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Abstract: Sustained growth and progress towards more equitable societies with better opportunities for all depends on how competitive a country could be, which in turn depends on the productivity of its economic sectors. The study aims to analyze the influence of technological innovation to Ecuador's gross domestic product, using a neutrosophic cognitive map that defines the factors that directly affect technological innovation. The PESTEL framework is used to identify the political, economic, social, technological, ecological, and legal factors that contribute to technological innovation in Ecuador's gross domestic product. For this purpose, a quantitative analysis was carried out based on the static analysis and neutrosophic numbers, which facilitated the applicability of the proposal. The main contribution present work is the analysis of interrelations and uncertainty/indeterminacy for analysis of technological innovation. The results show the importance of political and legal factors related to technological innovation projects to gross domestic products growth in Ecuador. The work ends with the conclusion and recommendations for future work.

Keywords: Technological innovation; PESTEL; neutrosophic numbers, neutrosophic cognitive maps; static analysis

1. Introduction

Latin America has made significant progress in stabilizing macroeconomic policies that have kept its economies growing, even in an adverse international context. However, sustained growth and progress towards more equitable societies with better opportunities for all depend on how competitive the region can be, which in turn depends on the productivity of its economic sectors. It is a fact that Latin America has significant lags in productivity and competitiveness compared to other developing regions [1].

Ecuador is not an exception, macroeconomic stability has improved, and gross domestic product (GDP) grew more than 5% according to [2]. However, behind this past growth, there is a little diversified economy that concentrates on products and exports that are not very intensive in specialized knowledge and added value. This entails a risk for the country's growth in the long term, which is as imminent as it is worthy.

The issue of innovation must be analyzed with a systemic approach, which addresses not only the individual performance of the parties but also their interactions. Investment in innovation, acquisition, absorption, modification, and creation of technological and non-technological knowledge are indispensable activities for the development of any economy [3]. When dealing with activities that demand sophisticated inputs, which involve risks and face market failures, their success depends on the systemic and systematic interaction of the public sector, the private sector and the entities capable of generating knowledge.

These coordination needs require a national strategy with short, medium and long term objectives. It is also for this reason that the theme of innovation must be analyzed with a systemic approach, which addresses not only the individual performance of the parties but also their interactions.

The National Innovation System of Ecuador is characterized by unprecedented public investment in innovation activities and the creation of a highly qualified human talent base. This analysis benefits from unprecedented quantitative information on the subject of entrepreneurship and highlights the presence of a critical mass of entrepreneurs who innovate and generate growth opportunities for the country, especially in the services sector.

It should be noted that Ecuador has shown a relatively good economic performance in recent years, but its low starting point means that it still has a way to go before reaching the average level of per capita income in the region. Even high levels of poverty and inequality pose the imperative of growth.

One of the weakest points for Ecuador's growth is the low level of total factor productivity (TFP), which explains more than 70% of the income gap with the United States are is where the role of innovation as an engine of economic growth and productivity takes relevance.

The existence of a causal link between innovation (especially I+D) and growth is reflected in the positive social returns of innovation activities. In the case of Ecuador, the social return rate of investment in I+D would be around 47% and that of investment in physical capital around 12%. This would imply that investing in I+D is almost four times more profitable than an investment in capital, which shows the vast space that exists to invest in I+D and generate value.

Despite the above, innovation does not occur at optimum levels automatically, since there is a set of problems or failures that make the investment in innovation by agents less than the social optimum. These problems can be grouped into four categories:

1. Insufficient appropriation of benefits
2. Information asymmetries
3. High uncertainty
4. Coordination problems

From the analysis of existing indicators and the processing of quantitative information, it is observed that Ecuador has a long way to go. Concerning the regulatory framework and the business climate, in Ecuador, people need a lot of days, procedures and money to open a company.

As for the protection of intellectual property, it is inferior to that of all the reference countries in the region. The levels of use of standards remain low compared to the rest of the region

Tax schemes and benefits need higher specificity: they are incentives that favor the retention of profits, which affects the investment in working capital, but they do not point to invest in innovation in a particular way. On the positive side, levels of broadband penetration have increased steadily in recent years and are expected to continue to do so; even Ecuador has been the country in Latin America where the use of the Internet has grown fastest in recent years.

Respectively, different inputs for innovation are analyzed, both empirically and conceptually for the Ecuadorian case, where countries of the region and developed economies are used as a point of comparison. Specifically, investment in I+D and its composition, human talent, and access to credit through the financial market are studied.

The indicator traditionally used to measure the intensity of innovation activities in an economy is the expenditure made in I+D. Human talent is another indicator that is used to measure innovation concerning the Gross Domestic Product, in this sense, Ecuador has achieved significant improvements in the enrolment of students in educational institutions and adequate access to higher education of the students lower quintiles.

Concerning the quality of children's education, Ecuador has participated in some international comparative learning tests, in which it has been documented that the quality of a year in school for the average child in this country is well below international standards and, in the Latin American context, it is among the lowest. On the other hand, both the quality and relevance of the education of higher education also present deficiencies.

It should be noted that Ecuador is one of the Latin American countries with the lowest number of professionals trained in the fields of engineering and sciences. However, in recent years, the public sector has committed a significant amount of resources to reverse this situation. Along with the efforts aimed at raising the coverage and quality of education that is taught in the country, those aimed at promoting the advanced training of professionals, particularly abroad, stand out.

Economic growth, productivity, and innovation have unique importance concerning access to financing; specific data are not available for innovation activities for Ecuador. However, there is a history of access to credit by companies in general that have a direct impact on the Gross Domestic Product.

The main variables that allow us to estimate how successful the results of the inputs are in the contribution of technological innovation to the gross domestic product in Ecuador are those related to patents, publications, and the export of technology. With regard to the evolution of the number of applications entered and the registration of intellectual property in the Ecuadorian Institute of Intellectual Property (IEPI in Spanish), the country has not experienced a substantial change, but only minimal variations are recorded.

Regarding high technology exports, Ecuador has a very low share compared to the rest of the region. These pieces of evidence allow us to see in a general way the current panorama of the National System of Innovation (SNI in Spanish) of Ecuador, an economy that has made great efforts to strengthen its innovation activities, but with significant challenges still to be solved.

Consequently, the level of investment in innovation of an economy is determined by a series of factors, both on the side of inputs and environmental conditions, as well as the results that these inputs and the characteristics that the economy generate. On the side of the environmental factors that facilitate innovation, it is worth mentioning:

The regulatory framework

Protection of intellectual property

Quality control, standardization, and metrology

Tax incentives

Information and communication technologies (TIC)

Productivity is essential for economic growth and the competitiveness of an economy since it reflects the efficiency level of that economy in the generation of its product. Productivity is not everything, but in the long term, it is almost everything. A country's ability to improve its standard of living over time depends almost exclusively on its ability to increase its output per worker [4].

Total factor productivity represents economic growth that is not explained by productive factors, capital, and labor. The technology produces improvements in efficiency, as well as positive externalities that contribute to an increase in production. Therefore, if the productive factors were increased, production would grow more than proportionally, since technological improvement affects the final result.

Current approaches lack analysis of interrelations and uncertainty/indeterminacy for analysis of technological innovation contribution to gross domestic. The use of neutrosophy in cognitive maps is useful because it contributes to the treatment of indetermination and inconsistent information [5].

Neutrosophic cognitive maps (NCM) are an extension of fuzzy cognitive maps, including indetermination in causal relations [6, 7]. Fuzzy cognitive maps do not include an indeterminate relationship [8], making it less suitable for real-world applications.

In the present study, an analysis of the proposal is made where the possibility of dealing with the interdependencies, the feedback, and indetermination of the technological innovation, and its contribution to the Gross Domestic Product through the use of neutrosophic cognitive maps are presented.

Fuzzy cognitive maps (FCM) are a tool for modeling causal relations interrelations [9]. Connections in FCMs are just numeric, and the relationship between two events should be linear [10]. On the other hand, neutrosophy operates with indeterminate and inconsistent information, while fuzzy sets and intuitionistic fuzzy do not [5]. Neutrosophic cognitive maps (NCM) are an extension of FCM where was included the concept indeterminacy [6, 7], whereas of fuzzy cognitive maps fails to deal with this kind of relation [8]. Neutrosophics decision support is an area of active research with new development in areas of application [11, 12, 13] and group decision making for example [14,15].

In this paper, a model for the analysis of Technological Innovation projects contribution to Gross Domestic Product based on neutrosophic cognitive maps and PESTEL analysis is presented, providing methodological support and making possible dealing with real-world facts like interdependence, indeterminacy and feedback, indeterminacy. This paper continues as follows: Section 2 reviews some essential concepts about NCM. In Section 3, a framework for the show a static analysis based on NCM. Section 4, displays a case study of the proposed model. The paper finishes with conclusions and additional work recommendations.

2. Neutrosophic cognitive maps

Neutrosophic Logic (NL) is a generalization of the fuzzy logic that was introduced in 1995 [16]. According to this theory, a logical proposition P is characterized by three neutrosophic components:

$$NL(P) = (T, I, F) \quad (1)$$

Where the neutrosophic component the degree of true is T, the degree of falsehood is F, and I is the degree of indeterminacy [9]. Neutrosophic set (NS) was introduced by F. Smarandache, who introduced the degree of indeterminacy (i) as an independent component [11].

Additionally, a neutrosophic matrix is a matrix where the elements are $a = (a_{ij})$ have been replaced by elements in $\langle R \cup I \rangle$. A neutrosophic graph is a graph with at least one neutrosophic edge [7]. If a cognitive map includes indetermination, it is called the neutrosophic cognitive map (NCM) [9]. NCM is based on neutrosophic logic to represent uncertainty and indeterminacy in cognitive maps to deal with real-world problems [17]. An NCM is a directed graph in which at least one edge is an indeterminate border and is indicated by dashed lines [7] (Figure 2).

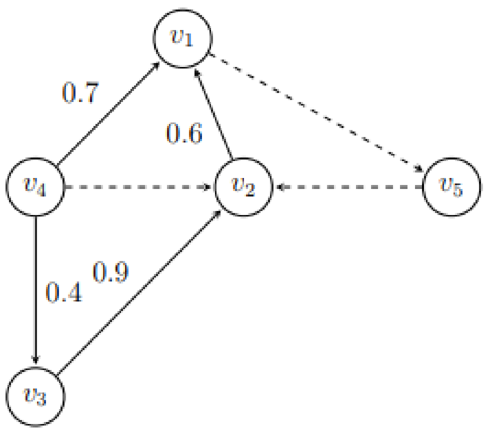

Figure 1. Neutrosophic Cognitive Maps example.

In [9] a static analysis of an NCM is presented. The result of the static analysis is in the form of neutrosophic numbers (a+bI, where I = indeterminacy). A neutrosophic number is a number as follows [14] :

$$N = d + I \quad (2)$$

Where d is the determinacy part, and i is the indeterminate part. For example s: a=5 +I si $i \in [5, 5.4]$ is equivalent to $a \in [5, 5.4]$.

Let $N_1 = a_1 + b_1 I$ and $N_2 = a_2 + b_2 I$ be two neutrosophic numbers then the following operational relation of neutrosophic numbers are defined as follows [17]:

$N_1 + N_2 = a_1 + a_1 + (b_1 + b_2)I$;

$N_1 - N_2 = a_1 - a_1 + (b_1 - b_2)I$

A de-neutrosophication process as proposed by Salmeron and Smarandache could be applied giving final ranking values [13]. In the de-neutrosophication process, a neutrosophic value is converted in an interval with two values, the maximum and the minimum value for I. The neutrosophic centrality measure will be an area where the upper limit has I =1 and the lower limit has I = 0.

3. Proposed Framework

The aim was to develop and further detail a framework based on PESTEL and NCM [15] to analyze the contribution of technology to Gross national product (GNP). The model was made in five steps (graphically, figure 3).

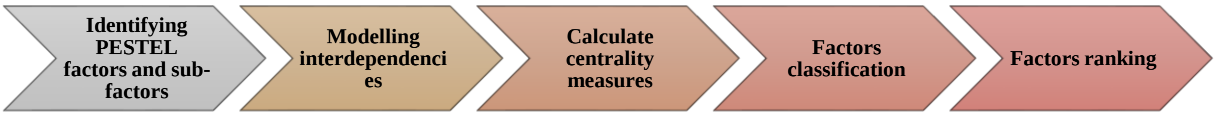

Figure. 2. The proposed framework for PESTEL analysis [15]

.3.1 Factors and sub-factors identification in the PESTEL method

In this step, the significant PESTEL factors and sub-factors were recognized. Identify factors and subfactors to form a hierarchical structure of the PESTEL model. Sub-factors are categorized according to the literature [18].

3.2 Modelling interdependencies

In this step, causal interdependencies between PESTEL sub-factors are modeled, consists of the construction of NCM of subfactors following the point views of an expert or a group of experts.

If a group of experts (k) participates, the adjacency matrix of the collective NCM is calculated as follows:

$$\mathrm{E} = \mu(\mathrm{E}_1, \mathrm{E}_2, \dots, \mathrm{E}_k) \quad (3)$$

The μ operator is usually the arithmetic mean [20].

3.3 Calculate centrality measures

Centrality measures are calculated [21] with absolute values of the adjacency matrix from the NCM [19]:

- Outdegree od (v_i) is the summation of the row of absolute values of a variable in the neutrosophic adjacency matrix and shows the aggregated strengths of connections (c_{ij}) leaving the node.

$$od(v_i) = \sum_{i=1}^{N} c_{ij} \quad (4)$$

- Indegree $id(v_i)$ is the summation of the column of absolute values of a variable, and it shows the total strength of variables entering into the node.
  $id(v_i) = \sum_{i=1}^{N} c_{ji}$ (5)
- The centrality degree (total degree $td(v_i)$), of a variable is the total sum of its indegree and outdegree
  $td(v_i) = od(v_i) + id(v_i)$ (6)

3.4 Factors classification and ranking

The factors were categorized according to the next rules:

- The variables are a Transmitter (T) when having a positive or indeterminacy outdegree, $od(v_i)$ and zero indegree, $id(v_i)$.
- The variables give a Receiver (R) when having a positive indegree or indeterminacy, $id(v_i)$., and zero outdegree, $od(v_i)$.
- Variables receive the Ordinary (O) name when they have a non-zero degree, and these Ordinary variables can be considered more or less as receiving variables or transmitting variables, depending on the relation of their indegrees and outdegrees.

The de-neutrosophication process provides a range of numbers for centrality using as a ground the maximum & minimum values of I. A neutrosophic value is changed to a value an interval from I=0 to I=1.

The importance of a variable in an NCM can be known by calculating its degree of centrality, which shows how the node is connected to other nodes and what is the total force of these connections. The median of the extreme values as proposed by Merigo [23] is used to give a real number as a centrality value :

$\lambda([a_1, a_2]) = \frac{a_1 + a_2}{2}$ (7)

Then

$A > B \Leftrightarrow \frac{a_1 + a_2}{2} > \frac{b_1 + b_2}{2}$ (8)

Finally, a ranking of variables is given.

3.3 Factor prioritization

The numerical value obtained in the previous step is used for sub-factor ranking and/or reduction [21,22]. Threshold values may be set for subfactor reduction. Additionally, sub-factor could be grouped to extend the analysis to ecological, economic, legal, political, social and technological general factors.

4. Case Study

Figure 4 shows the factors from the PESTEL model that are obtained for the analysis of the factors that have the greatest impact on technological innovation and that have an impact on Ecuador's gross domestic product.

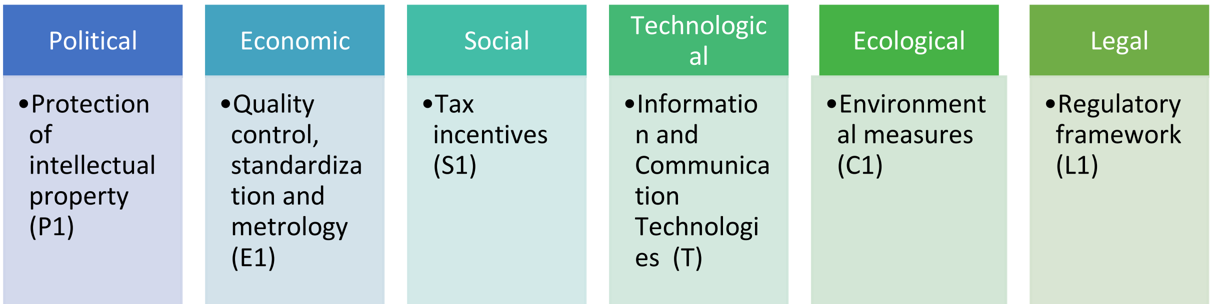

Figure 4. Factors identified through the PESTEL technique.

Obtained the characteristics corresponding to the factors of the PESTEL model, later are analyzed taking into account that the PESTEL model is a strategic analysis technique to define the context of a determined area through the analysis of a series of external factors [18, 19]. The PESTEL analysis incorporates in PEST analysis the ecological and legal factors into the so that in the present investigation, a PEST analysis was previously carried out and extended to include those factors.

In the present study, neutrosophic cognitive maps, for better interpretability is used as a tool for modeling the characteristics that are related the factors that affect technological innovation and that have an impact on Ecuador's gross domestic product.

For the evaluation of the PESTEL factors are modeling with a neutrosophic cognitive map. The factors found with the PESTEL technique and the causal connection to each factor that was represented in figure 4 are taken into account. NCM is used as a tool for modeling the characteristics that are related to the factors that affect technological innovation and that have an impact on Ecuador's gross domestic product. The neutrosophic cognitive map in the present study is developed through experts' knowledge. The neutrosophic adjacency matrix obtained is shown in Table 1.

Table 1. Neutrosophic adjacency matrix.

	P1	**E1**	**S1**	**T1**	**C1**	**L1**
P1	0	0	0	0	0	0
E1	0	0	0	0	0	0
S1	0.4	0	0	0	0	0
T1	0	0	0	0	0	0
C1	0	0	0	0	0.25	0
L1	0	0	0	0	0.25	0

Based on the neutrosophic adjacency matric centralities measures are calculates (Table 2)

Table 2. Measures of centrality, outdegree, indegree

Node	**Id**	**Od**
P1	0.4	0
E1	0	0
S1	0	0.4
T1	0	0
C1	0.25	0.25
L1	0	0.25

When the centrality measures are calculated, the nodes of the neutrosophic cognitive map are classified according to rules presented in section 3.4.

Table 3. Classification of the nodes.

	Transmitter node	**Receiving node**	**Ordinary**
P1		x	
E1			
S1	x		
T1			
C1			x
L1	x		

The total centrality (total degree $td\ (vi)$), is calculated through equation 6. Finally, we work with the mean of the extreme values, which is calculated through equation 7, which is useful to obtain a real number value [24]. A value that contributes to the identification of the characteristics to be prioritized according to the factors obtained with the PESTEL framework. The results are the same as those shown in Table 4.

Table 4. Total centrality.

	td
P1	0.4
E1	0
S1	0.4
T1	0
C1	0.50
L1	0.25

From these numerical values, the following ranking is obtained:

$$\mathbf{C_1 \succ P_1 \approx S_1 \succ L_1 \succ E_1 \approx T_1}$$

Factors to address in terms of technological innovation, which have an impact on Ecuador's gross domestic product, are mainly ecological, political, social and legal. The measures of the central position of the factors obtained through the PESTEL technique and analyzed according to the use of the static analysis in NCMS are shown in Figure 5. Each sub-factor were grouped to obtain the results.

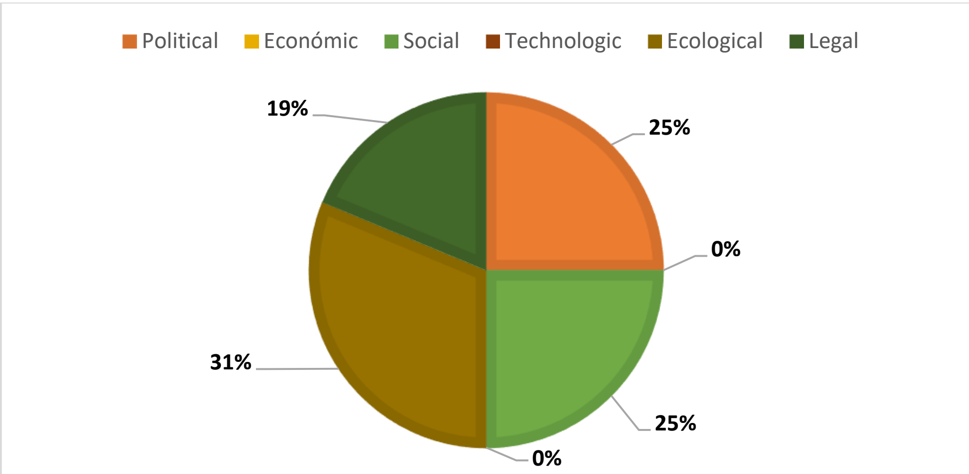

Figure 5. Central position values grouped by factors.

The results show the importance of political and legal factors related to technological innovation projects to gross domestic products growth in Ecuador. Furthermore, economical and technology factor have least importance but further work need to be developed. Handling the problem as a multiobjetive / multicriteria one [28,29], the use of SVN numbers and another neutrosophic tool for better interpretability are among future improvements in the method proposed in this paper [30, 31].

5. Conclusions

In the present study, a characterization of the factors to be attended in terms of technological innovation is carried out, according to its impact on Ecuador's gross domestic product. The PESTEL technique was used, which contributed to the analysis of the environment, identifying the fundamental factors that have a significant impact on technological innovation factors impacting Ecuador’s gross domestic product. The characteristics were modeled using neutrosophic cognitive maps, taking into account the indeterminacy and interdependencies between the characteristics and the factors identified with the PESTEL technique. A quantitative analysis based on the static analysis provided by the use was made of neutrosophic cognitive maps and centrality measures. It is shown that technological innovation, which has an impact on Ecuador's gross domestic product, must be addressed in terms of ecological, political, social and legal factors mainly. The case study shows the importance of political and legal factors related to technological innovation projects to gross domestic products growth in Ecuador

Future work will concentrate on extending the model to express importance and interrelation using Fuzzy/Neutrosophic Decisions Maps. Another are of future work is development of a software tool to support the process.

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Conflicts of Interest

The authors declare no conflict of interest.

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