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Analysis of innovation drivers with a mapping innovation approach: Practical application in Ecuador

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Abstract

Objective of the study: This study aims to identify and analyze the drivers of innovation in Ecuador.

Methodology/Approach: The significance of innovation drivers was investigated through an exploratory systematic review using a mapping innovation approach. Statistical methods were used to apply an empirical analysis based on the Ecuadorian survey on Science, Technology, and Innovation Activities (released 2017).

Originality/Relevance: As far as we are aware, this is the first study to investigate the drivers of innovation from a comprehensive approach of mapping innovation in Ecuador.

Main results: The management of innovation drivers in Ecuador often presents issues for 98% of non-innovative companies. The most relevant innovation driver in Ecuadorian companies is cooperation with external sources where partner geolocations worldwide play a significant role.

Theoretical/ Methodological Contribution: This study extends the framework of innovation drivers. The strengths and limitations of Ecuadorian innovation were identified from four perspectives of innovation drivers: internal innovation drivers, external innovation drivers, knowledge for innovation development, and investment in innovation.

Social/Management Contribution: This study contributes to the understanding of innovation drivers in developing countries.

Keywords: innovation drivers, mapping innovation, developing countries, PcoA, PAM, Logit

Análise de drivers de inovação com uma abordagem de mapa de inovação: Aplicação prática no Equador

Resumo

Objetivo de estudo: Este estúdio tem como objetivo identificar e analisar os drivers da inovação no Equador.

Metodologia / Abordagem: A importância dos drivers da inovação foi investigada por meio de uma revisão sistemática exploratória usando uma abordagem de mapeamento da inovação. Métodos estatísticos foram usados para aplicar uma análise empírica com base na pesquisa equatoriana de Atividades de Ciência, Tecnologia e Inovação (publicada em 2017).

Originalidade / Relevância: Até onde sabemos, este é o primeiro estudo a investigar os drivers da inovação no Equador a partir de uma abordagem abrangente de mapeamento da inovação.

Resultados principais: A gestão dos drivers da inovação no Equador costuma apresentar problemas para 98% das empresas não inovadoras. O driver de inovação mais relevante nas empresas equatorianas foi a cooperação com fontes externas, onde as geolocalizações dos parceiros em todo o mundo desempenham um papel significativo.

Contribuição Teórica / Metodológica: Este estudo amplia o quadro de drivers de inovação. Os pontos fortes e as limitações da inovação equatoriana foram identificados a partir de quatro perspectivas de seus drivers: drivers internos de inovação, drivers externos de inovação, conhecimento para o desenvolvimento da inovação e investimento em inovação.

Contribuição Social / Gestão: Este estudo contribui para a compreensão dos drivers da inovação nos países em desenvolvimento.

Palavras chave: drivers de inovação, mapeamento da inovação, países em desenvolvimento, PcoA, PAM, Logit

Análisis de conductores de la innovación con un enfoque de mapeo de la innovación: Aplicación práctica en Ecuador

Resumen

Objetivo del estudio: Este estudio tiene como objetivo identificar y analizar los drivers de la innovación en el Ecuador.

Metodología / Enfoque: Se investigó la importancia de los conductores de la innovación a través de una revisión sistemática exploratoria utilizando un enfoque de mapeo de la innovación. Se utilizaron métodos estadísticos para aplicar un análisis empírico basado en la encuesta ecuatoriana de Actividades de Ciencia, Tecnología e Innovación (publicada en 2017).

Originalidad / Relevancia: Hasta donde sabemos, este es el primer estudio que investiga los impulsores de la innovación en Ecuador desde un enfoque integral de mapeo de la innovación.

Resultados principales: La gestión de los impulsores de la innovación en Ecuador suelen presentar problemas para el 98% de las empresas no innovadoras. El conductor de la innovación más relevante en las empresas ecuatorianas fue la cooperación con fuentes externas donde las geolocalizaciones de socios en todo el mundo juegan un rol significativo.

Contribución teórica / metodológica: Este estudio amplía el marco de los conductores de la innovación. Se identificaron las fortalezas y limitaciones de la innovación ecuatoriana desde cuatro perspectivas de sus conductores: conductores de innovación internos, conductores de innovación externos, conocimiento para el desarrollo de la innovación e inversión en innovación.

Contribución social / de gestión: este estudio contribuye a la comprensión de los conductores de la innovación en países en desarrollo.

Palabras Clave: conductores de la innovación, mapeo de la innovación, países en desarrollo, PcoA, PAM, Logit

1 Introduction

Innovation is an important factor in a country's economic growth since it enables companies to generate new ideas, market new products or services, generate new business models, be more competitive, and internationalize (Rojo et al., 2019; Velázquez & Salgado, 2016). Despite the strategic importance of innovation, the literature shows that innovation in developing countries progresses slowly (Gamez et al., 2018).

The literature suggests that Latin American companies avoid developing Research, Development, and innovation (R&D&i) projects due to the poor likelihood of successful innovations (Alvarez & Crespi, 2011; Tello, 2017). In the Ecuadorian context, the evidence suggests that companies are very averse to the generation of innovation since innovation is considered an expense rather than an investment in competitiveness (AEI, 2014). In 2020, the World Intellectual Property Organization rated Ecuador's innovation as low, placing it in the 99th position out of 131 in the global innovation ranking, with a score of 0.24/1 (Soumitra et al., 2020). The aforementioned highlights the need to investigate innovation as a way to improve Ecuador's innovation policies.

Among the factors that affect the promotion of innovation in developing economies are evidenced the development of late and slow public policies, low scientific and technological levels, uneven development of the higher education system, and poor quality of life for its citizens (Altenburg, 2009; Guilarte et al., 2023; Peraza & Mendizábal, 2022).

One of the factors that limits the development of effective innovation policies in developing countries is the understanding lack of the components that drive innovation and its innovative potential for companies (Moreno Rojas, 2013; Talmar et al., 2018).

Companies from less developed countries are generally less diversified and have low levels of innovation, as they frequently overlook drivers of innovation such as investment and development of research and development activities (Peraza & Mendizábal, 2022). In Ecuador, the areas of production, human resources, finance, and advertising generally have low levels of innovation (Cadena et al., 2019; Ortega et al., 2017).

The literature explains that innovation is generated through a set of elements, rather than a single idea, from diverse sources (Conway & Steward, 1998; Nagles, 2007). In this context, it is important to develop research that allows for the orderly and structured interaction of different components that generate innovation in different areas of an organization (Conway & Steward, 1998; De Bruijn, 2004; Francis, 2003). A mechanism that enables systemic and integrative inquiries about the driving components behind innovation is mapping innovation (Lmbach et al., 1997; Pereira et al., 2019; Sörvik & Kleibrink, 2015).

The term mapping innovation refers to the dynamic relationships between companies and their environments to generate knowledge systems (Conway & Steward, 1998). One of the advantages of mapping innovation is its practical utility for studying innovation policy in developing countries since it can be applied to both Small-and medium-sized enterprises (SMEs) and large companies (Shapira et al., 2016).

SMEs make up 95% of the business fabric of developing countries. Although these SMEs would need to innovate to achieve sustained economic growth, most do not, which is a cause for concern (Gamez et al., 2018; Saavedra & Hernández, 2008).

At the business level, mapping innovation has been used to understand: i) the sources of business innovation; ii) the trajectory of the innovation protocols, iii) the flows between actors in the innovation system, iv) the development of technologies, v) the barriers that prevent the development of innovation and vi) the different R&D&i actors (Ardito et al., 2018; Djellal & Gallouj, 2005; Habiyaremye et al., 2017; Stevens, 1997; Wiesenthal et al., 2011).

This study took advantage of the existing literature on mapping innovation to investigate the driving components of innovation and its application to the Ecuadorian context from a comprehensive perspective. This study allows to determine a) strategic drivers of innovation, b) the importance received by innovation-generating drivers in Ecuadorian companies, c) the strengths and innovation weaknesses in a developing country, and d) global metrics associated with the presence of these key elements of innovation in Ecuadorian companies.

This study aims to map the drivers of innovation in developing countries. To this end, Ecuador was used as a case study. The Activities of Science and Technology (ACTI by its acronym in Spanish) survey was used as a source of information because of its proven acceptance in other scientific studies (C. Carpio et al., 2015; Grijalva et al., 2018).

The specific objectives of this study are as follows:

- Apply a perceptual mapping of drivers of innovation in Ecuadorian companies from a comprehensive approach.
- Classify the companies according to the presence and absence of the drivers of innovation.
- Determine the contribution of the drivers of innovation to explain innovation in the Ecuadorian context.
- Map from a geographical approach the most significant drivers of innovation.

It should be emphasized that this study is aligned with target 9 of the Sustainable Development Goals, which aims to foster innovation, particularly in developing economies.

2 Literature Review

2.1 Review of innovation drivers with a mapping innovation approach

A key element for the implementation of effective organizational innovation strategies is the recognition of innovation drivers that best match the traits of the company and its organizational environment (C. Franco & Landini, 2022). Drivers of innovation are the basis for transforming companies' innovation and deciding which technologies to use (Van Veldhoven & Vanthienen, 2022). Understanding them is of vital importance to take the appropriate policies in the development of innovations (Van Veldhoven & Vanthienen, 2022).

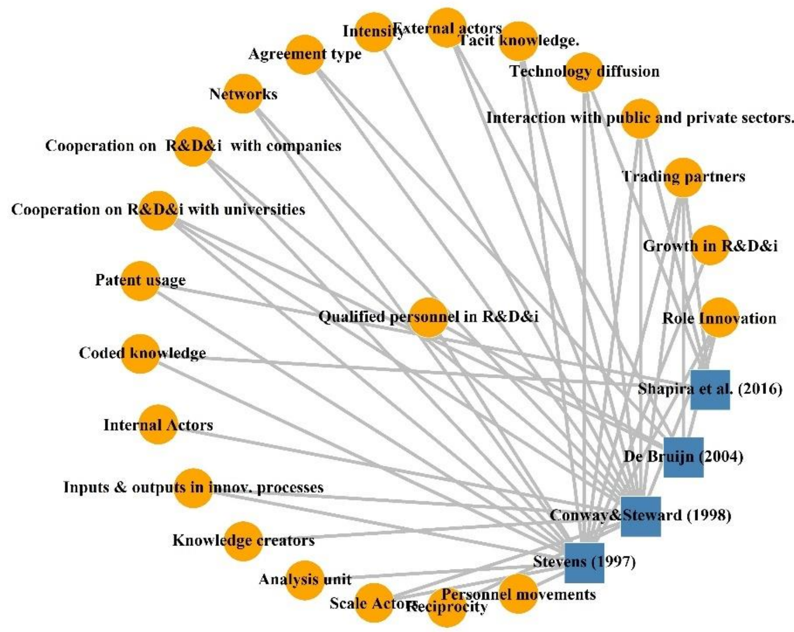
The mapping innovation framework proposed by Stevens (1997) was used as a reference when choosing the innovation drivers since it provides a systemic view of innovation. Mapping innovation is a good method to exploit the visual capabilities of human cognition to reveal the development of innovation and trace links between actors (Conway & Steward, 1998).

The mapping innovation approach proposed by Stevens (1997) seeks to: i) address innovation as a total system; ii) capture the interaction between the actors that make up the system within which knowledge is deployed; iii) identify the leverage points to improve the industrial competitiveness of the innovation system as a whole and iv) direct the attention of the decision makers towards possible systemic failures.

Stevens (1997) proposed some drivers to map innovation systems: tacit knowledge, codified knowledge, R&D&i cooperation between companies, public/private sector interaction, technology diffusion, and personnel movements. After Stevens (1997), Conway and Steward (1998), De Bruijn (2004), and Shapira et al. (2016) emphasized the importance of mapping the innovation system through the use of comprehensive approaches and have expanded the portfolio of its elemental drivers. Figure 1 collects the set of drivers of innovation proposed by these authors and which serve as the basis for conducting this study.

Figure 1

Drivers of innovation derived from the mapping innovation approach



Source: Own elaboration-based Stevens (1997), Conway and Steward (1998), De Bruijn (2004) and Shapira et al. (2016) for a comprehensive mapping of innovation at business level.

The examination of the innovation drivers collected in Figure 1 allowed their understanding into four major groups: (1) internal innovation drivers, (2) external innovation drivers, (3) knowledge for innovation development, and (4) investment in innovation.

This classification is consistent with Pucihar et al. (2019) who suggest that the innovation drivers come from external sources and different internal levels of the company. According to Morero (2016), internal and external innovation drivers must work in harmony for innovation in companies to be successful.

The development of knowledge for innovation is a strategic axis that supports the productive growth of companies and society at large (Herrera & Gutiérrez, 2011). While investment in innovation enables a company to develop its innovative capabilities, acquire cutting-edge technology, and establish deeper connections with other companies to produce original and novel items for the market (Paunov, 2012).

2.2 Internal innovation drivers

The first driver of innovation considered was the development of R&D&i activities in companies. Anzola et al. (2018) suggest that developing internal R&D&i activities is a key component to generating successful innovations in organizations that are highly committed to technological development and have inventive processes.

In keeping with Stevens (1997), a focus was placed on R&D&i initiatives conducted in the fields of production and marketing. Dwivedi & Pawsey (2023) suggest that innovation in marketing is considered the basis of differentiation and competitiveness for companies. While the production departments accumulate knowledge for the generation of innovation, given its value to create innovative products that are released onto the market (Dosi & Cimoli, 1994).

This study also considered the methods of organization of responsibilities and decision-making. This driver allows the implementation of innovation techniques such as the empowerment of workers in decision-making or the reduction of costs by introducing new forms of organization in companies (Afcha, 2011).

2.3 External innovation drivers

In order to solve great challenges at the level of innovation, it is necessary to involve the company with external actors (Cai, 2023). External parties contribute with important knowledge and innovative ideas for the creation of better products, procedures, or services (Lambe & Spekman, 1997; Teece, 1986). Carpio (2020) suggests that regional cooperation between different actors fosters global competitiveness.

Innovation cooperation with external partners is a frequent innovation practice where the parties involved take advantage of the skills of their counterparts to improve their understanding of a particular topic and increase business performance (Koza & Lewin, 1998). In the same way, there is growing recognition of the potential synergy between universities and companies for R&D&i initiatives, particularly in sectors with significant market potential and technological frontier (Cai, 2023; Liu et al., 2023).

Depending on the sort of connection with the strategic partners, there may be R&D&i cooperation for technological, commercial, emerging, or social purposes (Petraite et al., 2022). These networks may come from suppliers, customers, competitors, research institutions, or industrial partners (Petraite et al., 2022).

Carpio (2020) contends that one factor promoting global competitiveness is cooperation with foreign partners. However, the most frequent networks in innovation occur at the national level rather than at the international level. In this line, the present study analyzes the link with international partners for the generation of innovation in Ecuador.

The formalization of cooperative agreements for R&D&i is a crucial step in developing cooperative connections (OECD, 2015). Hagedoorn (1993); Surroca & Santamaría (2007) contend that cooperation agreements have a good impact on company innovation since they allow access to new markets and new business niches.

Thus, this study assesses the significance of external cooperation sources with a focus on collaboration with external partners and collaboration with universities using the mapping innovation approach proposed by Stevens (1997). In addition, the importance of the diversity of partners by type of relationship, foreign partners, and the diversity of cooperation agreements was examined.

2.4 Knowledge for innovation development

Knowledge development is a dynamic process that, when properly managed, has a positive impact on outcomes and the creation of competitive advantage in companies

(Guadamillas & Donate, 2008). The review of the mapping innovation approach allowed us to identify four drivers of innovation associated with the use of knowledge in innovation: (1) use of existing knowledge in scientific databases, (2) training in R&D&i, (3) level of education of human resources, and (4) creation of patents (Stevens, 1997).

According to Dou (2004), the availability of scientific databases presents a chance to provide access to knowledge for a variety of groups, including researchers, students, and decision-makers, leading to advancement for underdeveloped nations. The use of existing knowledge in the form of publications, knowledge, values, and experiences is a form of competitive advantage that might result in new organizational goods, procedures, or services (Davenport & Prusak, 2001; Nagles, 2007).

In accord with Zahera (1996), one of the success factors for innovation is the hiring and advancement of highly qualified personnel in companies, since it enables access and assimilation of technical information to acquire skills and develop technological know-how.

In keeping with Citraro (2015), education level is a critical component that influences innovation; hence it is crucial to promote research and engagement in innovation processes at the higher education level.

Additionally, patents are one resource for safeguarding human invention and intellectual property for commercial reasons (Hernández Cerdán, 2003; Yang et al., 2017). According to Galicia et al. (2022); Hernández & Díaz (2007), patents are a quantitative measure of commercial innovation.

2.5 Investment in innovation

Through the mapping innovation approach were recognized the investment in R&D&i, adoption of information and communication technology (ICT), government finance, and private banking finance as drivers of investment in innovation (Conway & Steward, 1998; De Bruijn, 2004; Shapira et al., 2016; Stevens, 1997). This group of drivers is oriented to the allocation of R&D&i resources to create customer value, generate competitive advantage, and foster sustainable business growth.

Innovation investment is characterized by high risk, systematic complexity, and long-cycle nature (Yuan et al., 2022). Additionally, ICT investment is regarded as a driver of innovation since it enables companies to improve productivity growth, optimize resource use, save costs, access new markets, and decrease communication obstacles (Costa et al., 2018; C. Franco & Landini, 2022).

At the level of financing, Pastor et al. (2017) mention that public financing is a valuable instrument to increase research, technological development, and innovation activities. According to Torres (2020), bank financing for innovation is a crucial component that enables businesses to undertake significant changes at the corporate level, such as the development of new goods and services.

3 Method

3.1 Analysis unit and database

This study was conducted in Ecuador, South America. In 2019, 882,766 companies were registered in this country (INEC, 2020). These companies were mainly characterized by slow economic growth and a lack of innovation (Mendoza et al., 2021). The stimulation of innovation through the registration of patents was well below the reference levels in South America (Waguespack et al., 2005). Additionally, the little innovation that materialized was insufficient to stimulate productivity or replicate in contexts with similar characteristics (Mendoza et al., 2021).

Innovation research in Ecuador is extremely limited (Mendoza et al., 2021). The ACTI reference survey was conducted in 2015 using data from 2014. This database complies with the international quality parameters established in the Oslo Manual of the Organization for Economic

Cooperation and Development (OECD, 2015). The survey contained information on 6,275 companies. In this study, we used data from 5,149 companies, and the rest were not considered because they contained insufficient information for this study.

The ACTI survey showed that the review of innovation by the Ecuadorian government in 2014 reflected the good economic performance of this region in the period 2000-2012 (Guaipatin & Schwartz, 2014). Additionally, the science, technology, and innovation policies implemented in that period resulted in the country's economy from exports to being based on knowledge and the production of processed products (Cadena et al., 2019).

The unit of analysis of the ACTI survey considered the economic sectors of mining and quarrying, trade, services, and manufacturing, all of which represent 86.66% of Ecuadorian companies, with innovation levels of 49.6%, 51.1%, 54.9%, and 66.5%, respectively (INEC, 2016b).

The ACTI survey is focused on small, medium, and large companies, representing 9.12% of all existing companies in Ecuador (INEC, 2020) with innovation levels of 53.6%, 58.3%, and 60%, respectively (Senescyt, 2016). This revealed the role of company size in the levels of innovation (Laforet, 2008).

The ACTI survey served as an input for collecting metrics associated with proposed innovation drivers. Table 1 includes the metrics that served as the basis for analyzing innovation under the mapping innovation approach. Moreover, Appendix A describes the measurement of the proposed metrics using the ACTI survey.

Table 1

Proposed metrics for analyzing Ecuador's innovation drivers using data from the ACTI survey

Conductores de la innovación	ID	Métrica
Internal innovation drivers	1	Importance of internal sources of innovation
	2	Development of internal R&D&i activities
	3	R&D&i activities in the areas of marketing and production
	4	Methods of organizing responsibilities and decision-making
External innovation drivers	5	Use of external sources of R&D&i
	6	Cooperation with universities
	7	Cooperation for develop products, services, or process
	8	Diversity of partners by geolocation
	9	Diversity of partners by type of relationship
	10	Diversity of agreements cooperation
	11	Importance of external sources of R&D&i
Knowledge for innovation development	12	Training in R&D&i
	13	Education level of human resource
	14	Use of existing knowledge in scientific databases
	15	Creation of patents
Investment in innovation	16	Investment in R&D&i
	17	Introduction of ICT
	18	Private bank financing
	19	Government sector financing

Source: Prepared by the author

3.2 Tools for the perceptual mapping and classification of Ecuadorian companies according to the drivers of innovation

To map the similarities and differences existing in Ecuadorian companies concerning the use of innovation drivers (InDri), the matrix of similarities and dissimilarities was first calculated with an appropriate measure for the mixture of numerical, nominal, binary, and ordinal variables, such as the Gower distance (Grané et al., 2020). Subsequently, a dimension reduction model was used to convert the distance matrix into a two-dimensional interpretive space using principal coordinate analysis (PCoA). As PCoA generally results in eigenvalues less than zero, Mardia's criterion was applied to determine the percentage of explained variance (Kimber & Everitt, 1995; Mardia et al., 1994).

One of the limitations of the PCoA model is that it does not provide a biplot representation of the variables, as in the statistical models of principal components analysis or multiple correspondence analysis (Xia et al., 2018). Thus, weighted averages (WA) were used to interpret the relationships between the variables and their respective dimensions as weighted averages of their contributions to the axes (Xia et al., 2018). This interpretation is similar to that of the correspondence analysis model with Scale 2 (Borcard D; Gillet F, 2018).

To better understand the importance of InDri in Ecuador and interpret the PCoA model, the matrix of similarities and dissimilarities calculated with the Gower distance was used to classify the companies by employing the partitioning around medoids (PAM) method (Borcard D; Gillet F, 2018).

The silhouette score was used to determine the similarity of a medoid with its cluster (Aytaç, 2020; Kim et al., 2020) and thus determine the optimal number of clusters to represent through PAM. This test indicates that the closer the score is to one, the better the fit of the medoid to the cluster (Aytaç, 2020).

The *daisy* function of the *cluster* library allowed the calculation of the Gower distance (Maechler et al., 2021).

The PCoA model was calculated using the *cmdscale* function (Yang et al., 2017). This approach is often referred to as perceptual mapping because it results in a spatial map of the respondents' perceptions of the set of objects (Greenacre, 2010).

WA scores were estimated using the *wascores* function of the *vegan* library (Oksanen et al., 2020).

The PAM classification was performed using the *pam* function of the *cluster* library (Maechler et al., 2021).

3.3 Tools for analyzing the significant differences in innovation according to the use of global metrics of the InDri

The generation of global metrics from the PCoA model and the classification made with PAM was proposed as a first step to analyze the existence of significant differences at the level of innovation. The potential of PCoA to explain the variation of many variables in a few dimensions has motivated its use to develop indicators that support decision-making (Crespo & Crespo, 2016). PCoA is part of the research field of indexes based on dimension reduction models (Reckien, 2018). Accordingly, the PCoA model was translated into an interpretive scale [0-1] (Reckien, 2018). Therefore, the dimension that explains the greatest variance (Dim1) of the drivers of innovation was used, and a min-max rescaling was applied to obtain a calibrated metric in the range [0-1] (Yoon, 2012). In the case of PAM, a variable that considers the presence of InDri from a binary approach (clusters 1 and 2) was considered. Both measures (PCoA and PAM) allow for explaining the importance of innovation drivers through a global approach.

Second, the significant differences between innovative and non-innovative companies and the proposed metrics were studied. In the case of PCoA, the type III sum of squares of the ANOVA test was used for unbalanced designs (Fox et al., 2021). In the case of PAM, Pearson's chi-square test was used for analyzing categorized data together with Cramer's V coefficient to determine the strength of the association between innovation and the classification proposed by this algorithm (R Core Team, 2023). The ANOVA test was performed using the *car* library and Cramer's V coefficient employing the *assocstats* function of the *vcd* library of R software (Meyer et al., 2021). The *chisq.test* function (R Core Team, 2023) was used to calculate the chi-square test.

3.4 Analysis of the InDri contribution to innovation in the Ecuadorian context

To explain the relationships between innovation and InDri, three logistic models were used: a model in which individual drivers are used as explanatory variables, and two models that are estimated with the global metrics of PAM and PCoA. Logit models are appropriate for explaining a binary or dichotomous response variable based on independent variables (Díaz & Duque, 2021). These models represent generalized linear models, in which the link function is the logarithm of the odds ratios, that is, the logit function (Faraway, 2016). The logit model was implemented using the *glm* function of the R software (R Core Team, 2023).

The dependent variable in the present study is innovation presence (1 = innovative company, 0 = non-innovative company) which is defined as the introduction/creation of a new or significantly enhanced good, service, or process, as well as the introduction of organizational or commercial changes that lead to organizational improvement (INEC, 2016a).

4 RESULTS

4.1 Perceptual mapping of innovation drivers

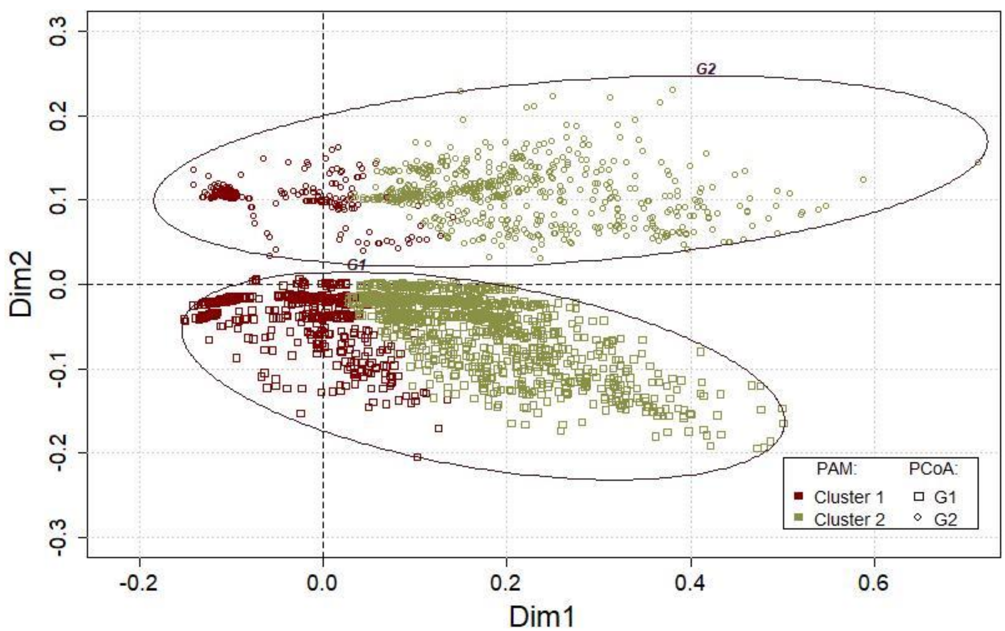
The PCoA model used to analyze the behavior of the companies with respect to InDri explained 89.70% of the variance. The first dimension (Dim1) explained 86.18%, followed by the second dimension (Dim2) explaining 3.52% of the variance.

Figure 2 shows the configuration of companies in the biplot. The PCoA model shows the level of differentiation of Ecuadorian companies regarding the use of InDri from left to right. The less differentiated companies were on the left (the most similar), and the more differentiated companies were on the right (the most dissimilar). PAM complements the results obtained using the PCoA model since classified the InDri similarities of companies into two clusters: Cluster 1= “companies with little differentiation in the use of innovation drivers” and Cluster 2 = “companies with greater differentiation in the use of innovation drivers.”

Additionally, the PCoA model allowed for the generation of two groups (G1 and G2). G2 represents the companies that have implemented new methods of organizing responsibilities and decision-making (ID=4). G1 represents companies that have not adopted G2.

Figure 2

Mapping and classification of Ecuadorian companies based on InDri strategy they adopted. G2: Companies that have implemented new methods of organizing responsibilities and decision making. G1: Companies that have not implemented G2

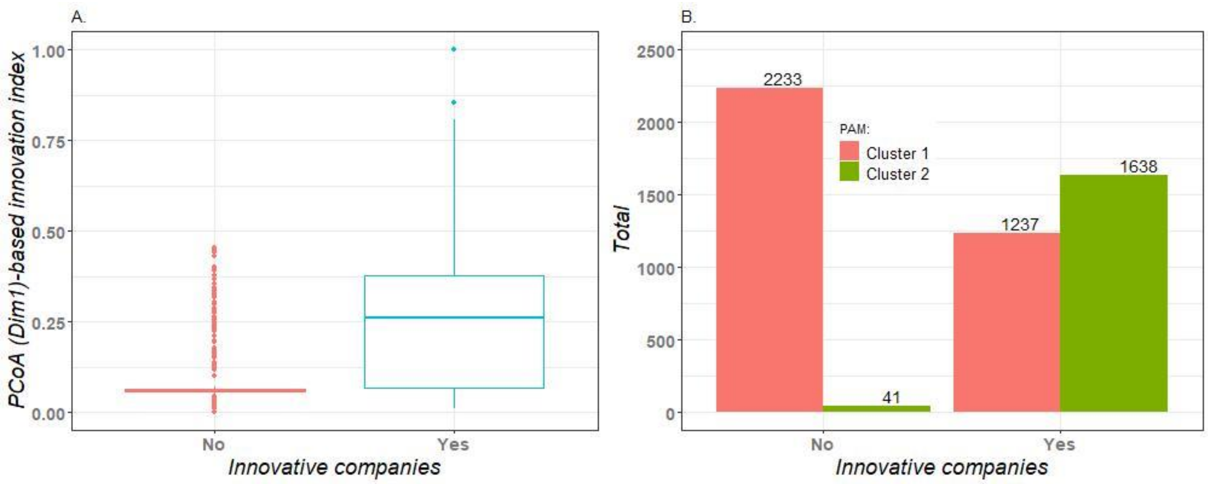


4.2 Global metrics of innovation drivers

Figure 3 shows the importance of the proposed InDri in explaining innovation through a quantitative indicator (based on PCoA) and a qualitative indicator (based on PAM). Part A of Figure 3 suggests that the use of innovation drivers could affect the innovation levels of companies. The ANOVA type III test for unbalanced data showed that a greater differentiation in the use of InDri has a significant effect on innovative companies, with a Pr(> F) < 0.05.

Figure 3

Analysis of the importance of InDri using global metrics. Part A shows the importance of InDri using a boxplot (PCoA-based metric). Part B shows the importance of InDri using a bar chart (PAM-based metric)



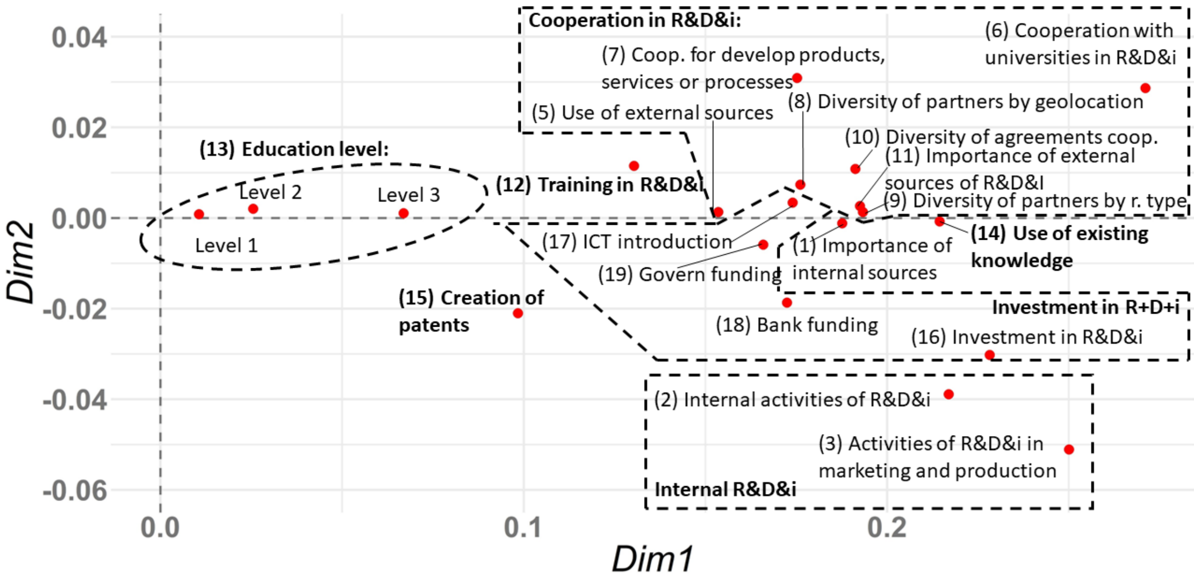
Similarly, part B of Figure 3 shows that it is likely for companies to innovate as long as the proposed drivers are managed (1,638 companies out of 1,679 managed some InDri to innovate according to the PAM model). The Pearson chi-square test with Yates continuity correction revealed that these two indicators may have some relationship. Additionally, Cramer's V coefficient suggests an association strength of 0.584/1 between innovation and the classification proposed by PAM.

4.3 Perceptual mapping of innovation drivers

Figure 4 presents the WA score analysis to map the importance of InDri modeled with PCoA in the biplot. This analysis showed the most common InDri on the left of the biplot and the least frequent on the right. In this line, the most common InDri are related to the education of human resources (ID=13): level 1 (primary and secondary) > level 2 (technical and undergraduate) > level 3 (masters and doctorates). While the less common InDri is related to cooperation with universities for the generation of R&D&i (ID=6).

Figure 4

WA scores to represent the variables of the principal coordinate analysis (PCoA) model in the biplot. "ID=4: Methods of organizing responsibilities and decision-making" is at position [(Dim1=0.068, Dim2=0.10)]



The vertical axis of Figure 4 displays the InDri linked with cooperation with external sources in the upper part. While the lower part shows the Indri associated with institutional strengthening through investment in R&D&i and the development of internal R&D&i activities. WA score analysis showed that Ecuadorian companies place a slightly higher weight on external sources (ID=5) than on internal sources (ID=2) for the generation of R&D&i.

Figure 4 shows that the geolocation of partners worldwide (ID=8), the diversity of cooperation agreements that can be negotiated (ID=10), and the diversity of partners by relationship type (ID=9) are given high priority when working with external sources to generate R&D&i.

According to the WA score analysis, public funding (ID=19) receives slightly more attention for innovation investment than private banks (ID=18). In terms of internal innovation, ICT introduction (ID=17) receives more attention than the development of R&D&i activities in the areas of marketing and production (ID=3).

The educational level of human resources was the most notable factor at the level of knowledge for innovation development (ID=13), followed by training in R&D&i (ID=12) and application of pre-existing R&D&i knowledge (ID=14).

Finally, the creation of patents (ID=15) emerged as an element that receives a lot of attention for the development of R&D&i compared to the other InDri examined, since it is situated just below the level of education of human talent (ID=13).

4.4 Contribution of innovation drivers to innovation in Ecuador

This section shows the contribution of InDri to innovation in Ecuadorian companies. Table 2 shows three logit regression models that explain innovation using the proposed InDri indicators (model 1), PCoA metric (model 2), and PAM metric (model 3). The AIC and pseudo-R^2 coefficients suggest that innovation is best explained by model 1 (model 1 > model 2 > model 3). The p-value calculated from the Wald Z statistic $Pr(> |z|) < 0.05$ indicates that the independent variables contribute significantly to explaining innovative companies. Column 2 (Exp(β)) of Table 2 shows the contribution of the variables to the odds ratio.

Table 2

Results of the logit regression explaining the innovation through InDri in its individual form (Model 1), aggregated through the first component of principal coordinate analysis (PCoA) (Model 2), and through partitioning around medoids (PAM) (Model 3)

Variable name	Exp(*β*)	z value	Pr(> |z|)	
Model 1				
(Intercept)	0.287	-17.328	2.913E-67	***
Knowledge for innovation development				
(12) Training in R&D&i	1.642	8.088	6.068E-16	***
(13) Education level (2)	1.104	2.935	3.338E-03	**
Internal innovation drivers				
(1) Importance of internal source of R&D&i	1.098	2.465	1.371E-02	*
(2) Internal R&D&i activities	2.624	3.189	1.429E-03	**
External innovation drivers				
(5) Use of external sources of R&D&i	8.491	8.84	9.600E-19	***
(10) Diversity of partners by geolocation	2.531	4.177	2.951E-05	***
Investment in innovation				
(18) Private bank financing	3.348	3.98	6.881E-05	***
(17) Introduction of ICT	2.558	4.211	2.542E-05	***
Model 2				
(Intercept)	1.071	-16.665	2.363E-62	***
PCoA(Dim1)-based index	2.071	26.403	1.260E-153	***
Model 3				
(Intercept)	0.554	-30.881	2.138E-209	***
PAM: Cluster 2	72.119	27.427	1.289E-165	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01

Pseudo-R^2 (Model 1): (Cragg-Uhler) = 0.60 (McFadden) = 0.44

Pseudo-R^2 (Model 2): (Cragg-Uhler) = 0.56 (McFadden) = 0.40

Pseudo-R^2 (Model 3): (Cragg-Uhler) =0.46 (McFadden) = 0.31

AIC: Model 1= 4001.5, Model 2 = 4269.80, Model 3 = 4909.9

Model 1 shows eight metrics explaining innovation in the Ecuadorian context. Considering the confusion matrix, model 1 explains 74% of “innovation” and 96% of “no innovation." The intercept indicates the expected value of the odds of a company innovating in the absence of drivers. Thus, model 1 was used to obtain that the probability of a company to innovate in the absence of the drivers is 22% (0.287/[1+0.287]*100).

The Indri that provided the biggest contributions to innovation in the Ecuadorian context were those connected to the geolocation of partners worldwide and the development of cooperative ties with external sources. Second, the logit model highlighted the availability of private bank financing to produce R&D&i and the introduction of ICT. Third, the development of activities and the importance placed on internal R&D&i activities were noted. Fourthly, education at the technical and undergraduate levels [education level (2)] as well as the investment in training in R&D&i were recognized as drivers that influence innovation.

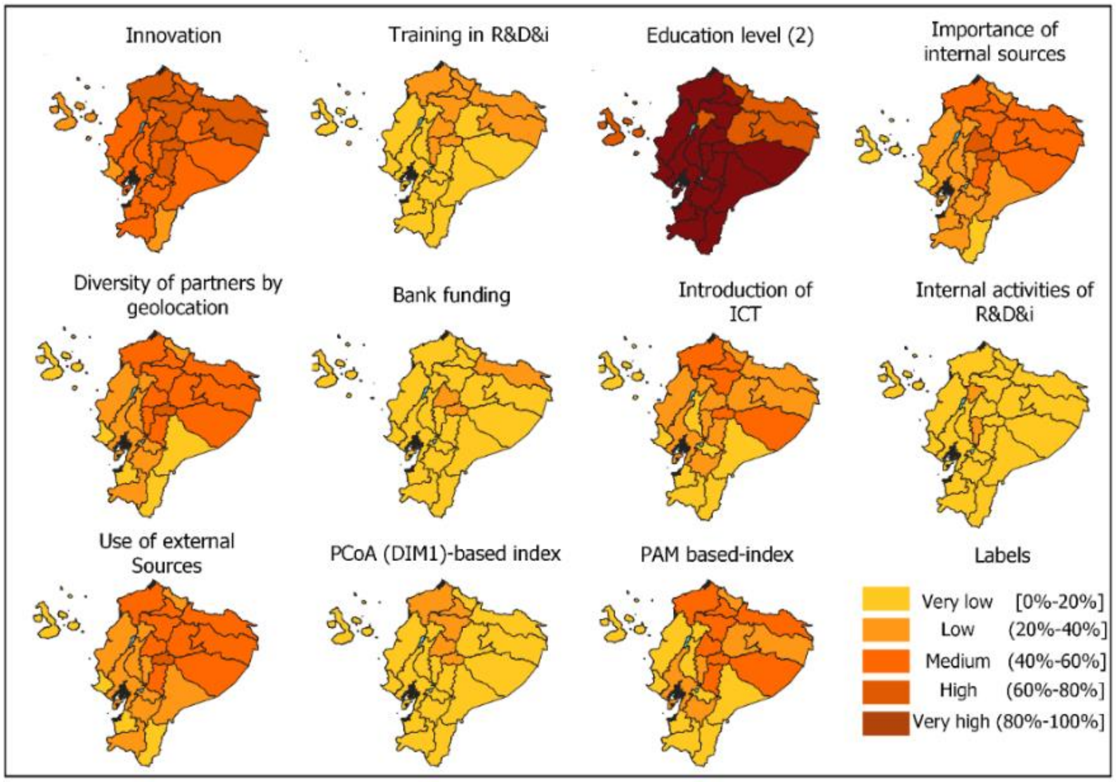
Models 2 and 3 complement the results detailed in Figure 4 and shown that the global metrics proposed with PCoA and PAM can be used to explain InDri from a global approach.

4.5 Geographical map of drivers of innovation

This section uses prevalence rates to show the geographic distribution of Ecuador's eight most significant InDri (see Table 2) at the province level. Figure 4 shows that the technical and undergraduate levels of human resources are the InDri best represented at the provincial level, while the drivers with the lowest representation are those related to bank financing, the development of internal activities of R&D&i, and training investment related to R&D&i generation.

Figure 5

Geographical representation of the prevalence of innovation, most representative InDri and the global InDri metrics. The maps were performed with QGIS free software



The innovation map displayed in Figure 5 shown that the companies with high innovation levels in Ecuador are mostly located in the north of the country (Esmeraldas, Imbabura, Sucumbíos, Pichincha, Cotopaxi, Bolívar y Tungurahua). The provinces where the InDri are higher have the highest levels of innovation, corroborating through a geographic map that the InDri behave directly proportional to the high levels of innovation.

The global metrics based on PCoA and PAM show from a global perspective that the most innovative provinces often stimulate the drivers examined in this study under the mapping innovation approach.

5 Discussion

According to our results, the most important factor for the creation of innovation in the setting of Ecuador is the development of cooperation ties with outside sources (See Table 2). This finding is consistent with Salas (2021), who notes that cooperation with external actors has a favorable impact on the launch of new goods, marketing innovations, and organizational changes in Ecuador, particularly in terms of technical support, training, and technological acquisition. As a result, we maintain that connection with external actors is crucial to develop successful innovations in Ecuador.

The development of connections with foreign actors was found to be a significant factor in the creation of innovation in Ecuador (see Table 2). Astudillo (2018) suggests that one of the key advantages of international R&D&i cooperation ties in Ecuadorian companies is the decrease in expenses associated with manufacturing or service processes. Additionally, there is evidence that suggests Ecuador engages in international cooperation initiatives with nations outside of the region, such as Corea del Sur, with whom industrial-scale cooperation is conducted (Gutiérrez, 2013).

In keeping with our research, cooperation between universities and businesses for the generation of innovation is not significant in Ecuador. This supports Coronado et al. (2014); Hewitt (2013); Velez et al. (2019), the assertion that, in contrast to developed economies like the United States, where companies have more effective relations to promote innovation, there is very low cooperation between universities and companies to generate innovation in the Ecuadorian context and throughout Latin America in general. Among the main limitations that make cooperation between companies and universities difficult are differences in culture, style, use of time, and organizational goals (Vega et al., 2011). In this way, the need for a policy that brings companies and universities closer to the generation of innovation becomes evident.

The current study provided evidence that the introduction of ICT is a significant driver that encourages innovation in Ecuador (see Table 2). Vásquez (2021) concurs with our findings, particularly in the context of large Latin American companies, where the adoption of ICT policies is nimbler and quicker due to their purchasing power, prior technological exposure, adaptability, and organizational climate.

On the other hand, bank financing, the development of internal R&D&i activities, and training in R&D&i were variables with minimal prevalence at the provincial level in the Ecuadorian context, despite being significant factors in the generation of innovation (see Table 2):

- According to Franco et al. (2019), there are not many financing options for innovation projects in Ecuador, which is a constraint on a company's expansion into new markets. According to Sierra (2018), this issue is especially prevalent in the context of small and medium-sized companies because bank funding is difficult for them to obtain due to the high cost of interest rates; as a result, they are forced to rely on their own money, family, or friends.
- According to published research, most Ecuadorian companies lack internal R&D&i departments and instead typically use outside consultants for these tasks (Seclén, 2016). Therefore, internal frameworks are necessary to promote innovation, improve corporate procedures, and gain a competitive edge (Seclén, 2016).
- At the level of training in R&D&i, we agree with Sumba and Santistevan (2018) who claim that there is little investment in training in R&D&i in the Ecuadorian context. One of the main causes that limits training in R&D&i is the high expense of this kind of service, as demonstrated by Maliqueo et al. (2021).

It is noteworthy to note that the level of education linked to master's and doctoral degrees at the time of analysis was a factor that the current study did not find to be statistically significant. Our findings imply that, at the time of analysis, the level of professionals is insufficient to influence innovation, despite the assertions made by authors like Hitner & Tapia (2018) that educational attainment can have an impact on the processes of innovation. According to the Ecuadorian statistics, only 10 out of every 1,000 adults of working age in Ecuador hold master's or doctoral degrees, suggesting that there are not many professionals with these profiles (INEC, 2023; SENESCYT, 2023).

On the other hand, even though Ecuadorian companies place a high value on using patents to protect their intellectual property (see Figure 2), the logit model showed that the contribution of this variable is minimal in Ecuador. Our findings are in line with Loor and Carriel (2015) who suggest that intellectual protection mechanisms in Ecuador are undeveloped. Almeida et al. (2020) argues that one of the main causes that hinders Ecuador from using this intellectual property system is unawareness of it. Días (2019), Ortiz (2019) evinced that innovation in Ecuador and developing countries often fall short of international standards and consequently there is a low level of patenting.

The use of existing knowledge in scientific databases was another variable that was not explained by the innovation in the logit model (see Table 2). Our results showed that this InDri is underrepresented in Ecuador (see Figure 4). Among the factors that limit the use of databases for the generation of innovation are the high cost of access and the lack of understanding of the worth of this knowledge by companies, as can be deduced from Ferrer (2008).

Finally, Figure 5 showed that the geographical position of the companies played an important role in the Ecuadorian context in terms of innovation. This finding is in line with what

Ruiz (2008) suggested about the concentration of innovation in specific geographical areas and the reduction of innovation as they move away from the most innovative areas.

6 Final Considerations

Through the mapping innovation approach, it was feasible to analyze the drivers of innovation from four perspectives: a) internal drivers of innovation, b) external drivers of innovation, c) knowledge for innovation development, and d) investment in innovation. After reviewing the ACTI survey, we were able to come up with 19 metrics to explain the significance of these four innovation-related components in Ecuador. As far as we are aware, this is the first study to investigate the drivers of innovation from a comprehensive approach of mapping innovation in Ecuador.

The estimations of PCoA and PAM allow us to divide the level of differentiation of Ecuadorian companies regarding the use of innovation drivers into two categories: 1) companies with little differentiation in the use of innovation drivers (67% of the companies) and 2) companies with greater differentiation in the use of innovation drivers (33% of the companies). The creation of two global metrics based on the results of PAM and PCoA allowed us to analyze the importance of the use of InDri for Ecuadorian innovation. With the help of the ANOVA type III test for unbalanced data and the chi-square test, it is determined that a higher differentiation in the use of innovation drivers encourages a bigger development of innovation. This finding allowed us to suggest that increased use of the suggested drivers would increase the likelihood of innovation.

The most frequent drivers of innovation were related to the educational level of the human resource, training in R&D&i, the use of external sources of innovation, and the creation of patents (see Figure 4). As a result of our findings, it should be emphasized that innovation did not significantly depend on the usage of patents at the time of analysis.

The drivers of innovation that have been found to have the greatest contribution to Ecuadorian innovation are those connected to cooperation with external sources (see Table 2). Where the establishment of international cooperation links is a determining factor in the development of innovation of Ecuadorian companies.

At the level of internal sources of innovation, the development of internal R&D&i activities and the amount of importance leaders give to R&D&i sources were shown to be factors that influence the development of R&D&i (see Table 2).

According to our research, the innovation drivers related to knowledge that most significantly affect Ecuadorian innovation are training in R&D&i and education at the technical and undergraduate levels of human resources. It is interesting to note that, as of the analysis date, there is a demand for fourth-level specialists in innovation fields. The low use of scientific databases was also shown to be a barrier to innovation in areas where governments could implement innovation policies through institutions like government libraries.

Despite Ecuador's limited availability of finance for innovation, it was shown that private bank financing is a key factor in innovation at the investment level. The findings also stated that the introduction of ICT in companies hastens the development of innovation in Ecuador. Additionally, our results allowed us to draw the conclusion that Ecuador suffers from a lack of government funding for innovation (see Figure 4).

It is noteworthy to note that cooperation with universities, companies investment in R&D&i, and the development of R&D&i activities in the marketing and production divisions (see Figure 4) are the least frequent sources of innovation in Ecuador. Therefore, it is advised that R&D&i policies be supported to strengthen the development of these drivers as a measure to increase the level of innovation in Ecuadorian companies.

The geographical component is shown to be crucial in the creation of innovation in Ecuador. The most innovative companies typically operate in the northern and central regions of the nation, particularly the provinces of Esmeraldas, Imbabura, Pichincha, Cotopaxi, and Tungurahua (see Figure 5).

One of the great challenges of this study was managing the diversity of metrics, which varied among numerical, nominal, and binary. Most of the existing metrics in the databases of the region are based on the Oslo manual and respond to this characteristic (Guillard & Salazar, 2017). In the current study, Gower's measure and the PCoA model allowed us to address this particularity and complete a comprehensive mapping of the drivers of innovation. Considering this, we acknowledge for future research the need to develop a tool that would enable the analysis of innovation drivers with standard metrics that are easier to handle.

Finally, this study helped identify the strengths and weaknesses of innovation drivers in Ecuador. Thus, individuals responsible for generating public policies at the innovation level should recognize and promote these drivers and encourage the generation of new products or services at the business level.

In summary, the findings of our study benefit private organizations, the government of Ecuador, developed countries, and researchers by facilitating a better understanding of the drivers of innovation, thus allowing the formulation of strategies to promote R&D&i in less-developed countries. Furthermore, the proposed methodology provides a basis for a better understanding of the analyzed drivers not only at the organizational level but also at the national, or regional levels.

AUTHORS' CONTRIBUTIONS

Contribution	Hidrobo, M.J. T	Marcillo, D.J.C	García, C. A
Contextualization	X	X	X
Methodology	X	X	----
Software	X	X	----
Validation	X	X	X
Formal analysis	X	X	X
Investigation	X	X	X
Resources	------	------	X
Data curation	------	X	------
Original	X	X	X
Revision and editing	X	X	X
Viewing	X	X	X
Supervision	X	-------	X
Project management	X	-------	-------
Obtaining funding	-------	-------	-------

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APPENDIX A

Table 3

Measurement of proposed metrics through the ACTI 2015 survey

ID	Metric/Description of the ACTI survey variable	Variable type*
1	Importance of internal sources: Index of importance of internal and external sources of innovation (add the scale of importance of question VIII.1.1: none (0), low (1), medium (2), and high (3)).	polytomous
2	Internal activities of R&D&i: Units of the company that have conducted R&D&i (question V.2).	binary
3	R&D activities in the areas of marketing and production: Source of internal innovation (question V.2 c, f).	binary
4	Methods of organizing responsibilities and decision-making: Implementation of new methods for organizing responsibilities and making decisions (question XI.3 b).	binary
5	Use of external sources of R&D&i: External sources of innovation (question VIII.1 1.2 a-c, e).	binary
6	Cooperation with universities: Collaboration in R&D&i and innovation with universities (question VIII.2.e).	binary
7	Cooperation for develop products, services, or process: Cooperation for development of products, processes, or services (question III.2.b, IV.2.b, d).	binary
8	Diversity of partners by geolocation: Index corresponding to the geolocation of the innovation partners (count of variables from question VIII.3).	polytomous
9	Diversity of partners by type of relationship: Index of importance from different external sources (participation count on question VIII.1.2).	polytomous
10	Diversity of agreements cooperation: Index of objective of cooperation with companies (count of question VIII.2).	polytomous
11	Importance of external sources: Index of intensity of internal and external sources of innovation (add the scale of importance of question VIII.1.2: none (0), low (1), medium (2), and high (3)).	polytomous
12	Training in R&D&i: Total, people trained in R&D&i (question XIV.3).	scale

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13	Education level: Educational level of the workers measured in years ((sum of question XIV.1 ag multiplied by the years studied), level 1 (Primary (6) and Secondary (12)), level 2 (Technical (15) and third level (16)), and level 3 (Specialist (17), Master (18) and Doctorate (21))).	scale
14	Use of existing knowledge: Use of databases of scientific publications (question VIII.1 1.2 j-l).	binary
ID	**Metric/Description of the ACTI survey variable**	**Variable type***
15	Creation of patents: Formal protection methods for “patents” (question XV.3.b).	binary
16	Investment in R&D&i: Total expenditure on internal and external R&D&i in 2014 (question V.1).	scale
17	Introduction of ICT: Introduction of ICT innovations (question V.4, b, c, d, f).	binary
18	Private bank financing: Financing from "bank support” (question to VI.1, b).	binary
19	Government sector financing: Financing from “government support” (question to VI.1, a).	binary

Note: /* scale variables were used in their logarithmic form by applying $log(x + 1)$