Journal of Positive School Psychology http://journalppw.com
2022, Vol. 6, No. 6, 8611-8619

Gii Innovation Resource Index And Agriculture In The Province Of Los Ríos; An Analysis Using Neural Networks

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Abstract

Innovation is one of the main and fundamental tools for the development of the agricultural system, since it increases the productivity and competitiveness of any country. The objective of this research is to analyze the status of companies and enterprises as a development factor in the agricultural sector of the province of Los Ríos-Ecuador through the components of the Global Innovation Index (GII) based on the resources they possess for innovation. Within the methodology, principal component analysis, multiple linear correlation and ANOVA analysis of variance were used to relate the aforementioned territorial cut and the GII indexes. In addition, a neural network model was developed to analyze the importance of each factor; within the main deductions, it can be established that there is a relationship between the main innovation factors (innovation resources index) and the state of agricultural enterprises and ventures in the province of Los Ríos. Furthermore, the factors with the highest hierarchy for the development of the province based on the results of neural networks are: market sophistication, institutions, business sophistication, and based on the beta relationship coefficient the most important causality variables can be determined based on the development of the agricultural sector such as: infrastructure, human capital and institutions. With these results, it would be convenient to propose integral strategies based on Technology and Innovation Management models, focused on all the elements of innovation (Institutions, Human Capital, Infrastructure, Market Development, Business Development).

Keywords: Innovation, agriculture, Global Innovation Index (GII), neural networks, neural networks.

Resumen

La innovación es una de las herramientas principales y fundamentales para el desarrollo del sistema agropecuario, ya que aumenta la productividad y competitividad de cualquier país. El objetivo de esta investigación es analizar el estado de las empresas y emprendimientos como factor de desarrollo en el sector agrícola de la provincia de Los Ríos–Ecuador a través de los componentes del índice global de innovación (GII- Global Innovation Index) en base a los recursos que posean para su innovación. Dentro de la metodología, se consideró el análisis de componentes principales, correlación lineal múltiple y aanálisis de la varianza ANOVA esto para relacionar el corte territorial antes mencionado y los índices GII: además, se elaboró un modelo de redes neuronales para analizar la importancia de cada factor; dentro de las principales deducciones se puede establecer que existe relación entre los principales factores de innovación (índice de recursos para la innovación) y el estado de las empresas y emprendimientos agrícolas de la provincia de Los Ríos; además, los factores con mayor jerarquía para el desarrollo de la provincia en base a los resultados de redes neuronales son: sofisticación del mercado, instituciones, sofisticación del negocio, y en función al coeficiente de relación beta se pueden determinar las variables de causalidad más importantes en base al desarrollo del sector agrícola como: la infraestructura, el capital humano y las instituciones. Con estos resultados sería conveniente plantear estrategias integrales basadas en modelos de Gestión de la Tecnología e Innovación, enfocados a todos los elementos de innovación, (Instituciones, Capital Humano, Infraestructura, Desarrollo de Mercado, Desarrollo empresarial)

Palabras clave: Innovación, agricultura, Índice Global de Innovación (GII), redes neuronales

INTRODUCTION

Ecuador is located in South America, composed of four regions: Coast, Highlands, Amazon and Galapagos and divided into 9 territorial zones with 24 provinces, its economy has a Gross Domestic Product (GDP) of 108.4 billion dollars with a growth rate of 1.4% per year and a GDP per capita of 6,344.87 of dollars, its primary sector is composed of agriculture and mining employs 40% of the country's working population contributing almost 50% of the foreign exchange that enters the national territory (Ministry of Foreign Affairs and Cooperation, 2019) - (World Bank, 2020).

The impact of this study is the novelty and the theoretical-practical contribution of new knowledge as a result of the research process on the management of GI innovation. The objective of this research is to analyze the innovation of the agricultural sector in the Province of Los Ríos based on the components of the Global Innovation Index (GII) using a neural network model.

Based on the Global Innovation Index 2020 (GII-Global Innovation Index), Ecuador is in the global innovation ranking in 99th place among 131 countries. This location gives indications of a low performance in innovation due to the lack of investment in research and development (R&D), in which inadequate regulation of intellectual property protection and insufficient synergy between higher education institutions, government and private institutions index. It should be noted that the GII study evaluates seven important aspects: institutions, human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technology outputs and creative outputs (Soumitra & Sacha, 2020)-(ANGULO, 2020)- (World Intellectual Property Organization -WIPO, 2020).

According to the Research on Science, Technology and Innovation Activities applied by the National Institute of Statistics and Census (INEC) and the National Secretariat of Higher Education, Science, Technology, and Innovation (SENESCYT), in 2014, 37 % of Ecuadorian companies would have made some financial effort with the purpose of innovating, due to the fact that there is no innovation ecosystem in the country. Furthermore, this research shows that there are no companies in the agricultural sector that have stood out as agents of innovation, which is evidence of a lack of innovation in state policies (Medina, 2019).

Los Ríos is one of the 24 provinces of Ecuador, located in the coastal region of the country. Its capital is the city of Babahoyo and the most populated town is the city of Quevedo, which has 13 cantons (Canton Babahoyo, Mocache, Urdaneta, Buena Fe, Puebloviejo, Montalvo, Palenque, Valencia, Ventanas, Quevedo, Baba, Vinces), noted for its agriculture in general, particularly for rice cultivation, and fishing activities. It is one of the most densely populated provinces in the country.

Figure 1 Los Ríos Province

Its economy is supported mainly by the agricultural sector, especially the banana and corn sector according to the BCE, (2020), agricultural activities such as livestock, accounted for 40% of the total foreign exchange of the province; which also represented USD 1,415 million.

Quevedo, Babahoyo, Valencia, Pueblo Viejo, and Ventanas are the main producing cantons of the agricultural sector, having as main products: green plantations, rice, cocoa corn; corn production is concentrated in Ventanas, being this locality responsible for collecting an average of 5.5 million quintals each year. Also, the economy of Fluminense has an important contribution that comes from the commercial, construction and transportation sectors, generating 47% of foreign exchange of the provincial trade, with USD 223 million, being the following Babahoyo with 69 million dollars and Ventanas with 39 million dollars (Terán, 2018).

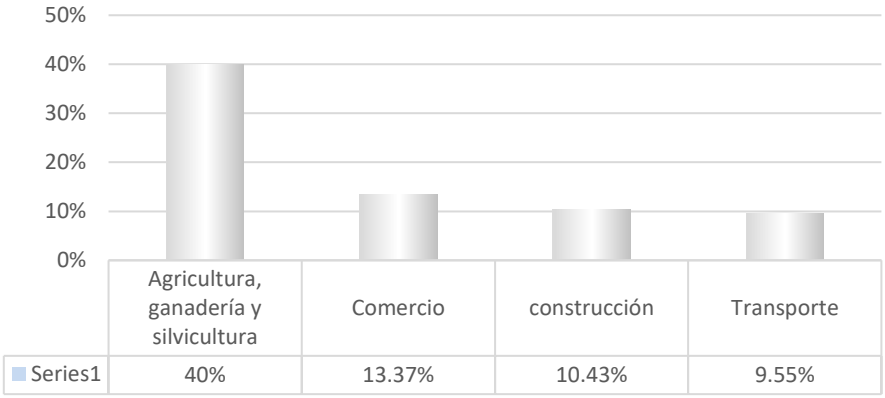

Figure 2. Sector Divisions in Los Ríos
SOURCE: (BCE, 2020)

METHODOLOGY

The observation units considered were the companies and agricultural enterprises registered with the Servicio de Rentas Internas SRI and included in the ISIC-01 (International Standard Industrial Classification) in agriculture in the province of Los Ríos and its cantons: Baba, Babahoyo, Buena Fe, Mocache, Montalvo, Palenque, Pueblo Viejo, Quevedo, Quinsaloma, Urdaneta, Valencia, Ventanas, Vinces, which represented a total of 16852 observation elements (Table N°1).

Table 1. Agricultural enterprises in Los ríos

Detail	Frequency	Percentage
Baba	560	3,3
Babahoyo	3131	18,6
Buena Fe	1236	7,3
Mocache	1891	11,2
Montalvo	662	3,9
Palenque	1222	7,3
Pueblo Viejo	1104	6,6
Quevedo	1811	10,7
Quinsaloma	581	3,4
Urdaneta	568	3,4
Valencia	955	5,7
Ventanas	1604	9,5
Vinces	1527	9,1
Total	**16,852**	**100.0**

For this article, two different databases were considered, the first was from the Internal Revenue Service of Ecuador (SRI) and the second was from the Global Innovation Index 2020 (GII - Global Innovation Index), which is relevant information for this research.

The predominant factors assessed within the SRI Ecuador database are number of companies and businesses engaged in agriculture, location, status (active and inactive), International Standard Industrial Classification (ISIC). The GII data were business development, infrastructure, creative production, institutions, human capital, scientific production, market development. For the processing of the information, a data set was created by joining the two aforementioned bases, this was done in the software 〖SPSSSS〗^R, taking into account the following criteria: year of incorporation, year of market exit and also that they are subject to the different factors GII and ISIC-01 A / within the Table 2.

Table 2. Factors identified from the Global Innovation Index

SRI Data Bank	Information
Internal Revenue Service (SRI) Ecuador	-Farming enterprises
	-Location
	-Status (active and inactive)
	- (CIIU)/01 Agricultura
GII Data Bank	**Innovation coefficients**
Global Innovation Index (GII)	-Business development
	-Infrastructure
	-Institutions
	-Human capital
	-Market Development

Study Variables

Dependent Variable

The following are considered as dependent variables; status of agricultural enterprises within the province of Los Ríos; active companies are companies or enterprises that are in operation within the market and the inactive ones are businesses that in the course of time ended their economic activities (Monge & Amparo, 2016).

Independent Variable

The GII coefficients were considered as independent variables for innovation resources (Institutions, Human Capital, Infrastructure, Market Development, Business Development), as detailed in Table 3.

Table 3. GII innovation coefficients

Detail	Factor	KPI
Innovation resource index	Institutions	Political environment
		Regulatory environment
		Business environment
	Human Capital	Education
		Third level training
		Research and development
	Infrastructure	ICT
		Energy
		General infrastructure
	Market Development	Credit environment
		Investment environment
		Business environment
	Business development	Job specialization
		Ecosystems and innovation
		Knowledge absorption

Source: (Baratas, 2021)

Models used

Multiple linear regression tries to fit linear or linearizable models between a dependent variable and the independent variables (Montero Granados, 2016), in this type of models it is important the heteroscedasticity, multicollinearity and the function that relates the dependent variable with the independent variables, i.e.: r=(σxy)/(σxσy) (Amat, 2016).

The Analysis of Variance (ANOVA) constitutes the tool for the study of the effect of one or more factors on the mean of a continuous variable, the statistic (Ordaz et al., 2021) is the ratio between the variance of the means of the groups and the average of the variance $F = (S_1^2/\sigma_1^2)/(S_2^2/\sigma_2^2)$ with $(N_1 y\, N_2)$ degrees of freedom, given that two of the conditions are the normality of the groups and the homoscedasticity of variance, it can be determined that ($\sigma\ n_1 \dots n_x = \sigma\ n_1 \dots n_x$) (Amat, 2020).

A neural network (NN) is a model composed of "neurons", which in turn are organized into groups called layers. The purpose of the neurons is to apply a transformation to the data received in (x) and predict a continuous or categorical value in the last layer. Each neuron presents two sets of parameters, weights and biases (Velo Fuentes, 2020). When the input data arrives at a neuron, a linear function is computed. That is: Z=W*X+b where X, W and b are the input data, weights and biases respectively. When it is desired that the NN "learns" nonlinear patterns, a new function is applied to Z. This is known as the activation function: A=g(Z)=g(W*X+b), this process is repeated for each neuron until reaching the output layer to compare the output of the network with the data to be predicted, the loss function is used taking into account the mean square error (MSE), where y_i is the output of the neural network - (Repetur, 2019).

$$\mathrm{MSE} = \frac{\sum_{i=1}^{N}(y_i - \hat{y}_i)^2}{N}$$

RESULTS

Based on the analysis of the dependence between the dependent and independent variables, methods used were principal component analysis: multiple linear correlation, analysis of variance ANOVA; then the causality analysis is presented through beta analysis and finally the results of the importance model by neural networks.

Principal component analysis

Based on the principal component analysis, a Kaiser-Meyer-Olkin measure of 0.505 with a Chi-square approximation of 278139.724 and a significance of 0.00 can be determined, which indicates that there is a relationship between different variables (Institutions, Human Capital, Infrastructure, Market Development, Business Development), and can also be grouped into different components.

Table 4. KMO and Bartlett's test

Measurement Kaiser-Meyer-Olkin	**0,504**
Approx. Chi-square	278139,724
Gl	10
Sig.	0,000

The total variance explained shows that with 82.45% of the total variables, the research can be explained by two main components; the first with the factors: human capital, market sophistication, institutions and the second with infrastructure and business sophistication.

Table 5. Component matrix[a]

Detail	Component	
	1	2
Infrastructure	0,283	0,628
Human Capital	0,994	-0,101
Business Sophistication	0,162	0,791
Market Sophistication	0,994	-0,100
Institutions	0,994	-0,107

Extraction method: principal component analysis.
a. 2 components extracted.

From the grouping of the components represented in Figure 3, it can be determined that there is a significant relationship between human capital, market sophistication, institutions, this may be due to the fact that the political and business environment, the market

and investment credit environment is linked to the people who manage it, this creates susceptibility within these processes, while business sophistication is subject to the business ecosystem, work specialization, plant automation, information and communication technologies; this creates a differentiating plus between each organization and its environment.

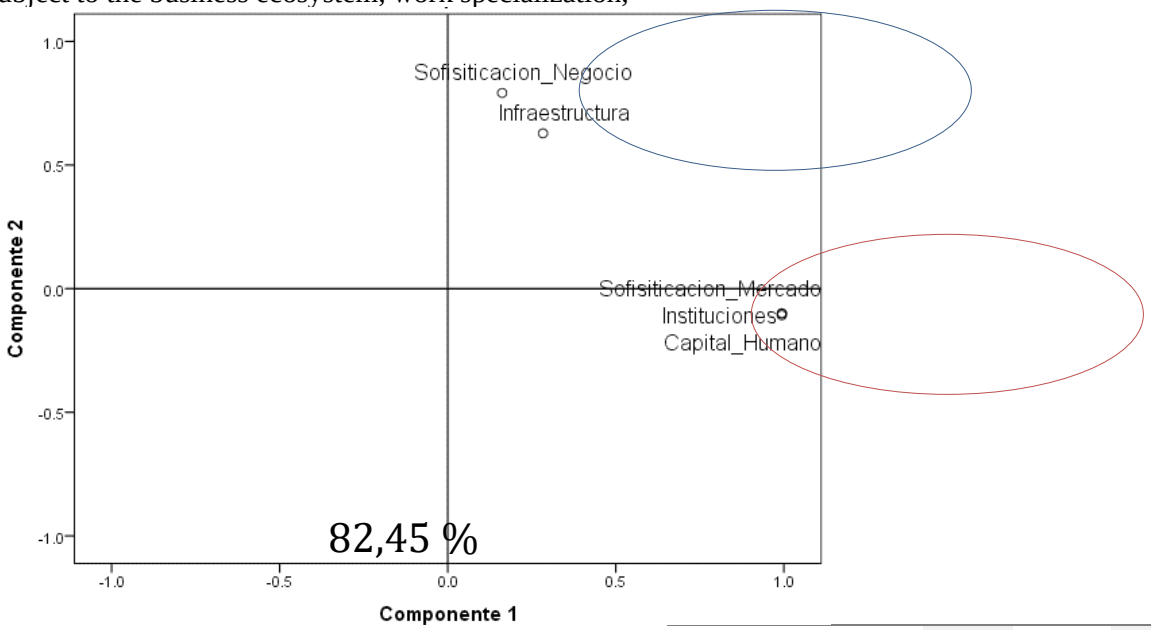

Figure 3. Principal component plot
Source: SPSS

Multiple linear regression

Considering Table 6, based on the multiple correlation, it was determined that there is a correlation between the development of the agricultural sector in the province of Los Ríos-Ecuador and the GII innovation factors, with an R of 0.247 and a significance of 0.00 in F.

Table 6. Summary of the multiple regression model[b]

Model	R	R square	Standard error of the estimate	Sig. change in F
1	0,247a	0,061	0,468	0,00

a. Predictors: (Constant), Institutions, Business Sophistication, Infrastructure, Human Capital.
b. Dependent variable: ESTABLISHMENT_STATUS

From the analysis of variance (ANOVA), in which an assimilation was performed between the active and liquidated companies of the agricultural sector of the province of Los Ríos - Ecuador and the resource factors for innovation within the GII, a significance in F of 274.25 with 4 degrees of freedom and a significance of 0.000 was established, this determined that there is a relationship between the study variables, (Table 7).

Table 7. ANOVA[a]

Model	Sum of squares	Gl	Root mean square	F	Sig.
Regression	240.779	4	60.195	274.254	0.000[b]
Residual	3697.666	16847	0.219	-----	-----
Total	**3938.445**	**16851**	-----	-----	-----

a. Dependent variable: ESTABLISHMENT_STATUS.
b. Predictors: (Constant), Institutions, Business_Sophistication, Infrastructure, Human_Capital

This highlights what Vargas Canales et al. (2016) mentioned that innovation is a factor that is closely related to boosting agriculture, as it drives the growth of human capital, the development of supply chains and key, value-adding, and operational processes within institutions. Likewise, taking (Villalobos et al., 2020), who suggests that innovation is a fundamental tool for improving productivity, efficiency, social, and environmental economic impact of the agri-food sector.

Within the analysis of the beta coefficients, of causality with relation for each GII factor as innovation resources and the state of the companies and enterprises of the agricultural sector (Table 8). It was determined that there was a relation between infrastructure, human capital and institutions with Sig of 0.00 - 0.049 - 0.00 consecutively. The factors that did not have a strong dependence were business and market sophistication, which may be due to the agricultural development in the area, its technification in the processes, and the lack of development of supply chains and distribution channels.

Table 8: Coefficients[a]

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Standard error	Beta		
(Constant)	1,332	0,349		3,821	0,000
Infrastructure	0,000	0,000	-,037	-4,831	0,000
Human Capital	0,000	0,000	0,508	1,970	0,049
Sophistication Business	0,002	0,001	0,010	1,184	0,236
Institutions	0,000	0,000	-0,745	-2,889	,004
Excluded variables[a]					
Sophistication Market	-7.810[b]	8,553E-05	-0,075	-9,703	0,000

a. Dependent variable: ESTABLISHMENT_STATUS.
b. Predictors in the model: (Constant), Institutions, Business Sophistication, Infrastructure, Human Capital.

Neural network

Based on the neural network model, the gradient method was used with a normal layer and four hidden layers. This process is repeated based on different iterations; within the process, a training of the network was performed with 70% of the total population and tests with the remaining 30% without any excluded data within the pattern.

Table 9. Case processing summary (neural network)

Model NN	N	Percentage
Training	11818	70,1 %
Tests	5034	29,9 %
Valid	16852	100,0 %
Excluded	0	-----
Total	**16852**	-----

Three practices were proposed with one with an activation function, taking an output layer and an initial lambda of 0.0000005, as well as an initial sigma of 0.00005 and a significance of +- 0.5, in which the relative error of the test is less than the training, this means that there is greater normality between the data and the information that they will yield within the neural network model.

Table 10. Summary of the model

Training	**Sum of squares error**	**5600,209**
	Relative error	0.948
	Stopping rule used	-of error[a]
	Preparation time	0:00:00,03
Tests	Sum of squares error	2395.807
	Relative error	0.941

Dependent variable: ESTABLISHMENT_STATUS
a. Error calculations are based on the check sample.

In the normalization of the neural network (NN), it can be indicated that the variables with the highest hierarchy within the model is market sophistication with 100% normalization importance, followed by the variables of institutions and business sophistication, with a total of 76.2% between them, while those with the lowest impact are: human capital and infrastructure with a total percentage of 23.7% (Table 11).

Table 11. Importance of independent variables

Detail	Importance	Percentage	Standardized importance
Infrastructure	0,132	13,2%	35,30%
Human Capital	0,105	10,5%	28,10%
Business Sophistication	0,18	18,0%	48,10%
Market Sophistication	0,374	37,4%	100,00%
Institutions	0,208	20,8%	55,50%

In terms of the agricultural sector, it can be determined that it has natural potential to increase its production levels within the province of Los Ríos, together with an appropriate market system with sufficient support from different public and private institutions. The development of human capital (education, professional training, training), research and development (R&D), and infrastructure as a development variable (installed

plant, management of automation systems, administration of information and communication technologies, development of agriculture) as the main axis in a new way of doing business in the agricultural sector are points to be improved.

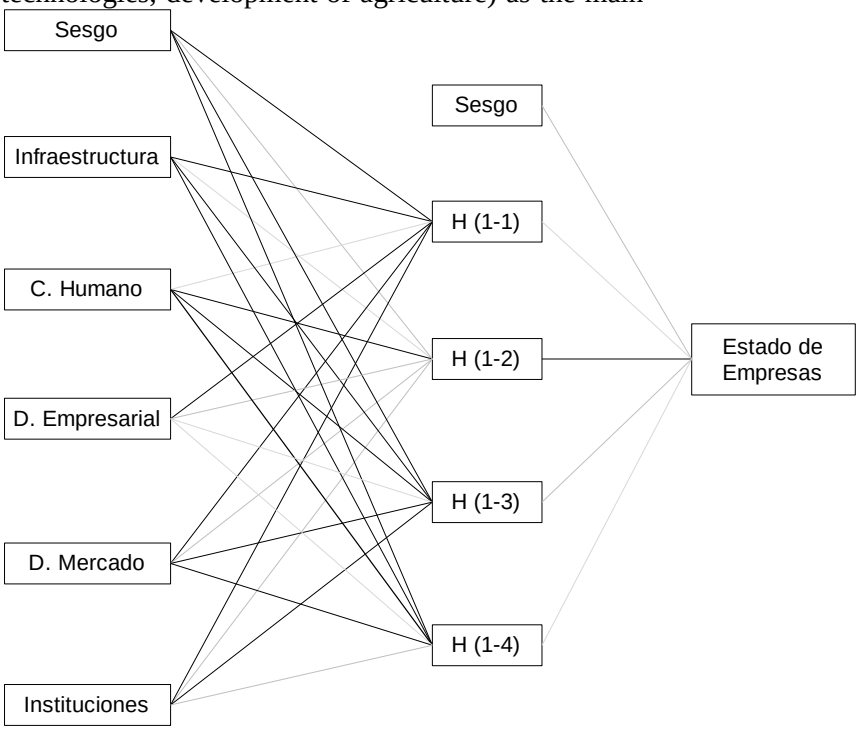

Figure 4. Innovation and Agriculture Neural Network of the province of Los Ríos

CONCLUSIONS

The main results of this research are as follows:

- The statistical analyses performed (KMO, multiple linear correlation and Analysis of Variance ANOVA) reiterated a relational inference between the main factors of innovation development of the GII and the status of agricultural enterprises and ventures as a factor of development in the province of Los Ríos.

- The neural network analysis indicates that the factors with the highest hierarchy for the development of the province based on the results of neural networks are: market sophistication, institutions, business sophistication, results, while those that precede are: human capital and infrastructure; in addition, taking the principal component analysis, it can be determined that it extends related variables in two large devices (human capital, market sophistication and institutions)-(infrastructure, business sophistication).

- Based on the beta relationship coefficient, it can be determined that the most important causal variables for the development of the agricultural sector in the Province of Los Ríos are: infrastructure, human capital, and institutions; this describes a cause-and-effect relationship in the agricultural development within the study area.

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