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Research Article

Multiple Indicators and Multiple Cause of Resilience Around the SDGs

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Abstract

Resilience is a factor that explains the implementation of the Sustainable Development Goals (SDG) in institutions or organizations that form intellectual capital. The objective of this work was to establish a model based on the contrast between the relationships of dimensions reported in the literature with respect to the observations of this work. A transversal, correlational and explanatory work was carried out with a sample of 100 students selected for their affiliation to a university committed to the formation of intellectual capital based on the certification in sustainability. The findings demonstrate the incidence of age on the factor that is configured by two of five theoretical indicators. In relation to the state of the art where entrepreneurial structures prevail, this work suggests the extension of the model in order to increase the percentage of variance of the factorial structure analyzed.

Keywords: Confirmatory Factor Analysis; Multiple Cause; Multiple Indicator; Resilience; SDG's

Introduction

The history of resilience and the Sustainable Development Goals (SDGs) in relation to climate change is a topic that has gained importance in recent decades as the world faces unprecedented environmental challenges [3]. The term "resilience" began to be used in ecology to describe the ability of a natural system to absorb disturbances and reorganize while maintaining its essential function. The notion of resilience expanded beyond ecology into disciplines such as psychology, sociology, and economics. It began to be applied to human communities, describing the ability to adapt and recover from crises such as natural disasters. During the Earth Summit in Rio de Janeiro, the United Nations Framework Convention on Climate Change (UNFCCC) was established, marking a global recognition of the threat of climate change.

The Millennium Development Goals (MDGs) were adopted by the UN, highlighting the need to address sustainable development [1]. However, climate change was not yet a prominent priority. The 17 Sustainable Development Goals (SDGs) are adopted as part of the UN Agenda 2030. SDG 13, "Climate Action," highlights the need to take urgent action to combat climate change and its impacts. Resilience became a central theme within the SDGs, especially in vulnerable contexts where communities must adapt to the impacts of climate change.

The SDGs have driven global policies and actions focused on increasing climate resilience [15]. This includes adopting sustainable technologies, promoting resilient agricultural practices, and strengthening infrastructure to withstand extreme weather events. Linked to the SDGs, the Paris Agreement establishes global commitments to limit global warming and promote adaptation to climate change, highlighting resilience as a key strategy. Resilience has been integrated into many national and international policies. Current efforts focus on strengthening the capacity of communities and ecosystems to adapt to new climate realities, ensuring that progress towards the SDGs is not compromised. Technological innovations, such as renewable energy and early warning systems, are being developed to improve resilience to climate change.

The most vulnerable communities, especially in developing countries, continue to face significant challenges in their ability to adapt to climate change [10]. Despite progress, greater international collaboration is needed to meet the SDGs related to resilience and climate change. The story of resilience and the SDGs in the face of climate change is an evolving narrative, marked by a growing recognition of the interconnection between sustainable development and climate adaptation.

Resilience theory, in the context of the Sustainable Development Goals (SDGs) and climate change, is a conceptual framework that addresses how systems, communities and ecosystems can adapt and recover from disturbances or crises [4]. Below is a detailed explanation of how this theory intertwines with the SDGs in the fight against climate change. Resilience refers to the ability of a system, whether ecological, social or economic, to absorb disturbances, reorganize and continue functioning without altering its fundamental characteristics. In ecology, resilience relates to the ability of ecosystems to resist and recover from extreme events, such as fires, droughts or floods, while maintaining their biodiversity and ecological functions. This objective focuses on taking urgent measures to combat climate change and its effects. Resilience is key to achieving this, since it involves strengthening the capacity to adapt to climate risks and natural disasters. Resilience is also applied in the fight against poverty and hunger, by promoting resilient agricultural systems, improving food security and ensuring sustainable livelihoods for vulnerable populations.

Climate change is an example of a systemic challenge that affects multiple levels of organization, from individuals to ecosystems and economies [5]. Resilience theory offers a way to understand how these systems can adapt to new climate realities. Within the framework of resilience theory, adaptation refers to strategies to adjust human and natural systems to climate change. Mitigation, on the other hand, involves actions to reduce greenhouse gas emissions, which also strengthens resilience by preventing extreme climate scenarios. Resilience theory emphasizes the importance of diversity (biological, economic, cultural) and redundancy (having multiple ways of performing a function) to absorb shocks and avoid collapses. In the context of the SDGs, this means diversifying energy sources, agricultural practices and development strategies. Maintaining and strengthening connections between different actors (governments, communities, companies) is essential to share resources, information and responses to climate change.

Resilience includes the ability to learn from past experiences, which is crucial for developing more effective policies and practices in implementing the SDGs and adapting to climate change [13]. Build infrastructure that can withstand extreme weather events, such as transportation systems and buildings designed to withstand floods or earthquakes. Promote agricultural practices that improve soil health, conserve water and reduce dependence on external inputs, making agricultural systems more resilient to climatic variations. Strengthen the capacity of communities to plan and respond to natural disasters, through education, preparedness and inclusive policies that consider the most vulnerable groups. A key challenge is how to measure resilience effectively, as it is a multifaceted concept that varies depending on context. Some critics argue that resilience theory may not adequately address the structural inequalities that make certain communities more vulnerable to climate change.

Resilience is not only a response to climate change, but a comprehensive strategy that supports the achievement of all the SDGs [9]. By strengthening resilience, a more sustainable and equitable development is promoted, capable of facing the environmental, social and economic challenges of the future. Resilience theory provides a powerful framework for understanding and addressing climate change within the 2030 Agenda. Its focus on adaptation, resilience and transformation is essential to ensure that progress towards the SDGs is durable and equitable in the face of climate change. to climate challenges (see Table 1).

However, the relationship between resilience and OD has not been analyzed from its mediating link with respect to climate change. That is, resilience as a factor that regulates the execution of the SDGs, since in an increasingly extreme environment, resilience emerges as a predominant factor among those who seek to carry out the SDGs. Therefore, the objective of this work is to compare the theoretical structure of resilience associated with the SDGs with respect to the observations of this work with a sample of students assigned to institutes and organizations that are distinguished by their resilience in the face of crises, imponderables and the contingencies.

Are there differences between the theoretical structure of resilience reported in the literature with respect to the empirical structure observed in the present work with a sample of resilient

Table 1: Comparative between dimensions of resilience around SDG's.

Dimension	Description	Related SDGs
Economic Resilience	The ability of economies to absorb shocks, recover, and transform to ensure sustainable growth.	SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), SDG 12 (Responsible Consumption and Production)
Environmental Resilience	The capacity of ecosystems to withstand, adapt, and recover from environmental challenges.	SDG 13 (Climate Action), SDG 14 (Life Below Water), SDG 15 (Life on Land)
Social Resilience	The ability of communities to adapt, recover, and thrive in the face of social and cultural challenges.	SDG 1 (No Poverty), SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 10 (Reduced Inequalities)
Institutional Resilience	The strength of governance systems and institutions to respond to crises effectively.	SDG 16 (Peace, Justice, and Strong Institutions), SDG 17 (Partnerships for the Goals)
Technological Resilience	The ability to utilize innovation and technology to adapt to changing conditions and risks.	SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities)
Cultural Resilience	The ability to preserve cultural identity, practices, and heritage during times of change.	SDG 4 (Quality Education), SDG 11 (Sustainable Cities and Communities)
Health Resilience	The ability of healthcare systems to respond to health crises and provide continued services.	SDG 3 (Good Health and Well-being), SDG 6 (Clean Water and Sanitation)

people?

The premise that follows this work suggests that resilience regulates the impact of climate change on the execution of the SDGs. Consequently, significant differences are expected between the theoretical structure of resilience compared to the observations of the present work.

Method

Design

A cross-sectional, correlational and psychometric study was carried out with a sample of 100 students selected for their affiliation to institutions and organizations that specialize in adapting to changes in terms of their organization and permanence.

Instrument

The resilience scale was used (see annex A) which includes the dimensions of adaptive capacity, knowledge and awareness, resources and infrastructure, and social support. Each item includes response options ranging from 0 = "it's not like my situation" to 5 = "it's quite similar to my situation". The reliability of the instrument reached an alpha value of 0.789 and omega of 0.760, the validity ranged between 0.324 and 0.546 (see Table 2).

Procedure

The students were contacted through institutional email in order to be able to invite them to focus groups to homogenize the contents of the resilience scale. They were informed about the objectives of the study and the functions of each project manager. The surveys were administered in the students' classrooms and they were asked to send the results to their email. At all times, it was made clear to them that their participation would not imply remuneration or any monetary or in-kind perks.

Analysis

The data were captured in Excel and processed in Google Colab (see Annex B). Regression and mediation coefficients were estimated in structural equation models using the Lavan algorithm. Values close to unity were assumed as evidence of non-rejection of the hypothesis (see Table 3).

Results

The analysis of the predictive coefficients suggests the anticipation of the common factor based on the socioeconomic and sociodemographic determinants with which the indicators interact and form, in turn, a complex factorial structure (see Table 4). The results indicate that age is the predictor of the factor, although the significance levels indicate a new specification.

Table 2: Psychometrics properties.

Dimension	Conceptual Definition	Operational Definition	Instrument Name	Sample	Psychometric Properties
Economic Resilience	The ability of economies to absorb, adapt, and recover from economic shocks.	Measured through income stability, job security, and access to resources post-crisis.	Economic Resilience Scale (ERS)	500 professionals in urban areas	Cronbach's Alpha = 0.85; CFA confirms 3-factor structure.
Environmental Resilience	The capacity of ecosystems and individuals to adapt and recover from environmental changes.	Assessed via sustainable practices and environmental adaptation strategies.	Environmental Resilience Index	300 rural community households	Cronbach's Alpha = 0.82; Validity (Convergent = 0.78).
Social Resilience	The ability of individuals or communities to adapt, recover, and grow after adversities.	Measured through social networks, community support, and perceived well-being.	Social Resilience Scale (SRS)	400 community leaders	Cronbach's Alpha = 0.88; Test-Retest Reliability = 0.81.
Institutional Resilience	The ability of organizations and systems to respond effectively to crises.	Evaluated through governance, response strategies, and institutional trust.	Institutional Resilience Survey	350 public sector employees	Cronbach's Alpha = 0.87; Good model fit (RMSEA = 0.05).
Technological Resilience	The capacity to utilize and adapt technology to overcome disruptions or challenges.	Measured via innovation adoption and technology infrastructure in crises.	Technological Resilience Scale	200 tech industry workers	Cronbach's Alpha = 0.84; Factor loadings > 0.70.
Cultural Resilience	The ability to preserve cultural identity and heritage in changing environments.	Assessed through cultural practices, identity preservation, and adaptability.	Cultural Resilience Inventory	250 indigenous community members	Cronbach's Alpha = 0.83; Construct Validity = 0.79.
Health Resilience	The ability of healthcare systems to maintain and restore essential services during crises.	Evaluated via system preparedness, access to care, and patient outcomes.	Health Resilience Assessment	300 healthcare professionals	Cronbach's Alpha = 0.89; ICC = 0.80 (inter-rater reliability).

Table 3: Statistics analysis.

Coefficient	Definition	Application	Interpretation
Standardized Path Coefficient (β)	Indicates the strength and direction of the relationship between observed causes and latent variables.	Used to assess causal relationships in MIMIC models.	Values range from -1 to 1; closer to 1 (positive) or -1 (negative) shows stronger relationships.
Factor Loading (λ)	Measures the relationship between latent variables and their observed indicators.	Evaluates how well indicators reflect the underlying latent construct.	Values > 0.50 suggest a strong relationship; loadings close to 1 indicate a very reliable indicator.
R-squared (R^2)	Proportion of variance in an indicator explained by the latent variable.	Measures model fit and explanatory power for observed indicators.	Values range from 0 to 1; higher values indicate better explanatory power of the latent construct.
Model Fit Indices (CFI, TLI)	Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) assess overall model fit.	Used to test how well the model replicates the data.	Values > 0.90 indicate acceptable fit; values > 0.95 reflect excellent fit.
Root Mean Square Error of Approximation (RMSEA)	Measures model fit based on residuals (differences between observed and estimated data).	Applied to verify if the model has a reasonable approximation of real data.	Values < 0.08 indicate acceptable fit; values < 0.05 show excellent fit.
Standard Error (SE)	Estimates the accuracy of coefficients for paths or loadings in the model.	Evaluates precision and significance of path coefficients or factor loadings.	Smaller SE values indicate greater precision in estimates.
p-value	Statistical significance of coefficients, indicating whether effects are non-random.	Applied to test hypotheses in MIMIC models.	A p-value < 0.05 indicates statistical significance of the coefficient.
Variance Inflation Factor (VIF)	Measures multicollinearity among observed causes in the model.	Evaluates whether multiple causes are highly correlated.	VIF values > 10 suggest multicollinearity issues; values < 5 are acceptable.

Table 4: Predictor coefficients.

					95% Confidence Interval Standardized				
Predictor	**Estimate**	**Std. Error**	**z-value**	**p**	**Lower**	**Upper**	**All**	**LV**	**Endo**
Age	-0.068	0.060	-1.137	0.255	-0.186	0.049	-0.122	-0.068	-0.068
Income	-4.046×10^{-5}	4.915×10^{-5}	-0.823	0.410	-1.368×10^{-4}	5.588×10^{-5}	-0.090	-4.002×10^{-5}	-4.002×10^{-5}

The analysis of the indicators reflects a common factor that the literature identifies as resilience (see Table 5). The findings demonstrate the prevalence of two of the five indicators that make up the factor structure.

Structural analysis suggests the interaction of socioeconomic and sociodemographic determinants with respect to the indicators insofar as these reflect a common factor, the determinants configure formative relationships with the common factor (see Figure 1).

Table 5: Indicator coefficients.

					95% Confidence Interval Standardized				
Indicator	**Estimate**	**Std. Error**	**z-value**	**p**	**Lower**	**Upper**	**All**	**Latent**	**Endo**
ER	1.810	0.250	7.248	< .001	1.321	2.300	0.690	1.830	0.690
EVR	1.987	0.211	9.403	< .001	1.573	2.402	0.858	2.009	0.858
SR	1.672	0.184	9.066	< .001	1.310	2.033	0.839	1.690	0.839
IR	0.591	0.288	2.053	0.040	0.027	1.155	0.229	0.597	0.229
HR	-0.300	0.287	-1.043	0.297	-0.863	0.263	-0.113	-0.303	-0.113

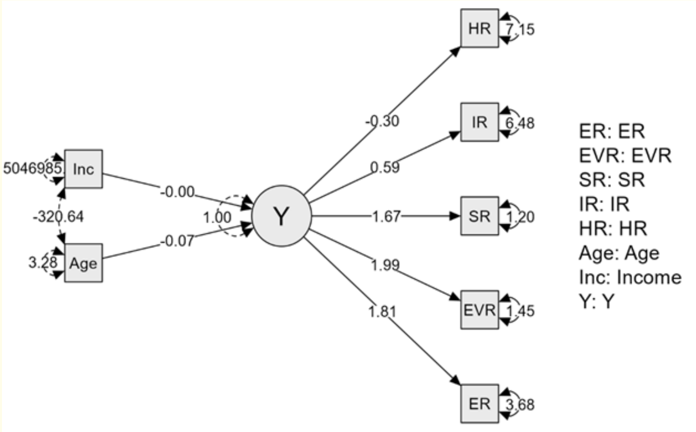

Figure 1: Multiple Indicators and Multiple Cause.

The results demonstrate the prevalence of age with respect to the common factor of resilience and its reflection in two of five indicators.

The fit and residual values suggest that the hypothesis regarding significant differences between the theoretical structure reported in the literature and the observations made in this work should not be rejected.

Discussion

The contribution of this work to the state of the art lies in the establishment of a regulatory model for the risks of labor flexibility and the emergence of leadership. In such a process, resilience inhibits the incidence of risks.

The literature on risk and resilience in the context of the Sustainable Development Goals (SDGs) spans various studies and perspectives [7]. It highlights the need to increase efforts in disaster risk management and building urban resilience to disaster risk management and reduction, with the aim of aligning with the SDGs and the Sendai Framework for Disaster Risk Reduction [11]. The importance of risk assessment for the sustainability of communities is emphasized. coastal areas and noted the critical status of Guangdong Province in terms of achieving SDG-13 [14]. The health impacts of water-related disasters were analyzed globally, and gaps were identified. the SDG indicator framework to monitor these impacts [2]. highlights the role of technology in building resilience in smart cities, particularly in the context of COVID-19.

The role of youth in achieving disaster resilience goals within the SDGs emphasizes the need to expand youth participation programs [8]. The importance of establishing connections through resilience indicators to address global challenges related to the SDGs, disaster risk reduction (DRR) and climate change adaptation (CCA). They focus on informal cadastres as facilitating tools for disaster risk management, in line with SDGs 1 and 3 [6]. The impact of climatic and hydrological factors on flood hazards and resilience, using modified UNDRR indicators.

Overall, the literature review on risk and resilience in the context of the SDGs highlights the importance of addressing disaster risks, building urban resilience, assessing the sustainability of coastal communities, monitoring disaster impacts on health, harnessing technology for resilience in smart cities, engaging youth in disaster resilience efforts, establishing connections through resilience indicators, using informal cadastres for disaster risk management, and understanding the impact of disasters. climatic and hydrological factors on flood hazards and resilience [12]. These studies collectively contribute to ongoing efforts to achieve the SDGs and improve global resilience to various risks and challenges.

Unlike the state of the art in which resilience is an annex of the SDGs, this work highlights its regulatory function of the risks in compliance with the SDGs, such as the leadership and flexibility required to carry out the objectives. That is, the area of opportunity of the study lies in the observation of the SDGs in the face of risks or contingencies, but the advantage of the study lies in the observation of the mediating function of resilience. In this sense, it is recommended to establish a model that measures the impact of the SDGs on resilience and its regulation in leadership and labor flexibility.

The mediational analysis suggests the degree of regulation of the impact of exogenous variability on the mediating factors and these on the target variability. The results demonstrate the negative regulatory impact of resilience on leadership based on risks (-0.11). The mediational values suggest the non-rejection of the hypothesis related to the significant differences between the theoretical structure of resilience as a mediating factor with respect to the observations of the present work.

The analysis of the prediction coefficients suggests the impact of socioeconomic and sociodemographic variables. The results indicate that no independent variable anticipates the environmental resilience factor. Analysis of the reflective coefficients suggests seven indicators of the environmental resilience factor. The findings suggest consistent indicators around the emerging factor. Structural analysis suggests determining relationships of independent variables with respect to the formative factor of environmental resilience. The results confirm the factorial structure, but not the regression analysis. The adjustment and residual parameters suggest that the hypothesis regarding the theoretical structure of the determinants and indicators of resilience with respect to the structure observed in this work is not rejected. Resilience is a factor observed in contingent, exceptional and risky situations, but this work investigates its regulatory function of these externalities that determine leadership and work flexibility. The results suggest that resilience inhibits the impact of risks, but not as an emergent factor but as a mediating factor. It is recommended to investigate the emerging function of resilience to compare both functions and establish a comprehensive model of adaptation to change.

Conclusion

The objective of the present work was to compare the theoretical structure of resilience as a factor derived from the SDGs against the observations of the present work in which resilience is appreciated as a regulatory factor of the impact of risks on leadership and work flexibility. In relation to the state of the art where resilience is a derivative of the SDGs, the present work suggests that more bin is a regulator of risks and thereby anticipates the achievement of the SDGs.

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Annex A

Instrument to Measure Dimensions of Resilience in the Context of SDG Implementation

Instructions:

This questionnaire is designed to measure various dimensions of resilience relevant to the implementation of the Sustainable Development Goals (SDGs). Please respond to each statement based on your level of agreement, using the following scale:

1 = **Strongly Disagree**

2 = **Disagree**

3 = **Neutral**

4 = **Agree**

5 = **Strongly Agree**

Section 1: Economic Resilience

1. My organization/community is able to recover quickly from economic setbacks.
2. Resources are allocated efficiently to respond to unexpected economic challenges.
3. Job opportunities remain stable during times of economic hardship.
4. Investments in innovation support long-term economic recovery.
5. Our local economy adapts effectively to external disruptions.

Section 2: Environmental Resilience

6. We implement strategies to reduce the impact of environmental crises (e.g., floods, droughts).
7. Natural resources are managed sustainably to prevent future depletion.
8. Our community can adapt to changing climate conditions.
9. Environmental protection initiatives are prioritized during times of crisis.
10. There are effective policies to restore ecosystems after damage.

Section 3: Social Resilience

11. The community comes together to support vulnerable groups during crises.
12. Social networks (e.g., families, friends, organizations) provide strong emotional and material support.
13. Educational services continue to function during difficult circumstances.
14. The community promotes equality and inclusion, even during hardships.
15. Social systems (e.g., healthcare, welfare) remain reliable during times of crisis.

Section 4: Institutional Resilience

16. Local and national institutions effectively respond to unexpected challenges.
17. Governance systems are transparent and maintain public trust during crises.
18. Institutions are adaptable to changing circumstances.
19. Emergency policies are quickly implemented when needed.
20. Partnerships and collaborations improve institutional responses to crises.

Section 5: Technological Resilience

21. Technology is used to maintain essential services during disruptions (e.g., remote work, education).
22. Investments in technology help mitigate risks and improve recovery efforts.
23. Technological infrastructure is reliable during times of crisis.
24. Innovations support long-term resilience in my community/organization.
25. Access to technology remains equitable for all groups during hardships.

Section 6: Cultural Resilience

26. Local traditions and cultural practices are preserved during crises.
27. Cultural identity helps strengthen community solidarity in difficult times.
28. Arts and cultural activities provide emotional and psychological support.
29. Efforts are made to pass cultural values and knowledge to younger generations.
30. Cultural heritage initiatives are prioritized in rebuilding efforts after crises.

Section 7: Health Resilience

31. Healthcare services remain accessible and effective during crises.
32. Our community has systems to address both physical and mental health challenges.
33. Emergency health responses are well-coordinated and timely.
34. Efforts are made to provide clean water and sanitation during disruptions.
35. Health policies support long-term well-being in the face of challenges.

Annex B

```
# Install necessary libraries
!pip install semopy pandas matplotlib

# Import required libraries
import pandas as pd
from semopy import Model, Optimizer, inspect
import matplotlib.pyplot as plt

# Sample Data Creation: Replace this with your actual dataset
# Assume resilience dimensions (multiple causes) and indicators (multiple effects)
data = {
    'Economic_Resilience': [4.5, 3.8, 4.0, 4.2, 3.7, 4.1, 4.4, 3.9],
    'Environmental_Resilience': [3.9, 4.2, 4.1, 4.0, 4.3, 3.8, 4.4, 4.1],
    'Social_Resilience': [4.1, 4.0, 4.3, 4.2, 3.9, 4.5, 4.0, 4.1],
    'Health_Resilience': [4.0, 4.1, 3.9, 4.3, 4.0, 4.1, 4.2, 4.0],
    'Technological_Resilience': [3.8, 4.1, 4.0, 4.2, 3.9, 4.3, 4.1, 4.0],
    'Cultural_Resilience': [4.2, 4.0, 4.1, 4.3, 3.8, 4.4, 4.2, 4.1],
    'Indicator1': [3.9, 4.0, 4.1, 4.2, 3.8, 4.3, 4.1, 4.0],
    'Indicator2': [4.0, 3.8, 4.1, 4.2, 4.0, 4.3, 4.1, 3.9],
    'Indicator3': [4.1, 4.0, 4.3, 4.2, 3.9, 4.4, 4.0, 4.1],
    'Indicator4': [3.8, 4.1, 4.2, 4.0, 4.3, 3.9, 4.1, 4.0]
}
df = pd.DataFrame(data)

# Display the sample data
print("Sample Data:")
print(df.head())
```

```
# Define the MIMIC model for resilience dimensions (latent variables) and indicators
model_description = “””
Resilience =~ Indicator1 + Indicator2 + Indicator3 + Indicator4
Resilience ~ Economic_Resilience + Environmental_Resilience + Social_Resilience + Health_Resilience + Technological_Resilience + Cultural_Resilience
“””

# Build the SEM model
model = Model(model_description)
opt = Optimizer(model)
results = opt.optimize(df)

# Print results
print(“\nModel Summary:”)
print(inspect(model, what=’summary’))

print(“\nParameter Estimates:”)
print(inspect(model, what=’estimates’))

# Visualize the model path diagram
from semopy.examples import plot_model
fig = plot_model(model, figsize=(10, 8))
plt.title(“MIMIC Model: Resilience Dimensions and Indicators”)
plt.show()
```