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A Neutrosophic Approach to Analyzing Determining Factors in RIMPE Tax Collection in Ecuador

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Abstract. This study analyzed the factors influencing tax collection under the RIMPE regime in Ecuador, applying neutrosophic logic to address the uncertainty and ambiguity inherent in decision-making within fiscal analysis. The employed methodology included an adaptation of the ELECTRE I method with bipolar neutrosophic numbers, enabling the integration of diverse perspectives into the decision-making process. The results obtained highlighted the simplicity of the regime and the control of the SRI as the most influential factors in fiscal revenue collection. The approach applied in the study facilitates a more accurate and efficient evaluation of fiscal policies, promoting greater equity and efficiency in the tax system.

Keywords: fiscal revenue collection, RIMPE regime, neutrosophic logic, ELECTRE I, multi-criteria decision-making.

1 Introduction

Tax revenue plays a central role in the economic and social development of any nation, serving as the primary source of funding for essential public services such as healthcare, education, and security. In Ecuador, the Simplified Tax Regime for Entrepreneurs and Popular Businesses (RIMPE) emerges as a fiscal policy designed to simplify tax compliance and promote the economic formalization of traditionally marginalized sectors. Implemented in 2022, this regime replaced previous tax systems, such as the Simplified Tax Regime (RISE) and the Microenterprise Regime (RIM), intending to revitalize the economy and ensure a more equitable distribution of the tax burden. However, despite its significance, the factors influencing its effectiveness remain poorly understood, highlighting the need for a more in-depth analysis. [1]

Although RIMPE has gained attention for its potential to integrate small businesses into the tax system, the conditions determining its performance across the country's provinces may vary, offering opportunities for improvement in this indicator. In particular, the COVID-19 pandemic, with its devastating economic effects, has raised questions about how the exceptional circumstances of recent years have affected taxpayers' ability to adapt to this new scheme [2]. Moreover, Ecuador's socioeconomic and demographic heterogeneity suggests that fiscal revenue dynamics can vary significantly, requiring an analytical approach capable of capturing these differences and proposing effective solutions.[3]

In this context, informed decision-making becomes an indispensable tool for understanding and optimizing tax revenue collection. Multi-criteria decision-making (MCDM) methods play a critical role in this regard, as they integrate multiple factors and variables into an analytical framework that facilitates the identification of patterns, significant relationships, and priority areas for intervention [4], [5]. However, uncertainty is a constant in real-world scenarios, particularly in fiscal policy, where data are often incomplete, ambiguous, or contradictory [6]. In the case of RIMPE, such uncertainties can manifest in diverse ways, ranging from discrepancies in tax information to unforeseen impacts of external policies.

Neutrosophy, developed by philosopher and mathematician Florentin Smarandache in the late 20th century, has emerged as a significant theoretical framework for tackling uncertainty and ambiguity in decision-making across diverse domains, including science, business, and industry. This conceptual framework posits that truth, untruth, and indeterminacy can coexist inside a single statement or argument, so encapsulating the inherent complexity present in many decision-making contexts [7,8].

Neutrosophic logic, by expanding the analytical capabilities of traditional methods, offers a robust framework for dealing with the limitations inherent in the real world. Its application in this study not only allows for a more accurate representation of reality but may also open up new opportunities for research and policy implementation.

The primary objective of this study is to identify the key factors influencing tax collection within the RIMPE regime in Ecuador using neutrosophic logic. In doing so, the study aims to provide a solid knowledge base to enhance the efficiency and equity of the tax system, contributing to the strengthening of public finances and the country's economic development.

To conduct this analysis, the study proposes an adaptation of the ELECTRE I method, expanded through a neutrosophic structure based on the incorporation of bipolar neutrosophic numbers [9]. This approach is well-suited to manage the uncertainties and ambiguities inherent in the field of study more precisely and effectively. The implementation of bipolar neutrosophic numbers enables the integration of diverse perspectives and levels of indeterminacy into the decision-making process [10], making it an essential tool for addressing the complexity of the dynamics associated with tax collection in Ecuador.

2.1 Preliminaries

Definition 1[11,12, 13]. Let X be a space of points or objects, with its generic elements represented as x. A single-valued neutrosophic set (SVNS) A in X is characterized by three membership functions: $T_A(x)$, indicating truth membership; $I_A(x)$ defining indeterminacy membership; and $F_A(x)$, indicating falsehood membership. Consequently, an SVNS A can be expressed as $A = \{x, T_{A(x)}, I_{A(x)}, F_{A(x)x} \in X\}$, where $T_{A(x)}, I_{A(x)}, F_{A(x)} \in [0,1]$ for each x in X. Furthermore, these membership functions satisfy the condition $0 \le T_{A(x)} + I_{A(x)} + F_{A(x)} \le 3$.

Definition 2 [14, 15, 16]. A bipolar neutrosophic set A in X is defined as an object of the form.

$$\tilde{A} = \{x, \langle T_A^+(x), I_A^+(x), F_{\tilde{A}}^+(x), T_{\tilde{A}}^-(x), I_{\tilde{A}}^-(x), F_{\tilde{A}}^-(x)\rangle \big| x \in X\}, \quad (1)$$

where the functions $T_A^+(x), I_A^+(x), F_{\tilde{A}}^+(x): X \to [0,1]$ represent the positive values of truth, indeterminacy, and falsehood membership, respectively, while $T_{\tilde{A}}^-(x), I_{\tilde{A}}^-(x), F_{\tilde{A}}^-(x): X \to [-1,0]$ correspond to their negative values.

The method used paper considers the existence of a set $S = \{S_1, S_2, \cdots, S_m\}$ representing m selection alternatives, and a set $T = \{T_1, T_2, \cdots, T_n\}$ denoting n attributes or evaluation criteria. Additionally, the weight vector associated with the evaluation criteria is denoted as $W = [w_{1w_2} \cdots w_n]^T$ where $0 \le wj \le 1$ and $\sum j = 1_{nwj} = 1$. Assuming the decision-maker assigns a rating to each alternative Si, (i=1,2, ⋯,m) concerning each attribute Tj, (j=1,2,⋯,n) in the form of bipolar neutrosophic sets (BNSs), which represent truth, falsity, and indeterminacy on positive and negative scales[17, 18].

The adapted ELECTRE I method incorporates these evaluations, leveraging concordance and discordance indices to rank alternatives [19]. This approach enhances the analysis by addressing ambiguity and complexity, providing a nuanced evaluation framework for fiscal policy.

3 Methods

3.1 Bipolar ELECRTE I method

The method used in this paper can be outlined shown in Figure 1.

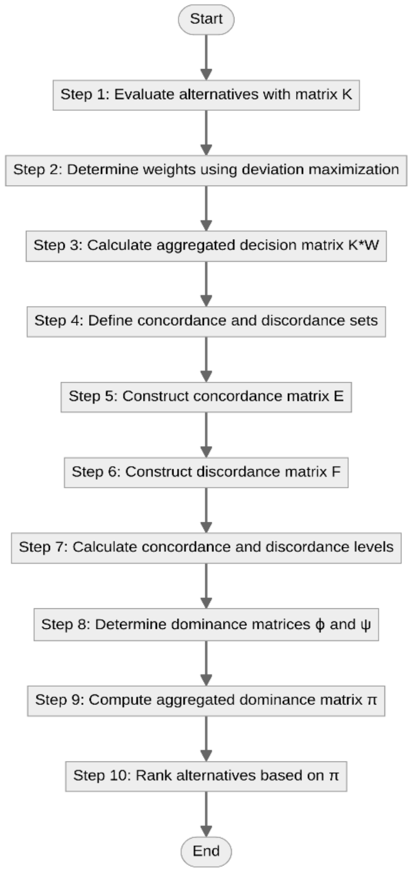

Figure 1. Decision-Making Process

Step 1. Each alternative is evaluated based on multiple criteria. The evaluation of each alternative concerning each criterion is represented using BNSs, which can be expressed in the decision matrix as:

$$K = [k_{ij}]_{m\times n} = \begin{bmatrix} k_{11} & k_{12} & \cdots & k_{1n} \\ k_{21} & k_{22} & \cdots & k_{2n} \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ k_{m1} & k_{m2} & \cdots & k_{mn} \end{bmatrix}$$

Each entry $k_{ij} =< T_{ij}^{+}, I_{ij}^{+}, F_{ij}^{+}, T_{ij}^{-}, I_{ij}^{-}, F_{ij}^{-} >$ is characterized as follows:

$T_{ij}^{+}, I_{ij}^{+}, F_{ij}^{+}$, represent the positive truth, indeterminacy, and falsehood membership degrees, respectively, while $T_{ij}^{-}, I_{ij}^{-}, F_{ij}^{-}$ represent the negative truth, indeterminacy, and falsehood membership degrees. These values satisfy the constraints $T_{ij}^{+}, I_{ij}^{+}, F_{ij}^{+} \in [0,1]$, $T_{ij}^{-}, I_{ij}^{-}, F_{ij}^{-} \in [-1,0]$, y $0 \leq T_{ij}^{+}, I_{ij}^{+}, F_{ij}^{+}, T_{ij}^{-}, I_{ij}^{-}, F_{ij}^{-} \leq 6$, where i=1,2,3,…,m and j=1,2,3,…,n.

Step 2. When the weights of the criteria are not evenly distributed and their values are unknown to the decision-maker, the deviation maximization method is employed to determine the unspecified criterion weights. Consequently, the weight of the attribute T_j is calculated as follows:

$$w_j = \frac{\sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}|}{\sqrt{\sum_{j=1}^{n} \left(\sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}|\right)^2}}, \quad (2)$$

And the normalized weight of the attribute T_j is determined as described in Equation (3):

$$w_j^* = \frac{\sum_{i=1}^{m}\sum_{l=1}^{m}|k_{ij}-k_{lj}|}{\sum_{j=1}^{n}\left(\sum_{i=1}^{m}\sum_{l=1}^{m}|k_{ij}-k_{lj}|\right)}. \quad (3)$$

Step 3: The weighted bipolar neutrosophic aggregated decision matrix is computed by multiplying the attribute weights with the aggregated decision matrix as follows:

$$K * W = [k_{ij}^{w_j}]_{m\times n} = \begin{bmatrix} k_{11}^{w_1} & k_{12}^{w_2} & \cdots & k_{1n}^{w_n} \\ k_{21}^{w_1} & k_{22}^{w_2} & \cdots & k_{2n}^{w_n} \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ k_{m1}^{w_1} & k_{m2}^{w_2} & \cdots & k_{mn}^{w_n} \end{bmatrix} \quad (4)$$

Where

$$k_{ij}^{w_j} =< T_{ij}^{w_j+}, I_{ij}^{w_j+}, F_{ij}^{w_j+}, T_{ij}^{w_j-}, I_{ij}^{w_j-}, F_{ij}^{w_j-} >$$
$$=< 1-(1-T_{ij}^{+})^{w_j}, (I_{ij}^{+})^{w_j}, (F_{ij}^{+})^{w_j}, -(-T_{ij}^{-})^{w_j}, -(-I_{ij}^{-})^{w_j}, -(1-(1-(-F_{ij}^{-}))^{w_j}) >$$

Step 4: The bipolar neutrosophic concordance sets E_{xy} and discordance sets F_{xy} are defined as:

$$E_{xy} = \{1 \le j \le n | \rho_{xj} \ge \rho_{yj}\}, x \ne y, x, y = 1,2,\cdots,m,$$
$$F_{xy} = \{1 \le j \le n | \rho_{xj} \le \rho_{yj}\}, x \ne y, x, y = 1,2,\cdots,m, \quad (5)$$

where $\rho_{ij} = T_{ij}^{+} + I_{ij}^{+} + F_{ij}^{+} + T_{ij}^{-} + I_{ij}^{-} + F_{ij}^{-}, i = 1,2,\cdots,m$ and $j = 1,2,\cdots,n$

Step 5: The bipolar neutrosophic concordance matrix E is constructed as:

$$E = \begin{bmatrix} - & e_{12} & \cdot & \cdot & \cdot & e_{1m} \\ e_{21} & - & \cdot & \cdot & \cdot & e_{2m} \\ \cdot & & & & & \\ \cdot & & & & & \\ \cdot & & & & & \\ e_{m1} & e_{m2} & \cdot & \cdot & \cdot & - \end{bmatrix}$$

where the bipolar concordance indices e_{xy}'s are calculated using (6):

$$e_{xy} = \sum_{j\in E_{xy}} w_j \quad (6)$$

Step 6: The bipolar neutrosophic discordance matrix F is constructed as:

$$F = \begin{bmatrix} - & f_{12} & \cdot & \cdot & \cdot & f_{1m} \\ f_{21} & - & \cdot & \cdot & \cdot & f_{2m} \\ \cdot & & & & & \\ \cdot & & & & & \\ \cdot & & & & & \\ f_{m1} & f_{m2} & \cdot & \cdot & \cdot & - \end{bmatrix},$$

where the bipolar discordance indices f_{xy}'s are determined by:

$$f_{xy} = \frac{\max_{j\in F_{xy}} \sqrt{\frac{1}{6n}\begin{Bmatrix} (T_{xj}^{w_j+}-T_{yj}^{w_j+})^2+(I_{xj}^{w_j+}-I_{yj}^{w_j+})^2+(F_{xj}^{w_j+}-F_{yj}^{w_j+})^2+ \\ (T_{xj}^{w_j-}-T_{yj}^{w_j-})^2+(I_{xj}^{w_j-}-I_{yj}^{w_j-})^2+(F_{xj}^{w_j-}-F_{yj}^{w_j-})^2 \end{Bmatrix}}}{\max_{j} \sqrt{\frac{1}{6n}\begin{Bmatrix} (T_{xj}^{w_j+}-T_{yj}^{w_j+})^2+(I_{xj}^{w_j+}-I_{yj}^{w_j+})^2+(F_{xj}^{w_j+}-F_{yj}^{w_j+})^2+ \\ (T_{xj}^{w_j-}-T_{yj}^{w_j-})^2+(I_{xj}^{w_j-}-I_{yj}^{w_j-})^2+(F_{xj}^{w_j-}-F_{yj}^{w_j-})^2 \end{Bmatrix}}} \quad (7)$$

Step 7: The levels of concordance and discordance are calculated to rank the alternatives. The bipolar neutrosophic concordance level $\hat{e}$ is computed as:

$$\hat{e} = \frac{1}{m(m-1)} \sum_{\substack{x=1,\\ x\neq y}}^{m} \sum_{\substack{y=1,\\ y\neq x}}^{m} e_{xy} \tag{8}$$

Similarly, the bipolar neutrosophic discordance level $\hat{f}$ is given by:

$$\hat{f} = \frac{1}{m(m-1)} \sum_{\substack{x=1,\\ x\neq y}}^{m} \sum_{\substack{y=1,\\ y\neq x}}^{m} f_{xy} \tag{9}$$

Step 8: The bipolar neutrosophic concordance dominance matrix ϕ and discordance dominance matrix ψ, are determined as:

$$\phi = \begin{bmatrix} - & \phi_{12} & \cdot & \cdot & \cdot & \phi_{1m} \\ \phi_{21} & - & \cdot & \cdot & \cdot & \phi_{2m} \\ \cdot & & & & & \\ \cdot & & & & & \\ \cdot & & & & & \\ \phi_{m1} & \phi_{m2} & \cdot & \cdot & \cdot & - \end{bmatrix},$$

$$\psi = \begin{bmatrix} - & \psi_{12} & \cdot & \cdot & \cdot & \psi_{1m} \\ \psi_{21} & - & \cdot & \cdot & \cdot & \psi_{2m} \\ \cdot & & & & & \\ \cdot & & & & & \\ \cdot & & & & & \\ \psi_{m1} & \psi_{m2} & \cdot & \cdot & \cdot & - \end{bmatrix}$$

,

Where

$$\phi_{xy} = \begin{cases} 1, & \text{if} e_{xy} \geq \hat{e}, \\ 0, & \text{if} e_{xy} < \hat{e}. \end{cases} \tag{10}$$

$$\psi_{xy} = \begin{cases} 1, & \text{if} f_{xy} \leq \hat{f}, \\ 0, & \text{if} f_{xy} > \hat{f}. \end{cases} \tag{11}$$

Step 9: The aggregated bipolar neutrosophic dominance matrix π is computed by combining the matrices ϕ and ψ, as:

$$\pi = \begin{bmatrix} - & \pi_{12} & \cdot & \cdot & \cdot & \pi_{1m} \\ \pi_{21} & - & \cdot & \cdot & \cdot & \pi_{2m} \\ \cdot & & & & & \\ \cdot & & & & & \\ \cdot & & & & & \\ \pi_{m1} & \pi_{m2} & \cdot & \cdot & \cdot & - \end{bmatrix}$$

Where

$$\pi_{xy} = \phi_{xy}\psi_{xy} \tag{12}$$

Step 10: Finally, the alternatives are ranked based on the dominance values π_{xy}.

For each pair of alternatives S_x and S_y:

(a) A single arrow from S_x to S_y indicates S_x is preferred.

(b) Two arrows indicate indifference between S_x and S_y.

(c) No arrow signifies incomparability between S_x and S_y

4 Results

Based on the conducted literature review, four primary factors were identified as pivotal for determining the most influential ones regarding fiscal revenue collection under the RIMPE regime in Ecuador. The elements considered for evaluation include:

S1. Simplicity and clarity of the regime: The ease of understanding and applying tax regulations under the RIMPE framework emerges as a critical factor. A straightforward system that avoids overburdening microenterprises is likely to enhance compliance, thereby improving fiscal revenue collection.

S2. Macroeconomic conditions: Variables such as inflation, GDP growth, and employment levels significantly affect the purchasing power and income-generating capacity of microenterprises. A stable or growing economy generally correlates with increased fiscal revenues.

S3. Fiscal incentives and benefits: Tax exemptions, discounts, or other fiscal advantages provided under the RIMPE regime can influence microenterprises' willingness to register and fulfill their tax obligations, ultimately affecting revenue collection.

S4. Control and oversight by the Internal Revenue Service (SRI): The SRI's ability to monitor, detect, and penalize non-compliance is essential. Effective oversight and an appropriate sanctions policy contribute to higher compliance rates and improved fiscal revenue performance.

For the evaluation of these factors, a series of criteria will be considered.

C1. Impact on revenue collection efficiency: This criterion evaluates the extent to which each alternative contributes to maximizing fiscal revenue within the RIMPE regime.

C2. Ease of implementation: Measures the technical and operational feasibility of implementing each alternative, including the clarity of regulations, administrative costs, and the ability of microenterprises to adapt to the proposed changes.

C3. Tax equity: Analyzes how each alternative affects the fairness of the tax system, ensuring that fiscal burdens are proportionally distributed among microenterprises based on their economic capacity.

C4. Taxpayer acceptance: Assesses the perception and willingness of microenterprises to comply with the proposed measures, taking into account factors such as the simplicity of the regime and the fiscal benefits offered.

Based on the previously established criteria, the experts assessed the factors analyzed in the study. Table 1 presents the bipolar numerical decision matrix derived for this purpose.

Table 1: Decision matrix.

	C1	C2	C3	C4
S1	(0.3, 0.4, 0.2, -0.4, -0.3, -0.7)	(0.3, 0.5, 0.2, -0.3, -0.8, -0.5)	(0.8, 0.5, 0.7, -0.3, -0.4, -0.3)	(0.4, 0.4, 0.4, -0.7, -0.5, -0.4)
S2	(0.3, 0.4, 0.1, -0.5, -0.5, -0.5)	(0.3, 0.6, 0.1, -0.5, -0.3, -0.7)	(0.4, 0.2, 0.5, -0.6, -0.3, -0.1)	(0.2, 0.5, 0.2, -0.5, -0.4, -0.2)
S3	(0.5, 0.1, 0.5, -0.3, -0.4, -0.4)	(0.1, 0.2, 0.3, -0.6, -0.2, -0.4)	(0.2, 0.3, 0.5, -0.3, -0.2, -0.3)	(0.4, 0.7, 0.3, -0.3, -0.5, -0.4)
S4	(0.5, 0.5, 0.3, -0.2, -0.1, -0.3)	(0.7, 0.4, 0.3, -0.1, -0.3, -0.4)	(0.6, 0.3, 0.6, -0.5, -0.4, -0.2)	(0.3, 0.3, 0.2, -0.1, -0.3, -0.1)

The weight vector for the evaluation criteria is expressed as $w = (0.3, 0.25, 0.2, 0.25)$. By integrating these weights with the initial decision matrix, the normalized matrix is derived. This process involves scaling each value in the decision matrix according to the corresponding criterion weight, as outlined in Equation (4). Based on this information, the bipolar neutrosophic concordance sets and discordance sets can be established, as presented in Tables 2 and 3.

Table 2: Bipolar neutrosophic concordance sets

E_{xy}	1	2	3	4
E_{1y}	{-}	{1, 2, 3}	{3}	{3}

E_{xy}	1	2	3	4
E_{2y}	{4}	{-}	{0}	{0}
E_{3y}	{1, 2, 4}	{1, 2, 3, 4}	{-}	{3}
E_{4y}	{1, 2, 4}	{1, 2, 3, 4}	{1, 2, 4}	{-}

Table 3. Bipolar neutrosophic discordance sets

F_{xy}	1	2	3	4
F_{1y}	-	{0}	{1, 2, 3, 4}	{1, 2, 3, 4}
F_{2y}	{1, 2, 3, 4}	-	{1, 2, 3, 4}	{4}
F_{3y}	{1,2}	{3}	-	{1, 2, 4}
F_{4y}	{0}	{0}	{3}	-

Based on the collected data and applying equations (6) and (7), the calculation and construction of the bipolar neutrosophic concordance matrix E_{xy} and the bipolar neutrosophic discordance matrix F_{xy} are performed. These matrices provide a quantitative representation of the concordance and discordance relationships among the evaluated alternatives, thereby facilitating the decision-making process.

$$E_{xy} = \begin{bmatrix} - & 0.75 & 0.20 & 0.20 \\ 0.25 & - & 0.00 & 0.00 \\ 0.80 & 1.00 & - & 0.20 \\ 0.80 & 1.00 & 0.80 & - \end{bmatrix} \qquad F_{xy} = \begin{bmatrix} - & 0.67 & 1.00 & 1.00 \\ 1.00 & - & 1.00 & 0.00 \\ 1.00 & 0.00 & - & 1.00 \\ 0.41 & 0.00 & 0.444 & - \end{bmatrix}$$

Based on the calculations, the bipolar neutrosophic concordance and discordance levels were determined as 0.5 and 0.71, respectively. By applying equations (10) - (11), the dominance matrices for bipolar neutrosophic concordance and discordance were generated. These matrices support the ranking of alternatives and the selection of the most suitable strategy based on the established criteria.

$$\pi = \begin{bmatrix} - & 1 & 0 & 0 \\ 0 & - & 0 & 0 \\ 0 & 1 & - & 0 \\ 1 & 1 & 1 & - \end{bmatrix}$$

According to the results, an arrow from S1 to $S2$ $\pi_{\{12\}} = 1$ was observed, indicating a preference for *Simplicity and clarity of the regime* over *Macroeconomic conditions*. This result highlights the greater importance of regulatory simplicity compared to macroeconomic factors. Additionally, *Control and oversight by the SRI* demonstrated dominance over all other factors $\pi_{\{41\}} = \pi_{\{42\}} = \pi_{\{43\}} = 1$, highlighting its relevance as a key criterion.

The analysis also revealed that S2 and S3 lacked outgoing arrows toward other factors, indicating a lower influence compared to the remaining factors. These findings suggested that effective oversight was the most influential factor, emphasizing the critical role of efficient supervision in improving fiscal revenue collection.

5 Conclusion

The conducted study identified the most relevant factors influencing fiscal revenue collection under the RIMPE regime in Ecuador, highlighting the simplicity of the regulatory framework and the control exercised by the Internal Revenue Service (SRI) as key determinants. Regulatory simplicity was preferred over macroeconomic conditions, underscoring the importance of a clear and accessible framework to encourage tax compliance. The application of the ELECTRE I method, enhanced with bipolar neutrosophic numbers, proved effective in addressing the uncertainty and complexity inherent in fiscal analysis, enabling a more precise representation of relationships between factors. This approach demonstrated its usefulness in prioritizing strategies to improve fiscal revenue collection and promote equity within the tax system. Further integration of advanced multi-criteria methods is recommended to optimize tax policies, taking into account regional dynamics and the impact of changing socioeconomic contexts.

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