REVISTA DE MÉTODOS CUANTITATIVOS PARA LA ECONOMÍA Y LA EMPRESA (35). Páginas 34-56.
Junio de 2023. ISSN: 1886-516X. D.L: SE-2927-06.
www.upo.es/revistas/index.php/RevMetCuant/article/view/5475

Relationship between Productivity and Efficiency with Sustainable Development Goals: The Case of the Manufacturing Industry in Pichincha, Ecuador

IBUJÉS-VILLACÍS, JUAN
Escuela Politécnica Nacional (Ecuador)
Correo electrónico: juan.ibujes@epn.edu.ec

FRANCO-CRESPO, ANTONIO
Escuela Politécnica Nacional (Ecuador))
Correo electrónico: antonio.franco@epn.edu.ec

ABSTRACT

In 2015, at the United Nations forum, the 17 Sustainable Development Goals (SDGs) were approved to be met by 2030. This research aims to know what has been the behavior of productivity and efficiency of the manufacturing industry in the province of Pichincha, Ecuador, and the relationship with the achievement of some goals of the SDG 8, 9 and 12. The research methodology has a quantitative, non-experimental, and longitudinal approach. The information from the economic and financial reports of the manufacturing companies between 2010 and 2018 was processed. The values of efficiency were estimated using the data enveloping analysis technique. With the annual information, the evolution of productivity and efficiency was predicted until 2022. In the nine years, the results show that the productivity indicators and the number of companies that are related to goals 8.2 and 8.3 depend on the size of the companies and would maintain a constant trend until 2022. In addition, in the same period, it was shown that efficiency has had variations, and its trend is to remain constant until 2022, which shows that there will be no progress in meeting the targets 9.4, and 12.2 of the SDGs for this industrial sector.

Keywords: data envelopment analysis; efficiency; forecast; manufacturing industry; productivity; sustainable development goals.
JEL classification: C14, D61, L25, L6, Q01.
MSC2010: 62G05, 62H20, 62P20, 90C08.

Artículo recibido el 4 de diciembre de 2020 y aceptado el 29 de junio de 2022

Relación entre productividad y eficiencia con los Objetivos de Desarrollo Sostenible: el caso de la industria manufacturera en Pichincha, Ecuador

RESUMEN

En 2015, en el foro de Naciones Unidas, se aprobaron los 17 Objetivos de Desarrollo Sostenible (ODS) para ser cumplidos hasta el 2030. Esta investigación tiene como objetivo conocer cuál ha sido el comportamiento de la productividad y eficiencia de la industria manufacturera en la provincia de Pichincha, Ecuador, y la relación con el logro de algunas metas de los ODS 8, 9 y 12. La metodología de investigación tiene un enfoque cuantitativo, no experimental y longitudinal. Se procesó la información de los informes económicos y financieros de las empresas manufactureras entre 2010 y 2018. Los valores de eficiencia se estimaron mediante la técnica de análisis envolvente de datos. Con la información anual se pronosticó la evolución de la productividad y la eficiencia hasta el 2022. En los nueve años, los resultados muestran que los indicadores de productividad y el número de empresas que se relacionan con las metas 8.2 y 8.3 dependen del tamaño de las empresas y mantendrán una tendencia constante hasta el 2022. Además, en el mismo período, se demostró que la eficiencia ha tenido variaciones, y su tendencia es mantenerse constante hasta el 2022; lo que demuestra que, no habrá avances en el cumplimiento de las metas 9.4, y 12.2 de los ODS para este sector industrial.

Palabras clave: análisis envolvente de datos; eficiencia; pronóstico; industria manufacturera; productividad; objetivos de desarrollo sostenible.
Clasificación JEL: C14, D61, L25, L6, Q01.
MSC2010: 62G05, 62H20, 62P20, 90C08.

1. Introduction

At the Rio + 20 Summit in Rio de Janeiro, Brazil, the United Nations (UN) representatives renewed their political commitment in favor of sustainable development, and the promotion of an institutional framework to promote an economically, socially, and environmentally sustainable future for our planet and present and future generations (United Nations, 2012). This was done to recognize unanimously that the work to alleviate poverty and achieve sustainable economic progress must be a global effort.

Years later, the UN recognized that reducing poverty and close inequality gaps between rich and emerging countries must continue, and proposed new strategies. Thus, in September 2015, representatives of 193 countries approved a resolution in this world forum that included 17 Sustainable Development Goals (SDGs) and 169 targets for 2030 (United Nations, 2015). These objectives, shown in Table 1, are part of the 2030 Agenda for Sustainable Development (United Nations, 2016), and include aspects that range from preserving the environment to governance.

Diverse researches, projects, and public or private initiatives have been carried out related to the progress and challenges of compliance with the SDGs in Ecuador (Ibujés-Villacís & Franco-Crespo, 2019; Technical Secretariat-Plan Ecuador, 2019). However, there are no specific studies on the relationship of the actions of the manufacturing industry with the SDGs. Research on how the industry contributes to sustained, inclusive, and sustainable economic growth is essential to meet significant challenges in promoting inclusive and sustainable industrialization, environmentally and socially responsible business practices, fostering innovation, and providing decent employment (Ali et al., 2018; Betti et al., 2018; Cordova & Celone, 2019; Sullivan et al., 2018).

These challenges are increasingly urgent in a globalized world environment and meeting them will require companies to adopt new technologies gradually, make efficient use of their resources and capacities, and create infrastructures for production to achieve greater internal productivity and competitiveness in the markets (Castells, 1996). As such, this research addresses the productivity, growth, and technical efficiency of the manufacturing industry and its relationship with the SDGs' achievement, taking manufacturing companies in the province of Pichincha in Ecuador as the object of study.

That is why this research contributes to the determination and evaluation of the productivity and efficiency of the manufacturing industry, through the estimation of quantitative indicators in a nine-year time period; achieving an advance compared to other studies that have been carried out in different areas of the Ecuadorian economy and with shorter time horizons (Ibujés-Villacís, 2019; Ibujés-Villacís & Morales, 2018; Ibujés & Benavides, 2017). Therefore, the objective has been to evaluate these indicators' historical behavior and show the changes that have occurred over these nine years with their corresponding trends and do so in such a manner that a way of comparison with the achievement of the SDGs targets can be found.

This work has been structured as follows. In the first part, the researchers execute a theoretical review of the SDGs and the relationship of some of the goals of objectives 8, 9, and 12 with the indicators related to the productivity and efficiency of manufacturing companies. Additionally, the concept of technical efficiency and the methods of calculating it are proposed. The second part describes the methodology applied to estimate the productivity, business growth, and technical efficiency indicators, and how the indicators' forecasts were made. In the third section, the results are presented, and a discussion is made of them. Finally, the conclusions and reflections of the investigation are explained.

2. Theoretical elements

2.1. The SDGs and their relationship with the manufacturing industry

The private sector is a key factor in achieving the SDGs described in Table 1, through actions focused on business sustainability. Due to the wide scope of the SDGs, implementing them in their entirety by the industry can be overwhelming, which is why the selection and prioritization is a very important process; therefore, many transnational companies have prioritized the SDGs: 4, 8, 9, 11, 12, 14 and 17 (Ike et al., 2019). This research focuses explicitly on goals 8, 9, and 12 since they are related to productivity, business growth, and industry efficiency.

Table 1. Sustainable Development Goals.

SDG	Description
1	End poverty in all its forms everywhere.
2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
3	Ensure healthy lives and promote well-being for all at all ages.
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
5	Achieve gender equality and empower all women and girls.
6	Ensure availability and sustainable management of water and sanitation for all.
7	Ensure Access to affordable, reliable, sustainable and modern energy for all.
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
10	Reduce inequality within and among countries.
11	Make cities and human settlements inclusive, safe, resilient, and sustainable.
12	Ensure sustainable consumption and production patterns.
13	Take urgent action to combat climate change, its impacts.
14	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.
15	Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forest, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
17	Strengthen the means of implementation and revitalize the global partnership for sustainable development.

Source: United Nations, 2016.

This research focuses on analyzing some targets of the goals 8, 9, and 12 that are shown in Table 2; these will serve to examine the relationship of the SDGs with the management of the manufacturing industry.

Table 2. SDG's Target analyzed for the industrial sector.

SDG	Target	Target's description
8	8.2	Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labor-intensive sectors.
	8.3	Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services.
9	9.4	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.
12	12.2.	By 2030, achieve the sustainable management and efficient use of natural resources.

Source: United Nations, 2016.

There is a framework of global indicators related to the goals of the SDGs and that serve as reference measures for States to carry out their planning and application of continuous improvements to actions in the different areas proposed by the 2030 Agenda (UN Statistical Commission, 2017). However, these indicators are very generic and require a broader and more holistic set of variables and specific indicators, which must be easily operative and which allow a more precise and comprehensive explanation of progress in meeting the goals of the SDGs in different countries and regions of the world (Hák et al., 2016; Tayra & Ribeiro, 2006).

In this research, specific industrial quantitative indicators related to productivity, growth, and efficiency of the manufacturing industry have been chosen, which are shown in Table 3. These indicators will facilitate establishing the relationship of the SDGs with the economic results of the manufacturing companies in Pichincha. It also complements other initiatives and indicators compiled by Ecuador's government regarding compliance with the SDGs (Technical Secretariat-Plan Ecuador, 2019).

Table 3. Industry indicators related to the SDG targets.

SDG	Target	Indicator
8	8.2	Productivity to assets (*Pa*) Productivity to costs and expenses (*Pce*)
	8.3	Percentage of large (*Lc*), medium (*Mc*), and small (*Sc*) manufacturing companies.
9, 12	9.4 and 12.2	Technical efficiency

Source: Own elaboration.

The study object is large, medium, and small companies in the manufacturing sector of the province of Pichincha, Ecuador. Table 4 indicates the characteristics that determine the division between companies' categories that correspond to the research's target population (SUPERCIAS, 2020b) .

Table 4. Company categorization.

Company	Number of workers	Annual Income (US$)
Large	More than 200	More than 5,000,001.00
Medium	50 - 199	1,000,001.00 – 5,000,000.00
Small	10 - 49	100,000.00 – 1,000,000.00

Source: SUPERCIAS, 2020b.

The manufacturing industry is one of the most important economic sectors for Ecuador; Thus, in 2017, large and medium-sized manufacturing companies generated 35.6% of national production and had an intermediate consumption of 43.1%, ahead of sectors such as services, commerce, mining, and construction (INEC, 2019a). According to the same source, in 2017, 51.2% of the spending on salaries of large and medium-sized companies corresponds to manufacturing industries and wholesale and retail trade. In addition, between 2014 and 2019, manufacturing fluctuated between the second and third place of the economic activities that provided full employment in Ecuador, with rates between 12.4% and 13% (INEC, 2019b).

2.2. Productivity and technical efficiency

The measurement of productivity and efficiency is an activity that companies usually do on an ongoing basis intending to incorporate the results into their corporate strategies. The calculation of efficiency should be carried out considering the operational data of the companies that operate in the same economic area, since in this way individual decision-making will be facilitated and linked to the actions of their economic area and national policies (Paradi et al., 2018).

Productivity is related to the improvement of production processes and represents a comparison between the amount of goods or services produced, including in some cases even recycled material, concerning the amount of resources used (Andersen, 2018). Therefore, productivity is an index that relates between outputs and inputs in a productive system. In this research, the output variable is income. The input variables are related to the assets, costs, and expenses involved in the manufacturing industry's business management.

Technical efficiency is related to the use of installed capacity and reflects whether the resources are exploited to the maximum of their productive capacity or not; that is, if the productive factors are being used one hundred percent, or if there is idle capacity (Cachanosky, 2012). Farrell (1957) quoted by Sánchez de Pedro (2013) and other authors as Färe et al. (1994) contributed substantially to the study of efficiency, developing a method for calculating the efficient frontier, the same one that is formed for the performance of the best companies observed and that achieves two objectives. On the one hand, the computation serves as a reference to measure each company's relative efficiency; on the other hand, it allows separating efficiency into two components: technical and allocative.

Technical efficiency (TE) refers to the efficiency of transformation of inputs into outputs, and allocative efficiency (AE) to the proportion of inputs necessary to generate the minimum cost for the production of a certain level of output (Álvarez, 2013; Santos et al., 2013; Tofallis, 2001). It can be said in another way that TE consists of obtaining the maximum product given a specific combination of resources or in the use of the resources strictly necessary for a level of production. It should be noted that the products obtained can be "good" or "bad" (Färe et al., 1989; Farzipoor, 2010). In this research, it will be considered that the products obtained are unique. The qualitative approach will not be considered of the products obtained because this information is not available and it is not the objective of the investigation.

The efficient frontier's empirical estimation is usually divided into three broad groups: parametric, non-parametric, and another, a combination of both defined as artificial neural networks (Cordero, 2006). Non-parametric methods do not require the imposition of a particular form of production function like parametric methods, being sufficient with the definition of a set of formal properties that must satisfy the set of production possibilities (Quindós et al., 2003; Sueyoshi & Goto, 2018). This is the case with the Data Envelopment Analysis (DEA) method.

The DEA is a non-parametric tool that allows specifying the technological frontier based on productive units or DMU (Decision Making Units) which, due to their good results, are those that execute the best production practices concerning other units from the same production area (Charnes et al., 1979). According to the authors, this analysis methodology has two fundamental advantages: on the one hand, its greater standardization, and on the other, it allows considering multiple inputs and outputs.

In a DEA analysis, two processes are carried out simultaneously through the use of linear programming algorithms: obtaining the efficient frontier and estimating the inefficiency, which turns out to be relative since each organization is compared with those that operate with a similar value of inputs and outputs (Sherman & Zhu, 2006). The original DEA model expresses that efficiency is a mathematical relationship between the total weighted sum of the outputs or desirable results and the total weighted sum of the inputs. Furthermore, the efficiency estimate must be made by comparing technologically similar companies (Sueyoshi & Goto, 2018).

2.3. DEA-CCR Method

One of the methods used by the DEA to calculate technical efficiency is the one developed by Charnes et al. (1979) and it is known as CCR in honor of its authors, or it is also known as the constant returns to scale model (CRTS). Through this method, a company can be compared with others that are substantially larger or smaller (Quindós et al., 2003). This method is mathematically described through equations 1, 2, and 3 in the input-oriented version, seeking to maximize outputs and form part a series of calculations of a linear programming algorithm (Ramanathan, 2003; Sueyoshi & Goto, 2018).

Maximize: $$ho = \sum_{j=1}^{s} W_j Y_{j0} \quad [1]$$

$$\sum_{i=1}^{m} V_i X_{i0} = 1 \quad [2]$$

s.t
$$\sum_{j=1}^{s} W_j Y_{jm} - \sum_{i=1}^{m} V_i X_{im} \leq 0$$
$$m = 1, 2, 3, \dots, n. \quad [3]$$
$$W_j \geq 0; \; j = 1,2, \dots,,, s.$$
$$V_i \geq 0; \; i = 1,2, \dots,,, r.$$

where:

Yjo = output j of DMU 0; *Xio* = input *i* of DMU 0; *Wj* = weight for output j; *Vi* = weight for input *i*; *n* = number of DMUs; *s* = number of outputs; r = number of inputs.

3. Methodology

3.1. Population and sample size

The research has a quantitative, non-experimental, and longitudinal approach, uses a quantitative methodology to analyze the probability of meeting the SDGs' goals, taking as a reference, indicators of productivity, growth, and efficiency of manufacturing companies.

The object of study of this research is the companies of the manufacturing economic sector of the province of Pichincha, Ecuador. These companies belong to classifier C of the International Standard Industrial Classification (INEC, 2012) and are registered in four categories: large, medium, small, and micro-companies; this research did not take microenterprises into account. Until January 2020, the manufacturing companies that had submitted their economic and financial reports from 2010 to 2018 are shown in Table 5 (SUPERCIAS, 2020b).

Table 5. Research population.

Year Companies	2010	2011	2012	2013	2014	2015	2016	2017	2018
Large	230	237	185	214	230	175	211	131	169
Medium	375	381	357	354	346	201	355	276	289
Small	656	667	1163	608	583	617	678	649	554

Source: SUPERCIAS, 2020b.

To calculate the samples' size for each category of the company, a proportional sampling was used for a finite population, since there was the same probability that the companies studied met or did not meet the characteristics to be investigated. The sample size was determined with equation 4 (Lohr, 2019; Ott & Longnecker, 2016).

$$n = \frac{Z^2 Npq}{E^2(N-1) + Z^2 pq} \qquad [4]$$

where:

n = sample size, N = population size, E = sampling error, Z = confidence level, p = probability of success and q = probability of failure.

The parameters for the calculation of the sample are the following: N corresponding to the number of companies in each business group in each of the years of study, as shown in Table 5; E = 10% (percentage of error), Z = 1.96 (95% confidence level), p = 0.5 and q = 0.5. The equality between p and q allows finding the maximum sample size for the fixed error (Pérez, 2010). These parameters allow determining the size n of the samples for each business group and year of study, as shown in Table 6.

Table 6. Size of the studied samples.

Year / Companies	2010	2011	2012	2013	2014	2015	2016	2017	2018
Large	68	69	64	67	68	62	66	56	62
Medium	77	77	76	76	76	66	76	72	73
Small	84	85	89	84	83	84	85	84	82

Source: Own elaboration.

The sampling used was probabilistic and with equal probabilities. The selection of companies was carried out in a simple random manner without replacement to have the highest degree of representativeness of the sample (Pérez, 2010).

3.2. Data

The research data was obtained from the balance sheet and income statement accounts that the manufacturing companies individually reported between 2010 and 2018. Specifically, the information was obtained from form 101 that corresponds to the "Tax Declaration income and presentation of balance sheets" found in the corporate sector documents section (SUPERCIAS, 2020a).

From among the data from the financial reports for this study, the accounts detailed in Table 7 were chosen. These accounts are present in the balance sheets and income statement of for-profit companies (Harrison et al., 2018). Those that will be used in this investigation are the accounts of income, profits, current assets, non-current assets, sales costs, expenses in wages and salaries, operating expenses and non-operating expenses.

Table 7. Details of the financial statements' accounts.

Account	Description
Income (*Inc*)	Income
Profits (*Prf*)	Profits
Current assets (*Ca*)	Cash values, accounts, and notes receivable and inventories.
Non-current assets (*Nca*)	Property, plant and equipment, intangible assets, biological assets, and depreciation.
Cost of sales (*Cos*)	Purchases and imports.
Wages and salaries expenses (*Wse*)	Wages, salaries, social benefits, professional fees, employer's retirement, and eviction.
Operating Expenses (*Oe*)	Promotion and advertising, transportation, fuel consumption, travel expenses, management expenses, operating leases, supplies, tools, materials, spare parts, maintenance, and repairs.
Non-operating Expenses (*Noe*)	Financial expenses.

Source: SUPERCIAS, 2020a.

Regarding the indicators' obtention, the ratio related to the productivity to assets (*Pa*) was calculated using equation 5, while the indicator of productivity related to costs and expenses (*Pce*) was calculated using equation 6.

$$Pa = \frac{income}{assets} = \frac{Inc}{Ca + Nca} \quad [5]$$

$$Pce = \frac{income}{costs + expenses} = \frac{Inc}{Cos + Wse + Oe + Noe} \quad [6]$$

To calculate the percentage relationship of companies' categories concerning the total, the three categories are considered, except micro-companies, for each of the years of research.

3.3. Selection of input and output variables

For the estimation of technical efficiency applying the DEA methodology, the input variables, and the output variables were determined according to a set of criteria and techniques. Concerning the criteria, three were chosen: firstly, we choose the fewest possible number of variables; secondly, we choose those inputs that best reflect the outputs; and thirdly, we opting for those outputs relevant to the activity of the companies studied.

Regarding the selection techniques, there are some such as principal component analysis, variable correlation, multiple regression, multicriteria, among others, all of which seek to establish the best possible combinations between inputs and outputs, forming different scenarios to find the best average estimated efficiency (González-Araya & Valdés, 2009; Serrano-Cinca et al., 2005; Shiuh-Nan et al., 2016). The correlation technique between inputs and outputs was used, and the data from 2018 was taken as a reference for the three categories of companies.

Considering the criteria and the correlation technique between the variables described in Table 7, current assets, non-current assets, cost of sales, expenses in salaries and salaries, operating expenses, non-operational expenses were taken as input variables. While, as output variables, income and profit for the year were considered.

One of the DEA method restrictions was considered to avoid erroneous efficiency values, which is that the total number of variables (inputs + outputs) must be less than the number of observations (Andersen & Petersen, 1993). In addition, inequality 7 must be met, where m is the number of inputs, and t the number of outputs; since for a small sample of DMUs, the method does not discriminate, and all DMUs could be efficient (Cooper et al., 2011).

$$Number\ of\ DMUs \geq Max\ \{m * t, 3(m + t)\} \quad [7]$$

This study was worked with $m = 6$, $t = 1$. If the smallest number of DMUs or companies in Table 6 is taken into account, which corresponds to 56, it turns out that the number of DMUs is 2.6 times greater than the maximum of the condition. Therefore, the restrictions of the cited authors regarding the comparison between variables and DMUs that will be elements of the DEA method are met.

3.4. Estimation of technical efficiency indicators

Once the correlation between input and output variables was established, the TE was estimated considering the CCR method, using equations 1, 2, and 3, and their corresponding restrictions. The equations served as a reference to develop linear programming algorithms with the solver function and the Visual Basic programming language, incorporated in the MS Excel application (Sherman & Zhu, 2006). Equations 5 and 6 were used to estimate the productivity indicators. To standardize the number of companies for the calculation of the indicators of productivity and technical efficiency: 62 large, 73 mediums, and 82 small companies were taken as a reference sample for each of the years analyzed. This approximation represents one less variation 1% with respect to the error assumed in the sample size calculations.

3.5. Estimation of the forecasts of productivity and efficiency indicators

To find the trend of the productivity and efficiency indicators obtained between 2010 and 2018, we proceeded to estimate the indicators' forecasts and estimate their behavior from 2019 to 2022. For Guerrero (2003) and Lind et al. (2012), forecasting is a process of estimating a future event by projecting data from the past; In other words, the systematic combination of data allows an estimation of future events using a specific model.

The forecasting model was carried out by analyzing indicators in time series with data registered annually and the double exponential smoothing technique was used. The behavior was also predicted by decomposing the historical information into reference elements such as trend and seasonality, necessary procedures when analyzing time series (Guerrero, 2003; Webster, 2001). Double exponential smoothing requires the calculation of the forecast data through equations 8, 9, and 10.

$$S_i = \alpha x_i + (1-\alpha)(S_{i-1} + T_{i-1}) \quad [8]$$

$$T_i = \beta(S_i - S_{i-1}) + (1-\beta)T_{i-1} \quad [9]$$

$$F_{i+1} = S_i + T_i \quad [10]$$

where:

S_i = exponentially smoothed average of the series in period *i*; T_i = exponentially smoothed average of the trend in period i; α = smoothing parameter for the average, with a value between 0 and 1; β = smoothing parameter for the trend, with a value between 0 and 1; F_{i+1} = forecast for period *i+1*.

Additionally, as a result of the forecast, an error measure was determined that evidences the adjustment method's goodness to obtain the forecast. This measure was the root of the mean square error (RMSE). The RMSE is the most popular measure of error, also known as the quadratic loss function (Chai & Draxler, 2014). This error measure is defined as the average between the absolute values of the forecast errors, and it is used as a selection criterion for the best fit of time series models (Lakshmivarahan et al., 2017; Shcherbakov et al., 2013). Its form of calculation is made from equation 11.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(R_i - F_i)^2} \quad [11]$$

where *Ri* corresponds to the actual data for period *i*, *Fi* represents the predicted data for period *i*, and *n* represents the number of periods that have both a real and a predicted value. In order to automate and speed up the calculations of the forecasts and their errors, the data series were processed using the Risk Simulator 2019 software (Software-Shop, 2017).

4. Results

4.1. Correlations between the input and output variables

The results of the correlation between the input and output variables for each of the categories of companies and that correspond to the year 2018 are shown in Table 8. Since the correlation results are fixed values, a bootstrap analysis was performed from a simulation with 1000 DMUs and a 95% confidence level to estimate the correlation in a specific range of values. This procedure allows for correcting changes, inaccuracies, or uncertainty of the input and output variables used in applying the

DEA method (Cáceres et al., 2014; Cook & Seiford, 2009; Simar & Wilson, 2010; Simar & Wlson, 1998).

Table 8. Correlation between input and output variables.

Correlations								
			Outputs					
Inputs			Large		Medium		Small	
			Inc	Prf	Inc	Prf	Inc	Prf
Inc	Pearson correlation		1.00	0.469**	1.00	0.432**	1.00	0.348**
	Sig. (bilateral)			0.00		0.00		0.00
	Sm^{c} CI at 95%	Lw.	1.00	-0.09	1.00	0.22	1.00	0.14
		Up.	1.00	0.91	1.00	0.60	1.00	0.53
Prf	Pearson correlation		0.469**	1.00	0.432**	1.00	0.348**	1.00
	Sig. (bilateral)		0.00		0.00		0.00	
	Sm^{c} CI at 95%	Lw.	-0.09	1.00	0.22	1.00	0.14	1.00
		Up.	0.91	1.00	0.60	1.00	0.53	1.00
Ca	Pearson correlation		0.941**	0.539**	0.688**	0.433**	0.513**	0.488**
	Sig. (bilateral)		0.00	0.00	0.00	0.00	0.00	0.00
	Sm^{c} CI at 95%	Lw.	0.75	-0.11	0.56	0.25	0.44	-0.08
		Up.	0.99	0.95	0.80	0.65	0.72	0.81
Nca	Pearson correlation		0.581**	0.884**	0.464**	0.11	0.263*	0.09
	Sig. (bilateral)		0.00	0.00	0.00	0.34	0.02	0.40
	Sm^{c} CI at 95%	Lw.	0.40	0.48	0.26	-0.11	0.04	-0.30
		Up.	0.93	0.96	0.64	0.37	0.45	0.34
Cos	Pearson correlation		0.970**	0.295*	0.799**	0.13	0.688**	0.10
	Sig. (bilateral)		0.00	0.02	0.00	0.26	0.00	0.38
	Sm^{c} CI at 95%	Lw.	0.93	-0.20	0.73	-0.06	0.54	-0.14
		Up.	0.99	0.87	0.86	0.34	0.80	0.27
Wse	Pearson correlation		0.878**	0.463**	0.547**	0.22	0.590**	-0.05
	Sig. (bilateral)		0.00	0.00	0.00	0.06	0.00	0.64
	Sm^{c} CI at 95%	Lw.	0.73	0.00	0.34	0.06	0.43	-0.25
		Up.	0.96	0.86	0.70	0.41	0.72	0.14
Oe	Pearson correlation		0.686**	0.586**	0.680**	0.299*	0.452**	0.02
	Sig. (bilateral)		0.00	0.00	0.00	0.01	0.00	0.88
	Sm^{c} CI at 95%	Lw.	0.56	0.21	0.55	0.07	0.32	-0.13
		Up.	0.91	0.92	0.79	0.56	0.63	0.23
Noe	Pearson correlation		0.766**	-0.10	0.378**	-0.03	0.271*	-0.08
	Sig. (bilateral)		0.00	0.45	0.00	0.81	0.01	0.48
	Sm^{c} CI at 95%	Lw.	0.31	-0.39	0.17	-0.18	0.01	-0.49
		Up.	0.94	0.44	0.56	0.23	0.46	0.28

Notes:
Inc: Income; Prf: Profits; Ca: Current assets; Nca: Non-current assets; Cos: Cost of sales; Wse: Wages and salaries expenses; Oe: Operating expenses; Noe: Non-operating expenses.
**. The correlation is significant at the 0.01 level (bilateral).

*. The correlation is significant at the 0.05 level (bilateral).
Sm: Sampling simulation; CI: Confidence interval; Lw: lower limit; Up: upper limit.
c. The results of the sampling simulation are based on 1000 samples.
Source: Own elaboration.

Suppose the null hypothesis is considered as the fact that there is no relationship between inputs and outputs. In that case, according to Table 8, the relationship between inputs and the output *(Inc)*, the bilateral significance is less than 0.01 and 0.05, which means there is a probability close to one that there is some degree of relationship or association between inputs and *Inc*. For the relationship between inputs and output *(Prf)*, the significance level is more significant than 0.05 in some cases; consequently, there is no relationship between the five input variables and the output *Prf*. By the results of the correlation between inputs and outputs, it was decided to estimate the efficiency taking into account all input variables and only the variable *Inc*.

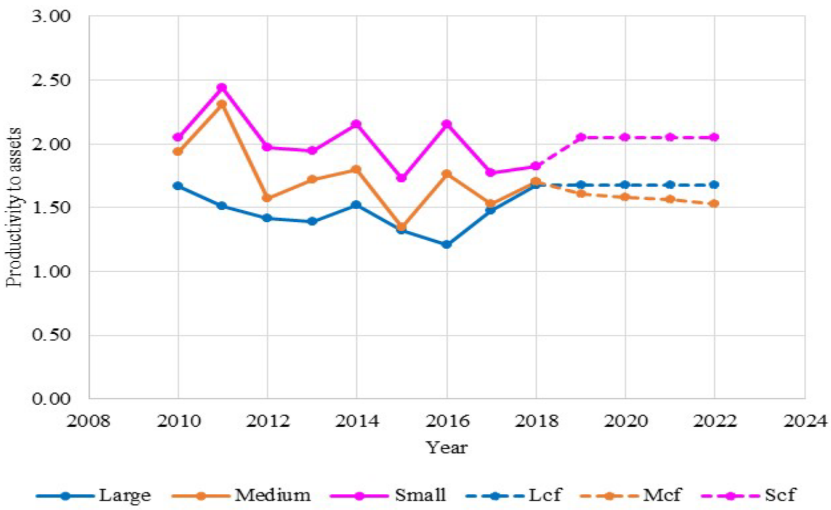
4.2. Forecast and trend of indicators related to SDG 8

In order to know the progress of the fulfillment of targets 8.2 and 8.3 by the manufacturing companies of Pichincha, the indicators of productivity, business growth, and technical efficiency were estimated, for which the data published among the years 2010 to 2018 (SUPERCIAS, 2020a).

4.2.1. Productivity to assets

Figure 1 shows the evolution of productivity to assets for each of the categories of companies, between 2010 and 2018; also, the productivity forecast from 2019 to 2022.

Figure 1. Evolution and forecast of productivity to assets.

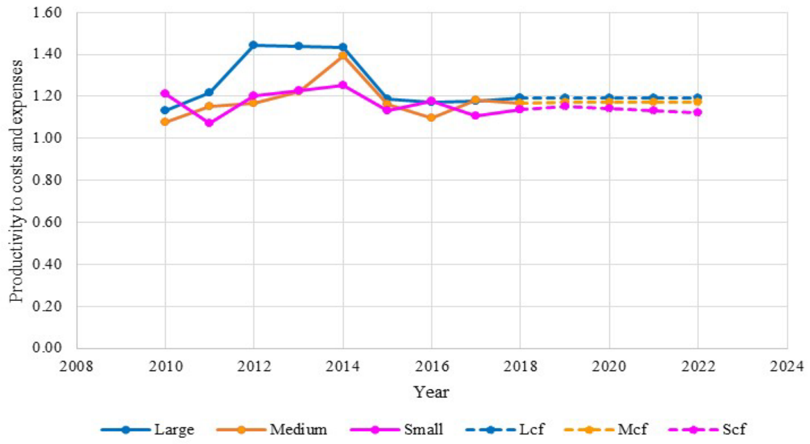


Notes:
Lcf = Large companies' forecast; Mcf = Medium companies' forecast; Scf = Small companies' forecast.
RMSE (Lcf) = 0.1627; RMSE (Mcf) = 0.2780; RMSE (Scf) = 0.1940.
Source: the authors.

4.2.2. Productivity to costs and expenses

Regarding to productivity to costs and expenses, Figure 2 shows the evolution of this indicator from 2010 to 2018. Additionally, it shows what the forecast would have been for the next four years.

Figure 2. Evolution and forecast of the productivity to costs and expenses.



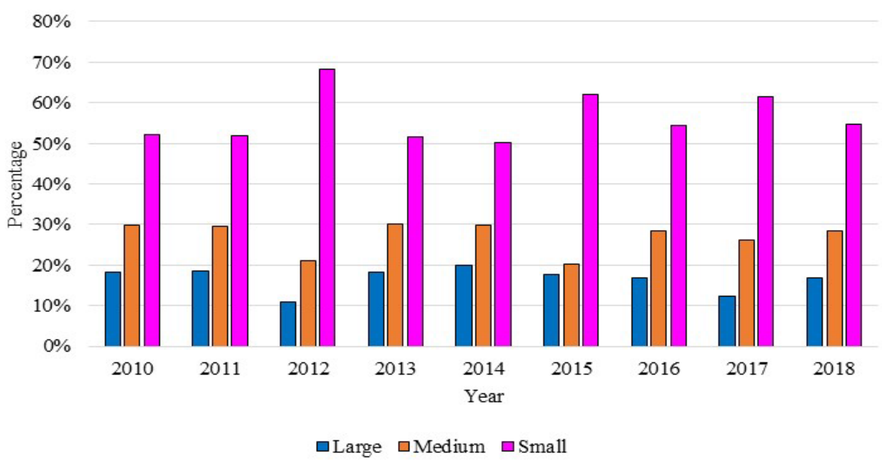
Notes:
Lcf = Large companies' forecast; Mcf = Medium companies' forecast; Scf = Small companies' forecast.
RMSE(Lcf)=0,1262; RMSE(Mcf)=0,1114; RMSE(Scf)=0,0457.

Source: Own elaboration.

4.3. Evolution of the manufacturing business structure

It is interesting to observe the variable evolution that the manufacturing industry's business structure in Pichincha has had between 2010 and 2018. Figure 3 shows the percentage relationship between the number of large, medium, and small companies.

Figure 3. Evolution of manufacturing companies.



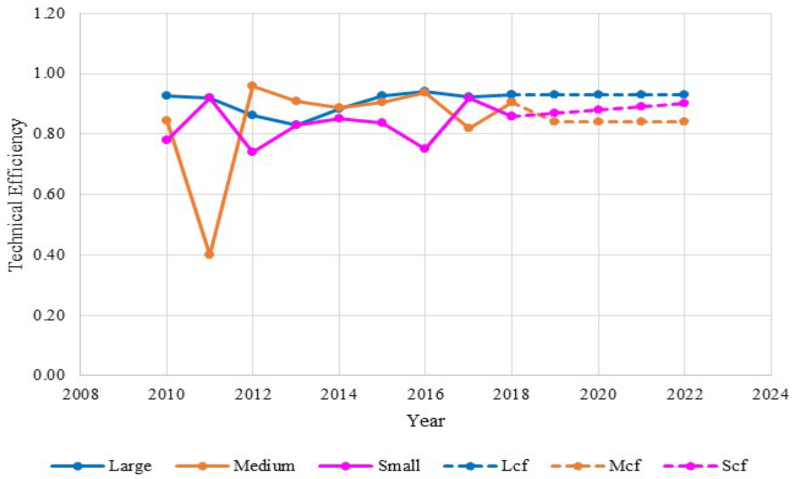
Source: Own elaboration.

Small companies are between 50% and 68%, medium-sized companies have varied between 20% and 30%, and large companies between 12% and 20%. In the nine years studied, the number of large and medium-sized companies has tended to remain constant and there has been a slight growth trend in small companies.

4.4. Forecast and trend of indicators related to SDG 9 and 12

To know the progress in the fulfillment of the target 9.4 and 12.2, the indicators related to technical efficiency, pure technical efficiency, and scale efficiency of the companies in the manufacturing industry of Pichincha are estimated. Figure 4 shows TE's behavior in the nine years and the forecast for the next four years.

Figure 4. Technical efficiency of manufacturing companies.



Notes:
Lcf = Large companies' forecast; Mcf = Medium companies' forecast; Scf = Small companies' forecast.
RMSE(Lcf)=0,0368; RMSE(Mcf)=0,0711; RMSE(Scf)=0,0545.
Source: Own elaboration.

According to the forecast, the TE in 2022 will be 0.93, 0.90, and 0.84 for large, small, and medium-sized companies, respectively. The trends are constant for large and medium-sized companies, while there is a slight growth for the small ones.

5. Discussion

Considering the results that are indicated in Table 8, current assets are the ones that most influence the income of manufacturing companies, while non-current assets are those that have the least relationship with income.

Longitudinal study of productivity to assets between 2010 and 2018 establishes that small companies are the most productive, followed by medium-sized and then large-sized, as shown in Figure 1. Furthermore, according to the annual variations that this indicator has had, it has remained practically constant throughout the nine years in all business categories. The fact that large companies are the least productive concerning assets occurs because as companies grow, they acquire more and more non-current assets, and their use, due to the results found, is not contributing to productivity.

Looking to the future, the fulfillment targets in goals 8, 9, and 12 are challenging to meet for the manufacturing area because from the perspective of sustainability, it is required to achieve high levels of productivity in the use of assets on a large scale. Maximizing the use of assets must be accompanied by the products' useful life maximization (Delgado & Delgado, 2020); this situation will require the manufacturing industry to work on innovative solutions, process adaptation, responsible and efficient usage of resources, recycling of materials, repurpose of components, among others, in order to minimize and eliminate environmental and social damage.

Analyzing productivity with respect to costs and expenses analysis in the three categories of companies, cost of sales is the input variable that is best related to income. In other words, purchases and imports are the variables that have a decisive influence on the amount of income that companies receive and their influence grows as the size of the company increases.

When the behavior of productivity to costs and expenses is historically analyzed, it is determined that large companies are the most productive, followed by medium-sized and then small, as shown in Figure 2. Furthermore, according to the Annual variations that this indicator has had, it is determined that it has practically remained constant throughout the nine years in all categories of companies. If this indicator's forecast is considered, it will remain constant for all companies, then the increase in productivity of costs and expenses will be recovered as production and sales increase, as shown in Figure 2. If that does not happen, it would complicate the fulfillment of the goals of SDG 8, 9 and 12.

In last nine years, the average percentage of small companies has remained around 55% with a slight growth trend, while the medium ones have remained at 28% and the large ones at 17% with a tendency to remain constant. Additionally, according to Figure 3, the number of small companies had notable changes in 2012 and 2013, the medium ones in 2015 and 2016, and the large ones between 2016 and 2018. This reality shows that the factors on which companies' permanence in the market depend have not been affected with the same intensity in specific years.

Given the consequences of the COVID-19 pandemic, it is very likely that the trends in the volume of companies will vary towards decrease for the entire business group, especially for smaller companies. This forecast is ratified with the details of the Economic Commission for Latin America and the Caribbean (ECLAC), since they state that the impact of the pandemic will bring negative consequences to all companies in the Latin America and the Caribbean (LAC) region regardless of their size (ECLAC, 2020b). These consequences undoubtedly go against the fulfillment of target 8.3 of the SDGs.

When looking at the results of the companies' efficiency changes, it is determined that technical efficiency vary in different periods of time for each company size. According to Figure 4, the trend of technical efficiency towards 2022 is to remain constant and with similar values for the three sizes of companies. This situation shows that in the absence of an increase in efficiency, there will be no positive progress in meeting the goals of SDG 9 and 12. This situation is similar to the results of systematic reviews of the literature on progress in meeting the SDGs (Navarrete et al., 2020), and to the experience of countries in the LAC region, which have adopted a series of practices in the industry that are related to the SDGs (De Oliveira et al., 2019; Martins et al., 2020).

Having sustained growth in efficiency will mean that less efficient companies depend on the use of technology, research and development (R&D), and especially on the development of innovations. This scenario is possible since, in the period between 2009 and 2014, the manufacturing area had second place in investments in R&D compared to areas such as services, commerce, and mining (SENESCYT-INEC, 2015).

Synthesizing the results of productivity, growth, and efficiency, the manufacturing companies of Pichincha have responded differently to the challenges posed by the SDGs. This is most likely related to the lack of a common approach to the concept of sustainability in the industry. The definition of critical issues to achieve a sustainable industry is still pending, a situation that at first appears very complicated. The SDGs are interconnected (Pizzi et al., 2020; Wynn & Jones, 2020). Therefore, the contribution of companies to the achievement of these objectives will require firm and effective management, and thus, face a series of potentially difficult and costly challenges, which could threaten their current business models and possibly their very existence.

If the impact that the consequences of COVID-19 will produce on the economy is added to this reality, then it turns out that the forecasts do not accompany the fulfillment of the SDG goals in the foreseen terms before the pandemic (ECLAC, 2020c). So much so that, the economic growth of Ecuador will fall in 2020 to -6.0%, with estimates made up to April, due to the pandemic (World Bank, 2020); while in Ecuador it was calculated that this decrease could be up to 10% (Central Bank of Ecuador, 2020). However, to the extent that appropriate decisions are made in the social, political, and economic spheres, the crisis will fade, and growth will recover 3.4% in 2021 and improve little by little in the following years (International Monetary Fund, 2020).

Therefore, achieving the goals is away from fulfillment, but not impossible to reach. The LAC region despite the pandemic, will continue to have as a collective and urgent roadmap, the implementation, follow-up and monitoring of the of the achievements of the SDGs and their progress in the medium and long term (ECLAC, 2020b, 2020a). All the actions that facilitate the achievement of the SDGs will require the participation of all sustainable development actors, since these objectives interact in the social, political and economic context of society (Griggs et al., 2013; Nilsson et al., 2018).

6. Conclusions

This research has made it possible to determine Pichincha's manufacturing industry's productivity and efficiency trajectory from 2010 to 2018 and establish the relationship with targets 8.2, 8.3, 9.4, and 12.2 of the goals 8, 9, and 12 of sustainable development, promoted by the United Nations.

It was determined that the relevant variables to estimate the indicators of productivity to assets, cost and expense productivity, technical efficiency, pure technical efficiency, and scale efficiency of the manufacturing companies are current assets, non-current assets, cost of sales, expenses in wages and salaries, operational expenses, non-operational expenses, and income.

It was found that in estimating the productivity of assets, non-current assets are those that are most related to the income of companies. In contrast, for estimating cost and expense productivity, the most related variables to income are costs of sales, representing purchases and imports made by companies for their operation.

The longitudinal study of productivity to assets establishes that small companies are the most productive. The forecast of this indicator is to maintain a constant trend between 2019 and 2022. However, due to the effects of the pandemic, it is estimated that it will decrease in 2020, making it challenging to meet goal 8.2 in perspective. Regarding the indicator of the productivity to costs and expenses, large companies have turned out to be the most productive, and regarding the forecast of the fulfillment of goal 8.2, the result will be similar to that of Productivity to assets. In other words, it will be left behind.

The average percentage of small businesses is around 55% in the study period, while the medium ones at 28% and the large ones at 17%. The trend in the number of large and medium-sized companies has remained roughly constant, while the trend of the small ones has been slightly increasing. This reality shows the stable constitution of this economic area in Ecuador's industrial context, which corroborates its primary contribution in aspects such as total production, intermediate consumption, added value, and workers' wages (INEC, 2019a). Given the COVID-19 pandemic consequences, it is very likely that the trend in the number of companies will decrease for the entire manufacturing business group and, therefore, target 8.3 of the SDGs will not be met.

It is predicted that SDG targets 9.4 and 12.2 will not make significant progress until 2022, as the indicators related to efficiency tend to remain constant for the three company sizes. For this reason, companies must strengthen the management related to human capacities, technologies, assets, commerce, among other aspects.

The research results can guide the manufacturing industry to propose improvement strategies and execute the appropriate actions to increase economic productivity, strengthen creativity, promote innovation, and carry out sustainable management, as proposed by the analyzed SDGs in this investigation. In addition, the timely execution of a set of strategies will undoubtedly not only serve to mitigate the impacts produced by the consequences of the pandemic but also promote sustainable economic growth in the manufacturing industry in Pichincha and the rest of Ecuador.

6.1. Limitations and future lines of research

This research has been limited to the manufacturing companies of Pichincha, Ecuador. Therefore, it is proposed as future lines of research, to evaluate the relationship between productivity and efficiency indicators and the SDGs in other areas of the Ecuadorian economy. These new studies could apply alternative methods (Eustachio et al., 2019), and use official and unofficial statistics, to solve the lack of data on the fulfillment of the SDGs (Lafortune et al., 2020), so the next few years could have more intense debates on the SDGs in conferences and special issues.

References

Ali, S., Hussain, T., Zhang, G., Nurunnabi, M., & Li, B. (2018). The Implementation of Sustainable Development Goals in "BRICS" Countries. *Sustainability (Switzerland)*, *10*(7), 1-14. https://doi.org/10.3390/su10072513

Álvarez, A. (2013). *La medición de la eficiencia y la productividad* (Measuring efficiency and productivity) (1st ed.). Ediciones Pirámides.

Andersen, P., & Petersen, N. C. (1993). A Procedure for Ranking Efficient Units in Data Envelopment Analysis. *Management Science*, *39*(10), 1261-1264. https://doi.org/10.1287/mnsc.39.10.1261

Andersen, P. (2018). Sustainable Operations Management (SOM) Strategy and Management: An Introduction to Part I. In L. Boer & P. Andersen (Eds.), *Operations Management and Sustainability: New Research Perspectives* (pp. 15-26). Palgrave Macmillan. https://doi.org/10.1007/978-3-319-93212-5_2

Betti, G., Consolandi, C., & Eccles, R. G. (2018). The relationship between investor materiality and the sustainable development goals: A methodological framework. *Sustainability (Switzerland)*, *10*(7), 2248. https://doi.org/10.3390/su10072248

Cáceres, H., Kristjanpoller, W., & Tabilo, J. (2014). Análisis de la eficiencia técnica y su relación con los resultados de la evaluación de desempeño en una Universidad chilena (Analysis of technical efficiency and its relationship with the results of the performance evaluation in a Chilean University). *Innovar*, *24*(54), 199-217. https://doi.org/10.15446/innovar.v24n54.46720

Cachanosky, I. (2012). Eficiencia técnica, eficiencia económica y eficiencia dinámica. *Procesos de Mercado: Revista Europea de Economía Política*, *IX*(2), 51-80.

Castells, M. (1996). La era de la informacion (The age of information). *Economia Sociedad y Cultura*, *1*, 1-29.

Central Bank of Ecuador (2020). *El covid-19 pasa factura a la economía ecuatoriana: decrecerá entre 7,3% y 9,6% en 2020 (COVID-19 takes its toll on the Ecuadorian economy: it will decrease between 7.3% and 9.6% in 2020)*. Central Bank of Ecuador. https://www.bce.fin.ec/index.php/boletines-de-prensa-archivo/item/1366-el-covid-19-pasa-factura-a-la-economia-ecuatoriana-decrecera-entre-73-y-96-en-2020

Chai, T., & Draxler, R. (2014). Root mean square error (RMSE) or mean absolute error (MAE)? - Arguments against avoiding RMSE in the literature. *Geoscientific Model Development*, *7*(3), 1247-1250. https://doi.org/10.5194/gmd-7-1247-2014

Charnes, A., Cooper, W.W., & Rhodes, E. (1979). Measuring the efficiency of decision-making units. *European Journal of Operational Research*, *3*(4), 339. https://doi.org/10.1016/0377-2217(79)90229-7

Cook, W., & Seiford, L. (2009). Data envelopment analysis (DEA) – Thirty years on. *European Journal of Operational Research*, *192*, 1-17. https://doi.org/10.1016/j.ejor.2008.01.032

Cooper, W., Seiford, L.M., & Zhu, J. (2011). Data Envelopment Analysis: History, Models, and Interpretations. In *Handbook on Data Envelopment Analysis* (2nd ed., Vol. 164, pp. 1-40). Springer. https://doi.org/10.1007/978-1-4419-6151-8

Cordero, J.M. (2006). *Evaluación de la eficiencia con factores exógenos mediante el análisis envolvente de datos. una aplicación a la educación secundaria en España* [Universidad de extremadura]. http://dialnet.unirioja.es/servlet/tesis?codigo=1488

Cordova, M.F., & Celone, A. (2019). SDGs and Innovation in the Business Context Literature Review. *Sustainability (Switzerland)*, *11*(24), 1-14. https://doi.org/10.3390/su11247043

De Oliveira, G.C., Ferreira, J.M., Silva, P.C., de Oliveira, A.G., & Lucato, W.C. (2019). Cleaner Production in the textile industry and its relationship to sustainable development goals. *Journal of Cleaner Production*, *228*, 1514-1525. https://doi.org/10.1016/j.jclepro.2019.04.334

Delgado, M., & Delgado, M. (2020). Sustainable Development Goal 12 and Its Relationship with the Textile Industry. In M. A. Gardetti & S. Senthilkannan Muthu (Eds.), *The UN Sustainable Development Goals for the Textile and Fashion Industry* (pp. 21-46). Springer.

ECLAC (2020a). *Alicia Bárcena Calls for Rethinking the Model and Consolidating the Economic, Social and Environmental Dimensions of Sustainable Development so as to Leave No One Behind*. Economic Commission for Latin America and the Caribbean. https://www.cepal.org/en/pressreleases/alicia-barcena-calls-rethinking-model-and-consolidating-economic-social-and

ECLAC (2020b). Latin America and the Caribbean and the COVID-19 pandemic. Economic and social effects. In *Economic Commission for Latin America and the Caribbean* (Issue 1). https://repositorio.cepal.org/bitstream/handle/11362/45351/S2000263_en.pdf?sequence=4&isAllowed=y

ECLAC (2020c). Report on the economic impact of coronavirus disease (COVID-19) on Latin America and the Caribbean. In *Economic Commission for Latin America and the Caribbean* (Issue March). https://repositorio.cepal.org/bitstream/handle/11362/45603/1/S2000312_en.pdf

Eustachio, J.H.P.P., Caldana, A.C.F., Liboni, L.B., & Martinelli, D.P. (2019). Systemic indicator of sustainable development: Proposal and application of a framework. *Journal of Cleaner Production*, *241*. https://doi.org/10.1016/j.jclepro.2019.118383

Färe, R., Grosskopf, S., Lovell, C. A. K., & Pasurka, C. (1989). Multilateral productivity comparisons when some outputs are undesirable: A nonparametric approach. *Review of Economics and Statistics*, *71*(1), 90-98. https://doi.org/10.2307/1928055

Färe, R., Grosskopf, S., Norris, M., & Zhang, Z. (1994). Productivity growth, technical progress and efficiency Change in Industrialized Countries. *The American Economic Review*, *84*(1), 66-83. https://doi.org/10.1111/j.1467-8268.2004.00089.x

Farrell, M. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society*, *120*, 253-290.

Farzipoor, R. (2010). Developing a new data envelopment analysis methodology for supplier selection in the presence of both undesirable outputs and imprecise data. *International Journal of Advanced Manufacturing Technology*, *51*(9-12), 1243-1250. https://doi.org/10.1007/s00170-010-2694-3

González-Araya, M., & Valdés, N. (2009). Metodo de selección de variables para mejorar la discriminación en el análisis de eficiencia aplicando modelos DEA. *Ingeniería Industrial*, *2*(8), 45-56.

Griggs, D., Stafford-Smith, M., Gaffney, O., Rockström, J., Öhman, M.C., Shyamsundar, P., Steffen, W., Glaser, G., Kanie, N., & Noble, I. (2013). Sustainable development goals for people and planet. *Nature*, *495*(7441), 305-307. https://doi.org/10.1038/495305a

Guerrero, V. (2003). *Análisis estadístico de series de tiempo económicas (Statistical analysis of economic time series)* (2nd ed.). International Thomson Editores.

Hák, T., Janoušková, S., & Moldan, B. (2016). Sustainable Development Goals: A need for relevant indicators. *Ecological Indicators*, *60*, 565-573. https://doi.org/10.1016/j.ecolind.2015.08.003

Harrison, W., Horngren, C., Thomas, W., Tietz, W., Berberich, G., & Seguin, C. (2018). *Financial Accounting* (6th ed.). Pearson.

Ibujés-Villacís, J. (2019). La eficiencia técnica de las medianas empresas de manufactura de Quito. *Debates Sobre Innovación. XVIII Congreso Latinoamericano de Gestión Tecnológica*, *3*(1), 1126-1141. https://economiaeinnovacionuamx.org/revista/secciones/articulos/7

Ibujés-Villacís, J., & Franco-Crespo, A. A. (2019). Use of ICT and its relationship with the Objectives of Sustainable Development in Ecuador. *RETOS. Revista de Ciencias de la Administración y Economía*, *9*(17), 37-53. https://doi.org/10.17163/ret.n17.2019.03

Ibujés-Villacís, J., & Morales, E. (2018). Uso de las TIC y relación con la eficiencia técnica en las medianas empresas del área comercial de Quito. *XIV Foro Internacional Del Emprendedor*, 166-182. http://revistas.uazuay.edu.ec/index.php/memorias/article/view/185

Ibujés, J., & Benavides, M. (2017). Contribution of technology to the productivity of small and medium-sized enterprises in the textile industry in Ecuador. *Cuadernos de Economia*, *41*(115), 140-150. https://doi.org/10.1016/j.cesjef.2017.05.002

Ike, M., Donovan, J. D., Topple, C., & Masli, E. K. (2019). The process of selecting and prioritising corporate sustainability issues: Insights for achieving the Sustainable Development Goals. *Journal of Cleaner Production*, *236*, 117661. https://doi.org/10.1016/j.jclepro.2019.117661

INEC (2012). *CIIU 4.0. Clasificación Nacional de Actividades Económicas* (p. 234). INEC. https://aplicaciones2.ecuadorencifras.gob.ec/SIN/descargas/ciiu.pdf

INEC (2019a). Encuesta a Empresas. Encuesta Estructural Empresarial. In *Instituto Nacional de Estadísticas y Censos*. http://www.ecuadorencifras.gob.ec/encuesta-a-empresas/

INEC (2019b). Encuesta nacional de empleo, desempleo y subempleo. In *Instituto Nacional de Estadísticas y Censos*. https://www.ecuadorencifras.gob.ec/documentos/web-inec/EMPLEO/2019/Junio/201906_Mercado_Laboral_final.pdf

International Monetary Fund (2020). *World Economic Outlook. Chapter 1: The Great Lockdown*. IMF. https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo-april-2020

Lafortune, G., Fuller, G., Schmidt-Traub, G., & Kroll, C. (2020). How Is Progress towards the Sustainable Development Goals Measured ? Comparing Four Approaches for the EU. *Sustainability (Switzerland)*, *12*(18), 1-24. https://doi.org/10.3390/su12187675

Lakshmivarahan, S., Lewis, J. M., & Jabrzemski, R. (2017). *Forecast Error Correction using Dynamic Data Assimilation* (Springer (ed.); 1st ed.). https://doi.org/10.1007/978-3-319-39997-3

Lind, D., Marchal, W., & Wathen, S. (2012). *Estadística aplicada a los negocios y la economía (Statistics applied to business and economy)* (McGraw-Hill (ed.); 15th ed.).

Lohr, S.L. (2019). Simple Probability Samples. In *Sampling. Design and Analysis* (2nd ed., pp. 25–72). CRC Press.

Martins, V.W.B., Rampasso, I.S., Siltori, P.F.S., Cazeri, G.T., Anholon, R., Quelhas, O.L.G., & Leal, W. (2020). Contributions from the Brazilian industrial sector to sustainable development. *Journal of Cleaner Production*, *272*, 1-25. https://doi.org/10.1016/j.jclepro.2020.122762

Navarrete, S.D.S., Borini, F.M., & Avrichir, I. (2020). Environmental upgrading and the United Nations Sustainable Development Goals. *Journal of Cleaner Production*, *264*, 121563. https://doi.org/10.1016/j.jclepro.2020.121563

Nilsson, M., Chisholm, E., Griggs, D., Howden-Chapman, P., McCollum, D., Messerli, P., Neumann, B., Stevance, A. S., Visbeck, M., & Stafford-Smith, M. (2018). Mapping interactions between the sustainable development goals: lessons learned and ways forward. *Sustainability Science*, *13*(6), 1489-1503. https://doi.org/10.1007/s11625-018-0604-z

Ott, R.L., & Longnecker, M. (2016). Inferences About Population Central Values. In *An Introduction to Statistical Methods & Data Analysis* (Seventh, pp. 232-299). Cengage Learning.

Paradi, J.C., Sherman, H.D., & Tam, F.K. (2018). *Data Envelopment Analysis in the Financial Services Industry*. Springer. https://doi.org/10.1007/978-3-319-69725-3

Pérez, C. (2010). *Técnicas de muestreo estadístico (Statistical sampling techniques)* (I. Publicaciones (ed.); 1.a). Ibergarceta Publicaciones.

Pizzi, S., Caputo, A., Corvino, A., & Venturelli, A. (2020). Management research and the UN sustainable development goals (SDGs): A bibliometric investigation and systematic review. *Journal of Cleaner Production*, *276*, 124033. https://doi.org/10.1016/j.jclepro.2020.124033

Quindós, M. del P., Rubiera, F., & Vicente, M. R. (2003). Análisis envolvente de datos: una aplicación al sector de los servicios avanzados a las empresas del Principado de Asturias). *Rect@*, *11*(1), 21.

Ramanathan, R. (2003). An introduction to Data Envelopment Analysis. In *SAGE Publications* (1st ed.). Sage Publications, Inc.

Sánchez de Pedro, E. A. (2013). *Nivel de competitividad y eficiencia de la producción ganadera (Level of competitiveness and efficiency of livestock production)* [Universidad de Córdoba]. https://helvia.uco.es/xmlui/handle/10396/10498

Santos, J., Negas, E., & Cavique, L. (2013). Introduction to Data Envelopment Analysis. In *Efficiency Measures in the Agricultural Sector* (1st ed., Issue January, p. 16). Springer. https://doi.org/10.1007/978-94-007-5739-4

SENESCYT-INEC (2015). Principales indicadores de actividades de ciencia, tecnología e innovación. In *Secretaría de Educación Superior, Ciencia, Tecnología e Innovación*. http://www.ecuadorencifras.gob.ec/documentos/web-inec/Estadisticas_Economicas/Ciencia_Tecnologia/Presentacion_de_principales_resultados_ACTI.pdf

Serrano-Cinca, C., Fuertes-Callén, Y., & Mar-Molinero, C. (2005). Measuring DEA efficiency in Internet companies. *Decision Support Systems*, *38*, 557-573. https://doi.org/10.1016/j.dss.2003.08.004

Shcherbakov, M., Brebels, A., Shcherbakova, Nataliya Tyukov, A., Janovsky, T., Kamaev, V., & Brebels, A. (2013). A Survey of Forecast Error Measures. *World Applied Sciences*, *24*(4), 171-176. https://doi.org/10.5829/idosi.wasj.2013.24.itmies.80032

Sherman, D., & Zhu, J. (2006). *Service Productivity Management. Improving Service Performance using Data Envelopment Analysis (DEA)* (Springer (ed.); 1st ed.).

Shiuh-Nan, H., Hsuan-shih, L., & Zhu, J. (2016). *Handbook of Operations Analytics Using Data Envelopment Analysis*. Springer. https://doi.org/10.1007/978-1-4899-7705-2

Simar, L., & Wilson, P. W. (2010). A general methodology for bootstrapping in non-parametric frontier models. *Journal of Applied Statistics*, *27*(6), 779-802. https://doi.org/10.1080/02664760050081951

Simar, L., & Wilson, P. (1998). Sensitivity Analysis of Efficiency Scores: How to Bootstrap in Nonparametric Frontier Models. *Management Science*, *44*(1), 49-61. https://doi.org/10.1287/mnsc.44.1.49

Software-Shop (2017). *Software Shop - Risk Simulator*. 2018. https://www.software-shop.com/producto/risk-simulator

Sueyoshi, T., & Goto, M. (2018). *Environmental Assessment on Energy and Sustainability by Data Envelopment Analysis* (1st ed.). John Wiley & Sons Ltd.

Sullivan, K., Thomas, S., & Rosano, M. (2018). Using industrial ecology and strategic management concepts to pursue the Sustainable Development Goals. *Journal of Cleaner Production*, *174*, 237-246. https://doi.org/10.1016/j.jclepro.2017.10.201

SUPERCIAS (2020a). *Consulta y recepción de estados financieros*. Recepción Estados Financieros. https://appscvsmovil.supercias.gob.ec/portaldedocumentos/consulta_cia_param.zul

SUPERCIAS (2020b). *Ranking de compañías*. Ranking Empresarial del Ecuador. https://appscvs.supercias.gob.ec/rankingCias/

Tayra, F., & Ribeiro, H. (2006). Modelos de indicadores de sustentabilidade: síntese e avaliação crítica das principais experiências (Models of sustainability indicators: synthesis and critical evaluation of the main experiences). *Saúde e Sociedade*, *15*(1), 84-95. https://doi.org/10.1590/s0104-12902006000100009

Technical Secretariat-Plan Ecuador (2019). *Informe de avance del cumplimiento de la Agenda 2030 para el desarrollo sostenible*. https://www.planificacion.gob.ec/wpcontent/uploads/downloads/2019/07/Informe-Avance-Agenda-2030-Ecuador-2019.pdf

Tofallis, C. (2001). Combining two approaches to efficiency assessment. *Journal of the Operational Research Society*, *52*(11), 1225-1231. https://doi.org/10.1057/palgrave.jors.2601231

UN Statistical Commission (2017). Global Indicator Framework for the Sustainable Development Goals and Targets of the 2030 Agenda for Sustainable Development. In *Statistical Commission pertaining to the 2030 Agenda for Sustainable Development*. https://unstats.un.org/sdgs/indicators/Global Indicator Framework after 2019 refinement_Eng.pdf%0Ahttps://unstats.un.org/sdgs/indicators/Global Indicator Framework_A.RES.71.313 Annex.pdf

United Nations (2012). *Río+20. Conferencia de las Naciones Unidas sobre el Desarrollo Sustentable (Rio + 20. United Nations Conference on Sustainable Development)*. https://doi.org/10.1373/clinchem.2005.055160

United Nations (2015). Transforming our World: the 2030 Agenda for Sustainable Development. In *General Assembley 70 session* (Issue October). https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf

United Nations (2016). *Agenda 2030 y los objetivos de desarrollo sostenible: una oportunidad para América Latina y el Caribe (Agenda 2030 and the Sustainable Development Goals: an opportunity for Latin America and the Caribbean)*. https://repositorio.cepal.org/handle/11362/40155

Webster, A. (2001). *Estadistica aplicada a los negocios y la economia (Statistics applied to business and economy)* (McGraw-Hill (ed.); 3rd ed.).

World Bank (2020). *The Economy in the Time of Covid-19* (Issue April). https://openknowledge.worldbank.org/bitstream/handle/10986/33555/9781464815706.pdf?sequence=4&isAllowed=y

Wynn, M., & Jones, P. (2020). *The Sustainable Development Goals: Industry Sector Approaches.* Taylor & Francis Group. Routledge.