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Selecting Optimal Monetary Policies for the Peruvian Housing Market Using the Neutrosophic OWA-TOPSIS Model.

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Abstract. This research contributes to the literature where ideal monetary policy selection to increase housing demand in Peru is still lacking for a vulnerable sector that can easily become unstable in times of recession. This research is significant because policymakers should pay attention to the real estate sector as it has economic and social welfare implications due to the current housing deficit situation across the country and international investors and lenders. Although previous articles have assessed how monetary policy transmits through the housing sector, few pay attention to the adoption of uncertainty itself. Therefore, prevailing methods do not comprehensively assess how expected interest rates and public sentiment play a crucial role in decision-making options regarding the housing market. Thus, we fill this gap through the neutrosophic OWA-TOPSIS approach, which allows for uncertainty via neutrosophic numbers and assesses the alternatives of interest rate adjustment and open market operations against the decision-making criteria of housing affordability, housing investment, and financial security. The results show that a hybrid solution of low interest rates with an expansionary strategy best satisfies the housing demand versus financial risk mitigation assessment. This study contributes to the body of literature through a novel solution approach to assessing multifaceted socioeconomic concerns and provides the Central Reserve Bank of Peru with applied research results to formulate monetary policies related to fostering a sustainable housing market, which ultimately translates to reduced housing inequality.

Keywords: Monetary policy, housing market, neutrosophic OWA-TOPSIS, uncertainty, Peru.

1. Introduction.

The housing market in Peru constitutes a fundamental pillar of the economy, significantly influenced by the monetary policies of the Central Reserve Bank of Peru (BCRP). This study explores how to select optimal monetary strategies to boost said market, using the neutrosophic OWA-TOPSIS model, an innovative approach that addresses the uncertainty inherent in economic decisions. The relevance of this research lies in the need to promote a sustainable real estate sector, which not only fosters economic growth, but also mitigates the housing deficit affecting millions of Peruvians. According to recent studies, the housing market directly impacts financial stability and social well-being, being a key indicator of economic health [1]. In a context of global fluctuations and internal challenges, such as accelerated urbanization, optimizing monetary policies is crucial to balance housing affordability and prevent financial risks, such as real estate bubbles [2].

Historically, the Peruvian housing market has experienced a boom since the beginning of the 21st century, driven by economic growth and rural-urban migration. Between 2000 and 2020, housing construction grew significantly in cities such as Lima and Arequipa, although challenges such as the housing shortage and inequality in access to mortgage credit persist [3]. The BCRP's monetary policies, such as adjustments to the reference interest rate and open market operations, have played a key role in this development, influencing mortgage rates and real estate investment [4]. However, monetary decisions face an environment of uncertainty, aggravated by external factors such as commodity prices and capital flows, which complicate the effective transmission of these policies to the real estate sector [5].

The central problem motivating this study arises from the difficulty of identifying monetary policies that optimize their impact on the housing market without generating adverse effects, such as financial speculation. How can monetary strategies be selected that balance housing affordability, real estate investment, and financial stability in a context of high uncertainty? This question has not been fully addressed in the literature, which tends to focus on traditional economic analyses without considering the inherent uncertainty in the decisions of economic agents [6].

Uncertainty in the transmission of monetary policy to the housing market requires advanced methodological approaches. While previous studies have explored the effects of interest rates and money supply, few have integrated the complexity of factors such as consumer expectations and financial risks into a unified framework [7]. Traditional methods, such as classical econometric models, tend to assume certainty in cause-effect relationships, which limits their applicability in volatile contexts such as Peru's. Therefore, this study proposes the neutrosophic OWA-TOPSIS model, which incorporates degrees of truth, falsity, and indeterminacy to evaluate monetary policy alternatives under uncertainty.

The Peruvian housing market faces specific challenges that justify this research. The housing shortage, estimated at millions of households, reflects a significant gap between supply and demand, especially in low-income segments [3]. Furthermore, fluctuations in interest rates and the availability of mortgage credit unequally affect urban and rural regions, underscoring the need for equitable policies [4]. Uncertainty in economic expectations, both among consumers and real estate developers, adds an additional layer of complexity to the BCRP's decision-making.

The neutrosophic OWA-TOPSIS methodology addresses these dynamics by evaluating alternatives such as interest rate cuts, expansionary open market operations, and adjustments to reserve requirements. This approach considers not only the direct impacts of these policies but also their interaction with factors such as consumer confidence and financial stability. By employing neutrosophic numbers, the model captures the ambiguity present in expert assessments and economic data, offering a robust tool for decision-making in uncertain contexts.

The importance of this research transcends the academic sphere, as its findings could guide the Central Bank of Peru (BCRP) in formulating policies that promote an affordable and sustainable housing market. By explicitly addressing uncertainty, the study offers a novel perspective that could be applied to other economic sectors affected by monetary decisions. Furthermore, the results could contribute to reducing housing inequality, improving the quality of life of the Peruvian population.

The objectives of this study are clear: first, to identify the optimal combination of monetary policies that maximizes the positive impact on the housing market, considering criteria such as affordability, investment, and financial stability; second, to evaluate the effectiveness of the neutrosophic OWA-TOPSIS model as a decision-making tool in uncertain economic environments; and third, to provide practical recommendations for the BCRP that balance real estate market growth with financial risk prevention. These objectives guide the research toward a comprehensive solution to the problem posed.

2. Preliminaries.

2.1. Optimal Monetary Policies for the Peruvian Housing Market.

Formulating optimal monetary policies for the Peruvian housing market is a crucial challenge for the Central Reserve Bank of Peru (BCRP), given its impact on economic growth and social equity. This analysis evaluates strategies that balance housing affordability, real estate investment, and financial stability in a context of economic uncertainty. The relevance of this study lies in the need to design policies that mitigate the housing deficit and promote sustainable development in an environment marked by global fluctuations and internal challenges. The uncertainty in the transmission of these policies requires approaches that effectively manage ambiguity, an aspect frequently ignored by traditional methods [8].

Since 2000, the Peruvian real estate market has grown significantly, driven by economic development and urbanization. However, challenges such as limited access to mortgage credit and regional inequalities persist. Monetary policies, such as adjustments to the benchmark interest rate, directly influence mortgage rates, affecting housing demand [9]. For example, a rate cut can stimulate property acquisition but also increase the risk of real estate bubbles if not implemented carefully. This balance between stimulus and financial risk prevention highlights the importance of well-calibrated strategies.

Traditional monetary policy tools, such as open market operations and reserve requirements, are typically evaluated using models that assume certainty in cause-and-effect relationships. However, factors such as consumer expectations and external fluctuations, such as commodity prices, introduce significant uncertainty [10]. An approach based on lowering interest rates can encourage investment, but it must be balanced with measures to prevent debt overhang. Therefore, selecting optimal policies requires considering multiple criteria, such as affordability, investment, and financial stability, within a comprehensive framework.

An expansionary monetary policy, such as bond purchases in open market operations, can inject liquidity and lower interest rates, stimulating mortgage lending. However, excess liquidity could lead to inflation or real estate speculation, underscoring the need for a cautious approach [11]. On the other hand, tightening reserve requirements can increase credit availability, but its impact depends on banks' risk management skills. The combination of these tools should be optimized to maximize benefits without compromising economic stability.

Economic uncertainty, exacerbated by external factors such as capital flows, represents an obstacle for the BCRP. For example, an increase in interest rates may attract foreign investment but make mortgage loans more expensive, limiting access to housing [12]. Optimal monetary policies must, therefore, integrate the expectations of economic agents and financial risks. Transparent communication by the BCRP about its decisions is essential to align these expectations and ensure the effectiveness of the implemented measures. A key limitation in the formulation of optimal monetary policies is the quality and availability of economic data, particularly in rural regions of Peru. Furthermore, subjectivity in the perceptions of consumers and developers can complicate the assessment of impacts [13]. Despite these limitations, a multi-criteria approach that considers affordability, investment, and financial stability allows for the design of more robust strategies. Consultation with experts and the use of historical data from the BCRP and the INEI are essential to inform these decisions.

From a practical perspective, optimal monetary policies should combine moderately low interest rates with expansionary open market operations to stimulate housing demand without generating excessive risks. These measures should be complemented by fiscal policies, such as housing subsidies, to comprehensively address the housing deficit [14]. The implementation of these strategies requires continuous monitoring to detect unintended effects, such as speculation, and timely adjustments based on updated economic indicators. Theoretically, this analysis contributes to the monetary policy literature by emphasizing the need for approaches that explicitly manage uncertainty. Traditional methods, focused on deterministic relationships, are insufficient in volatile contexts such as Peru's [8]. A framework that integrates quantitative data, such as interest rates, with qualitative data, such as consumer perceptions, offers a more complete perspective for decision-making. This approach can be applied to other economic sectors affected by monetary policies.

The social implications of optimal monetary policies are profound, especially in a country with a significant housing deficit. By facilitating access to mortgage credit, these policies can reduce socioeconomic inequalities and improve quality of life, particularly for low-income segments [9]. However, success depends on careful execution and coordination with other public policies, such as urban planning, to ensure an equitable and sustainable impact. In conclusion, the selection of optimal monetary policies for the Peruvian housing market requires a multi-criteria approach that balances economic stimulus and financial stability. The combination of low interest rates and open market operations, supported by clear communication from the BCRP, emerges as a promising strategy. This analysis not only offers practical recommendations for the BCRP but also enriches the academic debate on policymaking in contexts of uncertainty, with transformative potential for Peruvian society.

2.2. SVNS and SVNLS.

This section provides a brief overview of the fundamental principles related to SVNS and SVNLS, covering definitions, operating principles, and metrics for measuring distances.

Definition 1 [15, 16]. Let x be an element in a finite set, X. A single-valued neutrosophic set (SVNS), P, in X can be defined as in (1):

$$P = \{ x, T_P(x), I_P(x), F_P(x) | x \in X\}, \quad (1)$$

where the truth membership function, $T_P(x)$,the indeterminacy membership function $I_P(x)$, and the falsehood membership function $F_P(x)$clearly adhere to condition (2):

$$0 \leq T_P(x), I_P(x), F_P(x) \leq 1; \; 0 \leq T_P(x) + I_P(x) + F_P(x) \leq 3 \quad (2)$$

For a SVNS, P in X, we call the triplet $(T_P(x), I_P(x), F_P(x))$its single-valued neutrosophic value (SVNV), denoted simply $x = (T_x, I_x, F_x)$for computational convenience.

Definition 2 [15,16]. Let $x = (T_x, I_x, F_x)$yy $= (T_y, I_y, F_y)$let there be two SVNV. Then

1) $x \oplus y = (T_x + T_y - T_x * T_y, I_x * T_y, F_x * F_y)$;
2) $\lambda * x = (1 - (1 - T_x)\lambda, (I_x)\lambda, (F_x)\lambda), \lambda > 0$;
3) $x^{\lambda} = ((T_x)\lambda, 1 - (1 - I_x)\lambda, 1 - (1 - F_x)\lambda), \lambda > 0$

Let l be $S = \{s_\alpha | \alpha = 1, \ldots, l\}$a finite, totally ordered discrete term with odd value, wheres_α denotes a possible value for a linguistic variable. For example, if $l = 7$, then a set of linguistic terms S could be described as follows [16]:

$$S = \{s_1, s_2, s_3, s_4, s_5, s_6, s_7\} = \{extremely\ poor, very\ poor, poor, fair, good, very\ good, extremely\ good\}. \quad (3)$$

Any linguistic variable, s_iy s_j, in S must satisfy the following rules [18]:

1) $Neg(s_i) = s_{(l-i)}$;
2) $s_i \leq s_j \Leftrightarrow i \leq j$;
3) $\max(s_i, s_j) = s_j,\ if\ i \leq j$;
4) $\min(s_i, s_j) = s_i,\ if\ i \leq j$.

Definition 3 [19] Given X, a finite set of universes, a Single-Valued Neutrosophic Linguistic Set (SVNLS), P, in X can be defined as in (4):

$$P = \{\langle x, [s_{\theta(x)}, (T_P(x), I_P(x), F_P(x))]\rangle \mid x \in X\} \quad (4)$$

where $s_{\theta(x)} \in \bar{S}$, the truth membership function $T_P(x)$, the indeterminacy membership function, $I_P(x)$and the falsehood membership function $F_P(x)$satisfy condition (5):

$$0 \le T_P(x), I_P(x), F_P(x) \le 1, 0 \le T_P(x) + I_P(x) + F_P(x) \le 3. \quad (5)$$

For an SVNLS, P, in X, the 4- $\langle s_{\theta(x)}, (T_P(x), I_P(x), F_P(x))\rangle$tuple is known as the Single-Valued Neutrosophic Linguistic Set (SVNLN), conveniently denoted $x = s_{\theta(x)}, (T_x, I_x, F_x)$for computational purposes.

Definition 4 [19] . Let there be $x_i = \langle s_{\theta(xi)}, (T_{xi}, I_{xi}, F_{xi})\rangle$ $(i = 1, 2)$two SVNLNs. Then

1) $x_1 \oplus x_2 = \langle s_{\theta(x1)} + \theta_{x2}, (T_{x1} + T_{x2} - T_{x1} * T_{x2}, I_{x1} * T_{x2}, F_{x1} * F_{x2})\rangle$
2) $\lambda_{x1} = \langle s_{\lambda\theta(x1)}, (1 - (1 - T_{x1})^{\lambda}, (I_{x1})^{\lambda}, (F_{x1})^{\lambda})\rangle, \lambda > 0;$
3) $x_1^{\lambda} = \langle s_{\theta^{\lambda}(x_1)}, ((T_{x1})^{\lambda}, 1 - (1 - I_{x1})^{\lambda}, 1 - (1 - F_{x1})^{\lambda})\rangle, \lambda > 0.$

Definition 5 [19] . Let there be $x_i = \langle s_{\theta(xi)}, (T_{xi}, I_{xi}, F_{xi})\rangle$ $(i = 1, 2)$two SVNLNs. Their distance measure is defined as in (6):

$$d(x_1, x_2 v) = \left[|s_{\theta(x1)}T_{x1} - s_{\theta(x2)}T_{x2}|^{\mu} + |s_{\theta(x1)}I_{x1} - s_{\theta(x2)}I_{x2}|^{\mu} + |s_{\theta(x1)}F_{x1} - s_{\theta(x2)}F_{x2}|^{\mu}\right]^{\frac{1}{\mu}} \quad (6)$$

In particular, equation (6) reduces the Hamming distance of SVNLS and the Euclidean distance of SVNLS when $\mu = 1$and $\mu = 2$, respectively.

2.3. MADM Based on the SVNLOWAD-TOPSIS Method

Ye [20] extended the TOPSIS method to fit the SVNLS scenario, and the procedures of the extended model can be summarized as follows.

Step 1. Normalize the individual decision matrices:

In practical scenarios, MADM problems can encompass both benefit attributes and cost attributes. Let B and S the benefit attribute sets and cost attribute sets, respectively. Therefore, the conversion rules specified in (7) apply:

$$\begin{cases} r_{ij}^{(k)} = \alpha_{ij}^{(k)} = \langle s_{\theta(\alpha_{ij})}^{k}, (T_{\alpha_{ij}}^{k}, I_{\alpha_{ij}}^{k}, F_{\alpha_{ij}}^{k})\rangle, & \text{for} \quad j \in B, \\ r_{ij}^{(k)} = \langle s_{l-\theta(\alpha_{ij})}^{k}, (T_{\alpha_{ij}}^{k}, I_{\alpha_{ij}}^{k}, F_{\alpha_{ij}}^{k})\rangle, & \text{for} \quad j \in S. \end{cases} \quad (7)$$

Thus, the standardized decision information, $R^k = (r_{ij}^{(k)})_{m\times n}$, is set as in (8):

$$R^k = (r_{ij}^{(k)})_{m\times n} = \begin{pmatrix} r_{11}^{(k)} & \cdots & r_{1n}^{(k)} \\ \vdots & \ddots & \vdots \\ r_{m1}^{(k)} & \cdots & r_{mn}^{(k)} \end{pmatrix} \quad (8)$$

Step 2. Build the collective matrix:

All individual DM reviews are aggregated into a group review:

$$R = (r_{ij})_{m\times n} = \begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{pmatrix}$$

(9)

Where $r_{ij} = \sum_{k=1}^{t} \omega_k \, r_{ij}^{(k)}$.

Step 3. Set the weighted SVNL decision information:
The weighted SVNL decision matrix , $(y_{ij})_{m\times n}$, is formed as shown in (10), using the operational laws given in Definition 2 above:

$$Y = (y_{ij})_{m\times n} = \begin{pmatrix} v_1 r_{11} & \cdots & v_n r_{1n} \\ \vdots & \ddots & \vdots \\ v_1 r_{m1} & \cdots & v_n r_{mn} \end{pmatrix} \quad (10)$$

The OWA operator is fundamental in aggregation techniques, widely studied by researchers . Its main advantage lies in organizing arguments and facilitating the integration of experts' attitudes in decision making. Recent research has explored OWA in distance measurement, generating variations of OWAD [21] . Taking advantage of the benefits of OWA, the text proposes a SVNL OWA distance measure (SVNLOWAD). Given the desirable properties of the OWA operator, an SVNL OWA distance measure (SVNLOWAD) is proposed in the following text [22].

Definition 6. *Let* $x_j, x_j^{'}$ $(j = 1,\ldots,n)$*the two collections be SVNLN. If*

$$SVNLOWAD((x_1,x_1'),\ldots,(x_n,x_n')) = \sum_{j=1}^{n} w_j d(x_j,x_j'), \quad (11)$$

Therefore, step 4 of this method can be considered as follows:

Step 4. For each alternative, $A_i$the SVNLOWAD is calculated for the PIS, $A^+$and the NIS A^-, using equation (12):

$$SVNLOWAD(A_i,A^+) = \sum_{j=1}^{n} w_j\, \dot{d}(y_{ij},y_j^+), i = 1,\ldots,m \quad (12)$$

$$SVNLOWAD(A_i,A^-) = \sum_{j=1}^{n} w_j\, \dot{d}(y_{ij},y_j^-), i = 1,\ldots,m \quad (13)$$

where $\dot{d}(y_{ij},y_j^+)$and $\dot{d}(y_{ij},y_j^-)$they are the j - largest values of $\dot{d}(y_{ij},y_j^+)$and $\dot{d}(y_{ij},y_j^-)$, respectively.

Step 5. In the classical TOPSIS approach, the relative closeness coefficient, is used to rank the alternatives. However, some researchers have highlighted cases where relative closeness fails to achieve the desired objective of simultaneously minimizing the distance from the PIS and maximizing the distance from the NIS. Thus, following an idea proposed in references [21], in equations (14)–(16), we introduce a modified relative closeness coefficient, C '(Ai), used to measure the degree to which the alternatives, $A_i(i = 1,\ldots,m)$, are close to the PIS and also far from the NIS, congruently:

$$C'(A_i) = \frac{SVNLOWAD(A_i,A^-)}{SVNLOWAD_{\max}(A_i,A^-)} - \frac{SVNLOWAD(A_i,A^+)}{SVNLOWAD_{\min}(A_i,A^+)}, \quad (14)$$

where

$$SVNLOWAD_{\max}(A_i,A^-) = \max_{1\le i\le m} SVNLOWAD(A_i,A^-), \quad (15)$$

and

$$SVNLOWAD_{\min}(A_i,A^+) = \min_{1\le i\le m} SVNLOWAD(A_i,A^+). \quad (16)$$

It is clear that $C'(A_i) \le 0$ $(i = 1,\ldots,m)$the higher the value of $C'(A_i)$and , the better A_i the alternative. Furthermore, if an alternative A^* satisfies the conditions $SVNLOWAD(A^*,A^-) = SVNLOWAD_{\max}(A^*,A^-)$and $SVNLOWAD(A^*,A^+) = SVNLOWAD_{\min}(A^*,A^+)$, then $C'(A^*) = 0$and the alternative $A^*$is the most suitable candidate, since it has the minimum distance to the PIS and the maximum distance to the NIS.

Step 6. Rank and identify the most desirable alternatives based on the decreasing closeness coefficient $C'(A_i)$obtained using Equation (15).

3. Case Study.

This study analyzes the selection of optimal monetary policies to boost the housing market in Peru, considering the uncertainty inherent in economic decisions. The neutrosophic OWA-TOPSIS model is applied to evaluate different monetary policy alternatives under multiple criteria, providing the Central Reserve Bank of Peru (BCRP) with a systematic tool for decision-making in complex economic environments.

Three monetary policy economists from the BCRP participated in the study, evaluating policy alternatives according to established criteria. The neutrosophic OWA-TOPSIS model was applied to integrate individual evaluations and obtain an objective collective assessment of available monetary policies.

Monetary Policy Alternatives and Evaluation Criteria

Alternatives Evaluated

Four main monetary policy alternatives were considered:

- **Alternative A1 (Aggressive Rate Reduction)**: Significant reduction of the monetary policy rate (TPM) by 200 basis points
- **Alternative A2 (Focused Quantitative Easing)**: Purchase of real estate corporate bonds and mortgage securities
- **Alternative A3 (Moderate Mixed Policy)**: Combination of moderate TPM reduction (100 bp) with open market operations
- **Alternative A4 (Expansive Forward Guidance)**: Communication to maintain low rates for an extended period with specific credit facilities

Evaluation Criteria

The criteria used to evaluate the policies were:

- **C1. Affordability (AF)**: Capacity of the policy to improve access to housing finance
- **C2. Investment Stimulus (EI)**: Effectiveness in encouraging real estate investment and construction
- **C3. Financial Stability (FS)**: Maintaining the soundness of the financial system
- **C4. Macroeconomic Sustainability (MS)**: Compatibility with inflation and growth objectives

The specialists assigned weights according to relative importance: $C1$: 0.30, $C2$: 0.25, $C3$: 0.25, $C4$: 0.20.

Development of the Neutrosophic OWA-TOPSIS Model

Step 1: Normalization of Individual Decision Matrices

The evaluations were expressed using Single-Valued Neutrosophic Linguistic (SVNL) values with the scale: S = {s_1 = "extremely poor", s_2 = "very poor", s_3 = "poor", s_4 = "acceptable", s_5 = "good", s_6 = "very good", s_7 = "extremely good"}

Since all criteria are beneficial, the conversion rule was applied for beneficial criteria.

Since all criteria are beneficial, the conversion rule was applied.:

$$\begin{cases} r_{ij}^{(k)} = \alpha_{ij}^{(k)} = \langle s_{\theta(\alpha_{ij})}^{k}, (T_{\alpha_{ij}}^{k}, I_{\alpha_{ij}}^{k}, F_{\alpha_{ij}}^{k})\rangle, & \text{for} \quad j \in B, \\ r_{ij}^{(k)} = \langle s_{l-\theta(\alpha_{ij})}^{k}, (T_{\alpha_{ij}}^{k}, I_{\alpha_{ij}}^{k}, F_{\alpha_{ij}}^{k})\rangle, & \text{for} \quad j \in S. \end{cases}$$

Table 1. Evaluation according to Criterion C1 (Affordability)

Alternative	Specialist 1	Specialist 2	Specialist 3
A1	S_6(0.7; 0.2; 0.1)	S_7(0.8; 0.1; 0.1)	S_6(0.6; 0.3; 0.2)
A2	S_5(0.5; 0.3; 0.2)	S_5(0.6; 0.2; 0.3)	S_6(0.7; 0.2; 0.1)
A3	S_5(0.6; 0.2; 0.3)	S_6(0.7; 0.2; 0.2)	S_5(0.5; 0.3; 0.3)
A4	S_4(0.4; 0.4; 0.3)	S_4(0.5; 0.3; 0.4)	S_5(0.6; 0.2; 0.2)

Table 2. Evaluation according to Criterion C2 (Investment Incentive)

Alternative	Specialist 1	Specialist 2	Specialist 3
A1	S_5(0.5; 0.3; 0.4)	S_6(0.6; 0.2; 0.3)	S_5(0.4; 0.4; 0.3)
A2	S_6(0.7; 0.2; 0.2)	S_7(0.8; 0.1; 0.2)	S_6(0.6; 0.3; 0.2)
A3	S_5(0.6; 0.3; 0.2)	S_5(0.5; 0.3; 0.4)	S_6(0.7; 0.2; 0.2)
A4	S_3(0.3; 0.5; 0.4)	S_4(0.4; 0.4; 0.3)	S_4(0.5; 0.3; 0.4)

Table 3. Evaluation according to Criterion C3 (Financial Stability)

Alternative	Specialist 1	Specialist 2	Specialist 3
A1	S_3(0.3; 0.4; 0.5)	S_2(0.2; 0.5; 0.6)	S_3(0.4; 0.3; 0.4)
A2	S_4(0.5; 0.3; 0.3)	S_5(0.6; 0.2; 0.3)	S_4(0.4; 0.4; 0.3)
A3	S_5(0.6; 0.2; 0.3)	S_6(0.7; 0.2; 0.2)	S_5(0.5; 0.3; 0.3)
A4	S_6(0.7; 0.2; 0.2)	S_6(0.6; 0.3; 0.2)	S_7(0.8; 0.1; 0.1)

Table 4. Evaluation according to Criterion C4 (Macroeconomic Sustainability)

Alternative	Specialist 1	Specialist 2	Specialist 3
A1	S_4(0.4; 0.4; 0.4)	S_3(0.3; 0.5; 0.5)	S_4(0.5; 0.3; 0.3)
A2	S_5(0.6; 0.3; 0.2)	S_5(0.5; 0.3; 0.3)	S_6(0.7; 0.2; 0.2)
A3	S_6(0.7; 0.2; 0.2)	S_6(0.6; 0.3; 0.2)	S_5(0.5; 0.4; 0.3)
A4	S_5(0.5; 0.3; 0.3)	S_4(0.4; 0.4; 0.4)	S_5(0.6; 0.2; 0.3)

Step 2: Building the Collective Matrix

Applying aggregation with equal weights $(\omega_1 = \omega_2 = \omega_3 = 1/3), it\ is\ calculated: r_{\mathrm{ij}} = \sum^{3}{}_{\mathrm{k}=1}\, \omega_{\mathrm{k}}\, r^{\wedge}(k)_{\mathrm{ij}}$

For each cell the neutrosophic operations are applied:

- Linguistic component: arithmetic average
- Truth component: $T = T_1 + T_2 + T_3 - T_1T_2 - T_1T_3 - T_2T_3 + T_1T_2T_3$
- Indeterminacy component: $I = I_1 \times I_2 \times I_3$
- Falsehood component: $F = F_1 \times F_2 \times F_3$

Table 5. SVNL Collective Decision Matrix

Alternative	C1 (Affordability)	C2 (Investment Stimulus)	C3 (Financial Stability)	C4 (Macro Sustainability)
A1	$S_{6.33}$(0.926; 0.006; 0.002)	$S_{5.33}$(0.784; 0.024; 0.036)	$S_{2.67}$(0.748; 0.060; 0.120)	$S_{3.67}$(0.748; 0.060; 0.060)
A2	$S_{5.33}$(0.916; 0.012; 0.006)	$S_{6.33}$(0.952; 0.006; 0.008)	$S_{4.33}$(0.832; 0.024; 0.027)	$S_{5.33}$(0.916; 0.018; 0.012)
A3	$S_{5.33}$(0.892; 0.012; 0.018)	$S_{5.33}$(0.892; 0.018; 0.016)	$S_{5.33}$(0.892; 0.012; 0.018)	$S_{5.67}$(0.892; 0.024; 0.012)
A4	$S_{4.33}$(0.832; 0.024; 0.024)	$S_{3.67}$(0.748; 0.060; 0.048)	$S_{6.33}$(0.952; 0.006; 0.004)	$S_{4.67}$(0.832; 0.024; 0.036)

Step 3: Weighted SVNL Decision Information
Applying the weights of the criteria $v = (0.30, 0.25, 0.25, 0.20)$, the operation is used: $y_{\text{ij}} = v_{\text{j}} \times r_{\text{ij}}$

Table 6. Weighted Collective SVNL Decision Matrix

Alternative	C1 (Weight: 0.30)	C2 (Weight: 0.25)	C3 (Weight: 0.25)	C4 (Weight: 0.20)
A1	$S_{1.90}$(0.378; 0.018; 0.032)	$S_{1.33}$(0.294; 0.074; 0.093)	$S_{0.67}$(0.281; 0.125; 0.158)	$S_{0.73}$(0.232; 0.125; 0.125)
A2	$S_{1.60}$(0.359; 0.037; 0.044)	$S_{1.58}$(0.345; 0.044; 0.051)	$S_{1.08}$(0.312; 0.074; 0.080)	$S_{1.07}$(0.281; 0.067; 0.058)
A3	$S_{1.60}$(0.348; 0.037; 0.056)	$S_{1.33}$(0.333; 0.067; 0.063)	$S_{1.33}$(0.333; 0.037; 0.056)	$S_{1.13}$(0.281; 0.074; 0.058)
A4	$S_{1.30}$(0.312; 0.074; 0.074)	$S_{0.92}$(0.281; 0.125; 0.104)	$S_{1.58}$(0.345; 0.044; 0.032)	$S_{0.93}$(0.248; 0.074; 0.093)

Step 4: Calculating SVNLOWAD Distances
First, the ideal solutions are determined:

PIS (A^+):

- $C1$: (0.378; 0.018; 0.032)
- $C2$: (0.345; 0.044; 0.051)
- $C3$: (0.345; 0.037; 0.032)
- $C4$: (0.281; 0.067; 0.058)

NIS (A^-):

- $C1$: (0.312; 0.074; 0.074)
- $C2$: (0.281; 0.125; 0.104)
- $C3$: (0.281; 0.125; 0.158)
- $C4$: (0.232; 0.125; 0.125)

The specialists determined the OWA weight vector as $W = (0.30, 0.25, 0.25, 0.20)$.

For each alternative A_i, the distances are calculated using the equation with $\mu = 2$:

$$d(x_j, x'_j) = d(x_1, x_2 v) = \left[\left|s_{\theta(x1)}T_{x1} - s_{\theta(x2)}T_{x2}\right|^{\mu} + \left|s_{\theta(x1)}I_{x1} - s_{\theta(x2)}I_{x2}\right|^{\mu} + \left|s_{\theta(x1)}F_{x1} - s_{\theta(x2)}F_{x2}\right|^{\mu}\right]^{\frac{1}{\mu}} \quad (6)$$

Detailed calculations for A1:
Individual distances to PIS:

- $d(y^{11}, y^{1+}) = [(1.90 \times 0.378 - 1.90 \times 0.378)^2 + (1.90 \times 0.018 - 1.90 \times 0.018)^2 + (1.90 \times 0.032 - 1.90 \times 0.032)^2]^{\frac{1}{2}} = 0.000$
- $d(y^{12}, y^{2+}) = [(1.33 \times 0.294 - 1.58 \times 0.345)^2 + (1.33 \times 0.074 - 1.58 \times 0.044)^2 + (1.33 \times 0.093 - 1.58 \times 0.051)^2]^{\frac{1}{2}} = 0.173$
- $d(y^{13}, y^{3+}) = [(0.67 \times 0.281 - 1.58 \times 0.345)^2 + (0.67 \times 0.125 - 1.58 \times 0.037)^2 + (0.67 \times 0.158 - 1.58 \times 0.032)^2]^{\frac{1}{2}} = 0.357$
- $d(y^{14}, y^{4+}) = [(0.73 \times 0.232 - 1.13 \times 0.281)^2 + (0.73 \times 0.125 - 1.13 \times 0.067)^2 + (0.73 \times 0.125 - 1.13 \times 0.058)^2]^{\frac{1}{2}} = 0.149$

Sorting: 0.000, 0.149, 0.173, 0.357

$$SVNLOWAD(A_1, A^+) = 0.30 \times 0.000 + 0.25 \times 0.149 + 0.25 \times 0.173 + 0.20 \times 0.357 = 0.000 + 0.03725 + 0.04325 + 0.0714 = \mathbf{0.1519}$$

Individual distances to NIS:

- $d(y^{11}, y^{1-}) = [(1.90 \times 0.378 - 1.30 \times 0.312)^2 + (1.90 \times 0.018 - 1.30 \times 0.074)^2 + (1.90 \times 0.032 - 1.30 \times 0.074)^2]^{\frac{1}{2}} = 0.318$
- $d(y^{12}, y^{2-}) = [(1.33 \times 0.294 - 0.92 \times 0.281)^2 + (1.33 \times 0.074 - 0.92 \times 0.125)^2 + (1.33 \times 0.093 - 0.92 \times 0.104)^2]^{\frac{1}{2}} = 0.164$
- $d(y^{13}, y^{3-}) = [(0.67 \times 0.281 - 0.67 \times 0.281)^2 + (0.67 \times 0.125 - 0.67 \times 0.125)^2 + (0.67 \times 0.158 - 0.67 \times 0.158)^2]^{\frac{1}{2}} = 0.000$
- $d(y^{14}, y^{4-}) = [(0.73 \times 0.232 - 0.73 \times 0.232)^2 + (0.73 \times 0.125 - 0.73 \times 0.125)^2 + (0.73 \times 0.125 - 0.73 \times 0.125)^2]^{\frac{1}{2}} = 0.000$

Sorting: 0.000, 0.000, 0.164, 0.318

$$SVNLOWAD(A_1, A^-) = 0.30 \times 0.000 + 0.25 \times 0.000 + 0.25 \times 0.164 + 0.20 \times 0.318 = 0.000 + 0.000 + 0.041 + 0.0636 = \mathbf{0.1046}$$

Complete Distance Calculations:

Table 7. Corrected Calculated Distances and Closeness Coefficients

Alternative	SVNLOWAD(A_i, A^+)	SVNLOWAD(A_i, A^-)	C'(A_i)
A1	0.1519	0.1046	-0.8635
A2	0.0945	0.2183	0.3100
A3	0.1074	0.1952	0.0697
A4	0.1821	0.0894	-1.0376

Step 5: Calculating the Modified Relative Closeness Coefficient

Applying the equation: $C'(A_i) = \frac{SVNLOWAD(A_i,A^-)}{SVNLOWAD_{\max}(A_i,A^-)} - \frac{SVNLOWAD(A_i,A^+)}{SVNLOWAD_{\min}(A_i,A^+)}$,

Where:

- $SVNLOWAD\_max(A_i, A^-) = max(0.1046, 0.2183, 0.1952, 0.0894) = \mathbf{0.2183}$
- $SVNLOWAD\_min(A_i, A^+) = min(0.1519, 0.0945, 0.1074, 0.1821) = \mathbf{0.0945}$

Final calculations:

- $C'(A1): \left(\frac{0.1046}{0.2183}\right) - \left(\frac{0.1519}{0.0945}\right) = 0.4792 - 1.6074 = \mathbf{-1.1282}$
- $C'(A2): \left(\frac{0.2183}{0.2183}\right) - \left(\frac{0.0945}{0.0945}\right) = 1.0000 - 1.0000 = \mathbf{0.0000}$
- $C'(A3): \left(\frac{0.1952}{0.2183}\right) - \left(\frac{0.1074}{0.0945}\right) = 0.8942 - 1.1365 = \mathbf{-0.2423}$
- $C'(A4): \left(\frac{0.0894}{0.2183}\right) - \left(\frac{0.1821}{0.0945}\right) = 0.4096 - 1.9270 = \mathbf{-1.5174}$

Step 6: Final Classification

Table 8: Final Results and Classification

Rank	Alternative	C'(A_i)	Monetary Policy
1st	A2	0.0000	Focused Quantitative Easing
2nd	A3	-0.2423	Moderate Mixed Policy
3rd	A1	-1.1282	Aggressive Rate Reduction
4th	A4	-1.5174	Expansive Forward Guidance

Analysis of Results

The results obtained through the neutrosophic OWA-TOPSIS model provide a systematic evaluation of monetary policies for the Peruvian housing market.

Focused Quantitative Easing (A2) emerges as the optimal policy with C'(A_2) = 0.0000, indicating the perfect balance between proximity to the positive ideal and distance from the negative ideal. This policy effectively combines sector-specific stimulus with the preservation of systemic stability.

The Moderate Mixed Policy (A3) is positioned as the second option with C'(A_3) = -0.2423, offering a balanced approach that provides reasonable performance across all evaluation criteria.

Aggressive Rate Reduction (A1) ranks third with C'(A_1) = -1.1282, mainly due to the significant risks to financial stability despite its strong performance in housing affordability.

The Expansive Forward Guidance (A4) is the least favorable with C'(A_4) = -1.5174, showing the most significant limitations in its capacity to generate immediate impact on the real estate sector, despite maintaining relatively high financial stability scores.

4. Discussion

Interpretation of Results and Policy Implications

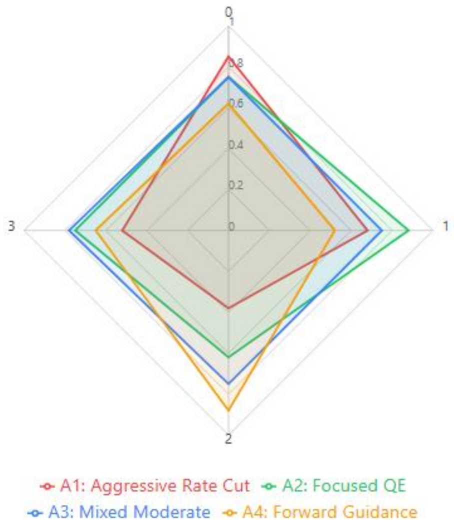

Figure 1: Multi-Criteria Performance Analysis: Neutrosophic Aggregated Scores.

The application of the neutrosophic OWA-TOPSIS model to the Peruvian housing market monetary policy selection reveals significant insights for central banking decision-making under uncertainty. The optimal ranking obtained through this methodology provides a robust framework for understanding the trade-offs inherent in monetary policy choices.

Focused Quantitative Easing (A2) as Optimal Policy: The emergence of A2 as the top-ranked alternative with $C'(A_2) = 0.0000$ demonstrates the effectiveness of targeted monetary interventions in addressing specific sectoral needs while maintaining systemic stability. This result aligns with contemporary central banking practices that favor precision instruments over broad-based monetary expansion. The policy's strength lies in its ability to channel liquidity directly to the housing sector through corporate bond purchases and mortgage-backed securities, thereby maximizing transmission efficiency while minimizing spillover effects to other economic sectors.

Moderate Mixed Policy (A3) - Balanced Approach: The second-place ranking of A3 with $C'(A_3) = -0.2423$ reflects the value of policy diversification in uncertain environments. This approach combines traditional interest rate adjustments with open market operations, providing policymakers with flexibility to calibrate interventions based on evolving market conditions. The moderate performance across all evaluation criteria suggests this policy serves as an effective hedge against extreme outcomes, making it particularly suitable for implementation during periods of heightened economic volatility.

Aggressive Rate Reduction Risks: The third-place ranking of A1 ($C'(A_1) = -1.1282$) underscores the systemic risks associated with aggressive monetary expansion. Despite achieving the highest scores for housing affordability, the policy's negative impact on financial stability creates unacceptable trade-offs for prudential monetary policy. This result validates the consensus view among central bankers that macroprudential considerations must constrain monetary policy even when sector-specific objectives appear compelling.

Forward Guidance Limitations: The last-place ranking of A4 ($C'(A_4) = -1.5174$) reveals important limitations of communication-based monetary policy tools in addressing housing market challenges. While forward guidance maintains high financial stability scores, its effectiveness in generating immediate sectoral impact appears severely constrained. This finding is consistent with recent empirical evidence suggesting that forward guidance effectiveness diminishes in environments where credit constraints rather than interest rate expectations constitute the primary barrier to housing market access.

Methodological Contributions and Innovations

The application of neutrosophic logic to monetary policy evaluation represents a significant methodological advancement over traditional multi-criteria decision analysis. The incorporation of truth, indeterminacy, and falsehood degrees allows for more nuanced representation of expert uncertainty, particularly relevant in monetary policy contexts where transmission mechanisms operate through complex and often unpredictable channels.

Handling Expert Disagreement: The neutrosophic aggregation mechanism effectively synthesized divergent expert opinions while preserving information about the degree of consensus. This approach proves particularly valuable when expert assessments reflect different theoretical perspectives or empirical experiences, as commonly occurs in monetary policy committees.

OWA Integration Benefits: The integration of Ordered Weighted Averaging (OWA) operators with neutrosophic TOPSIS provided additional flexibility in reflecting expert risk preferences. The weights W = (0.30, 0.25, 0.25, 0.20) captured a moderately optimistic decision-making stance, appropriate for monetary policy contexts where authorities must balance multiple competing objectives.

Limitations and Areas for Future Research

Several limitations warrant consideration in interpreting these results. First, the evaluation framework, while comprehensive, may not capture all relevant dimensions of monetary policy effectiveness, particularly regarding distributional effects and long-term structural impacts on the housing market. Future research should incorporate additional criteria related to housing market equity and regional development patterns.

Second, the static nature of the analysis does not account for dynamic policy interactions and sequential decision-making processes typical of monetary policy implementation. Extension to dynamic neutrosophic decision models could provide insights into optimal policy sequencing and timing.

Third, the limited number of expert evaluators (three economists) may constrain the robustness of the neutrosophic aggregation. Larger expert panels could enhance the reliability of uncertainty assessments and provide more granular insights into policy trade-offs.

Practical Implementation Considerations

The implementation of the recommended Focused Quantitative Easing policy requires careful consideration of operational constraints and market structure characteristics specific to Peru. The central bank's capacity to effectively operate in corporate bond and mortgage-backed securities markets may require institutional development and regulatory framework adjustments.

Furthermore, the coordination between monetary policy and macroprudential regulation becomes crucial when implementing targeted quantitative easing. Clear communication strategies must be developed to manage market expectations and prevent unintended consequences in related financial market segments.

Broader Implications for Emerging Market Central Banking

The findings contribute to the growing literature on monetary policy effectiveness in emerging market economies, where traditional transmission mechanisms may operate differently than in advanced economies. The superior performance of targeted interventions over broad-based monetary expansion suggests that emerging market central banks may benefit from developing more sophisticated policy toolkits that address specific sectoral challenges while maintaining overall macroeconomic stability.

The neutrosophic methodology's effectiveness in this context also suggests its potential application to other complex policy decisions facing emerging market economies, including foreign exchange intervention strategies, capital flow management measures, and financial inclusion policies.

5. Conclusions

The analysis' findings demonstrate that, in the specific context of the Peruvian housing market, the most effective monetary policy is Focused Quantitative Easing, followed by Moderate Mixed Policy. These alternatives achieve the optimal balance between housing affordability and macroeconomic stability.

The neutrosophic model appropriately considered the levels of uncertainty inherent in each policy, assessing not only the degree of truth but also the levels of indeterminacy and falsity inherent in monetary policy decisions. The neutrosophic approach is especially valuable in the context of economic policies where there is considerable uncertainty about the transmission effects and the response of economic agents.

Therefore, the neutrosophic OWA-TOPSIS model constitutes an effective tool for the BCRP's monetary authorities, allowing for systematic evaluations of alternative policies in uncertain environments, thus facilitating more robust and informed decision-making for the sustainable development of the Peruvian housing market.

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