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Neutrosophic model for the analysis of criminal behaviour in Quevedo, Ecuador, from a spatial econometric analysis

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Abstract. The environments of poverty, marginalization, overcrowding, lack of resources and opportunities are influential factors in the behavior of individuals. The externalities, evaluated from the context and their influence on criminal behavior, are the object of study of the legal sciences. This research process leads the authors to determine dimensions and indicators in order to assess the effectiveness of the legal system, from sources manifested in material reality. Poverty is a contingent phenomenon, built on social inequality that affects the actions of the individual and that the law cannot ignore given its connotation and conditioning capacity and in particular because the phenomenon of poverty constitutes a fundamental factor in the criminal behavior of citizens. For this reason, the objective of this paper is to analyze the criminal behavior achieved in Quevedo, Ecuador, based on the use of spatial econometric techniques and the use of Neutrosophy, which are useful for the evaluation of the impact of the indicators of greater incidence on the criminal behavior achieved in the aforementioned region.

Keywords: Violence, crime, citizen security, development problems, poverty, spatial econometrics and neutrosophic logic

1 Introduction

In the essay written in 1849, "Wage labor and capital," [1] Karl Marx warned of the relative essence of poverty and well-being, pointing out that: "A house can be big or small; as long as the surrounding houses are equally small, it satisfies all the social demands of a dwelling. However, if a palace arises next to the little house, the little house is reduced to a hut [2]. Needs and pleasures arise from society; this is measurable by society and not by the objects of its satisfaction, because they are of a social character and of a relative nature.

The increase in crime rates and violence is the main problem that afflicts Ecuador, over and above issues such as unemployment and the economic crisis. This behavior on an international scale is the matrix that continues to remain intact in the region.

Studies on citizen security show that these problems have the same relevance as the inequity, poverty and unemployment of the 1970s [3]. The problem of citizen security represents one of the fundamental axes within the policy managed by the Ecuadorian administration.

One of the findings that is frequently presented and that mark problems of formulation in the local policies of Ecuador are those related to poverty. Expressed as a social and economic situation, characterized by a marked lack of satisfaction of basic needs[4].

The notion of poverty expresses situations of lack of economic resources or living conditions that society considers basic in accordance with social reference standards that reflect minimum social rights and public objectives. These norms are expressed in absolute and relative terms, which are variables over time and in different national spaces [4].

Absolute poverty is linked to the situation in which a person or a household is poor given its own situation of dissatisfaction with a set of needs and opportunities, or the lack of a minimum level of income or expenditure to ensure the satisfaction of those needs. Relative poverty is related to the fact that a person is poor when being in a

situation of clear economic and social disadvantage in relation to the rest of the people around him, this is affirmed [5] when he mentions that poverty is a contingent and socially constructed phenomenon, and that it varies according to societies and time.

Another finding considered to support the effective formulation of local public policies is economic development and the use of endogenous resources. According to [6], they are classified as a conception conceived from a process of structural deficit, which has its origins in decolonization.

A significant element is the demography that characterizes the city of Quevedo, Ecuador, where the relationship of rural, urban and semi-urban contexts stands out, and which constitute dimensions to analyze in order to support the effective formulation of local public policies. Its peri-urban and rural components, fed by rural-urban migration, are important elements to be taken into account in the formulation of public policies.

Rural poverty is exacerbated because certain groups are excluded from the fruits of productivity and employment growth, applicable to all economies, regardless of levels of development). This new perspective of analysis focused on causal assessment made it possible to identify some relevant aspects with a social impact.

The progress of these phenomena leads to other impact factors associated with the deterioration of the quality of life, such as urban settlement, pollution, stratification of wealth and malnutrition. Malnutrition is reflected in areas of extreme poverty, where inadequate and scarce food is notorious.

According to [7], malnutrition caused by a lack of economic income causes the death of children, due to a lack of resources, lack of public strategies and increased population growth. This is why Ecuadorians resort to migration, which is a notorious consequence of inadequate management of social and economic resources that generates poverty and in turn has a significant impact on delinquency.

With regard to the well-being of the different social groups in the city of Quevedo, Ecuador, it should be noted that most of the inhabitants are salaried workers, and few are the families that have an income from their own highly profitable activity. In accordance with the foregoing and based on the legal concept of salary, which groups together economic factors of individual income or gain, and constitutes a fundamental link in the analysis of criminal behavior in the city of Quevedo, Ecuador, salary is highlighted judiciously as the patrimonial advantage received as compensation for subordinate work.

Unemployment is a social reality faced by Ecuadorian families. It is considered as a factor of inclusion and integration in the society of which it is a part, of which it becomes a disintegrating factor; that reinforces marginality and exclusion, and is linked to the indices of delinquency present in Quevedo, Ecuador.

The aforementioned results are part of the documentary analysis carried out to find the aspects with the greatest incidence of crime in the city of Quevedo, Ecuador. Derived from this documentary analysis, it is corroborated that the city of Quevedo, Ecuador, has high rates of violence, all of which corresponds with the expression of the weak social, economic, political structure achieved by this society.

Based on the aforementioned, the technique of spatial econometrics is used for the analysis of the criminal behavior achieved by the society of Quevedo Ecuador, as an expression of the social, economic and political structure achieved by society, given the increase in insecurity that exists in each locality. The technique of spatial econometrics, is a discipline of general econometrics, which includes the set of techniques of specification, estimation, contrast and predictions necessary for the treatment of the data of a locality, in particular spatial data.

Refers [8], that econometrics can also be defined as the part dealing with the treatment of spatial interaction (spatial autocorrelation) and spatial structure (spatial heterogeneity) in cross-sectional and data regression models. Analyses based on spatial econometrics are similar to analyses carried out with Geostatistics or Spatial Statistics, which is used by physicists and geographers, according to the aforementioned author.

For the analysis based on spatial econometrics, we first consider the results that are made through empirical econometrics, which begins with the specification of a number of economic relationships (given in quantitative form). Subsequently, the variables involved and the functional forms that relate them are analyzed, as well as the results obtained with the theoretical models, which are used to obtain spatial data, normally of a micro-territorial scope, which do not exist, and which is what is known as spatial prediction[9].

In order to identify the incidence of the socioeconomic variables that have greater repercussion, for the analysis of the criminal behavior reached by the society of Quevedo Ecuador, an evaluation of such situation is made through the spatial econometric. The information analyzed comes from a documentary analysis of the communities with the highest incidence of crime and poverty in the Quevedo Ecuador region.

The results obtained when making use of spatial econometrics are later treated through a Neutrosophic model, useful for the treatment of the information obtained in linguistic terms. The use of Neutrosophy contributes to decrease the uncertainty, treat the data and obtain from them a greater interpretability.

2 Preliminaries

2.1 Neutrosophy

Neutrosophy is a new branch of philosophy that, according to [11], studies the origin, nature and scope of

neutrality, as well as its interactions with different ideational spectra, where (A) is an idea, proposition, theory, event, concept or entity; anti (A) is the opposite of (A); and (neut-A) means neither (A) nor anti (A), that is, the neutrality between the two extremes [12]. Etymologically neutrosophic [Frances neutre < Latin neuter, neutral, and Greek sophia, knowledge] means knowledge of neutral thoughts and began in 1995.

His fundamental theory states that every idea <A> tends to be neutralized, diminished, balaced by <noA> ideas (not just <antiA> as Hegel posed) in a state of equilibrium. <noA> = what is not <A>, <antiA> = the opposite of <A>, and <neutA> = what is not <A> or <antiA>. In their classical form <A>, <neutA>, <antiA> are disjointed two by two. As in several cases the boundaries between concepts are vague to imprecise, it is possible that <A>, <neutA>, <antiA> (and <nonA> of course) have common parts.

The original of truth value in neutrosophic logic is shown in [10]:

Definition 1 Let X be a universe of discourse, a space of points (objects) and x denotes a generic element of X. A *neutrosophic set A* in X is characterized by a truth-membership function $T_A(x)$, an indeterminacy-membership function $I_A(x)$, and a falsity-membership function $F_A(x)$. Where, $T_A(x)$, $I_A(x)$, $F_A(x) \subseteq]^-0, 1^+[$, i.e., they are real standard or nonstandard subsets of the interval $]^-0, 1^+[$. These functions do not satisfy any restriction, that is to say, the following inequalities hold:

$$^-0 \leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^+.$$

This theory has formed the basis for neutrosophic logic [11], neutrosophic sets[12] , neutrosophic probability, neutrosophic statistics and multiple practical applications [13]. For this reason it is used in the present investigation, from the spatial econometric analysis, which is carried out, to recommend which are the factors of greater incidence in criminal behavior in Quevedo, Ecuador.

2.2 Single valued neutrosophic numbers

Let X be a universe of discourse. A single valued neutrosophic set A over X is an object having the form [14] :
$$A = \{\langle x, u(x), rA(x), vA(x)\rangle : x \in X\} \qquad (1)$$

where $u_A(x): X \rightarrow [0,1]$, $r_A(x), : X \rightarrow [0,1]$ and $v_A(x): X \rightarrow [0,1]$ with $0 \leq u_A(x) + r_A(x) + v_A(x) \leq 3$ for all $x \in X$. The intervals $u_A(x)$, $r_A(x)$ y $v_A(x)$ denote the truth- membership degree, the indeterminacy-membership degree and the falsity membership degree of x to A, respectively.
Single valued neutrosophic numbers (SVN number) is denoted by $A= (a,b,c)$, where $a,b,c \in [0,1]$ and $a+b+c \leq 3$. In decision analysis schema aggregation operating are important for rating options. Some aggregation operators have been proposed for SVN numbers. Single valued neutrosophic weighted averaging (SVNWA) aggregation operator [15]:
$$F_w(A_1, A_2, \ldots, A_n) = \langle 1 - \prod_{j=1}^{n}\left(1 - T_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(I_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(F_{A_j}(x)\right)^{w_j} \rangle \quad (2)$$

The aggregation of information consists of the process of combining different data providing a single output. Aggregation operators are a type of mathematical function used for the purpose of merging information. They combine n values in a domain D and return a value in that same domain [16].

3 Materials and methods

Documentary analysis was carried out, in particular of information materials to obtain information on criminal behaviour in Quevedo, Ecuador. The technique of spatial econometrics was used to identify the incidence of the socioeconomic variables that have the greatest impact on the criminal behavior achieved by the society of Quevedo Ecuador. The results obtained are qualitative, which are interpreted through the use of Neutrosophy, particularly through the use of models based on the aggregation of information.

The workflow of the aggregation model in this research is shown in Figure 1.

Establish evaluation framework → Compilation of information → Valuing alternatives → Ranking
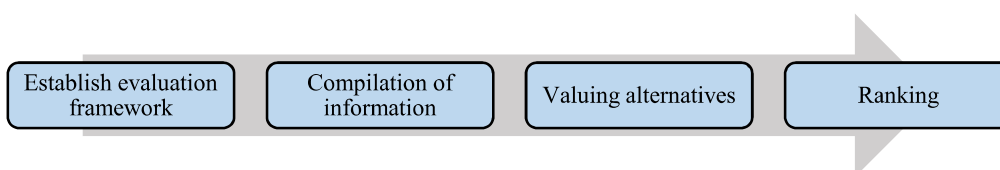
Figure 1: Neutrosophic model based on the aggregation of information for the analysis of criminal behavior in Quevedo, Ecuador.

To evaluate the results of the model proposed in Figure 1, the linguistic terms with their respective single-value neutrosophic numbers (SVNs) [11, 12] are used, as shown in Table 1. SVNs based on aggregation of information are expressed as A = (a,b,c), which are represented by tuples.

Linguistic term	SVN Number
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0.15,0.20)
Good (G)	(0.70,0.25,0.30)
Medium good (MDG)	(0.60,0.35,0.40)
Average (M)	(0.50,0.50,0.50)
Medium Bad (MDB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Table 1: Linguistic terms used [17].

The detailed description of each activity in the proposed model (Figure 1), for the analysis of criminal behavior in Quevedo, Ecuador is:

Phase 1. Establish an evaluation framework, where the criteria and alternatives to be evaluated are selected in order to prioritize the latter. The framework is defined as follows:

- $C = \{c1, c2, ..., cn\}$ with $n \geq 2$, a set of criteria
- $E = \{e1, e2, ..., ek\}$ with $k \geq 1$, a set of experts
- $X = \{x1, x2, ..., xm\}$ with $m \geq 2$, a finite set of alternatives

Phase 2. Information gathering, is the phase where information is obtained about the preferences of decision makers. The utility vector [13] is represented as follows:

Pj={p$_{j1}$, p$_{j2}$,...,p$_{jk}$}, where p$_{jk}$ is the preference in relation to the criterion c$_k$ of the alternative x$_j$

Phase 3. Valuing the alternatives, in this phase the alternative is constructed where the aggregation operators are used.

Phase 4. Ranking, phase where the alternatives are classified, to choose the most convenient through the scoring function that is applied. In accordance with the scoring and accuracy functions for SVN sets, a ranking order is generated for the set of alternatives [17] and then the option(s) with the highest scores is selected.

A scoring function defined by is used to rank alternatives:

$$s(Vj) = 2 + Tj - Fj - Ij \qquad (3)$$

In addition, the precision function is defined as follows:

$$(Vj) = Tj - Fj \qquad (4)$$

and then:

If s(Vj) < s(Vi), then Vj is less than Vi, denoted as Vj < Vi. In case of s(Vj)= s(Vi). If (Vj) < a(Vi), then Vj is less Vi, denoted by Vj < Vi. If a(Vj)= a(Vi), then Vj and Vi are equal, denoted by Vj= Vi. The ranking is carried out according to the scoring function of the evaluated alternatives.

4 Case Study

In order to apply the spatial econometric technique, an estimation model was carried out that made it possible to identify the incidence of the socioeconomic variables with the greatest incidence on criminal behavior in Quevedo, Ecuador. The estimation model was generally represented as; $y_i = f\,(poverty\ conditions_i, \text{checks}, \varepsilon_i)..$ Where; i represents the jurisdiction, the indicator witnessing problems (poverty, weight indicator) and ε is the end of the random disturbance (unemployment). The following 3 variables were analyzed in the estimation model:

1. Unemployed with work experience
2. Average monetary income
3. Monthly household expenditures

The unemployed variable with work experience is considered, the variable where there are incomes from less than the basic, to the living wage with the following percentages: Less than the basic 15 %, basic unified 50 %, more than the basic 25 %, living wage 10 %. The remaining two indicators unfold this indicator, standing out;

people with work and without work, who have other sources of income, where the largest source of income is from insurance which represents 38%, since this income runs on the part of companies, this indicator exceeds 39% of people who have none of these other sources of income.

As for monthly household expenditure, the values represented are in the direction of consuming wage income especially in food with 24% of income, followed by transport with 23%, similar situation with education with 22%, and also the situation referring to housing rent, which represents 18% of respondents' income, then health and clothing relegated to 7% and 6% respectively. It is inferred that families cannot dedicate a percentage of their income to savings since their income does not reach their wage income.

According to the results obtained, the data related to the indicators that represent existing poverty conditions in Quevedo, Ecuador, take on a spatial character (because they are georeferenced phenomena in a particular region), therefore the regression is carried out through spatial econometric models, with the objective of taking into account the possible existence of processes of spatial dependence and heterogeneity, which affect the quality of the estimates.

The problem of predicting the criminal behavior reached by the society of Quevedo Ecuador, under conditions of poverty, and the use of spatial econometric techniques is based on the localized spatial correlation. This approach considers that the observed results are related to each other, due to non-observable spatially correlated components in order to obtain efficient parameter estimates and make correct inferences.

Spatial econometrics is applied through a weighting matrix that takes into account the proximity between i and j observations. The weights are established on whether or not there is a common boundary between jurisdictions. The weighting matrix was standardized according to unemployed variables with work experience, average monetary income and monthly household expenditures.

On the results obtained, using the matrix of standardized weights, it was possible to obtain the residual spatial dependency value. Analysis where it is verified that the variable that has been robust in the econometric estimates is the density of poverty, based on low monetary income. Data reflected in a spatial error correlated between jurisdictions.

Of the aspects analyzed, through spatial econometrics, the density of poverty based on low monetary income is the variable to be analyzed, which has risk factors that positively affect the criminal behavior of Quevedo, Ecuador.

According to the results obtained when applying spatial econometrics, Neutrosophy is used to interpret the data, which have a qualitative structure and are referred to in linguistic terms. The neutrosophic model, based on ideal distance for the analysis of the risk factors that positively affect the criminal behavior of Quevedo, Ecuador, presents an evaluation framework, through the linguistic terms defined in Table 1, where the following 3 alternatives were evaluated:

- The risks of social exclusions (x_1)
- The risks of psychological exclusions (x_2)
- The risks of cultural exclusions (x_3)

  The criteria to be considered for the evaluation of the 3 alternatives referred to above are:

  The economic (c_1)
- The sociopolitical (c_2)
- Psychological or emotional (c_3)

Once the evaluation framework has been established, the information is collected, the results of which are shown in Table 2.

	x_1	x_2	x_3
c_1	MDG	EG	VG
c_2	G	MDG	B
c_3	MDG	MDG	G

Table 2: Results of the collection of information

The vector used has the following weights: W = (0.58, 0.28, 0.20). The opinions of the decision-makers are then aggregated using the aggregation operator that calculates the Single valued neutrosophic weighted averaging (SVNWA)(eq , proposed by [24], the result being shown in Table 3.

	Aggregation	Scoring	Ranking
x1	(0.53, 0.4, 0.56)	1.83	2
x2	(0.43, 0.0, 0.0)	2.53	1
x3	(0.66, 0.52, 0.63)	1.72	3

Table 3: Results for the evaluation

According to the scoring function the alternatives are ordered as follows: x2> x1> x3, which means that:

1. Psychological exclusions constitute the factor of greatest incidence in criminal behavior in Quevedo, Ecuador. A factor that contributes to people's extreme vulnerability.
2. The risk of psychological exclusions that leads to a high multidimensional poverty rate, given the set of deficiencies of households when considering three dimensions (health, education and standard of living), contributes to the fact that citizens have an impact on the criminal process.
3. The risks of cultural exclusion lead citizens to high economic consequences and give rise to characterizations of extreme poverty, low wages and lack of employment that lead them to severe criminal behaviour.

Conclusion

The paper analysis of criminal behaviour in Quevedo, Ecuador, identified the socio-economic factors with the greatest impact on the problems addressed. Spatial econometrics showed that these factors are interrelated. We obtained the risk factors associated with the socioeconomic factors detected in criminal behavior in Quevedo, Ecuador, which were analyzed through a neutrosophic model based on ideal distance, because the data obtained were qualitative and expressed in linguistic terms.

Through the use of the neutrosophic model, based on ideal distance, for the analysis of risk factors that positively affect the criminal behavior of Quevedo, Ecuador, it was possible to combine different data providing a single output. It was found that people who are psychologically excluded are more vulnerable to delinquency.

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