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Comparison of Fuzzy Cognitive Maps and SEM in Estimating the Perception of Corporate Social Responsibility

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Abstract: This study examines the impact of the perception of corporate social responsibility (CSR) on the perceptions of clients, employees, and managers in small and medium enterprises (SMEs) in Ecuador. Utilizing a combination of Structural Equation Modeling (SEM) and Fuzzy Cognitive Maps (FCM), the research addresses how CSR policies influence the various internal stakeholders of companies, identifying complex structures of interaction and perception dynamics that could impact organizational performance. This neutrosophic framework not only enhances the understanding of CSR but also promotes the development of workplace welfare policies that effectively cater to a diverse range of staff needs and expectations. SEM was used to estimate and validate the structural relationships, while FCM helped illustrate the dynamics within the CSR network, highlighting how different perceptions affect and are affected by other variables in the system. The study's findings indicate that the perception of CSR by employees and managers has a direct and significant effect on client perception, corroborating the importance of effective CSR management in enhancing customer satisfaction and overall business performance.

Keywords: Corporate Social Responsibility, Economic development, neutrosophic, SMEs, Fuzzy Cognitive Maps

1. Introduction

Corporate social responsibility (CSR) in small and medium-sized enterprises (SMEs) in Ecuador, and generally in Latin America, has evolved from a purely philanthropic perspective to a more comprehensive approach that includes economic, social, and environmental sustainability. Internal CSR in SMEs in Ecuador represents a comprehensive approach that goes beyond legal compliance and aims to enhance the well-being of employees and the local community. This practice is not only an ethical matter but also strategic, as it significantly influences the reputation and economic performance of the companies [1].

Firstly, implementing internal CSR practices in SMEs can lead to increased productivity and employee retention. When a company invests in a healthy work environment, professional development programs, and fair compensation, it fosters loyalty and motivation among staff. This results in a reduction of costs associated with employee turnover and absenteeism, and an increase in operational efficiency. Satisfied and committed employees are more likely to contribute to the growth and innovation within the company.

Furthermore, SMEs that adopt internal CSR tend to improve their image and relationship with customers and suppliers. In Ecuador, where the business fabric is largely community-based and consumers are increasingly aware of business practices, SMEs that demonstrate a commitment to the well-being of their team and community can gain a competitive edge. This approach can lead to greater customer loyalty, with customers preferring to buy products and services from socially responsible companies [2], [3].

Internal CSR also facilitates access to financing for SMEs. Financial institutions and development agencies are beginning to consider social responsibility practices as an important factor in risk assessment and lending decisions. An SME that shows a strong commitment to CSR can be seen as less risky and more sustainable in the long term, which may improve financing conditions.

By engaging in CSR, SMEs in Ecuador better align with government policies and the Sustainable Development Goals (SDGs) promoted by the UN. This not only contributes to the economic and social development of the country but also opens opportunities for collaborations with the public sector and international organizations that provide additional resources and visibility.

Empirical research has shown that conventional economic development models, based on technological advancement and profit maximization, have led to significant global inequalities, particularly in Latin American

countries. In response to the challenge of reducing these disparities, there has been a strong push to promote sustainable development. This concept aims fundamentally to conserve the environment and improve human well-being, using economic development and the political and institutional framework as means.

This vision necessitates examining the four dimensions of sustainable development. On one hand, there is the environmental dimension, where, according to the approach, the environment can be considered an essential and irreplaceable asset of the production process (strong sustainability), and in some cases, as in Ecuador, it is referred to as "natural heritage." This dimension is complemented by the socio-cultural dimension, focused on the living conditions of the local population, highlighting the importance of local policies that enhance ancestral knowledge, culture, social and human capital, through the transformation of consumption patterns.

The economic dimension proposes new business models and strategies for companies to address environmental conservation and the social well-being of their communities. Notably, the circular and collaborative economy, along with strategies for association and corporate social responsibility, especially in SMEs, aim to increase competitiveness and collaboration, which are the ultimate goals of sustainable development [4].

In this framework, corporate social responsibility (CSR) fosters the commitment of companies to act ethically and contribute to social well-being, integrating social, environmental, and ethical aspects into their business operations and decisions. Companies that adopt CSR commit to minimizing negative impacts and maximizing positive impacts on the communities where they operate. Thus, CSR promotes sustainable development goals, especially those related to responsible production and consumption, as well as the efficient use of ecosystem services, but from a territorial perspective, focusing on the regions and communities affected by business activities.

CSR is oriented toward commitment and ethics with all stakeholders, not only external ones such as the community, the environment, customers, and other businesses and suppliers but also internal ones, including employees and investors. CSR regarding employees seeks to ensure fair working conditions, promote diversity and equality of opportunity, and offer well-being and professional development programs. With customers, it strives to provide safe and quality products and services, promote fair and transparent business practices, and ensure data privacy and security [5].

Regarding the community, it strengthens initiatives and projects that contribute to local development, fostering civic participation and volunteering. In relation to the environment, it seeks to minimize the impact of operations, adopt sustainable resource management practices, reduce greenhouse gas emissions, and promote environmental conservation. Although in large companies CSR practices are an integral part of the organizational and strategic culture, in SMEs, it may be believed that these practices require additional financial resources and do not contribute to the company's performance or influence customer perception of the organization's reputation.

Several authors note that the limitations to implementing CSR policies in SMEs are related to a lack of resources and funding, a lack of awareness, the inclusion of family members as employees, and a lack of strategic planning. Even with CSR practices, a lack of communication and promotion limits the positive effects on stakeholders. However, CSR is as important for SMEs as it is for large corporations. Although SMEs may have fewer resources than large companies, implementing socially responsible practices can bring significant benefits both for the company and for society [6]–[9].

1.1 Application in Neutrosophy

In the realm of internal corporate social responsibility (CSR), especially in SMEs in Ecuador, neutrosophic studies gain relevance by enhancing a threshold of possibilities amidst the diverse indeterminacies that the SME field entails. In the context of Ecuadorian SMEs, these businesses analyze and assess the different degrees of truth and falsehood of internal opinions and perceptions regarding CSR policies. This allows for a deeper understanding of employee concerns and expectations, facilitating the creation of a work environment that balances operational and economic needs with employee well-being and motivation.

The application of neutrosophy in evaluating labor welfare policies enables SMEs in Ecuador to address the ambiguity and uncertainty inherent in employees' perceptions of these policies. By considering neutral states and their degrees, SMEs identify and develop wellness programs that are not only perceived as beneficial but also truly respond to a wide range of staff needs and expectations, thus enhancing their commitment and satisfaction, which is essential for the economic and social sustainability of the company.

Neutrosophy offers Ecuadorian SMEs a framework to develop CSR strategies that are inherently adaptive, considering the varying degrees of acceptance and resistance within the organization. This capability is particularly valuable in an economic context where market conditions are unstable, and SMEs need to quickly adapt their CSR practices to both internal and external variations. Such adaptability strengthens economic resilience and promotes sustainable development, ensuring that internal practices are in line with principles of equity and social responsibility.

The application of neutrosophy in managing internal CSR in Ecuadorian SMEs presents an opportunity to address the complexities and dynamics of internal needs and expectations more holistically and balanced. By integrating this approach, SMEs not only improve their internal environment and economic efficiency but also strengthen their commitment to sustainable development and social responsibility.

Against this backdrop, the present research aims to analyze how the perception of corporate social responsibility (CSR) impacts the perception of customers, employees, and managers in small and medium-sized enterprises (SMEs), using Structural Equation Models (SEM) and Fuzzy Cognitive Maps (FCM) to understand the structural relationships and dynamics among these groups.

2 Methodology

2.1 Structural Equation Modeling (SEM)

Structural Equation Modeling (SEM) is an advanced statistical technique that allows for the examination of complex relationships between observed and latent variables. This methodology combines elements of multiple regression analysis and factor analysis to estimate a series of interrelated equations. It is widely used in social sciences, marketing, behavioral studies, education, and more [10], [11].

To perform calculations in Structural Equation Modeling (SEM), various equations and mathematical procedures are used, which are outlined below:

1. Measurement Model: Defines how latent (unobserved) variables are related to observed variables (indicators) [12]. Having a latent variable η and observed variables $x_1, x_2, \dots, x_n$, the equations of the measurement model are:

$$x_1 = \lambda_{11\eta} + \delta_1 \quad (1)$$

$$x_2 = \lambda_{21\eta} + \delta_2 \quad (2)$$

$$x_n = \lambda_{n1\eta} + \delta_n \quad (3)$$

Where:

- $\lambda_{i1\eta}$ are the load factors, indicating how much the latent variable η contributes to each observed variable x_i.
- δ_i are the measurement errors for each observed variable.

In matrix form, this can be expressed as:

$$x = \Lambda_\eta + \delta \quad (4)$$

- x is the vector of observed variables.
- Λ is the load factor matrix.
- η is the vector of latent variables.
- δ is the vector of measurement errors.

2. Structural Model

The structural model defines the relationships between the latent variables [13]. If $\eta_1, \eta_2, \dots, \eta_m$ are latent variables, the equations of the structural model are:

$$\eta_1 = \gamma_{11}\xi_1 + \gamma_{12}\xi_2 + \cdots + \gamma_{1p}\xi_p + \zeta_1 \quad (5)$$

$$\eta_2 = \gamma_{21}\xi_1 + \gamma_{22}\xi_2 + \cdots + \gamma_{2p}\xi_p + \zeta_2 \quad (6)$$

$$\eta_m = \gamma_{m1}\xi_1 + \gamma_{m2}\xi_2 + \cdots + \gamma_{mp}\xi_p + \zeta_m \quad (7)$$

Where:

- γ_{ij} are the structural coefficients, which indicate how each exogenous variable ξ_j affects the latent variable η.
- ζ_i are the errors in the structural equations for each latent variable.

In matrix form, the structural model is expressed as:

$$\eta = \mathrm{B}_\eta + \Gamma\xi + \zeta \quad (8)$$

- η is the vector of endogenous latent variables.
- B is the coefficient matrix that describes the relationships between the endogenous latent variables.
- Γ is the coefficient matrix that describes the relationships between the exogenous latent variables ξ and endogenous latent variables η.
- ζ is the vector of errors in the structural equations.

3. Covariance Matrix

The modeled covariance matrix $\Sigma(\theta)$ depends on the parameter vector θ, and is calculated as follows:

$$\Sigma(\theta) = \Lambda\Phi\Lambda^{\intercal} + \Theta_\delta \quad (9)$$

Where:

- Λ is the load factor matrix.
- Φ is the covariance matrix of the latent variables.
- $\Theta_\delta$is the covariance matrix of measurement errors.

4. Parameter Estimation

Model parameters (factor loadings, structural coefficients, variances, and covariances) are commonly estimated using:
- Maximum Likelihood (ML)
- Generalized Least Squares (GLS)
- Asymptotically Weighted Least Squares (WLS)

5. Discrepancy Function

The discrepancy function F measures how different the observed covariance matrices S and the modeled $\Sigma(\theta)$ are.

$$F\big(S,\Sigma(\theta)\big) = trace\big(S\Sigma^{-1}(\theta)\big) - \log det\,\big(S\Sigma^{-1}(\theta)\big) - p \quad (10)$$

Where p is the number of observed variables.

6. Adjustment Indices

To evaluate how well the model fits the data, fit indices are calculated such as:

- Chi-squared (x^2): $x^2 = (N-1)F$, (11)

Where N is the sample size.
- RMSEA (Root Mean Square Error of Approximation)
- CFI (Comparative Fit Index)
- TLI (Tucker-Lewis Index)
- SRMR (Standardized Root Mean Square Residual)
- Likert

2.2 Fuzzy Cognitive Maps (FCM)

Fuzzy Cognitive Maps (FCMs) are fuzzy feedback models used to represent causality. They integrate theoretical tools from cognitive maps, fuzzy logic, neural networks, semantic networks, expert systems, and nonlinear dynamic systems [14]. This technique allows for modeling the system with feedback and fuzzy degrees of causality within the range [0,1]. In the diagram, each node represents a fuzzy set or event occurring to some degree. The nodes are causal concepts and can model events, actions, values, goals, or processes. This technique also offers benefits in visual modeling, simulation, and prediction [15].

In FCMs, there are three possible types of causal relationships between concepts:

- Positive causality (Wij> 0), indicating positive causality between the concepts Ci and Cj. That is, an increase (decrease) in the value of Ci leads to an increase (decrease) in the value of Cj.
- Negative causality (Wij < 0), indicating negative causality between the concepts Ci and Cj. That is, an increase (decrease) in the value of Ci leads to a decrease (increase) in the value of Cj.
- Non-existence of relationships (Wij = 0), indicating the absence of causal relationships between Ci and Cj.

An FCM can be represented through a directed graph in which the nodes represent concepts and the edges indicate causal relationships. The intensity of the causal relationship is represented by fuzzy values [16]. The values of the concepts are calculated at each step of the simulation. Depending on the initial vector, the FCM will converge to a fixed point, limit cycle, or chaotic attractor.

In this paper, the calculation will be developed as follows:

1. Selection of the most relevant indicators that affect the relevance of the scientific research of the IES.
2. Preparation of the adjacency matrix.
3. Static analysis: calculated for the absolute values of the adjacency matrix:
   - *Outdegree*, denoted by od(vi), is the sum for each row of the absolute values of a variable of the fuzzy adjacency matrix. It is a measure of the cumulative strength of the connections existing in the variable.
   - *Indegree*, denoted by id(vi), which is the sum for each column of the absolute values of a variable of the fuzzy adjacency matrix. Measures the cumulative input force of the variable.
   - The centrality or total degree of the variable is the sum of od(vi), with id(vi), as indicated below:

$$\mathrm{td(vi)} = \mathrm{od(vi)} + \mathrm{id(vi)} \quad (12)$$

Finally, the variables are classified according to the following criteria, see[17]:

a) The *transmitting variables* are those with $od(v_i) > 0$ and $id(v_i) = 0$
b) The *receiving variables* are those with $od(v_i) = 0$ and $id(v_i) > 0$
c) Ordinary variables satisfy both $od(v_i) \neq 0$ and $id(v_i) \neq 0$

They are ordered in ascending order according to the degree of centrality.

When a group of experts (k) participates, the adjacency matrix is formulated through an aggregation operator, such as the arithmetic mean. The simplest method involves finding the arithmetic mean of each connection for each expert. For k experts, the final Fuzzy Cognitive Map (FCM) adjacency matrix (E) is obtained as follows:

$$E = \frac{E_1 + E_2 + \cdots + E_k}{k} \quad (13)$$

This ease of aggregation allows the creation of collective mental models with relative ease.

2.3 Methodology

To verify the theoretical causality between corporate social responsibility considering external actors (customers) and internal actors (employees and managers), and the performance of SMEs, a structural equation model was estimated. This was subsequently compared using Fuzzy Cognitive Maps for a better perspective on the evaluation.

The evaluation was conducted for 351 SMEs across three sectors—commerce, services, and manufacturing—which represent the most significant sectors in the economic activity of the canton. For the application of the instrument, a customer, an employee, and a manager were selected from each of the companies.

Each unit of analysis had a specific instrument. The first one, concerning customers, included seven items querying about the information provided by the company regarding the use, consumption, and handling of its products; complaint resolution; the service offered; awareness of the company's activities; the quality of products and services; interest in community issues, and sustainability, social, and ecological commitment programs.

Regarding employees, the aspects addressed were related to criteria for hiring, training, promotion, and evaluation of staff; discrimination; working conditions; the opportunity to express ideas, suggestions, proposals, or complaints; the promotion of commitment; environmental training; strengthening the culture of environmental responsibility; processes for reducing and optimizing water and energy consumption; compliance with current environmental regulations and norms, and the implementation of measures that reduce environmental impact in the development of new products.

Lastly, consultations with managers or administrators were related to two areas. The first was related to the degree of development of organizational culture and strategic planning, linked to mission and vision, principles and values, environmental policies, and social responsibility policies. The second was related to performance, measured as financial results, quality of labor relations and products, and interest in community and environmental problems (Table 1).

Table 1: Table 1: Statements (items) of each instrument. Source: Own elaboration.

Analysis unit		
Customers	**Employees**	**Managers**
The company provides clear and precise information about the use, consumption, and handling of its products (frequency).	Application of criteria for hiring, training, promotion, and evaluation (degree).	Social responsibility is reflected in the company's mission and vision (degree).
The company resolves consumer complaints (frequency).	Application of mechanisms to prevent all forms of discrimination (degree).	The degree of alignment of principles and values with company management.
The quality of customer service provided by the company (satisfaction).	Application of mechanisms to improve working conditions in terms of physical environment, hygiene, ventilation, and lighting (degree).	Existence of your company's social responsibility policies (degree).
Identifies the activity or activities carried out by this company (degree).	Application of mechanisms to encourage workers to express their ideas, suggestions, proposals, or complaints (degree).	Existence of the organization's environmental management policies (degree).
The quality of the products and services offered by the company (degree).	Opportunities provided by the organization to increase employee commitment (frequency).	The degree to which financial results reflect the organization's performance.
The company's interest in community issues (degree).	Promotion of environmental education among employees and strengthening of the culture of responsibility (degree).	The company's compliance with labor conditions and regulations (degree).

Analysis unit		
The company's interest in sustainability programs, and social and ecological commitment (degree).	Reduction and optimization of water and energy consumption (degree).	The company's interest in environmental issues (degree).
	Compliance with current environmental regulations and standards (degree).	The organization's interest in community issues (degree).
	Implementation of measures to reduce the environmental impact in the development of new products (use of energy, recycling, pollution) (degree).	Quality of products and services (degree).

For the assessment, a Likert scale ranging from 1 to 5 was proposed, where one is considered "none," in terms of non-compliance, reach, or non-evidence of the situation outlined in the statement, while the maximum value of 5 corresponds to the category of "excellent" or complete development.

This instrument was designed considering the literature review as well as its validity and reliability. In the first case, a group of experts evaluated the relevance, clarity, and pertinence of each of the statements, while in the second case, Cronbach's Alpha and exploratory factor analysis were applied using the principal components method.

Exploratory factor analysis, like confirmatory analysis and structural equation modeling, does not start from the idea that variables are dependent or independent but rather classifies variables into observed variables collected in the instrument (statements) and latent or unobserved variables, which are given by the factors generated from the statements.

In the case of structural equation models, latent variables can be exogenous, if they do not receive the effect of any other variable and are those generated from the grouping of observed variables into a factor; but they can also be endogenous, which receive the effect of observed variables and other exogenous latent variables.

Generally, graphical representation is done through a path diagram where latent variables, whether exogenous or endogenous, are represented with a circle or oval, and observed variables with a square. The residuals from the estimates are also latent variables because they are generated in the system and, therefore, are schematized as such.

Exploratory factor analysis, therefore, allowed the identification of the underlying structure or latent variables in a set of observable variables. Its main objective is to reduce the dimensionality of the data and summarize the information into a smaller number of unobservable factors.

It starts with the extraction of factors or the determination of the number of latent variables generated from the statements, for which the Kaiser method was used, considering factors that report eigenvalues greater than 1 and explaining a significant percentage of the total variance. This allows selecting factors that, together, explain a substantial amount of variance, generally looking for a cumulative percentage higher than 70%.

Additionally, Bartlett's test of sphericity was applied to assess whether the correlation matrix among the observable variables is suitable for factor analysis. Its objective is to determine if there is enough correlation between the variables to justify the use of factor analysis.

It proposes the null hypothesis that the population correlation matrix is an identity matrix, meaning that there is no correlation between the variables. To consider the grouping valid, the null hypothesis is sought to be rejected, justifying a factor analysis.

After extracting the factors, a rotation is performed to facilitate the interpretation of these. The rotation used was orthogonal by the varimax method. The rotation seeks to simplify the factor structure and have clearer and more distinct factor loadings.

Once the factors are obtained and the rotation is done, they are interpreted based on factor loadings. Factor loadings represent the correlations between observable variables and factors. Factors with high loadings indicate that observable variables are strongly associated with that factor. Thus, an item is part of the factor or latent variable if its loading is equal to or greater than 0.50.

Once the exploratory factor analysis and the factors or latent variables are identified, confirmatory factor analysis is conducted, representing the so-called measurement model, which identifies errors in indicators and constructs, allowing the confirmation of the latent structures, to then define and estimate the structural model.

Initially, the measurement model starts by establishing the hypothesized theoretical model, which includes the latent variables, observable variables, and the relationships between them. Measurement equations are defined that relate the observable variables to the latent variables.

For this study, the endogenous latent variable is given by the client factor (CLI) which considers their perception of corporate social responsibility. This factor is caused by the factor of social responsibility valuation by employees (TH) and managers (AD), as shown in (Figure 1).

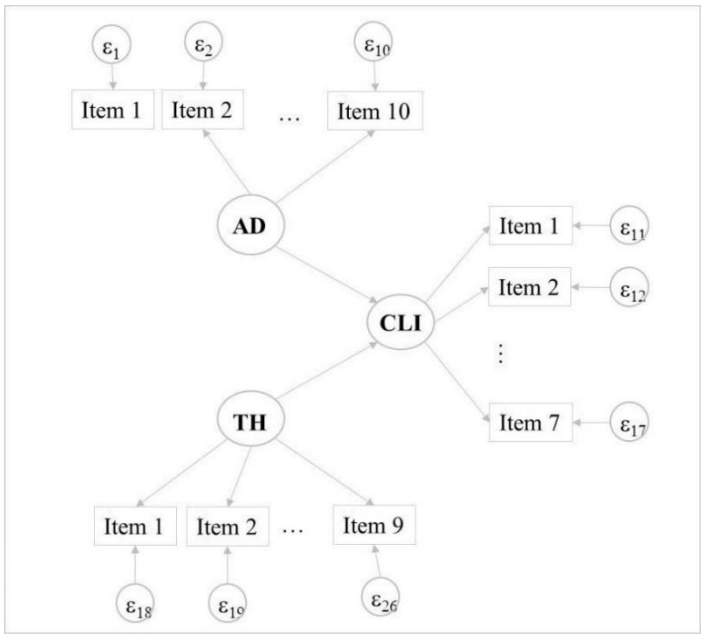

Figure 1: Path Diagram of the Measurement Model and the Structural Model. Source: Developed by the author.

The measurement model does not establish relationships among variables, latent or otherwise; these relationships are part of the structural model. The measurement model is limited to validating latent variables in terms of the statements that constitute them.

The confirmatory factor analysis or measurement model can be estimated using maximum likelihood, which assumes normality and is robust to violations of assumptions, as used in this study. However, other methods such as asymptotically distribution-free (weighted least squares), quasi-maximum likelihood, and handling missing values can also be utilized.

Once estimated, it is necessary to evaluate the fit of the model, internal consistency, convergent validity, and discriminant validity. Initially, the fit of the model to the observed data is assessed using various fit indices. These indices provide a measure of how well the theoretical model fits the observed data.

The indices considered in this study included the chi-square goodness of fit (or divided by degrees of freedom), the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), the Incremental Fit Index (IFI), the Root Mean Square Error of Approximation (RMSEA), the Standardized Root Mean Square Residual (SRMR), and the Coefficient of Determination (CD) [18], whose criteria are detailed in Table 2.

Table 2: Acceptance Criteria for Fit Indices of the Measurement Model. Source: Own elaboration.

Index		Criterion
Probability coefficient	Chi-squared Chi-square/degrees of freedom	The model fits when the value is not significant. The Chi-square value relative to the degrees of freedom can also be estimated, and it must be less than 3.
Errors	Root Mean Square Error of Approximation (RMSEA)	It should take values equal to or less than 0.05 and be statistically significant (probability less than or equal to 0.10).
Base comparison	Comparative Fit Index (CFI) Tucker-Lewis Index (TLI)	Optimal values should exceed 0.90. This value would indicate that the model is 90% better than one in which the items are not correlated.
Residual size	Standardized Root Mean Square Error (SRMR)	It should take values less than 0.08

If the model fit is not adequate, modifications can be made to the theoretical model, such as adding or removing relationships between variables or allowing correlations between measurement errors. These modifications are based on theoretical considerations and the analysis of fit statistics.

Secondly, internal consistency must be ensured, which corresponds to the reliability of the latent variable. For this purpose, Cronbach's Alpha is used, and its value must be higher than 0.70. Cronbach's Alpha measures the average correlation among all possible item combinations in a set of variables. This coefficient was complemented by the Raykov reliability coefficient, which must also exceed 0.70 to consider that there is internal consistency.

Thirdly, convergent validity was assessed, which is related to the degree of confidence that the items measure the latent variable. In this case, standardized factorial loads should be at least 0.50 to consider convergent validity (item weight on the latent variable).

Furthermore, for convergent and discriminant validity, the Average Variance Extracted (AVE) index must be calculated, and its value must be above 0.50. If this is not the case, it may be because there are items with loads below 0.50, which should be removed and the estimation and validation performed again.

If it is still impossible to verify convergent validity, the correlation between the predicted latent variables can be estimated and the unit values (variances) substituted by the square root of the AVE of each variable; if this value is greater than the correlations, convergence is achieved.

Once the measurement model is validated and adjusted due to high covariances between the items or latent variables, the validity of the latent variables and consistency can be ensured, allowing for the estimation of a system of equations to verify the theoretical causality between the endogenous latent variable and the exogenous ones, whether latent or observed.

3 Results and Discussion

As indicated, the process began with exploratory factor analysis to ensure the validity of the construct by identifying the factors or latent variables for each unit of analysis (customers, employees, and managers). For this, the different items in each of the instruments (Table 1) were considered, obtaining the results shown in Table 3.

Table 3: Results of the Exploratory Factor Analysis Note: Significant up to 1% (***), between 1% and 5% (**), and between 5% and 10% (*). Source: Own elaboration

	Items								
	1	2	3	4	5	6	7	8	9
Customers: Customer latent variable (CLI) – Single factor									
Factor loadings	0.786	0.695	0.696	0.631	0.717	0.723	0.632		
Kaiser, Meyer and Olin test (KMO)	0.846	0.878	0.879	0.899	0.891	0.765	0.739		
Bartlett's sphericity test	756.53***								
Employees: Employee latent variable (TH) – Single factor									
Factor loadings	0.674	0.663	0.702	0.742	0.736	0.725	0.660	0.699	0.632
Kaiser, Meyer and Olin test (KMO)	0.915	0.904	0.928	0.881	0.873	0.923	0.852	0.894	0.884
Bartlett's sphericity test	1142.72***								
Managers: Manager latent variable (AD) – A single factor									
Factor loadings	0.528	0.742	0.763	0.733	0.654	0.666	0.690	0.590	0.558
Kaiser, Meyer and Olin test (KMO)	0.901	0.871	0.901	0.854	0.912	0.891	0.870	0.854	0.841
Bartlett's sphericity test	926.25***								

For each instrument, the results indicate that the statements can be grouped into a single factor, indicating the presence of a single latent variable per unit of analysis. In all three cases, the factor loadings exceed the minimum acceptable value of 0.50, and there is excellent data suitability, as the values of the Kaiser-Meyer-Olkin (KMO) test exceed 0.80.

Regarding Bartlett's test of sphericity in the three analyses, the null hypothesis is rejected, demonstrating that there is a correlation among the observable variables (items) justifying their grouping into factors or latent variables.

Following the exploratory factor analysis, as outlined in the methodology, the confirmatory factor analysis was conducted. After estimating, the fit of the model was validated, and the internal consistency, convergent validity, and discriminant validity were evaluated.

Using modification indices, the fit of the original model was improved by incorporating the highest covariances between the customer instrument's items related to the company's interest in community problems and environmental programs. For employees, the items were mechanisms to express ideas and generate commitment.

Finally, for managers, the statements with the highest covariance were related to the company's environmental policy and the community's environmental issues. The results of the evaluation of the initial model's fit, as well as the one incorporating the indicated observed variables' covariances, are presented in Table 4.

Table 4: Evaluation of the Fit of the Original and Modified Models. Note: Significant up to 1% (***), between 1% and 5% (**), and between 5% and 10% (*). Source: Own elaboration

Criteria	Initial model	Modified model (covariances)
Chi-square/degrees of freedom	2,469	1982
Root Mean Square Error of Approximation (RMSEA)	0.066***	0.054***
Comparative Fit Index (CFI)	0.872	0.916
Tucker-Lewis Index (TLI)	0.859	0.906
Standardized Root Mean Square Error (SRMR)	0.058	0.057
Determination coefficient	0.99	0.99

In both models, the criteria are met, but the inclusion of covariances helps to reduce the Chi-square to degrees of freedom ratio, indicating a better model fit. It also reduces the value of the Root Mean Square Error of Approximation (RMSEA) and the Standardized Root Mean Square Residual (SRMR). The Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) are improved, while the Coefficient of Determination remains stable.

In addition to the model fit evaluation, internal consistency is also necessary through Cronbach's Alpha; the results indicate that in all cases the coefficient exceeds 0.70. For the latent variable of clients, the value was 0.814, for the latent variable or factor of employees it was 0.864, and for managers, it was 0.835.

Regarding the RayKov reliability factor, which should also exceed 0.70, superior values are also achieved, with 0.775 for clients, 0.852 for employees, and 0.823 for managers, thus validating internal consistency.

For convergent validity, while all observed variable coefficients in the modified estimation are above 0.50 and significant, the Average Variance Extracted (AVE) values do not exceed 0.50; for clients, it is 0.40, for employees 0.41, and managers 0.38.

Therefore, discriminant validity was analyzed by estimating the correlation matrix between the predicted latent variables, where substituting the diagonal variance (one) with the square root of the AVE for each latent variable shows that these values are higher than the correlations, thereby potentially verifying the model's discriminant validity (Fornell-Larcker criterion).

Once all validations of the modified model were resolved, the estimation of the Structural Equation Modeling (SEM) was carried out, incorporating the establishment of direct or indirect relationships and covariance in the measurement model.

The impact of the valuation of corporate social responsibility by employees and managers is statistically significant in customer perception, confirming the theoretical causality. In the case of the latent variable associated with managers, the coefficient was positive (0.33), as well as in the latent variable of employees (0.43), which are the direct effects of the estimation.

Also, when analyzing each construct, there are direct effects given by the coefficients of the estimations located on the straight arrows emanating from each latent variable towards the observed variable.

Regarding covariance relationships, and not causality, in the case of communication and commitment mechanisms in employees, it is 0.25; in the interest in community problems and environmental programs in the customer variable, it is 0.50, and in the case of the company's environmental policies and community environmental issues, it is 0.28.

Finally, the values associated with the observed variables correspond to the constants of each of the estimations for the latent variables or constructs. Specifically, the direct and indirect effects determined in the structural equation model are summarized in Table 5, for each latent, endogenous, or exogenous variable.

Table 5: Direct and Indirect Effects. Note: Significant up to 1% (***), between 1% and 5% (**), and between 5% and 10% (*). Values in parentheses correspond to standard errors. Source: Own elaboration.

	Direct effects			**Indirect effects**		
Variables	CLI	AD	TH	CLI	AD	TH
		Customer Instrument				
Information		1.00			0.33***	0.43***
					(0.12)	(0.08)
Complaints		0.92***			0.30***	0.39***
		(0.08)			(0.11)	(0.08)

	Direct effects	Indirect effects	
Service quality	0.78***	0.26***	0.33***
	(0.07)	(0.09)	(0.07)
Knowledge activity	0.71***	0.23***	0.30***
	(0.07)	(0.08)	(0.06)
Product Quality	0.82***	0.27***	0.35***
	(0.07)	(0.09)	(0.07)
Community interest	1.03***	0.34***	0.44***
	(0.10)	(0.12)	(0.09)
Sustainability interest	0.98***	0.32***	0.42***
	(0.12)	(0.12)	(0.09)
	Managers Instrument		
Strategic Plan	1.00		
Principles and values	1.26***		
	(0.16)		
CSR Policy	1.48***		
	(0.19)		
Environmental policy	1.58***		
	(0.21)		
Financial performance	1.15***		
	(0.16)		
Employee relationship	1.30***		
	(0.18)		
Environment relationship	1.39***		
	(0.19)		
Community relationship	1.06***		
	(0.16)		
Products Quality	0.80***		
	(0.12)		
	Employees Instrument		
Hiring	1.00		
Nondiscrimination	1.00***		
	(0.10)		
Labor conditions	0.88***		
	(0.09)		
Possibility of expression	1.01***		
	(0.10)		
Commitment	0.91***		
	(0.09)		
Environmental training	1.07***		
	(0.10)		
Water optimization	0.84***		
	(0.09)		
Environmental standard compliance	0.94***		
	(0.09)		
Proposal Environmental Measures	0.91***		
	(0.10)		
	Structural		
Latent managers (AD)	0.33***		
	(0.12)		
Latent employees (TH)	0.43***		
	(0.08)		

As observed, all direct effects are statistically significant and positive, indicating that each item directly impacts the latent variable. For the latent variable representing customers, the items related to the perception of the company's interest in environmental and community issues report the greatest effect, followed by the handling of complaints or claims.

Regarding the latent variable related to employees, the most influential factors in their valuation of CSR are the training provided on environmental topics and the opportunity to express their ideas. For the variable related to the managers' valuation, the company's environmental and CSR policies have the greatest impact. Although all direct effects are similar, the least significant is the quality of the product.

The indirect effects, also statistically significant and positive, relate to the influence of the items from the instrument applied to customers on the latent variables of employees and managers. It is evident in both cases that the effects are greater concerning interest in the community and the environment, as well as the information received by the customer.

Additionally, the fit of the estimation of the structural equation model was validated, similarly to what was done in the confirmatory factor analysis, using the criteria indicated in the methodology. The results are presented in Table 6.

Table 6: Evaluation of the Structural Equation Model Fit. Note: Significant up to 1% (***), between 1% and 5% (**), and between 5% and 10% (*). Source: Own elaboration.

Criteria	SEM
Chi-square/degrees of freedom	1982
Root Mean Square Error of Approximation (RMSEA)	0.054***
Comparative Fit Index (CFI)	0.916
Tucker-Lewis Index (TLI)	0.906
Standardized Root Mean Square Error (SRMR)	0.057
Determination coefficient	0.967

In all cases, the established criteria are validated, indicating that the estimated structural equation model is correctly fitted and can be used to verify the causality between the assessment of corporate social responsibility by employees and managers and the perception of the clients.

For a better analysis of the effects determined in the structural equation model, a comparison was made using Fuzzy Cognitive Maps. Studies of centrality regarding the variables Clients, Managers, and Employees were conducted as shown in Tables 7, 8, and 9. The presented results demonstrate the differences in how each group of components interacts and contributes to the overall structure of the model.

Table 7: Customer centrality analysis. Source: own elaboration.

Components	Indegree	Outdegree	Centrality	Type
Complaints	2.44	0.9199999999999999	3.36	ordinary
Quality service	2.04	1.67	3.71	ordinary
Knowledge activity	1.7200000000000002	1.88	3.6	ordinary
Product Quality	1.65	0.99	2.63999999999999997	ordinary
Interested community	1.5899999999999999	2.01	3.59999999999999996	ordinary
Sustainability interest	1.38000000000000001	0.97	2.35	ordinary
Information	0.49	2.87	3.3600000000000003	ordinary

The centrality values indicate the relative importance of each component within the customer group. Quality Service has the highest centrality at 3.71, standing out as a critical factor from the customers' perspective. Information also shows a significant centrality of 3.36, driven mainly by its high outdegree (2.87), indicating that this component has many outgoing connections, influencing other components.

Complaints and Knowledge Activity have similar centralities of 3.36 and 3.6, respectively, suggesting their active role in interacting with other aspects relevant to customers. The centrality demonstrates that customers value service quality, complaint management, and information as critical components.

Table 8: Manager Centrality analysis. Source: own elaboration.

Components	Indegree	Outdegree	Centrality	Type
strategic plan	2.15	4.13	6.279999999999999	ordinary
Quality Products	3.4	3.83	7.23	ordinary

Components	Indegree	Outdegree	Centrality	Type
community relationship	3.8199999999999994	0	3.8199999999999994	receiver
Principles and values	2.3600000000000003	3.16	5.5200000000000005	ordinary
Corporate social responsibility policies	2.49	4.4399999999999995	6.93	ordinary
Environmental policy	2.99	3.619999999999999	6.609999999999999	ordinary
Financial performance	3.64	1.75	5.390000000000001	ordinary
Environment relationship	4	3.4200000000000004	7.42	ordinary
Employee relationship	3.51	4.01	7.52	ordinary

Employee Relationship and Environment Relationship have the highest centralities at 7.52 and 7.42, respectively. This indicates that these components are extremely central from the managers' perspective, affecting and being affected by many other components. Quality Products and Corporate Social Responsibility Policies are also prominent with centralities of 7.23 and 6.93. This shows that managers view relationships with employees and the environment, along with product quality and social responsibility policies, as central to their management.

Table 9: Employee centrality analysis. Source: own elaboration.

Components	Indegree	Outdegree	Centrality	Type
Hiring	1.99	3.0799999999999996	5.069999999999999	ordinary
Nondiscrimination	2.94999999999999997	3.61	6.56	ordinary
Labor conditions	3.77	0.32	4.09	ordinary
Possibility of expression	3.13	2.63	5.76	ordinary
Commitment	2.73999999999999998	4.829999999999999	7.569999999999999985	ordinary
Environmental training	2.04	3.9800000000000004	6.0200000000000005	ordinary
Water optimization	2.639999999999999997	3.47	6.109999999999999	ordinary
Environmental standard compliance	3	2.7800000000000002	5.78	ordinary
Proposal Environmental Measures	3.6799999999999997	1.24	4.92	ordinary

Commitment has the highest centrality at 7.57, followed by Nondiscrimination at 6.56, and Environmental Training at 6.02. These components are critical from the employees' perspective. For employees, commitment, nondiscrimination, and environmental training are of utmost importance.

The correlation analysis between Structural Equation Modeling (SEM) and Fuzzy Cognitive Maps (FCM) in this context reveals that, although they use different theoretical and mathematical frameworks, both can effectively complement each other to provide a richer and more dynamic understanding of how corporate social responsibility influences the performance of SMEs. SEM provides a solid framework for estimating and validating the structural relationships between the perceptions of customers, employees, and managers, while FCM offers a flexible tool to explore how these perceptions influence and are influenced within the system, providing a more dynamic and adaptive view of the interaction between these factors.

4 Conclusions

This study applied Structural Equation Modeling (SEM) and Fuzzy Cognitive Maps (FCM) to analyze how the perception of corporate social responsibility (CSR) impacts the perception of customers, employees, and managers in small and medium-sized enterprises (SMEs) in Ecuador.

Exploratory factor analysis confirmed the presence of a single latent variable in each interest group (customers, employees, and managers), demonstrating that the items of each instrument can be effectively grouped under a single factor. This result is crucial as it simplifies the model structure and facilitates the interpretation of how CSR influences each group. The factor loadings obtained exceeded the acceptable minimum value of 0.50, and Bartlett's test of sphericity rejected the null hypothesis in all three cases, thus validating the grouping of items into latent factors due to the existence of significant correlation among the observable variables.

The direct and statistically significant effects indicate that each item of the instruments directly impacts its corresponding latent variable. Specifically, items related to the company's interest in environmental and community problems, and the handling of complaints, showed the greatest effects on customer perception. The evaluation of CSR by employees and managers had a significant impact on customer perception, with positive coefficients of 0.33 and 0.43, respectively. This underscores that a positive evaluation of CSR by employees and managers enhances customers' perception of the company.

Centrality analyses in the Fuzzy Cognitive Maps showed that for customers, aspects such as "Quality Service" and "Information" are critical, highlighting their importance in interacting with other variables. For managers, "Employee Relationship" and "Environment Relationship" were central, indicating their key role in CSR management. For employees, "Commitment", "Nondiscrimination", and "Environmental Training" had the highest centralities, reflecting their importance in the perception and practice of CSR within SMEs.

The integration of SEM and FCM not only allowed for the estimation and validation of structural relationships between the perceptions of different stakeholder groups but also explored how these perceptions interact and influence each other within the system. This dual approach provides a richer and more dynamic view of the influence of CSR on the performance of SMEs, offering a robust tool for understanding and improving CSR practices in the context of Ecuadorian SMEs.

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