subset 1).

Table 1. DMUs in Colombia - Parameters estimated using DEA (input-oriented and output-oriented models)
Tabla 1. UTD (es decir, unidad de toma de decisiones) en Colombia - Parámetros estimados mediante DEA (modelo con orientación a entradas y modelo con orientación a salidas)

	Input-oriented model		Output-oriented model	
Year	Constant Returns to Scale (CRS)	Variable Returns to Scale (VRS)	Constant Returns to Scale (CRS)	Variable Returns to Scale (VRS)
2016	0.5447	0.8287	0.5447	0.6422
2017	0.4560	0.7664	0.4560	0.6281
2018	0.4089	0.7609	0.4089	0.5522
2019	0.4009	0.7164	0.4009	0.5162

Source: Own work.

In broad terms, Colombian MSMEs accumulated a total efficiency loss of 16.28% between 2016 and 2017, followed by 10.33% between 2017 and 2018, and an additional slight loss of 1.96% between 2018 and 2019 (CRS mode or technology). The total efficiency loss for the entire period under analysis (2016–2019) was 26.40%. These results indicate that small Colombian companies progressively increased their use of inputs for each recorded level of output, leading to a continuous loss of productivity. Likewise, only a very small portion (7.14% of the SMEs included in the sample subset) achieved full efficiency by 2019, denoted by a total efficiency score equal to unity (Table 1). In addition, between 2016 and 2019, 20% to 26% of all the examined SMEs exhibited a technical efficiency below the first quartile (i.e., total efficiency values ranging from 0% to 25%). When the model was estimated using the input-oriented VRS mode or technology, similar results were obtained. In this case, the average technical efficiency of the Colombian SMEs decreased by 7.51% between 2016 and 2017, 0.71% between 2017 and 2018, and 5.85% between 2018 and 2019.

In analyzing the total technical efficiency for the six plants of the LSF DMU (sample subset 2), chosen to validate the system of indicators, an irregular or oscillatory behavior was observed from 2016 to 2019. When using both the input- and output-oriented CRS mode or technology, the efficiency of the set of production plants decreased by 17.69% between 2016 and 2017, increased by 30.83% between 2017 and 2018, and decreased again by 69.23% between 2018 and 2019. This latter value, given its magnitude, indicates an atypical behavior. In this case, the total productivity loss for the entire period under study was 66.86%. When using the input-oriented VRS mode or technology, a different pattern was observed. In this case, the magnitudes of the efficiency coefficients were smaller, showing an increase of 1.92% between 2016 and 2017, an increase of 17.43% between 2017 and 2018, and a decrease of 40.98% between 2018 and 2019. In this case, the loss over the entire period under analysis was 40.98%. Finally, when using the output-oriented VRS mode or technology, there was an increase of 6.89% between 2016 and 2017, followed by two consecutive contractions: a 2.75% decrease between 2017 and 2018 and a 49.96% decrease between 2018 and 2019. In this case, the loss over the entire period under study was 47.98% (Table 2). Additionally, the rank result for this DMU in 2019 places it below the first quartile, indicating that its total efficiency is within 25% of the least efficient DMUs in the sample for that year.

Table 2. DMUs of the LSF company- Parameters estimated using DEA (input-oriented and output-oriented models)

Tabla 2. UTD (es decir, unidad de toma de decisiones) de la empresa LSF - Parámetros estimados usando DEA (modelo con orientación a entradas y modelo con orientación a salidas)

	Input-oriented model		Output-oriented model	
Year	Constant Returns to Scale (CRS)	Variable Returns to Scale (VRS)	Constant Returns to Scale (CRS)	Variable Returns to Scale (VRS)
2016	0.3282	0.6658	0.3282	0.3402
2017	0.2701	0.6786	0.2701	0.3636
2018	0.3534	0.7969	0.3534	0.3536
2019	0.1088	0.4704	0.1088	0.1769

Source: Own work.

To calculate the MPIs, a restriction was imposed on sample subset 1 (i.e., the sample of Colombian SMEs) to include only DMUs with records of total and technical efficiency indicators in consecutive periods. The key findings are summarized in Table 3. As observed, the total factor productivity indicator (*TFPCH*) for this refined sample exhibited improvements across the three subperiods under study. According to theory, this rise is mainly attributed to improvements in technical efficiency in the early years. In this case, it evidences that the set of analyzed DMUs increased their technological capabilities. Also, it may indicate that Colombian SMEs incorporated advances in innovation into their production processes, which allowed them to improve the total efficiency of the factors used in production. Upon examining the entire set of Colombian SMEs included in this estimation, 50% of them were found to reduce their productivity in the 2016–2017 subperiod (Table 3). This figure increased to 59% in the 2017—2018 subperiod and further rose to 66% in the 2018–2019 subperiod. Such behavior suggests that the number of DMUs experiencing reduction in productivity tended to rise annually over the studied period. This, in turn, underscores the need to implement public policies and/or managerial decisions in such organizations to reverse this unfavorable trend.

Table 3. DMUs in Colombia - Estimated MPIs by time intervals

Tabla 3. UTD (unidades de toma de decisiones) en Colombia - Índices de productividad de Malmquist por intervalos de tiempo

Subsample: Colombian SMEs				
Time interval (Pdwise)	TFPCH	TECH	TECHCH	SECH
2016–2017	1.2413	1.0081	1.1672	1.0549
2017–2018	2.0973	1.2233	1.3136	1.3052
2018–2019	1.0772	0.9324	1.2478	0.9258

Source: Authors' own work.

Regarding the remaining Malmquist productivity indicators that were estimated (Table 3), Colombian SMEs consistently demonstrated improvements in technology (*TECCH*) throughout the studied period. A similar trend was observed between 2016 and 2018, when the *TECH* indicator (allocative efficiency) reflected improvements in terms of the proportions of used resources, as well as in scale efficiency in such period.

Furthermore, when analyzing the LSF DMU (Table 4), an irregular behavior was observed in the total factor productivity indicator (*TFPCH*). It initially experienced a decrease between 2016 and 2017, followed by a substantial growth in the following subperiod (2017–2018, with an improvement in TFP), and ultimately a significant reduction in TFP in the final subperiod (2018–2019). These results are mainly attributed to a reduction in efficiency. For its part, the technical efficiency indicator (*TECHCH*) showed a stable behavior but with values below one, indicating slight technological setbacks during the three studied subperiods.

Due to homogeneity limitations in the basic information, which prevented extending the study period, it was not possible to identify any clear trends (in the medium or long terms) for the four Malmquist indicators. Nevertheless, the fact that, in most of the subperiods (particularly in the last one), the *TFPCH* MPIs were below one serves as an indication of declines in productivity and technical efficiency for the LSF company.

Table 4. DMUs of the LSF company – Jointly estimated MPIs by time intervals

Tabla 4. UTD (unidades de toma de decisiones) de la empresa LSF - Índices de productividad de Malmquist conjuntos por intervalos de tiempo

Subsample: SMEs of the LSF company				
Time interval (Pdwise)	TFPCH	TECH	TECHCH	SECH
2016—2017	0.8124	1.0192	0.9795	0.8137
2017–2018	1.2130	1.1743	0.9127	1.1317
2018—2019	0.2440	0.5902	0.9063	0.4561

Source: Authors' own work.

Finally, the Malmquist indexes for each plant of the LSF DMU are summarized in Table 5. As can be seen, in the total efficiency component (average *TFPCH*), DMU_{S2} is the plant that exhibited the best performance in the analyzed subperiods. Nonetheless, similar to the other DMUs, the total productivity of its factors decreased between 2018 and 2019. This decline can be mainly attributed to the positive performance in terms of technical efficiency (*TECCH*), which denotes technological improvements or the application of innovation processes. In this regard, DMU_{S2} stands out as the only plant showing sustained improvements across all three subperiods. The remaining plants exhibited relative stability in the *TFPCH* MPI, with values close to one.

Concerning allocative efficiency (*TECH* indicator), almost all plants obtained values equal to one. The two exceptions were DMU_{S1} and DMU_{S2} between 2016 and 2017, as well as DMU_{U3} between 2018 and 2019 (with a slightly lower value). Therefore, the production units comprising the LSF DMU did not experience significant improvements in terms of the optimal proportions of inputs used during the period under study. Regarding the *SECH* indicator, only DMU_{S2} and DMU_{S3} in the 2016–2017 subperiod and DMU_{S2} in the 2018—2019 subperiod showed improvements in scale efficiency, while DMU_{U3} exhibited a decline in this indicator in the 2018–2019 subperiod. The remaining plants maintained average values equal to one, meaning they did not take advantage of economies of scales.

The joint analysis of the four Malmquist productivity indicators for the six plants comprising the LSF company revealed the need for a specific and in-depth analysis of plant DMU_{S1}. This analysis aimed

to identify which processes were or were not productive within the group of products that it manufactures. For this purpose, the Activity Based Costing (ABC) technique was applied to allocate indirect costs, employing the most representative direct costs based on their usage (coal, natural gas, electric power, packaging materials, raw materials, and use of facilities/depreciation). Then, productivity factors, along with outputs and inputs, were determined for the subsequent estimation of another DEA model for the seven products of DMU_{S1} for the years 2018 and 2019. According to the findings, two of the three main products generated in this plant showed a very low overall efficiency (with values of 0.43 and 0.51 in 2019 in the input-oriented CRS model), while three other products also exhibited overall inefficiencies. In these cases, the plant uses more inputs for the outputs produced; hence, they would have to reduce inputs by about 50% or double production with the existing inputs to be situated in the efficient frontier. This would explain why the productivity of this plant is so low.

Table 5. DMUs of the LSF company - Estimated MPIs of each plant by time intervals

Tabla 5. UTDs de la empresa LSF - Índices de productividad de Malmquist de cada planta por intervalos de tiempo

Subperiod	LSF facility	Average TFPCH	Average TECH	Average TECHCH	Average SECH
2016–2017	DMU_{S1}	0.9154	0.9620	1.0527	0.9040
	DMU_{S2}	1.4277	0.9897	1.3815	1.0442
	DMU_{S3}	1.1118	1.0000	0.9555	1.1635
	DMU_{As1}	1.6758	1.0000	1.6758	1.0000
	DMU_{As2}	1.0639	1.0000	1.0639	1.0000
	DMU_{U3}	0.6919	1.0000	0.6919	1.0000
Total 2016–2017		**1.1477**	**0.9920**	**1.1369**	**1.0186**
2017–2018	DMU_{S1}	0.8038	1.0108	0.8838	0.8998
	DMU_{S2}	3.3340	1.0399	2.5696	1.2477
	DMU_{S3}	0.9486	1.0000	0.9486	1.0000
	DMU_{As1}	0.7748	1.0000	0.7748	1.0000
	DMU_{As2}	0.7740	1.0000	0.7740	1.0000
	DMU_{U3}	0.7961	1.0000	0.7961	1.0000
Total 2017–2018		**1.2385**	**1.0084**	**1.1245**	**1.0246**
2018–2019	DMU_{S1}	1.1934	1.0284	0.8036	1.4441
	DMU_{S2}	1.0101	1.0000	1.0101	1.0000
	DMU_{S3}	0.8681	1.0000	0.8681	1.0000
	DMU_{As1}	0.8172	1.0000	0.8172	1.0000
	DMU_{As2}	1.0260	1.0000	1.0260	1.0000
	DMU_{U3}	0.7188	0.9894	0.9604	0.7565
Total 2018–2019		0.9389	1.0030	0.9142	**1.0334**
Overall total		**1.1084**	**1.0011**	**1.0585**	**1.0255**

Source: Authors' own work.

5. DISCUSSION

The literature review highlighted findings from various studies (e.g., Amézquita Zárate, 2007), indicating that Colombian MSMEs tend to focus their production preferentially on the domestic market, although some also operate in international markets (e.g., in 2019 they accounted for 75.1% of overall exporting companies, according to PROCOLOMBIA, 2020). To increase export orientation, Colombian MSMEs should invest in qualification/human capital to increase their productivity (Simancas Trujillo et al., 2018). This means taking into account factors that influence firm productivity, such as investments and savings in physical capital, new technologies, human capital, labor logistics, and (adequate) size. Other key factors include innovation in products, processes, and logistics (Salazar Otálora et al., 2023; Franco-Ángel & Urbano, 2019; Classen et al., 2014), communications (Muñoz Hernández, 2012), and ICTs (Castellanos Galeano et al., 2016)—some of which were incorporated as inputs in the productivity models presented in the quantitative section of this paper. Logistic resources and capabilities, as well as efficient business structure for production and distribution (Araya, as cited in Salazar Otálora et al., 2023), are also fundamental factors. Additionally, a company's growth over time is crucial for expanding into new markets, as it reflects the maturity of its products, its value-added processes, and its ability to address challenges (Araya, as cited in Salazar Otálora et al., 2023). In short, one way to improve productivity is to increase MSMEs' exporting activity, which implies effectively managing productive resources, logistics, and installed size or capacity.

Given the correlation between productivity and a country's economic growth, companies expect government entities to provide incentives or support for implementing corporate improvements (Simancas Trujillo et al., 2018). The analysis of the legal framework in Colombia demonstrated that, in fact, despite its heterogeneity, the central levels of government have widely recognized the importance of MSMEs in the economy. Since the 1970s, several laws have been enacted, including at least five directly addressing SMEs and MSMEs, as well as subsequent amendments and updates that aim to promote their creation (Ley 67 de 1979, Ley 78 de 1988, Ley 590 de 2000, Ley 905 de 2004, Ley 1151 de 2007). These laws, together with other legal provisions regulating or linked to MSME activity in the country, certain national plans (e.g., Law 1450 of 2011 and Law 1753 of 2015), other domestic decrees, and the adoption of international regulations such as the Decisions of the Organization of American States and United Nations (Organización de Estados Americanos [OAS-OAS], 2011a, 2011b; Programa de Naciones Unidas para el Desarrollo [UNDP], 1991) have brought positive effects for the MSME segment. As of 2000, this segment represented 99.47% of the business sector and held the fourth position in the 2019 Global Competitiveness Index (CPC, 2022).

Nevertheless, as evidenced throughout this paper, Colombian SMEs do not have the necessary technological tools to promptly identify productivity losses, often realizing them too late—when experiencing severe contractions in sales or market shares and declines in competitiveness. This indeed highlights the urgent need for measures aimed at improving their efficiency, developing competitive advantages, or reversing undesired behaviors. One of such measures is the implementation of a system of productivity indicators such as the one proposed here—together with conventional indicators based on financial ratios and variables used, for example, by Romero Espinosa et al. (2015)—to analyze business failures in Colombian SMEs. The basic inputs for such analysis are readily available in their accounting, enabling SMEs' decision-makers to identify the main sources of inefficiency in real-time and take the necessary corrective measures.

Regarding the parameters estimated using DEA, the input-oriented and output-oriented models presented in Table 1 revealed a clear decreasing trend in total efficiency, as an annual average for the sample of Colombian SMEs. This decline was observed under both the VRS and CRS modes or technologies, regardless of whether the estimation was input- or output-oriented. These findings indicate a sustained loss of productivity in such enterprises during the 2016-2019 period, which aligns with the observations made by Rodríguez-Lozano (2021) in some specific periods in the Colombian banking sector, particularly during and immediately after the global financial crisis at the end of the 2000s.

The second relevant result related to technical efficiency pertains to the coefficients estimated for each DMU in the sample. Approximately 25% of the studied enterprises exhibited a technical efficiency below the first quartile. This means that a significant portion of the population under analysis requires special attention because of their low performance in terms of productivity during the studied period (2016–2019). In addition, the model estimated under a VRS mode or technology and from an input-oriented perspective showed a decrease in the average technical efficiency of the DMUs over the studied period. In short, these results reveal a consistent annual decline in technical efficiency, indicating that Colombian SMEs were then using more inputs than necessary for their production processes. In other words, they inefficiently employed their inputs, resulting in productivity losses in the technical component. This behavior could be attributed to slight (or nonexistent) technological improvements in their production processes or a lack of innovation in the sector (Table 1). These findings, which show that companies can achieve improvements in productivity by reallocating their resources/inputs, are in line with those reported by Oliveros Contreras et al. (2019), in the case of Colombian textile enterprises.

Concerning the individual evaluation of the six plants comprising the LSF company, the main findings revealed similar trends, irrespective of whether the estimation method was input-oriented or output-oriented, and regardless of whether the mode or technology in inputs use was CRS or VRS. As a result, the joint efficiency of the set of production plants decreased between 2016 and 2017, increased between 2017 and 2018, and decreased again between 2018 and 2019. In addition, in some of the plants, the amount of inputs used exceeded what was necessary for the outputs generated, which suggests they are inefficient. Responsible managers should therefore consider improving the current mix of inputs used in those plants or increasing the current level of production. This is precisely one of the advantages of adopting a system of productivity indicators like the one developed and tested in this study.

Finally, with regards to the estimated Malmquist productivity indicators, the Colombian SMEs demonstrated improvements in technology (*TECCH*) during the entire studied period and in allocative efficiency (*TECH*) specifically during the 2016–2017 and 2017–2018 subperiods. This suggests improvements in technology or the application of innovation processes. These findings are similar to those of Rodríguez Lozano (2017), who observed improvements in the productivity of a set of Colombian enterprises in the real sector from 2015 to 2018 (despite efficiency setbacks in both indicators during the final year of study). Comparable results were also reported by De Jorge Moreno & Diaz Castro (2019) in their analysis spanning the years 2005–2010, where only 7 (out of 27 manufacturing sectors they analyzed) experienced increases in productivity. Moreover, Rodríguez-

Lozano (2021) documented a similar irregular behavior for a subset of Colombian banks from 2002 to 2016.

In sum, despite their economic importance, Colombian SMEs currently face severe challenges such as limited access to credit, technological backwardness, restricted access to knowledge (e.g., tools, methodologies, and national and international insertion/promotion policies), and low levels of ICT incorporation and innovation. As a result, they exhibit low productivity, posing a threat to their sustainability over time. Therefore, in line with the recommendations of Confecámaras (2016, 2018, 2022), urgent measures are needed in the country to strengthen this segment. These measures include providing technical assistance to enhance their productivity, fostering product differentiation through innovation, supporting the design of commercial strategies, and facilitating access to market information.

6. CONCLUSIONS

Globally—and Colombia is no exception—companies must contend with increasingly competitive environments and more demanding markets, as well as growing environmental demands in the midst of a global energy transition. Achieving sustainability, therefore, demands huge managerial and technological innovations. Despite their importance in terms of their contribution to employment and local development, MSMEs usually face more limitations than large companies in implementing major changes in their production processes. Some encounter limited access to cutting-edge or energy-efficient technologies, while others struggle to adopt non-linear and environmentally more sustainable production processes, especially when not integrated into value chains with greater geographical coverage or international reach.

To address these challenges faced by private economic actors, governmental intervention becomes pivotal through sector-specific public policies aimed at promoting and strengthening economic sectors or segments such as MSMEs. In Colombia, recognizing the importance of these organizations, the government established an important legal framework in the late 1980s, focused on fostering the creation and development of MSMEs. Its ultimate goal was to propel the segment, promote its scalability and export orientation, and simplify the procedures for the creation of these organizations while contributing to broader macroeconomic objectives, such as job creation and economic growth. Regarding the latter, this segment has been included as a key player in recent national development plans. At the beginning of the 2020s, MSMEs already represented more than 99.5% of the Colombian business landscape, accounting for almost four-fifths of employment and contributing approximately 40% to the national GDP. Despite the development of public initiatives and institutional support in recent decades, Colombian SMEs still face adverse conditions that affect their competitiveness and limit their potential in the national economy. Moreover, like their counterparts in Latin America, Colombian MSMEs exhibit low productivity and marked productivity gaps compared to large companies, which further complicates their sustainability over time and undermines the intended function that the government has assigned them.

In such a scenario, where external factors are beyond their control, a pragmatic approach to reverse this low productivity is to use the available information, technologies, and resources to improve their operability and competitiveness in the short, medium, and long term. With this perspective in mind, the second part of this article focused precisely on the design, validation, and implementation of a

set of productivity indicators. These indicators were estimated and analyzed for the particular case of SMEs in Colombia, offering real-time insights into their performance and recommending the adoption of necessary corrective measures. Clearly, government entities can complement these indicators with sector-specific policies, including providing financial support for this business segment.

This study shows that, by applying a system of indicators based on non-parametric techniques and using readily available information, any company or organization (regardless of its size, economic sector, or the area in which it operates) can assess its productivity in real time. It can also evaluate the productivity of the sector in which it operates and benchmark against other organizations or competitors in the market (an aspect not addressed in this article). Furthermore, companies or groups of enterprises can internally analyze their productivity within production processes, particular products or groups of products/services, or over time, among other applications. Using such a tool, they can also identify opportunities for improvement, either in terms of reducing the number of inputs used or increasing their products/services (outputs) at any stage of their production processes, product line, plants, or branch offices. In addition, through the decomposition of various ratios in the case of the Malmquist Productivity Index, companies could gain insights into business operations, market behavior, and competition. This information empowers managers to design the necessary strategies tailored to their organization, allowing them to control and enhance their competitiveness and profitability—a necessary condition for their sustainability over time. In summary, indicators based on DEA techniques or Malmquist indexes, as proposed in this study, could help Colombian MSMEs improve their productivity.

CONFLICTS OF INTEREST

The authors declare no conflict of financial, professional, or personal interests that may inappropriately influence the results that were obtained or the interpretations that are proposed here.

AUTHOR CONTRIBUTIONS

Both authors contributed significantly to this paper. Manuel Eduardo García Camacho and José Daniel Anido R. conceptualized and designed the original research project. Together, they reviewed secondary sources, analyzed, and interpreted the data used for estimation. Manuel Eduardo García Camacho formulated the models' specifications and conducted the estimations. Both authors jointly reviewed these aspects toward the end, in addition to drafting the paper and revising the English version.

REFERENCES

Abdella, G. M., Kucukvar, M., Ismail, R., Abdelsalam, A. G., Onat, N. C., & Dawoud, O. (2021). A mixed model-based Johnson's relative weights for eco-efficiency assessment: the case for global food consumption. *Environmental Impact Assessment Review*, *89*, 106588. https://doi.org/10.1016/j.eiar.2021.106588

Absah, Y., Sadalia, I., Yuliaty, T., & Ilham, R. N. (2023). Msmes In Medan City During the New Normal. *General Management*, *24*(193), 322-327. https://doi.org/10.47750/QAS/24.193.36

Villalobos, M. C., & Ramírez Vallejo, J. (2005). Diferencias regionales en la eficiencia técnica del sector confecciones en Colombia: un análisis de fronteras estocásticas. *Innovar, Revista de Ciencias Administrativas y Sociales*, *15*(26), 90-105. https://www.redalyc.org/articulo.oa?id=81802607

Ahmadi, M., Osman, M. H. M., & Aghdam, M. M. (2020). Integrated exploratory factor analysis and Data Envelopment Analysis to evaluate balanced ambidexterity fostering innovation in manufacturing SMEs. *Asia Pacific Management Review*, *25*(3), 142-155. https://doi.org/10.1016/j.apmrv.2020.06.003

Aldeanueva Fernández, I., & Cervantes Rosas, M. A. (2019). El desarrollo sostenible como imperativo estratégico: el contexto de la pequeña y mediana empresa latinoamericana. *Revista Lasallista de Investigación*, *16*(2), 28-43. https://dialnet.unirioja.es/servlet/articulo?codigo=7769773

Alfonso-Orjuela, L. C., Cancino-Gómez, Y. A., & Perea-Sandoval, J. A. (2022). Classification of SMEs according to their ICT implementation. *International Journal of Technology*, *13*(2), 229-239. https://doi.org/10.14716/ijtech.v13i2.4981

Al-Khasawneh, J. A., Essaddam, N., & Hussain, T. (2020). Total productivity and cost efficiency dynamics of US merging banks: A non-parametric bootstrapped analysis of the fifth merger wave. *The Quarterly Review of Economics and Finance*, *78*, 199-211. https://doi.org/10.1016/j.qref.2020.02.002

Amézquita Zárate, P. (2007). Efectos del TLC Colombia-EUA en las PYMES colombianas. *Análisis Económico*, *XXII*(50), 57-77. http://www.redalyc.org/articulo.oa?id=41305004

Asociación de Emprendedores de Latinoamérica-Laboratorio de Innovación del Banco Interamericano de Desarrollo. (2018). *Brechas para el emprendimiento en la Alianza del Pacífico*. Centro de Estudios Económicos. https://www.observatorioalianzadelpacifico.net/_files/ugd/438ac2_cffdb796328343bf97801691be38ca69.pdf

Asociación Nacional de Instituciones Financieras. (2018). *La gran encuesta PYME. Lectura Regional. I semestre 2018*. Centro de Estudios Económicos. https://bibliotecadigital.ccb.org.co/bitstream/handle/11520/20898/GEP%20REGIONAL%20I-2018.pdf?sequence=1&isAllowed=y

Asociación Nacional de Instituciones Financiera. (2020). *Indicador PYME ANIF: resultados del segundo semestre de 2019*. Centro de Estudios Económicos. https://www.anif.com.co/comentarios-economicos-del-dia/indicador-pyme-anif-resultados-del-segundo-semestre-de-2019/

Asociación Nacional de Instituciones Financieras. (2021). *MiPymes: el pilar para la reactivación económica*. Centro de Estudios Económicos. https://www.anif.com.co/wp-content/uploads/2021/05/carlos-prada-anif.pdf

Bain, D. (1985). *Productividad, la solución a los problemas de la empresa*. McGraw-Hill.

Barrios-Hernández, K. C., Contreras Salinas, J. A., & Olivero-Vega, E. (2019). La Gestión por Procesos en las Pymes de Barranquilla: factor diferenciador de la competitividad organizacional. *Información Tecnológica*, *30*(2), 103-114. http://dx.doi.org/10.4067/S0718-07642019000200103

Belacín, M., & Arnoletto, M. (2019). *Panorama de las empresas en Argentina*. Ministerio de Producción y Trabajo de la Nación. https://biblioteca.produccion.gob.ar/document/download/535

Buitrago Suescún, O. Y., Espitia Cubillos, A. A., & Molano García, L. (2017). Análisis envolvente de datos para la medición de la eficiencia en instituciones de educación superior: una revisión del estado del arte. *Revista Científica General José María Córdova*, *15*(19), 147-173. https://doi.org/10.21830/19006586.84

Cardozo, E., Velásquez de Naime, Y., & Rodríguez Monroy, C. (July 18-20, 2012). La definición de PYME en América: una revisión del estado del arte. En *XVI Congreso de Ingeniería de Organización*. Vigo, España. http://adingor.es/congresos/web/articulo/detalle/a/2294

Castellanos Galeano, J. F., Loaiza, M. E., & Cuesta Iglesias, C. A. (2016). Importancia de las TIC para la competitividad de las Pymes en Colombia. *Puente. Revista Científica*, *10*(1), 93-99. https://repository.upb.edu.co/handle/20.500.11912/7242

Caves, D. W., Christensen, L. R., & Diewert, W. E. (1982). The economic theory of index numbers and the measurement of input, output, and productivity. *Econometrica*, *50*(6), 1393-1414. https://doi.org/10.2307/1913388

Chauca Malásquez, P. M. (2014). Micro y pequeña empresa, actores sociales y contextos desde la perspectiva del desarrollo local. *Acta Universitaria*, *24*(1), 13-25. https://www.redalyc.org/articulo.oa?id=41648308002

Clampitt, P. G., & Downs, C. W. (1993). Employee perceptions of the relationship between communication and productivity: A field study. *The Journal of Business Communication*, *30*(1), 5-28. https://doi.org/10.1177/002194369303000101

Classen, N., Carree, M., Van Gils, A., & Peters, B. (2014). Innovation in family and non-family SMEs: An exploratory analysis. *Small Business Economics*, *42*(3), 595-609. https://doi.org/10.1007/s11187-013-9490-z

Clavijo, S. (2018). Resultados de la Gran Encuesta a las Microempresas 2018. *Diario La República*. https://www.larepublica.co/analisis/sergio-clavijo-500041/resultados-de-la-gran-encuesta-a-las-microempresas-2018-2718177

Coelli, T. J., Prasada Rao, D. S., & Battese, G. E. (1998). *An introduction to efficiency and productivity analysis.* Kluwer Academic Publishers.

Confederación Colombiana de Cámaras de Comercio. (2016). Nacimientos y supervivencia de las empresas en Colombia. *Confecámaras*. http://www.confecamaras.org.co/phocadownload/Cuadernos_de_analisis_economico/Cuaderno_de_An%D0%B0lisis_Economico_N_11.pdf

Confederación Colombiana de Cámaras de Comercio. (2018). *Informe de dinámica empresarial en Colombia*. https://bibliotecadigital.ccb.org.co/server/api/core/bitstreams/320d4d6f-97e0-487e-a932-030227f4311c/content

Confederación Colombiana de Cámaras de Comercio. (2022). *307.679 nuevas empresas se crearon en el país durante 2021, un aumento del 10,6% con respecto a 2020*. https://confecamaras.org.co/noticias/809-307-679-nuevas-empresas-se-crearon-en-el-pais-durante-2021-un-aumento-del-10-6-con-respecto-a-2020

Confirmado.net. (June 30, 2021). Microempresas y las pequeñas y medianas empresas festejaron su día. https://confirmado.net/2021/06/30/microempresas-y-las-pequenas-y-medianas-empresas-festejaron-su-dia/

Consejo Privado de Competitividad. (2014). *Índice Departamental de Competitividad 2014*. https://ccoa.org.co/wp-content/uploads/2020/12/indice-departamental-competitividad-2014-094438-1.pdf

Consejo Privado de Competitividad. (2016). *Índice Departamental de Competitividad (IDC)*. https://compite.com.co/wp-content/uploads/2016/07/CPC_IDC-2016.pdf

Consejo Privado de Competitividad. (2022). *Informe Nacional de Competitividad 2021-2022*. https://compite.com.co/wp-content/uploads/2021/12/CPC_INC_2021-2022-COMPLETO.pdf

Consejo Privado de Competitividad-Universidad de Rosario-Centro de Estudios para la Competitividad Regional. (2021). *Índice Departamental de Competitividad 2020-2021*. https://www.cchuila.org/wp-content/uploads/2021/10/IDC-2020-2021.pdf

Consejo Privado de Competitividad-Universidad de Rosario-Centro de Estudios para la Competitividad Regional. (2022). *Índice Departamental de Competitividad 2022*. https://compite.com.co/wp-content/uploads/2022/04/CPC_IDC_2022.pdf

De Jorge Moreno, J., & Díaz Castro, J. (2019). Análisis de la productividad, eficiencia y sus factores explicativos: el caso de las empresas colombianas, 2005-2010. *Revista de Métodos Cuantitativos para la Economía y la Empresa*, *26*, 315-343. http://www.upo.es/revistas/index.php/RevMetCuant/article/view/3834

Delfín Ortega, O. V., & Navarro Chávez, J. C. L. (2015). Productividad total de los factores en las terminales de contenedores en los puertos de México: una medición a través del índice Malmquist Total. *Contaduría y Administración*, *60*(3), 663-685. http://dx.doi.org/10.1016/j.cya.2015.05.011

Departamento Administrativo Nacional de Estadística. (2022). *Encuesta de micronegocios*. https://www.dane.gov.co/index.php/estadisticas-por-tema/mercado-laboral/micronegocios/micronegocios-historicos

Dini, M., & Stumpo, G. (Coords.). (2020). *Mipymes en América Latina: un frágil desempeño y nuevos desafíos para las políticas de fomento. Síntesis.* Comisión Económica para América Latina y el Caribe. https://repositorio.cepal.org/bitstream/handle/11362/44148/1/S1900361_es.pdf

European Commission. (2015). *User guide to the SME Definition*. https://op.europa.eu/en/publication-detail/-/publication/79c0ce87-f4dc-11e6-8a35-01aa75ed71a1

European Commission. (2022). *Las pequeñas y medianas empresas*. https://www.europarl.europa.eu/factsheets/es/sheet/63/las-pequenas-y-medianas-empresas

Escandón Barbosa, D. M., & Hurtado Ayala, A. (2014). Factores que influyen en el desarrollo exportador de las pymes en Colombia. *Estudios Gerenciales*, *30*(131), 172-183. https://doi.org/10.1016/j.estger.2014.04.006

Fernández Bustamante, P. A., & Meza Muñoz, K. M. (2019). El impacto del impuesto de renta dentro de la economía de las PyMEs de Colombia. *Revista Colombiana de Contabilidad*, *7*(13), 97-110. https://ojs.asfacop.org.co/index.php/asfacop/article/view/121

Ferraro, C., & Stumpo, G. (2010). *Políticas de apoyo a las Pymes en América Latina. Entre avances innovadores y desafíos institucionales.* CEPAL. https://www.cepal.org/es/publicaciones/2552-politicas-apoyo-pyme-america-latina-avances-innovadores-desafios-institucionales

Fontalvo, T., De La Hoz, E., & De La Hoz, E. (2018). Método análisis envolvente de datos y redes neuronales en la evaluación y predicción de la eficiencia técnica de pequeñas empresas exportadoras. *Información Tecnológica*, *29*(6), 267-276. https://dx.doi.org/10.4067/S0718-07642018000600267

Franco, M., De Fátima Santos, M., Ramalho, I., & Nunes, C. (2014). An exploratory study of entrepreneurial marketing in SMEs: The role of the founder-entrepreneur. *Journal of Small Business and Enterprise Development*, *21*(2), 265-283. http://www.emeraldinsight.com/1462-6004.htm

Franco-Ángel, M., & Urbano, D. (2019). Caracterización de las pymes colombianas y de sus fundadores: un análisis desde dos regiones del país. *Estudios Gerenciales*, *35*(150), 81-91. https://doi.org/10.18046/j.estger.2019.150.2968

Garcia-Martinez, L. J., Kraus, S., Breier, M., & Kallmuenzer, A. (2023). Untangling the relationship between small and medium-sized enterprises and growth: a review of extant literature. *International Entrepreneurship and Management Journal*, *19*, 455-479. https://doi.org/10.1007/s11365-023-00830-z

Gesellschaft für Technische Zusammenarbeit-Comisión Económica para América Latina-Centro Regional de Promoción de la MIPYME. (2009). *Manual de la Micro, Pequeña y Mediana Empresa. Una contribución a la mejora de los sistemas de información y el desarrollo de las políticas públicas*. https://repositorio.cepal.org/bitstream/handle/11362/2022/Manual_Micro_Pequenha_Mediana_Empresa_es.pdf?sequence=1

Glonti, V., Manvelidze, R., & Surmanidze, I. (2021). The contribution of SME to regional economic development: On example of Adjara Autonomous Republic. *European Journal of Sustainable Development*, *10*(1), 513-526. https://doi.org/10.14207/ejsd.2021.v10n1p513

Gobierno de España. Ministerio de Industria, Comercio y Turismo. (2022). *Cifras PyME. Datos mayo 2022*. https://industria.gob.es/es-es/estadisticas/Cifras_PYME/CifrasPYME-mayo2022.pdf

Gómez, H. J., & Steiner, R. (2015). La Reforma Tributaria y su impacto sobre la Tasa Efectiva de Tributación de las firmas en Colombia. *Coyuntura Económica*, *XLV*(1), 13-44. https://www.repository.fedesarrollo.org.co/bitstream/handle/11445/2885/Co_Eco_Junio_2015_G%C3%B3mez_y_Steiner.pdf?sequence=4&isAllowed=y

Granda, C., & Hamann, F. (February 2015). *Informality, saving and wealth inequality in Colombia*. Interamerican Development Bank. https://publications.iadb.org/en/informality-saving-and-wealth-inequality-colombia

Guzmán Raja, I., Arcas Lario, N., & García Pérez de Lema, D. (2006). La eficiencia técnica como medida de rendimiento de las cooperativas agrarias. *CIRIEC-España, Revista de Economía Pública, Social y Cooperativa,* (55), 289-311. http://www.redalyc.org/articulo.oa?id=17405511

Habibi, S. S., Tousi, S. N., Aram, F., & Mosavi, A. (2023). Spatial preferences of small and medium knowledge based enterprises in Tehran new business area. *Journal of Urban Management*. https://doi.org/10.1016/j.jum.2023.10.001

Hernández, A., Marulanda, C. E., & López, M. (2014). Análisis de capacidades de gestión del conocimiento para la competitividad de pymes en Colombia. *Información Tecnológica*, *25*(2), 111-122. http://dx.doi.org/10.4067/S0718-07642014000200013

Jácome Riera, E. E. (2018). *Medición de eficiencia y productividad en las pequeñas y medianas empresas del sector productor Metalmecánico del Distrito Metropolitano de Quito durante el período 2010 – 2015* [Tesis de grado, Escuela Politécnica Nacional]. http://bibdigital.epn.edu.ec/handle/15000/19338

Jaimes, L., Luzardo, M., & Rojas, M. D. (2018). Factores determinantes de la productividad laboral en pequeñas y medianas empresas de confecciones del área metropolitana de Bucaramanga, Colombia. *Información tecnológica*, *29*(5), 175-186. http://dx.doi.org/10.4067/S0718076420180005001 75

Lakatos, I. (1987). *Historia de la ciencia y sus reconstrucciones racionales*. Technos.

Leckel, A., Veilleux, S., & Dana, L. P. (2020). Local Open Innovation: A means for public policy to increase collaboration for innovation in SMEs. *Technological Forecasting and Social Change*, *153,* 119891. https://doi.org/10.1016/j.techfore.2019.119891

Ley 67 de 1979. *Por la cual se dictan las normas generales a las que deberá sujetarse el Presidente de la República para fomentar las exportaciones a través de las sociedades de comercialización internacional y se dictan otras disposiciones para el fomento del comercio exterior*. (1979, 26 de diciembre). Congreso de la República de Colombia. Diario Oficial No. 35.443. https://sice.oas.org/SME_CH/COL/Ley_67_de_1979_s.pdf

Ley 78 de 1988. *Por la cual se dictan disposiciones de fomento para la microempresa y la pequeña y mediana industria.* (1988, 21 de diciembre). Congreso de la República de Colombia. Diario Oficial No. 38.631. https://www.suin-juriscol.gov.co/viewDocument.asp?id=1790063

Ley 590 de 2000. *Por la cual se dictan disposiciones para promover el desarrollo de las micro, pequeñas y medianas empresa*. (2000, 10 de julio). Congreso de la República de Colombia. Diario Oficial No. 44.078. https://www.funcionpublica.gov.co/eva/gestornormativo/norma_pdf.php?i=12672

Ley 905 de 2004. *Por medio de la cual se modifica la Ley 590 de 2000 sobre promoción del desarrollo de la micro, pequeña y mediana empresa colombiana y se dictan otras disposiciones*. (2004, 2 de agosto). Congreso de la República de Colombia. Diario Oficial No. 45.628. https://minciencias.gov.co/node/297

Ley 1151 de 2007. *Por la cual se expide el Plan Nacional de Desarrollo 2006-2010.* (2007, 24 de julio). Congreso de la República de Colombia. Diario Oficial No. 46.700. http://www.secretariasenado.gov.co/senado/basedoc/ley_1151_2007.html

Ley 1450 de 2011. *Por la cual se expide el Plan Nacional de Desarrollo, 2010-2014*. (2011, 16 de junio). Congreso de la República de Colombia. Diario Oficial No. 48102. https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=43101#:~:text=Una%20estrategia%20de%20igualdad%20de,social%20o%20lugar%20de%20origen

Ley 1753 de 2015. *Por la cual se expide el Plan Nacional de Desarrollo 2014-2018 "Todos por un nuevo país"*. Congreso de la República de Colombia. (2015, 9 de junio). Diario Oficial No. 49.538. http://www.secretariasenado.gov.co/senado/basedoc/ley_1753_2015.html

Ley 1819 de 2019. *Por medio de la cual se adopta una Reforma Tributaria estructural, se fortalecen los mecanismos para la lucha contra la evasión y la elusión fiscal, y se dictan otras disposiciones*. (2019, 29 de diciembre). Congreso de la República de Colombia. Diario Oficial No. 50.101. http://www.secretariasenado.gov.co/senado/basedoc/ley_1819_2016.html

Lisi, S., Mignacca, B., & Grimaldi, M. (2023). Non-financial reporting and SMEs: A systematic review, research agenda, and novel conceptualization. *Journal of Management & Organization*, 1-23. http://doi.org/10.1017/jmo.2023.43

Medeiros, V., Gonçalves Godoi, L., & Camargos Teixeira, E. (2019). La competitividad y sus factores determinantes: un análisis sistémico para países en desarrollo. *Revista de la CEPAL*, (129), 7-27. https://www.cepal.org/sites/default/files/publication/files/45005/RVE129_Medeiros.pdf

Mesa, F., & Torres, R. (2019). Pymes manufactureras exportadoras en Colombia: un análisis de su actividad real. *Lecturas de Economía*, (90), 127-157. https://doi.org/10.17533/udea.le.n90a05

Ministerio de Comercio, Industria y Turismo. (2008). *Resolución número 3205 de 28 de noviembre de 2008. Por la cual se reglamentan las funciones de los Consejos Regionales de Mipymes (CRM) y se fijan directrices para su organización y funcionamiento.* Diario Oficial No. 47.275. https://www.mipymes.gov.co/mipymes/media/mipymes/Documentos/Resolucion-3205-del-28-de-Noviembre-2008.pdf

Ministerio de Comercio, Industria y Turismo. (2017). *Decreto número 1875 de 17 noviembre 2017 Por el cual se adiciona un Capítulo al Título 2 de la Parte 2 del Libro 2, se crea la Ventanilla Única Empresarial -VUE: y se adiciona un parágrafo al Artículo 2.2.2.38.6.4 del Decreto 1074 de 2015, Decreto Único Reglamentario del Sector Comercio, Industria y Turismo*. Diario Oficial No. 50420. http://www.sice.oas.org/SME_CH/COL/Decreto_1875_2017_s.pdf

Montalbán-Domingo, L., García-Segura, T., Sanz-Benlloch, A., Pellicer, E., Torres-Machi, C., & Molenaar, K. (2022). Assessing social performance of construction companies in public-works procurement: Data Envelopment Analysis based on the benefit of the doubt approach. *Environmental Impact Assessment Review*, *96*, 106844. https://doi.org/10.1016/j.eiar.2022.106844

Mosquera Palacio, C. A., & Díaz Córdoba, S. L. (2022). ¿Qué estrategias podrían implementar las PYMES del sector comercio de Antioquia para lograr un adecuado proceso de transformación digital? *Revista Ruta Académica*, *16*(1), 63-75. http://journal.iumafis.edu.co/index.php/RA/article/view/5/5

Muñoz Cardona, Á. E., & Mayor López, M. P. (2015). Las pyme en América Latina, Japón, la Unión Europea, Estados Unidos y los clúster en Colombia. *Administración & Desarrollo*, *45*(1), 7-24. https://revistas.esap.edu.co/index.php/admindesarro/article/view/1

Muñoz Hernández, M. H. (2012). Comunicación y productividad en pequeñas y medianas empresas de un clúster textil en Colombia. *Contaduría y Administración*, *57*(2), 223-244. https://www.redalyc.org/articulo.oa?id=39523159011

Murillo Lozano, M., & Restrepo Sánchez, L. M. (2016). *Nacimiento y supervivencia de las empresas en Colombia.* http://www.confecamaras.org.co/phocadownload/Cuadernos_de_analisis_economico/Cuaderno_de_An%D0%B0lisis_Economico_N_11.pdf

Niebles-Nuñez, W. A., Pitre-Redondo, R., & Hernández-Palma, H. (2022). Legal framework for entrepreneurship in Colombia. *Entramado*, *18*(1), e-862. https://dialnet.unirioja.es/descarga/articulo/8384564.pdf

Nursini, N. (2020). Micro, small, and medium enterprises (MSMEs) and poverty reduction: empirical evidence from Indonesia. *Development Studies Research*, *7*(1), 153-166. https://doi.org/10.1080/21665095.2020.1823238

Office of the United States Trade Representative. (2019). *Small and Medium-Sized Enterprises*. https://ustr.gov/trade-agreements/free-trade-agreements/trans-pacific-partnership/tpp-chapter-chapter-negotiating-8

Oliveros Contreras, D., Guzmán Duque, A. P., Mendoza García, E. M., & Blanco Álvarez, T. A. (2019). *La eficiencia y productividad del sector textil y confecciones en Colombia. Un enfoque DEA.* Universidad Autónoma de Bucaramanga Publicaciones. https://repository.unab.edu.co/handle/20.500.12749/7303

Organización de Estados Americanos. (May 27, 2011a). *Decisión 748 Creación del Comité Andino de la Micro, Pequeña y Mediana Empresa (CAMIPYME)*. https://faolex.fao.org/docs/pdf/anc103053.pdf

Organización de Estados Americanos. (May 27, 2011b). *Decisión 749 Creación e Implementación del Observatorio Andino de la MIPYME (OBAPYME)*. http://www.sice.oas.org/SME_CH/COL/Dec_749_s.pdf

Organización para la Cooperación y el Desarrollo Económico-Corporación Andina de Fomento. (2019). *Índice de Políticas PYME: América Latina y el Caribe 2019*. https://www.caf.com/es/actualidad/noticias/2019/04/indice-de-politicas-pyme-america-latina-y-el-caribe-2019/#:~:text=Las%20PYME%20representan%20m%C3%A1s%20del,de%20pol%C3%ADticas%20de%20la%20regi%C3%B3n.

Padilla Martínez, M. P., Lascano Pérez, L. F., & Jiménez Silva, W. R. (2018). La dinámica empresarial y el emprendimiento, factores determinantes para el desarrollo del ciclo de vida de las pymes. *Revista Publicando*, *5*(15), 308-325. https://core.ac.uk/download/pdf/236643847.pdf

Padrón Guillén, J. (1994). *El componente sociológico en los procesos de difusión y uso del conocimiento*. [Tesis postgrado, Universidad Simón Rodríguez]. https://www.researchgate.net/publication/277249659_EL_COMPONENTE_SOCIOLOGICO_EN_LOS_PROCESOS_DE_DIFUSION_Y_USO_DEL_CONOCIMIENTO

Presidencia de la República de Colombia. (2012). *Decreto número 2706 de 27 diciembre 2012 Por el cual se reglamenta la Ley 1314 de 2009 sobre el marco técnico normativo de información financiera para las microempresas*. Diario Oficial No. 48657. https://www.funcionpublica.gov.co/eva/gestornormativo/norma_pdf.php?i=51148

Presidencia de la República de Colombia. (2013). *Decreto número 489 del 14 de marzo de 2013 Por el cual se reglamenta parcialmente la Ley 1429 de 2010*. Diario Oficial No. 48732. https://www.funcionpublica.gov.co/eva/gestornormativo/norma_pdf.php?i=52301.

Presidencia de la República de Colombia. (2018). *Decreto 1357 de 31 de julio de 2018 Por el cual se modifica el Decreto 2555 de 2010 en lo relacionado con la actividad de financiación colaborativa*. Diario Oficial No. 50671. https://www.suin-juriscol.gov.co/viewDocument.asp?ruta=Decretos/30035534

PROCOLOMBIA. (2020). *Mipymes, las llamadas a dinamizar las exportaciones colombianas*. Sala de Prensa PROCOLOMBIA. https://prensa.procolombia.co/mipymes-las-llamadas-dinamizar-las-exportaciones-colombianas

Programa de Naciones Unidas para el Desarrollo. (1991). *Plan Nacional para el Desarrollo de la Microempresa PNUD 1991-1994*. https://colaboracion.dnp.gov.co/CDT/Conpes/Econ%C3%B3micos/2541.pdf

Pumisacho Álvaro, V. H., & Alvarado Ramírez, K. M. (2018). Evaluación de eficiencia y productividad de PyMEs productivas usando análisis envolvente de datos e índice Malmquist. *Espacios*, *39*(33), 10. https://www.revistaespacios.com/a18v39n33/18393310.html

Rodríguez Lozano, G. I. (2017). Evolución de la productividad de las empresas del sector real de la economía colombiana. *Revista Republicana*, (22), 259-275. http://dx.doi.org/10.21017/Rev.Repub.2017.v22.a28

Rodríguez-Lozano, G. (2021). Los cambios en la productividad del sector bancario colombiano en el período 2002-2016. *Apuntes del Cenes*, *40*(71), 105-132. https://doi.org/10.19053/01203053.v40.n71.2021.11120

Romero Espinosa, F., Melgarejo Molina, Z. A., & Vera Colina, M. A. (2015). Fracaso empresarial de las pequeñas y medianas empresas (pymes) en Colombia. *Suma de Negocios*, *6*(13), 29-41. https://doi.org/10.1016/j.sumneg.2015.08.003

Romero Luna, I. (2006). Las PYME en la economía global. Hacia una estrategia de fomento empresarial. *Problemas del Desarrollo. Revista Latinoamericana de Economía*, *37*(146), 31-50. http://www.redalyc.org/articulo.oa?id=11820858002

Salazar Otálora, G. E., Manrique Joya, G. M., & Cuy Rojas, A. L. (2023). Capacidades logísticas como factores determinantes para la internacionalización de las pymes: una revisión sistemática de literatura. *Revista CEA*, *9*(19), e2126. https://doi.org/10.22430/24223182.2126

Samuelson, P. A., & Nordhaus, W. D. (2010). *Economía. Con aplicaciones a Latinoamérica.* (19a. ed.). McGraw Hill Education.

Sanmartín-Durango, D., Henao-Bedoya, M. A., Valencia-Estupiñán, Y. T., & Restrepo-Zea, J. H. (2019). Eficiencia del gasto en salud en la OCDE y ALC: un análisis envolvente de datos. *Lecturas de Economía*, (91), 41-78. https://doi.org/10.17533/udea.le.n91a02

Sarria-Pedroza, J., & Fernández-Guadaño, J. (junio 15-18, 2022). Efecto de las políticas públicas en la productividad de las PYMEs. En *33 Congreso Internacional del CIRIEC,* Valencia, España. http://ciriec.es/valencia2022/wp-content/uploads/COMUN-180.pdf

Simancas Trujillo, R. A., Silvera Sarmiento, A. D. J., Garcés Giraldo, L. F., & Hernández Palma, H. G. (2018). Administración de recursos humanos: factor estratégico de productividad empresarial en pymes de Barranquilla. *Revista Venezolana de Gerencia*, *23*(82), 377-391. https://www.redalyc.org/articulo.oa?id=29056115008

Singh, M., Rathi, R., & Garza-Reyes, J. A. (2021). Analysis and prioritization of Lean Six Sigma enablers with environmental facets using best worst method: A case of Indian MSMEs. *Journal of Cleaner Production*, *279*, 123592. https://doi.org/10.1016/j.jclepro.2020.123592

Small Business Administration. (2019). *What is a small business?* https://www.state.gov/what-is-a-small-business/

Small Business Administration. (2021). *2021 small business profile*. https://advocacy.sba.gov/wp-content/uploads/2021/08/2021-Small-Business-Profiles-For-The-States.pdf

Soledispa Rodríguez, X. E., Pionce Choez, J. M., & Sierra González, M. C. (2022). La gestión administrativa, factor clave para la productividad y competitividad de las microempresas. *Dominio de las Ciencias*, *8*(Extra 1), 280-294. http://dx.doi.org/10.23857/dc.v8i1.2571

Suin Guaraca, L. H., Duque Rodríguez, M. A., & Aguirre Quezada, J. C. (2021). Análisis Envolvente de Datos (DEA) para el estudio de la eficiencia técnica en los Sistemas de Salud: una revisión bibliográfica y metodológica en el contexto ecuatoriano. *Revista de la Facultad de Ciencias Médicas de la Universidad de Cuenca*, *38*(3), 97-108. https://publicaciones.ucuenca.edu.ec/ojs/index.php/medicina/article/view/3311/2687

Superintendencia de Sociedades. (2020). *Base completa. Estados financieros 2019. Información financiera-NIIF, con corte al 31 de diciembre de 2019*. https://www.supersociedades.gov.co/delegatura_aec/Paginas/Base-completa-EF-2019.aspx

Superintendencia de Sociedades. (2023). *Sistema Integrado de Información Societaria. Superintendencia de Sociedades*. https://siis.ia.supersociedades.gov.co

Taborda Ocampo, M. A., Nova, L. D., & Bohórquez Sanabria, I. V. (2018). Importancia de las Pymes para el desarrollo económico de Chile en el siglo XXI. *Punto de Vista*, *9*(14), 1-18. https://doi.org/10.15765/pdv.v9i14.1179

Zamora Guzmán, I. (April 11, 2022). Fortalecer a las Pymes, el impulso para la reactivación económica. *Forbes México*. https://www.forbes.com.mx/red-forbes-fortalecer-a-las-pymes-el-impulso-para-la-reactivacion-economica/