

Innovative efforts and export performance in Ecuador's metal mechanics industry

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Abstract

This study aimed to investigate the innovation activities of exporting companies in the meta-mechanics industry in Ecuador using the Ecuadorian Science, Technology, and Innovation Activities (ACTI) survey database. A total of 219 metal-mechanical companies were selected, and a principal component analysis was conducted to identify the most commonly used innovation activities by exporting companies. Additionally, a logit econometric model was developed to determine the probability of exporting based on the selected innovation activities. The findings of this study indicate that not all innovation activities increase the probability of innovation in the metal-mechanic industry in Ecuador. Specifically, the acquisition of machinery and equipment increases the probability of innovation in the industry. Overall, this research contributes to our understanding of the innovation-export relationship in the meta-mechanics industry in Ecuador and has important implications for policymakers and businesses seeking to promote economic development and growth in this sector.

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1. Introduction

The metal mechanics industry plays a crucial role in the global context, including social, economic, labor, and environmental factors. Throughout history, the metal industry has been a cornerstone of national progress [1]. Simultaneously, it has fostered advancements in scientific production in the applied, exact, and social sciences, thereby promoting new technological trajectories, as well as social and sociotechnical structures. From an economic perspective, the metalworking industry has experienced a consistent global growth. In 2021, the market expanded from \$230.48 billion to \$254.79 billion in 2022 [2].

Latin America also makes a substantial contribution to the industry's global economy, with Mexico, Brazil, and Argentina being the key players. In Ecuador, the manufacturing sector represents 24.9% of national production [3] and employs 10% of the country's workforce [4]. It comprises several industries, but metalworking is one of the most important ones. It contributes 29.28% of the manufacturing production and 7.18% of the GDP [3].

The annual exports are approximately \$ 400 million [5], [6]. Its products are related to economic sectors, such as agriculture, agroindustry, hydrocarbons, energy, transportation, and telecommunications [6]. It is composed of companies that produce, import, distribute, and market finished and semi-finished products related to metals. It generates approximately 23.600 direct jobs and approximately 50.000 indirect jobs, which makes it essential for the development of Ecuador [7].

In this context, several studies have focused on analyzing the relationship between innovation activities and company exports. In India, the factors that determine the export capacity of medium-, low-, and high-technology manufacturing companies were analyzed, and it was found that R&D activities contribute to export competitiveness in medium- and low-technology industries [8]. In the United Kingdom, the probability of exporting innovative and non-innovative companies was analyzed, and the results showed that spending on R&D increases the probability of exporting non-innovative companies [9]. Recent work shows a positive relationship between human capital, R&D, and the propensity to export in Ghanaian companies [10]. In China, the propensity and intensity of exports are analyzed based on investments in internal and external R&D. The results show synergy between innovation activities and the propensity to export [11].

In the Latin American context, studies have analyzed the change in the global export model towards the export of goods from R&D activities [12]. It highlights, among others, the conceptual theoretical development of innovation and its contribution to the growth and development of Panama [13]. In Chile, innovation activities and exports were analyzed, finding that firms that join the innovative trend tend to export more than other companies within markets that differ in terms of quality from non-innovative firms [14]. The incidence of innovation and its effects on manufacturing companies' exports were studied in Uruguay. The results show that innovation in marketing and internal R&D activities has a higher incidence [15]. The relationship between innovation efforts, exports, and productivity in Peruvian companies was analyzed, and the results showed that exports are determinants of innovation [16].

Although innovation is generally considered an individual act of a company, it is conditioned by different factors and the aggregate impact on the economy is broad [17], [18]. Companies should conduct activities that promote innovation to grow and link themselves to new markets. Furthermore, studies highlight innovation and its activities as paths towards internationalization [19], [20].

Based on the above, this study aims to identify, in a disaggregated manner, the innovation activities of exporting companies in the metal-mechanical industry in Ecuador. This study contributes to the literature by empirically demonstrating exporting companies' main R&D activities. Additionally, this study contributes to the Latin American debate on innovation management and its results regarding the export of metal-derived products.

The structure of the work is as follows: i) a summary followed by an introduction; ii) a theoretical approach, in which a review of the theoretical bases supporting the work was carried out; iii) an explanation of the applied methodology and its data source; iv) a discussion and results; and v) the main conclusions of the research.

2. Theoretical framework

2.1. Innovation activities

In the academic and economic worlds, there is no doubt about the benefits of innovation for public and private companies in developed and developing countries, as demonstrated by works [16], [21], [22], [23]. However, innovation is not a spontaneous process; it requires support and incentives from the public sphere [24], [25] and businesses through innovation activities [26], [27]. The Oslo Manual states that innovation activities are scientific, technological, organizational, financial, and commercial actions that lead to the introduction of innovations in a real or intended manner [28]. Not only is R&D an innovation activity, it also encompasses support actions, training, and even the acquisition of incorporated or disembodied external knowledge and capital goods that are not part of R&D [29], [30]. However, most previous work has focused on analyzing R&D, and some aggregate all actions that lead to innovation within the terms "innovation activities," "R&D" or

“innovation.” This situation causes the business world to consider what constitutes the set of parts.

In India, Kumar analyzed the factors that determine the export capacity of medium-, low-, and high-technology manufacturing companies through a data panel made up of 640 companies, along with the variables of internal R&D intensity, informal innovation, and import of technology. R&D activities have been found to contribute to export competitiveness in low and medium-technology industries [31]. The probability of exporting innovative and non-innovative companies was analyzed using data from 320 companies in the United Kingdom. This study considers the variables human capital, number of innovations produced and used in the industrial sector, R&D spending, and a proxy for technological capabilities.

The study conducted by Wakelin [9] found that investing in research and development (R&D) increases the likelihood of a non-innovative company exporting its products. This study used data from 201 manufacturing companies in Africa and considered the factors of export behavior as explanatory variables: R&D, human capital (measured by education), formal training, and innovation. The results show a positive relationship between human capital, R&D, and the propensity to export in Ghana [10]. For China, a sample of 552 manufacturing exporting companies was analyzed to measure the propensity and intensity of exports based on investments in internal R&D, external R&D, and innovation in new products. The results show synergy between innovation activities and the propensity to export [11]. The commercial and competitive structure of Latin America, Europe, and Asia; the change in the export model in the world towards the export of goods from R&D activities, considering Latin American technological change and endogenous development, highlighting the process of transforming comparative advantages into competitive ones [12], [32]. A conceptual theoretical description of the innovation situation in Panama concludes that the lack of strength of the National Innovation System of this country has limited the growth of exports and a better insertion in international trade [12], [13].

In the research of Merin and Alegre, main objective is to investigate the impact of CEO managerial capabilities on business model innovation (BMI) and export performance in innovative small and medium-sized enterprises (SMEs). This study aims to understand how specific managerial capabilities such as CEO external connectivity and empowering leadership influence BMI and how BMI, in turn, affects export performance. This study contributes to the literature on dynamic managerial capabilities and international entrepreneurship by highlighting the role of individual-level managerial capabilities in driving BMI and enhancing international performance in SMEs. The conclusions of this study show that CEO external connectivity and empowering leadership significantly facilitate business model innovation (BMI) in international innovative SMEs, which is critical for innovative SMEs to respond to the needs and challenges of operating in foreign markets, thereby improving their international performance [33].

Through a case study in the manufacturing industry of Uruguay, two hypotheses were contrasted regarding the types of innovation and innovation activities in companies and the probability of exporting, for which a logistic regression was used. They find that innovation in marketing, internal R&D, and market studies is significant, increasing the probability of exports [34]. Other studies conducted in Peru consider the following variables: qualified workers, public and private financing for innovation activities, contracts for innovation activities, intellectual property, location, and size, among others. These results indicate that an increase in exports increases R&D spending. A similar situation occurs with an increase in productivity [35], [36]. In this line of thought, some studies propose that exports encourage innovation, and not vice versa.

Rauf and Ma explore the impact of domestic and foreign innovation activities, human capital, and government policies on the export performance of industrial enterprises in China. The authors showed that innovation is a crucial driver of export performance. This highlights the importance of various dimensions of technological innovation and their collective contribution to export success, particularly in emerging countries such as China. The findings emphasize that domestic R&D efforts, technology spillovers from foreign investment, innovation policies, and trade policies are critical determinants of export growth. Additionally, the quality of human capital in Chinese industrial firms is lacking, diminishing the pace of innovation growth and export performance [37].

In a study of Asian companies, considering different countries, company sizes, and whether they are local or foreign companies, it was found that there is an inverse or null relationship between R&D and exports [38]. This result was confirmed in research carried out with North American companies, which found that there is no evidence of the contribution of investment in different levels of R&D to the export dynamism of firms because investment in R&D is necessary but not sufficient [39]. In Italy, the findings indicate no association between R&D and exports, when firm size is considered [40].

As can be seen, there is still a latent debate on the benefits of R&D activities with respect to innovation, and it should be noted that few studies in the Latin American context explore this theoretical line. Therefore, it is necessary to conduct further research in South American countries.

3. Research method

This study aims to identify the R&D variables that explain the business export activities of the Ecuadorian metal-mechanic industry. This study utilized the database of the National Survey of Science, Technology, and Innovation Activities of Ecuador (ACTI) published by the National Institute of Statistics and Censuses of Ecuador (INEC) and the National Secretariat of Higher Education, Science, and Technology (SENESCYT). The database was updated with information from the period 2012-2014, and it was used to gather data for the study. The survey included 6275 companies. The sample of this work corresponds to 219 companies in the metal-mechanic sector, selected according to the International Standard Industrial Classification (ISIC); C24 to C30

To avoid problems of dispersion and insufficient data, some variables were integrated: the hardware and software acquisition variables were combined into a single explanatory variable "Acquisition of Information Technology."

First, with the data purified and ordered, principal component analysis was performed to reduce the dimension of the variables according to their linear relationship. Some studies use this technique to examine innovation, and factorial analysis to reduce the number of R&D variables [41].

The combination of the original variables is expressed in matrix form as

$$c = Yv \quad (1)$$

where Y represents the score of each individual.

v contains the coefficients of each combination of variables.

The maximum variance calculated from the principal component was restricted to module one.

$$S_c^2 = v^t, v = 1 \quad (2)$$

The Lagrange multiplier is entered to find the maximum subject to the constraints and is set to zero.

$$(V_y - \lambda I)v = 0 \quad (3)$$

In this case, I represents the identity matrix and v denotes the vector of the covariance and variance matrix of the data.

The information on these components can be expressed as follows:

$$\frac{S_{ch}^2}{\text{total Variance}} = \frac{S_{ch}^2}{\text{Traza}V_y} = \frac{\lambda_h}{\sum_{h=1}^p \lambda_h} \quad (4)$$

Table 1 presents the variables used in this study.

Table 1. Study variables

Name	Characteristics	Description
Export	Dependent	Dichotomous variable: if the company carried out export activity=1, 0 otherwise
Research and Development (R&D) External	Independent variable	Dichotomous variable: if the company carried out External Research and Development=1, 0 otherwise
Internal Research and Development (R&D)	Independent variable	Dichotomous variable: if the company carried out Internal Research and Development=1, 0 otherwise
Acquisition of machinery and equipment	Independent variable	Dichotomous variable: if the company made the acquisition of machinery and equipment=1, 0 otherwise
Recruitment of Consultancies and Technical Assistance	Independent variable	Dichotomous variable: if the company contracted consulting and technical assistance = 1, 0 otherwise
Staff training	Independent variable	Dichotomous variable: if the company carried out Staff Training=1, 0 otherwise
Information Technology Acquisition	Independent variable	Dichotomous variable: if the company made the Acquisition of Information Technology=1, 0 otherwise
Divestiture Technology Acquisition	Independent variable	Dichotomous variable: If the company made the Acquisition of Disincorporated Technology=1, 0 otherwise
Engineering and Industrial Design Activities	Independent variable	Dichotomous variable: If the company carried out Engineering and Industrial Design Activities = 1, 0 otherwise

3.1. Logistic regression

Logistic regression was used to determine the probability that the company was an exporter for each variable of the main component. This probabilistic model has been used in previous studies [42], [43], [44]. These references have the same purpose as this study: they relate innovation and development (R&D) activities to the export probability of companies.

$$Export(p) = \log \frac{p}{1-p} = \beta_0 + \beta_1 RDinternal + \beta_2 RDexternal + \beta_3 MachAcqin + \beta_4 RecruitConsult + \beta_5 training + \beta_6 TecAcqh + \beta_7 DivestTech + \beta_8 EngDisg \quad (5)$$

The logistic model is interpreted in a way contrary to linear models; the resulting coefficients are the variation in the rate of occurrence of the event product of the dependent variable with respect to the variation in the unit value of the independent variables. Therefore, the specifications of the model must have the following form.

$$Export(p) = \frac{1}{1+e^{-(\beta_0+\beta_1 X_1+\beta_2 X_2+\dots+\beta_1 X_1)}} \quad (6)$$

In this study, the results of the logistic model are presented in three different formats to provide a clearer understanding of the results: odds ratios, ratios, and marginal effects expressed as percentages.

To better understand the relevance, adjustment, and validation of the model, the following indicators and

validation tests were performed:

- a) Barlett's sphericity test
- b) Kaiser-Meyer-Olkin index
- c) Hosmer-Lemeshow
- d) R-squared values of the Cox and Snell.

4. Results and discussion

To determine how the innovation variables improve and promote the international competitiveness of companies in the metal-mechanic sector of Ecuador, two types of analyses were developed to determine the relationship and probability of companies' innovative export activities. To obtain the probability of the innovation variables' influence on companies' export activities, the variable is first coded. The value 0 represents companies that do not export in the metal-mechanic sector, and 1 refers to companies that do. It must be emphasized that the logistic model takes 219 cases, is a small sample, and does not contain any lost cases.

With the Hosmer and Lemeshow test, having a significance value of 0.89 in step 3, which is greater than 0.5, an adjusted model can be seen. In other words, because the value is close to 1, the model can be continued because this adjustment measures sensitivity and specificity. In the three Wald steps, 83.6% of the cases were correctly adjusted to the probability and well classified.

Table 2. Variables in the equation

B.		Standard error	Wald	gl	Next.	Exp(B)	95% IQ to EXP(B)	
							lower	Super
Acquisition machinery and equipment	2.04	0.58	12.36	1	0.00	7.70	2.47	24.02
Consultancies and technical assistance"	-1.04	0.54	3.78	1	0.05	0.35	0.12	1.01
Technology Acquisition	1.26	0.44	7.90	1	0.01	3.51	1.46	8.42
Constant	-3.30	0.52	41.09	1	0.00	0.04		

The first column in Table 2 shows the innovation variables evaluated using a logistic regression model. The Wald method was used and only the final step was interpreted. The second column presents the coefficients of the variables followed by their significance values (p-values). The Exp (B) column is important because the odds ratios are shown and the ratio coefficients are used for interpretation.

The most important effect is that of the variable "Acquisition of machinery and equipment" ($p=0.00$), with an odds ratio of 7.70. In other words, if a company purchases machinery and equipment, it is 7.7 times more likely to export them. The variable "Acquisition of Information Technology" ($p=0.005$) presents an odds ratio of 3.509. In other words, if a company acquires information technology, it is 3.5 times more likely to export. On the other hand, the variable "Recruitment of consultancies and technical assistance ($p= 0.05$) is at the limit of acceptance. However, because of its theoretical importance, it was considered significant; the odds ratio was relatively low (0.353) and less than 1. The inverse was calculated for analysis. This variable decreases 2,832 times the probability of exporting; therefore, it must be combined with other variables in the company to improve export results.

As previously stated, the process of technical change entails the adoption of processes, capacities, qualified personnel, and knowledge that help develop processes that contain innovative inputs. These factors contribute significantly to the development of business competitiveness; therefore, in an international market, a company can be incorporated more easily. To better relate the results of the logistic regression model, they are interpreted from the perspective of marginal changes, allowing a realistic example when executing an innovation variable in companies in the metal-mechanic sector.

The values of the coefficients obtained in Table 2 were replaced with the logistic regression model equation. The probability of export depends on machinery equipment, consultancies-technical assistance, and information technology. The coefficients for machinery equipment and information technology are positive, showing that if one explanatory variable increases, it positively affects the explained variable (export).

$$Prob(Exp) = \frac{1}{1 + e^{-(-3,304 + 2,041 MachAcq - 1,040 Training + 1,255 TechAcq)}} \quad (7)$$

5. Conclusions

The objective of this study was to analyze R&D activities and their influence on the export activities of metal-mechanical companies in Ecuador. This study uses the results of the INEC Innovation Survey (ACTI) and analyzes them using mathematical and econometric techniques.

Through empirical evidence, this study shows that superior capacity in innovation activities enables a company to bring its products to an international market. To achieve this, there must be a combination of i) machinery and equipment, ii) computer technology, iii) staff training, iv) internal R&D, v) external R&D, and vi) hired consultancies [45], [46]. In relation to the results of the principal component analysis, these six variables are the main component called "technical change," which correlates and explains the export model of the metal-mechanic sector in more than 50%, all of which are innovation activities, but those that comprise this component are more important for the study of this case. This result reinforces the idea of [47] that the search for new processes and products in developing countries depends on i) the capacities and stimuli generated by the company itself and ii) external causes for the company, such as R&D laboratories, information transmission and innovation processes, business interactions in the market, trained personnel, and consumer resistance to change, which are the foundations for a company to aspire to business success.

This study reinforces previous research on innovation and exports in manufacturing companies. Previous studies have found a positive relationship between carrying out learning processes and building competitive products; that is, a company's export experience also improves its innovative capacity, and R&D activities are not the only ones that promote the productive development of the company. Similarly, technological diffusion at the national and international levels helps both productivity and specialization in production processes [48], [49]. Regarding the results of the logistic regression model, the main variable that increases the probability of exports of metal-mechanic companies is "Acquisition of machinery and equipment" with a 22% increase in probability. According to Pianta [50] companies' strategies are divided into technological competitiveness and cost competitiveness; the latter has to do with process innovation, managing to increase efficiency through technology, which is why manufacturing companies make it easier for them to incorporate machinery and equipment that improve the efficiency of the processes by reducing labor rather than starting a structural R&D process [49].

The acquisition of information technology increases the probability that a company will be an exporter by 11%, which corroborates the idea of Dosi et al. [51], in which the technology that contributes to knowledge is considered as a recipe to achieve the final artifact. The change in technology generates an accumulation of knowledge, owing to new equipment and tools acquired from outside the company. Another study found that the acquisition of hardware and software creates better standards for companies that facilitate their internationalization [52]. The characteristic of not only considering information technology as a technological change or, in turn, calling the acquisition of machinery a technical change. Technical change entails generating internal innovative processes that include research and development, design, expenses to generate knowledge, and the simultaneous actions of those who exercise the processes. Exports are achieved when a company is internally efficient with external elements [16], [53].

This study highlights the importance of managing innovation in metal-mechanical companies in Tungurahua and Ecuador, beyond the little-studied theoretical implications for Latin American countries, which have

practical implications for managers and decision-makers in small and medium-sized companies in the Central Highlands of Ecuador. Likewise, this study can help generate government policies that support innovation in the analyzed sector. In this regard, the government plays a fundamental role in implementing tax incentives, subsidies for R&D, and training programs to improve the technological capabilities of this sector. These policies help minimize the technical and financial barriers that limit the ability of companies to be competitive. In addition, this work contributes to the academic literature in Ecuador, since it is one of the first works to relate innovation activities and the export of products in the metal-mechanic industry.

A limitation of this study is the lack of updating the Survey of Science, Technology, and Innovation Activities of Ecuador, the only innovation survey available in the country.

As future lines of research, the authors suggest making comparisons with other industrial sectors, analyzing the cases of neighboring countries, and considering other types of innovation.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests for any material discussed in this paper.

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Author contribution

The contribution to the paper is as follows: A. Argothy. J. Llamuca: study conception and design; F. Herrera: data collection; A. Argothy and J. Llamuca. Z.: Analysis and interpretation of results; X. Morales and C Guerrero-Velástegui: draft preparation interpretation of results. All authors approved the final version of the manuscript.

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