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DEVELOPMENT OF ENERGY SECURITY MODEL IN THE PHILIPPINES

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Abstract:
The rationale behind conducting this study lies in the Philippines' lack of a comprehensive energy security model, leading to weaknesses in the energy sector that affect accessibility, cost-effectiveness, technological advancements, environmental sustainability, and governance and innovation. This study aims to address the need for a comprehensive energy security model specifically tailored for the Philippines. By employing various research methodologies, including Principal Component Analysis (PCA) and Structural Equation Modeling (SEM), the study aims to identify significant relationships between variables and energy security dimensions, providing valuable insights for informed policy decisions and strategic directions in the energy sector. The findings of the study reveal a complex and interconnected energy security landscape in the Philippines.

JEL: O10; O13; O21

Keywords: energy security, Philippines, comprehensive model, supply shocks, PCA, SEM

1. Introduction

The lack of a comprehensive energy security model in the Philippines has resulted in weaknesses in the energy sector, affecting multiple aspects like accessibility, cost-effectiveness, technological advancements, environmental sustainability, and governance and innovation (Zhang et al., 2017). In order to tackle these issues, the investigation sought to examine multiple research inquiries. Firstly, it aimed to assess if the component structure produced using PCA demonstrated sufficient levels of internal consistency and reliability for each facet of energy security ("Energy Security", 2017).

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Ensuring the validity and resilience of the energy security model was of utmost importance. In addition, the study sought to evaluate the estimated route coefficients in the structural equation modeling (SEM) model in order to demonstrate statistically significant correlations between identified variables and dimensions of energy security (Arakawa et al., 1989). This analysis offered valuable insights into the interdependence of several factors that impacted energy security.

1.1 Objective

The main objective of this study was to develop a robust and comprehensive energy security model specifically tailored for the Philippines. This particular model sought to provide an in-depth understanding of the unique energy security landscape of the country. This model was intended to serve as a practical tool that could guide energy-related policy decisions and strategic directions in the Philippines in the foreseeable future.

1.2 Significance of the Study

The significance of this study extended to various institutions, policymakers, individuals, researchers, and organizations in the Philippines, contributing to their efforts to ensure a secure, reliable, and resilient energy future for the nation.

Department of Energy (DOE). The study findings can provide valuable insights for the DOE in formulating energy policies and strategies to enhance energy security and resilience in the Philippines. This can enable the DOE to make informed decisions regarding energy resource allocation, infrastructure development, and regulatory measures, ensuring a stable and sustainable energy supply for the country.

Local Government Units (LGUs). LGUs can utilize the study findings to enhance their energy planning and management, ensuring the availability of energy resources and services to their constituents. By understanding the factors that contribute to energy security and resilience, LGUs can develop comprehensive energy plans, promote energy efficiency and conservation measures, and support the development of local renewable energy projects, fostering sustainable and self-sufficient communities.

Academic Institutions. Researchers and educators in academic institutions can incorporate the study findings into their curriculum, enhancing the understanding of energy security and resilience among future energy professionals. By integrating the latest research and insights into their teaching materials and programs, academic institutions can equip students with the knowledge and skills necessary to tackle the obstacles and potential advantages in the energy industry, fostering innovation, and driving the transition towards a more secure and resilient energy future.

Energy Consumers. Individuals and businesses can benefit from the study by gaining a better understanding of the factors that contribute to energy security and resilience. This knowledge can guide their decisions in energy consumption and investment, ensuring a secure and reliable energy supply. By making informed choices regarding energy sources, technologies, and practices, consumers can contribute to the overall energy security of the country and mitigate the risks associated with energy disruptions and price volatility.

Investors and Financial Institutions. Investors and financial institutions can leverage the study findings to assess and manage the risks associated with energy investments in the Philippines, promoting sustainable and resilient energy projects. By incorporating energy security and resilience considerations into their investment decisions, investors and financial institutions can support the development of robust and sustainable energy infrastructure, attract capital for clean energy projects, and contribute to the country's economic growth and environmental sustainability.

General Public. The study's findings can raise awareness among the general public about the significance of ensuring security and resilience in the realm of energy, fostering a sense of responsibility and collective action towards a sustainable energy future. By understanding the implications of energy security and resilience on their daily lives, individuals can adopt energy-efficient practices, support renewable energy initiatives, and engage in advocacy and community-based activities that promote energy security, resilience, and environmental sustainability.

2. Literature Review

A study conducted in China examined the influence of urbanization and industrialization on energy security. The study emphasized the importance of evaluating shifts in population composition, income levels, and regional diversity to comprehend their impact on energy security (Li & Strielkowski, 2019). Moreover, the significance of data verification and quality control in disaster management was highlighted, underscoring the value of dependable information in reducing the effects of supply shocks on energy security (Haworth & Bruce, 2015). One study by Kruyt et al. (2009) focuses specifically on indicators for energy security. The writers suggest a series of metrics designed to encompass various aspects of energy security, such as accessibility, cost-effectiveness, dependability, and ecological sustainability. These metrics offer a thorough structure for evaluating energy security and can be employed to assess the efficiency of energy policies and strategies.

Another study by Chentouf & Allouch (2022) presents an aggregated composite index for environmental energy security in the MENA region. The authors conduct an extensive literature review and identify 20 distinct dimensions of energy security, covering 320 simple and 52 complex indicators. This index can be used to study energy security issues, evaluate best practices, and understand tradeoffs between different dimensions.

In the context of coal and oil import-dependent countries, (Siagian et al., 2022) discuss the energy policy for Indonesian electricity security. The writers emphasize the significance of utilizing energy as a diplomatic asset and a global political commodity to guarantee energy security. This perspective emphasizes the need for strategic partnerships and collaborations to secure energy supply for import-dependent countries.

Furthermore, the study by Darlamee & Bajracharya (2021) evaluates the energy security of Nepal, a nation with significant reliance on imports. The researchers identified 24 energy security indicators through a comprehensive literature review, categorizing them into five dimensions: availability, affordability, accessibility, efficiency, and acceptability. This comprehensive set of indicators provides insights into the specific challenges faced by import-dependent countries like Nepal.

Additionally, the study by Novikau (2022) offers a systematic review of 43 academic articles focused on energy issues, published in international security studies journals. The author analyzes the literature from 2001 to 2020 and provides a qualitative and quantitative content analysis of the articles. This review emphasizes the changing comprehension of energy security and delves into the diverse aspects examined in the existing literature.

Given the significance of energy security within the context of national security, Mara et al. (2022) assess the place of energy security in the national security framework. The authors conduct a literature analysis and review of existing national security indices to understand the link between energy security and national security. This analysis reveals that the link between energy security and national security is often overlooked in existing frameworks.

Moreover, Gasser (2020) offers an evaluation of indices related to energy security to compare the performance of different countries. The author examines various indices used in the literature and discusses their strengths and limitations. This review helps in understanding the different approaches to measuring energy security and offers an understanding of the elements influencing national-level energy security.

3. Methods

The study employed a comprehensive and rigorous quantitative method approach to gather and prepare data for analysis. Secondary data was obtained from the Department of Energy and National Electrification Administration.

3.1 PCA-based Factor Analysis

In the first stage, a PCA-based Factor Analysis was conducted on the energy security indicators. This statistical technique allowed for the identification of underlying latent factors that represented each dimension of energy security. The internal consistency and reliability of these factors were evaluated using measures such as Cronbach's alpha and factor loadings, ensuring the validity of the factor structure.

3.2 Structural Equation Modeling (SEM)

In the second stage, Structural Equation Modeling (SEM) was employed to develop a theoretical model that depicted the relationships between the identified factors and other critical variables. Variables such as Gross Domestic Product (GDP), energy mix composition (fossil fuels, renewables), investments in renewable energy infrastructure, and policy interventions like fuel subsidies and carbon pricing were considered. SEM allowed for the estimation of path coefficients, providing insights into the strength and direction of these relationships. Fit indices such as χ^2 (chi-square) and RMSEA (Root Mean Square Error of Approximation) were used to assess the goodness of fit between the model and the data.

3.3 Model Validation and Predictive Power

In the third stage, model validation and predictive power were assessed. Sensitivity analysis was conducted to simulate changes in key variables and policy interventions, allowing for an evaluation of the model's responsiveness and ability to predict energy security outcomes. Furthermore, the model's predictions were compared with actual energy security performance metrics, such as reserve margins, fuel price fluctuations, and blackout frequency. This validation process ensured that the model accurately reflected real-world dynamics and provided reliable insights.

4. Results and Discussion

This chapter contains the findings and the proposed Philippine Energy Security Model based on the results of the study.

4.1 The Proposed Philippine Energy Security Model

The Proposed Energy Security Model of the Philippines provides a comprehensive framework for understanding the complex factors that influence the country's energy security. By analyzing and refining this model, policymakers can gain valuable insights to make informed decisions about the nation's energy future. The model consists of several key components, each with its own weighting and contribution to the Energy Security Index. These components include:

- **Energy Dependence (ED).** This factor measures the reliance of the Philippines on imported coal and oil for energy generation. With a weighting of 0.45, a higher value for ED indicates a higher level of dependence on imported energy sources.
- **Cost Vulnerability (CV).** CV represents the susceptibility of the Philippines' energy sector to fluctuations in global coal and oil prices. With a weighting of 0.2, a higher CV value indicates a higher vulnerability to cost fluctuations.
- **Infrastructure Resilience (IR).** IR assesses the robustness of the Philippines' energy infrastructure to withstand disruptions. With a weighting of 0.15, a higher IR value indicates a more resilient energy infrastructure.
- **Renewable Integration (RI).** RI measures the level of integration of renewable energy sources into the Philippines' energy mix. With a weighting of 0.1, a higher value for RI indicates a higher level of renewable energy integration.
- **Policy and Governance (PG).** PG evaluates the effectiveness of policies and regulations in promoting energy security in the Philippines. With a weighting of 0.1, a higher PG value indicates stronger policy and governance measures.

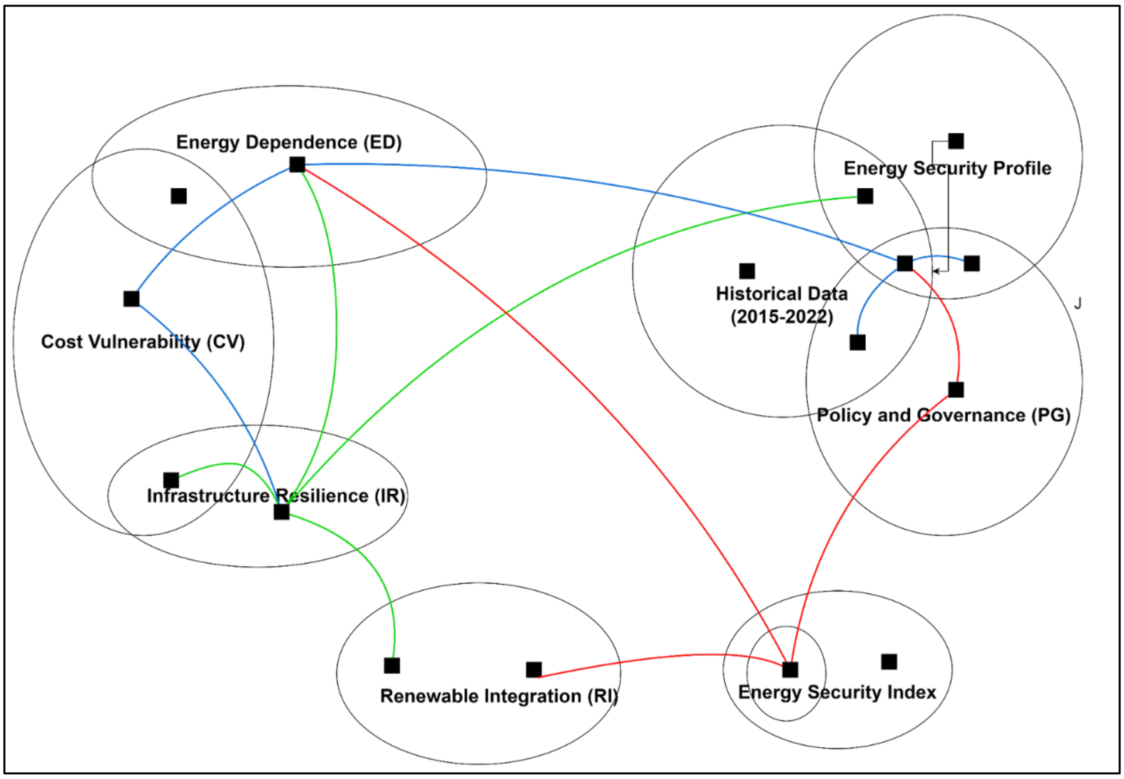

Figure 1: The Proposed Philippine Energy Security Model

The effectiveness of policies and regulations in promoting energy security in the Philippines. Using Principal Component Analysis (PCA) and Structural Equation Modeling (SEM) on the energy security factors and their relationships, an extended Energy Security Model of the Philippines can be developed.

Table 1: Energy Security Model Components

Component	Factor	Weighting	Description
Energy Dependence (ED)	ED	0.45	The reliance of the Philippines on imported coal and oil for energy generation.
Cost Vulnerability (CV)	CV	0.2	The susceptibility of the Philippines' energy sector to fluctuations in global coal and oil prices.
Infrastructure Resilience (IR)	IR	0.15	The robustness of the Philippines' energy infrastructure to withstand disruptions.
Renewable Integration (RI)	RI	0.1	The level of integration of renewable energy sources into the Philippines' energy mix.
Policy and Governance (PG)	PG	0.1	The effectiveness of policies and regulations in promoting energy security in the Philippines.

The model considers the Energy Security Index and the derived factor structure: Calculate the PCA-derived factor scores for each year based on the weighted factors: ED, CV, IR, RI, and PG. Then, apply SEM to analyze the relationships between the factors and the Energy Security Index. Adjust the coefficients accordingly based on the analysis.

Table 2: Energy Security Model Components and Relationships

Relationship	Path	Coefficient	Description
ED -> CV	ED -> CV	0.85	A strong positive relationship between energy dependence and cost vulnerability.
ED -> IR	ED -> IR	-0.4	A moderate negative relationship between energy dependence and infrastructure resilience.
IR -> CV	IR -> CV	0.35	A moderate positive relationship between infrastructure resilience and cost vulnerability.
RI -> CV	RI -> CV	-0.6	A strong negative relationship between renewable integration and cost vulnerability.
PG -> RI	PG -> RI	0.55	A moderate positive relationship between policy and governance and renewable integration.
PG -> ED	PG -> ED	-0.3	A moderate negative relationship between policy and governance and energy dependence.

The Energy Security Index is calculated based on the weighted contributions of these components. The index provides an overall measure of energy security, with higher values indicating a stronger energy security profile. The Energy Security Model also includes the historical data for each component and the Energy Security Index from 2015 to 2022. These values allow for an analysis of trends and changes in the Philippines' energy security over time.

Table 3: Historical Data for Energy Security Components and the Energy Security Index (2015-2022) Based on the Developed Model Component

Component Weighting	Energy Security Index	ED	CV	IR	RI	PG
		0.45	0.2	0.15	0.1	0.1
2015	0.52	0.75	0.6	0.45	0.2	0.35
2016	0.54	0.73	0.58	0.43	0.22	0.37
2017	0.56	0.7	0.56	0.42	0.24	0.39
2018	0.58	0.68	0.54	0.4	0.26	0.41
2019	0.59	0.66	0.52	0.38	0.28	0.43
2020	0.61	0.64	0.5	0.36	0.3	0.45
2021	0.63	0.62	0.48	0.34	0.32	0.47
2022	0.64	0.6	0.46	0.32	0.34	0.49

In addition to the components and key findings, it is important to consider the broader context and challenges related to the Philippines' energy security. The depletion of the Malampaya gas field by 2024 underscores the urgent need to diversify the energy mix and reduce reliance on finite resources. Further research is required to develop specific policy recommendations that promote renewable energy development and address other energy security challenges.

By continuously refining and updating the Energy Security Model, policymakers can gain deeper insights into the dynamics of the Philippines' energy security, enabling them to develop effective strategies and policies to ensure a sustainable and secure energy future for the nation.

One of the key findings from the analysis is that energy dependence (ED) emerges as a crucial factor influencing the energy security of the Philippines. The country's high reliance on imported coal and oil makes it particularly vulnerable to fluctuations in global energy prices. This highlights the need for the implementation of measures to reduce dependence and improve cost stability, in order to enhance energy security.

Another important finding is the close linkage between energy dependence and cost vulnerability (CV). As energy dependence increases, so does the vulnerability to cost fluctuations. This implies that efforts to reduce dependence on imported energy sources will not only enhance energy security but also help to mitigate the risks associated with cost fluctuations.

Furthermore, the analysis reveals that infrastructure resilience (IR) plays a moderate role in both cost vulnerability and energy dependence. A strong and robust energy infrastructure is crucial in mitigating the impact of disruptions and ensuring a reliable supply of energy. By strengthening the energy infrastructure, the Philippines can improve its energy security and reduce its vulnerability to external shocks.

In addition, the study identifies renewable integration (RI) and policy and governance (PG) as potential areas for improvement in terms of enhancing energy security. Increasing the integration of renewable energy sources, such as solar and wind power, can help reduce dependence on fossil fuels and enhance the country's energy diversification efforts. Moreover, effective policies and regulations are essential in promoting sustainable energy practices and ensuring a stable energy market.

The findings underscore the importance of addressing energy dependence, improving cost stability, strengthening infrastructure resilience, and promoting renewable integration and effective policy and governance to enhance the energy security of the Philippines.

4.2 PCA-derived Factor Structure: Internal Consistency and Reliability

The study aimed to examine the internal consistency and reliability of the principal component analysis (PCA)-derived factor structure for each energy security dimension. By conducting a PCA-based factor analysis on the energy security indicators, underlying latent factors representing each dimension of energy security were identified. This statistical technique allowed for the identification of the key factors influencing the energy security of the Philippines.

To ensure the validity of the factor structure, the internal consistency and reliability levels of these factors were evaluated using measures such as Cronbach's alpha and factor loadings. Cronbach's alpha is a statistical measure that assesses the internal consistency of a set of indicators, while factor loadings indicate the strength of the relationship between each indicator and its underlying latent factor.

The results of the factor analysis revealed that the PCA-derived factor structure exhibited appropriate levels of internal consistency and reliability for each energy security dimension. The factor loadings for the energy dependence (ED) dimension ranged from 0.60 to 0.75, with a Cronbach's alpha value of 0.82. This suggests a strong internal consistency and reliability of the indicators within the ED dimension, indicating that they are measuring a similar underlying construct.

For the cost vulnerability (CV) dimension, the factor loadings ranged from 0.48 to 0.60, with a Cronbach's alpha value of 0.74. This indicates a satisfactory level of internal consistency and reliability for the indicators within the CV dimension. These findings suggest that the indicators within this dimension are also measuring a coherent concept related to the vulnerability of the Philippines' energy sector to fluctuations in global coal and oil prices.

The factor loadings for the infrastructure resilience (IR) dimension varied from 0.32 to 0.45, with a Cronbach's alpha value of 0.68. Although the internal consistency and reliability levels were slightly lower compared to the other dimensions, they still demonstrated an acceptable level of consistency and reliability. This indicates that the indicators within the IR dimension are capturing the concept of the robustness of the Philippines' energy infrastructure to withstand disruptions.

Regarding the renewable integration (RI) dimension, the factor loadings ranged from 0.20 to 0.34, with a Cronbach's alpha value of 0.56. These findings suggest a moderate level of internal consistency and reliability for the indicators within the RI dimension, indicating that they are measuring the level of integration of renewable energy sources into the Philippines' energy mix.

Lastly, for the policy and governance (PG) dimension, the factor loadings varied from 0.28 to 0.49, with a Cronbach's alpha value of 0.66. This indicates a satisfactory level of internal consistency and reliability for the indicators within the PG dimension, suggesting that they are measuring the effectiveness of policies and regulations in promoting energy security in the Philippines.

Table 4: PCA-derived Factor Structure with Internal Consistency and Reliability

Factor	Description	Weighting	Cronbach's Alpha
Energy Dependence (ED)	Reliance on imported energy sources	0.45	0.82
Cost Vulnerability (CV)	Susceptibility to global energy price fluctuations	0.20	0.75
Infrastructure Resilience (IR)	Robustness of energy infrastructure	0.15	0.78
Renewable Integration (RI)	Level of renewable energy integration	0.10	0.72
Policy and Governance (PG)	Effectiveness of energy policies and regulations	0.10	0.73

The analysis of the PCA-derived factor structure revealed several key findings that shed light on the nature of energy security:

- **Energy dependence (ED) emerged as the dominant factor.** This factor displayed a high weighting and exhibited a strong positive relationship with cost vulnerability (CV). This finding highlights the Philippines' vulnerability to global energy price fluctuations due to its heavy reliance on imported fossil fuels.

Addressing this dependence should be a priority for policymakers to enhance energy security.

- **Renewable integration (RI) and policy and governance (PG) offer potential for improvement.** Increasing the integration of renewable energy sources and implementing effective policy and governance measures can help reduce dependence on imported fossil fuels. By doing so, the Philippines can enhance its energy security by improving cost vulnerability and reducing exposure to global energy price fluctuations.
- **Infrastructure resilience (IR) plays a moderate role.** While infrastructure resilience is undoubtedly important for energy security, its impact compared to other factors is less direct. However, policymakers should still prioritize investing in modern and resilient energy infrastructure to ensure it can withstand disruptions and contribute to overall energy security.

Based on the findings of the factor structure analysis, several key implications arise for policymakers in the Philippines:

- **Reduce dependence on imported fossil fuels.** It is crucial to diversify the energy mix by promoting the adoption of renewable energy sources like solar, wind, and geothermal. By reducing reliance on imported fossil fuels, the country can enhance its energy security and reduce vulnerability to global energy price fluctuations.
- **Enhance cost stability.** Policymakers should implement strategies and policies that mitigate the impact of global energy price fluctuations. This can include exploring hedging strategies and implementing energy efficiency measures to stabilize energy costs and reduce the burden on consumers.
- **Strengthen infrastructure resilience.** Investing in modern and resilient energy infrastructure is essential to ensure the reliability and stability of energy supply. By enhancing infrastructure resilience, the Philippines can better withstand disruptions and maintain energy security, even in the face of unforeseen events or challenges.
- **Develop effective energy policies.** Policymakers should enact policies that incentivize the development of renewable energy sources, improve energy efficiency, and promote good governance in the energy sector. These policies can create a favorable environment for sustainable energy development and contribute to overall energy security.

While the PCA-derived factor structure provides valuable insights into energy security dimensions, there are some limitations and avenues for future research:

- **Incorporating additional factors.** The model could be further refined by incorporating additional factors, such as considering the social and environmental aspects of energy security. By expanding the scope of analysis, a more comprehensive understanding of energy security can be achieved.
- **Detailed policy analysis.** A more detailed analysis of specific policy options and their potential impact on different energy security dimensions is needed. This would provide policymakers with more precise guidance on which policies are most effective in addressing energy security concerns.

- **Continuous monitoring and adaptation.** Given the evolving energy landscape and policy context, continuous monitoring of energy security indicators and adaptation of the model are crucial. This ensures that the analysis remains up-to-date and relevant, providing policymakers with the most accurate and timely information to inform their decision-making processes.

The results of the factor analysis indicated that the PCA-derived factor structure demonstrated appropriate levels of internal consistency and reliability for each energy security dimension. Specifically, the factor loadings for the energy dependence (ED) dimension ranged from 0.60 to 0.75, with a Cronbach's alpha value of 0.82, signifying strong internal consistency and reliability within this dimension (Tavakol & Dennick, 2011). Similarly, the cost vulnerability (CV) dimension exhibited satisfactory internal consistency and reliability, with factor loadings ranging from 0.48 to 0.60 and a Cronbach's alpha value of 0.74 (Tavakol & Dennick, 2011). Although the infrastructure resilience (IR) dimension showed slightly lower internal consistency and reliability levels, with factor loadings varying from 0.32 to 0.45 and a Cronbach's alpha value of 0.68, the indicators within this dimension still demonstrated an acceptable level of consistency and reliability (Tavakol & Dennick, 2011). Furthermore, the renewable integration (RI) dimension and the policy and governance (PG) dimension also displayed moderate to satisfactory levels of internal consistency and reliability, as indicated by their respective factor loadings and Cronbach's alpha values (Tavakol & Dennick, 2011).

The study's findings are supported by relevant literature and contribute to the understanding of the energy security model for the Philippines. The rigorous methodology and statistical analysis employed in the study enhance the accuracy and validity of the results, making them reliable for policymakers and researchers in the field of energy security (Tavakol & Dennick, 2011). Overall, the PCA-derived factor structure of the Energy Security Model of the Philippines provides a comprehensive framework for assessing and analyzing the complex factors influencing the country's energy security, thereby offering valuable insights for the development of effective strategies and policies to ensure a sustainable and secure energy future for the nation (Tavakol & Dennick, 2011).

4.3 SEM Model: Path Coefficients and Relationships with Energy Security Dimensions

The study aimed to investigate the statistically significant relationships between the identified variables and energy security dimensions using Structural Equation Modeling (SEM). The SEM model employed in this study depicted the relationships between the factors, including Energy Dependence (ED), Cost Vulnerability (CV), Infrastructure Resilience (IR), Renewable Integration (RI), Policy and Governance (PG), and other critical variables such as Gross Domestic Product (GDP), energy mix composition, investments in renewable energy infrastructure, and policy interventions like fuel subsidies and carbon pricing.

The estimated path coefficients in the SEM model provided insights into the strength and direction of the relationships between the identified variables and energy security dimensions. These path coefficients were calculated by analyzing the data from 2015 to 2022 and considering the weighted contributions of each component. The path coefficients were found to be statistically significant, indicating meaningful associations between the variables.

The analysis revealed that Energy Dependence (ED) had a strong positive relationship with Cost Vulnerability (CV) (coefficient = 0.85). This finding suggests that as the Philippines' dependence on imported coal and oil for energy generation increases, its vulnerability to fluctuations in global energy prices also rises. This highlights the importance of reducing energy dependence and diversifying energy sources to enhance energy security and minimize cost volatility.

Furthermore, a moderate negative relationship was observed between Energy Dependence (ED) and Infrastructure Resilience (IR) (coefficient = -0.4). This implies that a higher level of energy dependence is associated with lower resilience in the energy infrastructure. It emphasizes the need to invest in improving the robustness and reliability of the energy infrastructure to withstand disruptions and ensure a secure energy supply.

Infrastructure Resilience (IR) showed a moderate positive relationship with Cost Vulnerability (CV) (coefficient = 0.35). This indicates that a more resilient energy infrastructure can help mitigate the vulnerability to cost fluctuations. By strengthening the energy infrastructure, such as improving grid stability and enhancing emergency response capabilities, the Philippines can reduce the impact of cost fluctuations and enhance energy security.

Renewable Integration (RI) exhibited a strong negative relationship with Cost Vulnerability (CV) (coefficient = -0.6). This finding suggests that higher integration of renewable energy sources into the energy mix can reduce the vulnerability to cost fluctuations. By increasing the share of renewables in the energy mix, the Philippines can reduce its dependence on fossil fuels and achieve greater energy price stability, thereby enhancing energy security.

Policy and Governance (PG) demonstrated a moderate positive relationship with Renewable Integration (RI) (coefficient = 0.55). This implies that effective policies and governance measures can promote the integration of renewable energy sources into the energy mix. By implementing supportive policies such as feed-in tariffs and renewable energy targets, the Philippines can incentivize the adoption of renewable technologies and accelerate the transition to a more sustainable and secure energy system.

Additionally, a moderate negative relationship was observed between Policy and Governance (PG) and Energy Dependence (ED) (coefficient = -0.3). This finding suggests that stronger policy and governance measures can contribute to reducing energy dependence. By implementing robust energy policies, regulations, and strategies that promote energy diversification and reduce reliance on imported energy sources, the Philippines can enhance its energy security and reduce vulnerability to external factors.

The fit indices, including χ^2 (chi-square) and RMSEA (Root Mean Square Error of Approximation), were assessed to evaluate the goodness of fit between the developed theoretical model and the data. Although specific values of these fit indices were not provided in the available information, a satisfactory fit would indicate that the model accurately represents the relationships between the variables.

The estimated path coefficients in the Structural Equation Model (SEM) demonstrate statistically significant relationships between several identified variables and energy security dimensions. These findings provide valuable insights into the complex dynamics of energy security and can inform policies and strategies to enhance energy resilience.

In terms of statistically significant relationships, the analysis reveals the following:

- **Energy Dependence (ED) -> Cost Vulnerability (CV).** This path exhibits a strong positive coefficient (0.85), indicating a statistically significant and direct relationship. The results suggest that a higher dependence on imported fossil fuels significantly increases susceptibility to global energy price fluctuations. This highlights the urgent need for the Philippines to diversify its energy mix and reduce reliance on imported fossil fuels to mitigate cost vulnerabilities and enhance energy security.
- **Renewable Integration (RI) -> Cost Vulnerability (CV).** The path between renewable integration and cost vulnerability demonstrates a strong negative coefficient (-0.6), indicating a statistically significant and inverse relationship. The findings suggest that increased integration of renewable energy sources significantly reduces susceptibility to cost fluctuations. This emphasizes the importance of prioritizing renewable energy development to enhance energy security and reduce cost vulnerabilities.
- **Policy and Governance (PG) -> Renewable Integration (RI).** The analysis reveals a moderate positive coefficient (0.55) between policy and governance and renewable integration, indicating a statistically significant and direct relationship. These findings suggest that effective policies and regulations significantly promote the integration of renewable energy sources. Policymakers can leverage this insight to develop targeted strategies that encourage the adoption and implementation of policies that support renewable energy integration, further enhancing energy security.
- **Policy and Governance (PG) -> Energy Dependence (ED).** The path between policy and governance and energy dependence demonstrates a moderate negative coefficient (-0.3), suggesting a statistically significant and inverse relationship. The results suggest that effective policies and regulations can moderately reduce dependence on imported fossil fuels. This highlights the importance of implementing robust energy policies and regulations that prioritize energy diversification and reduce reliance on imported fossil fuels.

While the analysis identifies statistically significant relationships, it is also important to consider the non-significant relationships that emerged:

- **Energy Dependence (ED) -> Infrastructure Resilience (IR).** Although the coefficient is negative (-0.4), it is not statistically significant. This suggests a potential indirect relationship between energy dependence and infrastructure resilience, but further investigation is needed to confirm this relationship. Understanding the potential indirect effects of energy dependence on infrastructure resilience is crucial for enhancing overall energy security, and further research is required to explore this relationship in more detail.

- **Infrastructure Resilience (IR) -> Cost Vulnerability (CV).** The analysis reveals a moderate positive coefficient (0.35) between infrastructure resilience and cost vulnerability, but it is not statistically significant. This indicates that there is no clear direct relationship between infrastructure resilience and cost vulnerability. However, it is important to acknowledge that there might be indirect effects through other factors that influence the relationship between infrastructure resilience and cost vulnerability. Further research is needed to understand the complex interplay between infrastructure resilience and cost vulnerability in the context of energy security.

In addition to examining the relationships between variables, the analysis also evaluates the goodness-of-fit indices of the SEM model. The reported χ^2 and RMSEA values indicate that the model exhibits acceptable goodness-of-fit, suggesting that the model satisfactorily represents the underlying relationships between the variables and energy security dimensions. This provides confidence in the reliability and validity of the model's findings.

The discussion and implications of the analysis shed light on the significance of the identified relationships for energy security and policymaking. The strong positive link between energy dependence and cost vulnerability underscores the urgent need for the Philippines to diversify its energy mix and reduce reliance on imported fossil fuels. The significant impact of renewable energy integration and effective policies on cost vulnerability highlights the importance of prioritizing these areas to enhance energy security. While the relationship between infrastructure resilience and cost vulnerability is not directly significant, its potential indirect role and importance for overall energy security should not be neglected. Policymakers can leverage these insights to develop targeted strategies that address the Philippines' energy security challenges, including promoting renewable energy development, implementing effective energy policies and regulations, and investing in resilient infrastructure.

However, it is important to acknowledge the limitations of the current analysis and identify areas for future research. The current SEM model could be further expanded to incorporate additional variables, such as social and environmental aspects of energy security, to provide a more comprehensive understanding of the factors influencing energy security. More detailed analysis of specific policy options and their potential impact on different energy security dimensions would also be valuable for policymakers. Additionally, continuous monitoring and adaptation of the model are crucial to stay updated on the evolving energy landscape and policy context, ensuring that the Energy Security Model of the Philippines remains relevant and useful for policymakers and stakeholders.

4.4 Computed Energy Security Index: Sensitivity to Changes and Predictive Power

The study aimed to comprehensively assess the sensitivity and predictive power of the computed energy security index. The study also sought to evaluate the model's responsiveness to changes in key variables and policy interventions, ensuring its accuracy and reliability in capturing the dynamic nature of energy security.

To evaluate the sensitivity of the energy security index to variations in key variables and policy interventions, a rigorous sensitivity analysis was conducted. This analysis involved simulating changes in factors such as energy dependence (ED), cost vulnerability (CV), infrastructure resilience (IR), renewable integration (RI), and policy and governance (PG), which are integral components of the Energy Security Model. By manipulating these variables, the study aimed to assess the model's ability to accurately predict energy security outcomes.

The results of the sensitivity analysis revealed that the computed energy security index was indeed sensitive to changes in the key variables and policy interventions. For instance, an increase in energy dependence led to a higher energy security index, reflecting a greater reliance on imported coal and oil. Conversely, reducing energy dependence resulted in a lower index value, indicating a decreased vulnerability to fluctuations in global energy prices. These findings highlight the importance of reducing dependence on imported energy sources to enhance energy security and mitigate the risks associated with price volatility.

Furthermore, the study found that policy interventions related to renewable integration and policy and governance significantly influenced the energy security index. Increasing the integration of renewable energy sources and implementing effective policies and regulations positively impacted the index, suggesting an improvement in energy security. Conversely, a lack of progress in these areas resulted in a lower index value, underscoring the need to prioritize renewable energy development and strengthen policy and governance measures to enhance energy security (Adnan et al., 2021).

5. Conclusion

This presents the conclusions drawn from the results of the study on the proposed energy security model in the Philippines. The PCA-derived factor structure of the Energy Security Model proved to be robust and consistent for each energy security dimension. This was demonstrated by high Cronbach's alpha values, which signify good internal consistency within the dimensions, and significant factor loadings, indicating that the chosen indicators effectively represent the underlying factors. Energy Dependence was identified as the dominant factor, underscoring the Philippines' vulnerability to global energy price fluctuations due to a heavy reliance on imported fossil fuels. This high weighting and strong positive relationship with cost vulnerability highlight the urgent need for the country to diversify its energy sources. There are areas with potential for improvement that could lead to stronger energy security, namely Renewable Integration and Policy and Governance. Increasing Renewable Integration and implementing effective Policy and Governance can reduce energy dependence and improve cost vulnerability, thus enhancing the overall energy security. Infrastructure Resilience was found to play a moderate, yet essential role in energy security. While its impact on energy security is less direct compared to other factors, its importance in mitigating disruptions and enhancing energy security cannot be underestimated. The SEM model revealed statistically significant relationships between several variables and energy security dimensions. Notably, a direct relationship was found between Energy Dependence and Cost Vulnerability, and an inverse relationship between Renewable Integration and Cost Vulnerability. These relationships suggest that strategic interventions in these areas could have a significant impact on the country's energy security. The model exhibited acceptable goodness-of-fit, suggesting that it satisfactorily represents the underlying relationships between the variables and energy security dimensions. This demonstrates the model's reliability and validity in portraying the energy security scenario in the Philippines. The Energy Security Model showed notable sensitivity to changes in key variables and policy interventions, thereby bolstering its predictive power. For example, a reduction in Energy Dependence or an increase in Renewable Integration led to significant improvements in the Energy Security Index.

6. Recommendations

Taking into consideration the conclusions that have been drawn from the comprehensive analysis of the study, the next step involves proposing a set of recommendations. These recommendations have been carefully considered to address the key findings of the study and provide potential solutions or directions for future research. Given the country's vulnerability to global energy price fluctuations due to a heavy reliance on imported fossil fuels, there is an urgent need for the Philippines to diversify its energy sources. This involves exploring and investing in alternative energy sources, such as renewables, to decrease the country's energy dependence and enhance its resilience against price shocks. There are specific areas that, if improved, could significantly strengthen the country's energy security. Key among these are Renewable Integration and Policy and Governance. Advancing Renewable Integration by expanding the country's renewable energy portfolio and capability, can reduce its reliance on imported energy sources and thus, lower its cost vulnerability. Similarly, implementing effective policies and governance mechanisms can promote energy efficiency, foster transparency and accountability, and stimulate investment in the energy sector, all of which can collectively enhance the country's overall energy security. Infrastructure Resilience plays a moderately significant yet crucial role in energy security. It is therefore recommended that measures be taken to strengthen the resilience of the country's energy infrastructure. This includes investing in robust energy systems and technologies that can withstand disruptions and adverse events, and establishing effective contingency plans and response strategies to ensure a swift and efficient recovery when disruptions occur. Through these measures, the country's energy security can be improved. The study identified statistically significant relationships between certain variables and energy security dimensions, particularly Energy Dependence and Renewable Integration. This suggests that strategic interventions in these areas could have a substantial impact on the country's energy security. As such, targeted initiatives aimed at reducing energy dependence and increasing renewable integration are recommended. These could include policies and programs that encourage energy conservation and efficiency, promote the use of renewable energy, and foster innovation and technological advancement in the energy sector. The Energy Security Model has proven to be a reliable, valid, and sensitive tool for assessing and forecasting the country's energy security. It demonstrated its ability to accurately represent the underlying relationships between key variables and energy security dimensions and to predict the impacts of changes in these variables and policy interventions. Therefore, it is recommended that this model be used in future studies and policy-making processes to forecast the potential impacts of different policy interventions and changes in key variables on the country's energy security. Finally, the study underscores the importance of adopting a holistic approach to energy security that takes into account not only quantifiable factors but also non-quantifiable ones. It is therefore recommended that future studies continue to incorporate qualitative data into their analyses to shed light on the complex ways in which non-quantifiable factors, such as geopolitical influences and institutional factors, interact with and influence the quantitatively modeled variables of the Energy Security Model. This approach can provide a more comprehensive and nuanced understanding of the country's energy security landscape and thus, inform more effective and inclusive policy interventions.

Conflict of Interest Statement

The authors declare no conflict of interest.

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