

SEM-SAM Model for Strategic Management Toward Efficient and Sustainable Emerging Industries for Sustainable Future

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Received August 2, 2025, Revised October 4, 2025, Accepted October 8, 2025, Published July 1, 2026

Abstract. *This research aims to develop a model to define the causal relationships of factors influencing future energy consumption in Thailand's industrial sectors, aligned with the country's sustainable development goals. The study proposes a Structural Equation Modeling based on the Social Accounting Matrix (SEM-SAM model) as a key tool for effective national management in line with the carbon neutrality target by 2050. The findings reveal that from 1992 to 2025, there has been consistent growth in both the economic and social sectors. However, this growth has simultaneously led to significant environmental degradation. The study indicates that CO₂ emissions resulting from industrial energy consumption have surpassed the carrying capacity threshold of 65.05 Mt CO₂ Eq. (2025-2034), with a growth rate (2034/2025) of 30.45%, reaching 75.01 Mt CO₂ Eq. (2025-2034) during this period. As a solution, the research introduces a new scenario policy that incorporates increased use of biodiesel fuel and clean technologies, which helps reduce CO₂ emissions to only 45.05 Mt CO₂ Eq. (2025-2034). These findings highlight the potential of the proposed model as a decision-making tool for steering national policy toward a sustainable future.*

Keywords: industrial sector, management efficiency, sustainable development, development strategy, carbon neutrality

1 Introduction

The United Nations has held three major global conferences on environmental protection [1]. The first took place in 1972 in Stockholm, Sweden, and led to the establishment of a dedicated agency in 1983 called the United Nations Environment Programme (UNEP) [2, 3]. Later, in 1992, the major Earth Summit, also known as the Rio Conference or the UN Conference on Environment and Development (UNCED), was held in Rio de Janeiro, Federative Republic of Brazil [4]. The objective was to formulate strategies concerning the environment and development [5]. This summit was the first to outline solutions to environmental issues through a comprehensive approach based on the three pillars of sustainable development: society, economy, and environment [6]. The conference resolved to establish the Commission on Sustainable Development (CSD), comprising 53 member countries, tasked with overseeing sustainable development and implementing outcomes from the World Summit on Sustainable Development (WSSD) [6, 7]. The CSD reports its findings to the United Nations General Assembly, through the United Nations Economic and Social Council (ECOSOC). The conference endorsed three key documents and two international conventions: 1) Rio Declaration on Environment and Development, outlining principles on the rights and responsibilities of nations in environmental development to improve people's quality of life; 2) Statement of Forest Principles, a framework for sustainable forest resource management; and 3) Agenda 21, – a global action plan for sustainable development across the social, economic, and environmental dimensions [8]. The two conventions are: 1) The United Nations Framework Convention on Climate Change (UNFCCC), to which Thailand has ratified; and 2) The Convention on Biological Diversity (CBD). The most recent major conference was held in 2005 in Johannesburg, Italy. For all three conferences, Thailand has actively participated and strictly adhered to the agreements in order to reduce greenhouse gas emissions in line with the country's long-term national strategic goals [9].

Before and during the economic crisis, it was found that Thailand's previous efforts in sustainable development were not successful. This was due to a lack of economic growth and the onset of a financial crisis, which forced the country to borrow funds from abroad to stabilize the economy [1, 2, 10]. As a result, social development also stalled; public safety was compromised, and public health problems continued to rise. In addition, severe environmental degradation occurred, with greenhouse gas emissions increasing continuously. In response, from 2002 (B.E. 2545) onward, Thailand revised its national management strategy, placing strong emphasis on sustainable development [11]. The government formulated clear and concrete policies to guide the country's administration in line with these goals. Since then, Thailand has actively promoted economic growth alongside social development. These efforts have proven highly successful. For example, the country has continuously increased exports, diversified products to various trade partners, expanded export-oriented production bases, and built lasting confidence in the quality of Thai products [12, 13].

At the same time, Thailand has worked to reduce imports of certain goods by promoting domestic production and self-sufficiency [14]. The government has also encouraged foreign direct investment, particularly in the industrial sector, with a focus on nationwide expansion [15]. As a result, since 2002, energy consumption in Thailand's industrial sector has grown more than tenfold [16]. The government has supported this growth by providing critical funding, reducing administrative fees, and cutting

annual taxes. These measures have led to a surge in investment from both domestic and international investors, significantly boosting Thailand's Gross Domestic Product (GDP) [17]. In conclusion, the Thai government's economic policies have been effectively implemented and are considered successful in driving national development [18, 19].

In addition to the continued implementation of economic growth policies, the Thai government has also actively promoted social development, which has grown steadily as well. This social progress has been driven directly by economic expansion, alongside ongoing efforts to promote and support growth across all social dimensions. However, when considering the environmental dimension, it has been found that energy consumption has also continuously increased, accompanied by a steady rise in greenhouse gas emissions. Notably, CO₂ emissions have grown significantly, especially in the electricity sector, surpassing Thailand's carrying capacity. This indicates that the current sustainability policies are not yet being implemented effectively. Further study of existing research reveals that Thailand has faced several challenges in implementing its sustainable development plans in practice. Therefore, this research has been developed as a critical tool to support the formulation of strategic management policies that will guide Thailand toward a sustainable future, in alignment with its carbon neutrality targets. In this regard, the SEM-SAM model, an analytical framework that has not yet been applied in Thailand or elsewhere, offers a highly suitable approach for policy analysis, enabling more effective and efficient decision-making for the country's long-term development. Nevertheless, this study specifically seeks to address the research question: What factors influence the formulation of strategies that lead to greater effectiveness?

2 Material and Method

In this research, a newly developed analytical framework called the Structural Equation Modeling based on the Social Accounting Matrix (SEM-SAM model) has been applied. This model is an extension that integrates causal relationship analysis through path analysis, making it distinct from traditional models that typically examine relationships from only one perspective, such as the Vector Error Correction Models (VECM) and conventional SEM. Unlike those earlier approaches, the SEM-SAM model in this study employs national input-output (I-O) table data as a fundamental basis for estimation. The model is constructed upon the following principles [20]. The output of each economic sector is produced not only to supply as intermediate inputs for other producers but also to be sold to final consumers (final consumption) [21]. Therefore, the total output of any given economic sector can be expressed in the form of the following equation [22, 23]:

$$X_j = \sum_{i=1}^n x_{ij} + Y_j \quad (1)$$

Where a_{ij} is the output from production sector i (among n production sectors) that is purchased as an intermediate input for production sector j , and Y_j is the output from production sector j that is sold to final consumers [24, 25].

When organizing the input and output vectors for the n production sectors into matrices, each element of the matrix is defined as follows [20, 26]:

$$a_{ij} = x_{ij}/Y_j \quad (2)$$

The total output of the economic sectors can be represented in matrix form as follows [27]:

$$X = [I - A]^{-1}Y \quad (3)$$

Each element of the vector X represents the total output required to meet final consumer demand, which in turn induces demand for intermediate inputs from other economic sectors, including the sector itself [28]. This process repeats in successive layers, from the first upstream level to the second deeper upstream level, and so on, theoretically continuing to infinity. The details of the components within the economic matrix are illustrated in Figure 1.

When accounting for the net imports from abroad, the total output of the economic sectors can be predicted based on the volume of final consumption demand. It is assumed that the structural indices of imported goods and services are equivalent to those of domestic goods and services, as follows [29]:

$$X = [I - A - M]^{-1}Y \quad (4)$$

The matrix M represents the structure of intermediate inputs in terms of the value of net imports relative to the total output value of the economic sectors.

By developing the above equation for estimating the total output of the economic sectors into a model for assessing total energy demand, the following equation is obtained:

$$EI = F[I - A]^{-1}Y \quad (5)$$

From a review of related literature both domestically and internationally, it was found that previous models did not adequately address issues arising from estimation results that caused spurious values, leading to significant errors in forecasting. Past models

to from	004	055	062	084	093	135	137	139	...	Y _j
004	a 004,004	a 004,004	.	.	.	.	.	.	.	a 004,201
055	a 055,004	.	.	.	.	.	.	.	.	a 055,201
062	a 062,004	.	.	.	.	.	.	.	.	a 062,201
084	a 084,004	.	.	.	.	.	.	.	.	a 084,201
093	a 093,004	.	.	.	.	.	.	.	.	a 093,201
135	a 135,004	.	.	.	.	.	.	.	.	a 135,201
137	a 137,004	.	.	.	.	.	.	.	.	a 137,201
139	a 004,004	.	.	.	.	.	.	.	.	a 139,201
	a _i ,004	.	.	.	.	.	.	.	a _{ij}	a _i ,201
201	a 201,004	.								a 201,201

Figure 1: Structure of inputs and outputs.

typically analyzed only the relationships between dependent and independent variables, making it impossible to analyze latent variables through path analysis. As a result, these models could not distinguish between direct effects and indirect effects, nor were they able to identify new policy scenarios. In contrast, this research recognizes these shortcomings and has developed the SEM-SAM model to ensure that estimation results have validity and avoid problems such as autocorrelation, multicollinearity, and heteroskedasticity [30].

For this research, the researcher conducted a quantitative study using secondary data from the period 1992 to 2024. The data were sourced from official Thai agencies responsible for the relevant information, including the Office of the National Economic and Social Development Council (NESDB) [5], Thailand Greenhouse Gas Management Organization (public organization) [17], Department of Alternative Energy Development and Efficiency [9], and The National Statistical Office [18]. The research procedures were as follows:

1. Select variables and test for stationarity using the unit root test. If data were non-stationary, apply the first difference to correct it. If correction was not possible, the variable would be removed from the model, based on the approach by Dickey and Fuller [20].
2. Perform a co-integration test on the stationary variables following the methodology of Johansen [21, 22].
3. Check the model's properties and validate the model.
4. Forecast future CO₂ emissions for the period 2025-2034.

The research proposed two hypotheses: 1) Each latent variable has a relationship characterized by direct effects; and 2) Each latent variable has a relationship characterized by indirect effects.

3 Result

A. Selection of Indicators According to the National Sustainable Development Management Framework in the Industrial Sector

For this research, the selection of indicators was guided by Thailand's national sustainable development management framework, which encompasses all three dimensions; economic, social, and environmental. These indicators were assessed for their relevance and suitability, and the findings revealed that only 14 indicators were appropriate for use. The selection was based on official indicators that Thailand has consistently adopted in its strategic planning processes. These 14 indicators were then designated as observed variables to explain the variations in each latent variable. These were designated as observed variables to explain

the changes in each latent variable. The selected indicators are urbanization rate (X_1), industrial structure rate (X_2), foreign investment rate (X_3), total export rate (X_4), expenditure rate (X_5), employment rate (w_1), health and illness rate (w_2), education rate (w_3), protection rate (w_4), biodiesel rate (M_1), Clean technology rate (M_2), total energy consumption (Z_1), energy intensity rate (Z_2), and Carbon dioxide emissions (Z_3). All 14 indicators were logarithmically transformed and tested for stationarity using the Unit Root Test. The Augmented Dickey-Fuller (ADF) test results for all indicators showed values greater than the MacKinnon critical values at the first difference I(1) level, indicating statistical significance of 0.01 ($\alpha = 0.01$).

B. Analysis of Error Correction toward Long-run and Short-run Equilibrium

This research analyzed the ability to adjust toward equilibrium following the implementation of various policies using the co-integration test. The researcher used all indicators at the first difference level and tested them at a statistically significant level at $\alpha = 0.01$. The results are presented as follows:

Table 1: Test of error correction toward equilibrium

Production Sector	Trace Statistic Test	Max-Eigen Statistic Test	Error Correction Mechanism	MacKinnon Critical Value (p -Value)
Economics	279.05 ***	195.25 ***	-0.49 ***	$p < 0.01$
Society			-0.30 ***	$p < 0.01$
Environment			-0.81 ***	$p < 0.01$
Policy Formulation			0.00001 ***	$p < 0.01$

*** Significance level set at 1%

From Table 1, the results of the test for the error correction toward equilibrium after government policy implementation indicate that different production sectors have varying capacities to return to equilibrium. The analysis shows that each production sector's adjustment speed differs: the environmental sector has the slowest ability to adjust toward equilibrium, whereas the economic sector adjusts the fastest, both at the statistical significance level of $\alpha = 0.01$. Therefore, the government should prioritize policies focusing on the economic sector first to ensure the policy responses successfully achieve the intended goals.

C. Path Analysis of Causal Relationships

The results of the path analysis of the relationships among the latent variables, namely the economic, social, and environmental sectors, are as follows:

Table 2: Results of path analysis on the causal relationships from SEM-SAM model

Dependent Variables	Relationship Influence	Independent Variables			
		Economic Sector	Social Sector	Environmental Sector	Policy Formulation
Economic Sector	DE	-	-	-	0.85***
	IE	-	-	-	-
Social Sector	DE	0.69***	-	-	0.86***
	IE	-	-	-	0.05***
Environmental Sector	DE	0.86***	0.55***	-	0.90***
	IE	-0.6***	-	-	0.15***
Policy Formulation	DE	-	-	-	-
	IE	-	-	-	-

Significance is indicated by *** at the statistical level of $\alpha = 0.01$, DE refers to direct effects, and IE refers to indirect effects.

From Table 2, the researcher examined the validity, measurement of model fit, and white noise of the SEM-SAM model using various statistical criteria, detailed as follows:

1. The validity check of the SEM-SAM model showed that the model meets the criteria, with all statistical tests passing the evaluation thresholds, including $HTMT_{ij} = 0.777$, $AVE_q = 0.90$, Cronbach's alpha $\alpha_q = 0.95$, and Composite Reliability (CR) $pq = 0.08$.

2. The measurement of model fit passed all criteria.

3. The test for spuriousness showed no issues with heteroscedasticity ($LM - test > LM - value$), multicollinearity ($VIF = 2.55$), and autocorrelation (Durbin Watson: D.W. = 2.02).

Therefore, based on the above test results, the SEM-SAM model satisfies all evaluation criteria, confirming its suitability as a tool for long-term forecasting. In particular, the model's performance was validated and compared with previous forecasting

models, including the ARIMA model, BP model, and Fuzzy model. The results showed that the SEM-SAM model achieved significantly lower MAPE and RMSE values than those earlier models. Hence, the SEM-SAM model is highly appropriate for use in future forecasting, as outlined below:

D. Prioritization Analysis Results Using SEM-SAM

From the SEM-SAM model in this research, the suitability of indicators for defining new scenario policies was assessed, specifically the biodiesel rate (M_1) and clean technology rate (M_2). The study results are illustrated in the following figure:

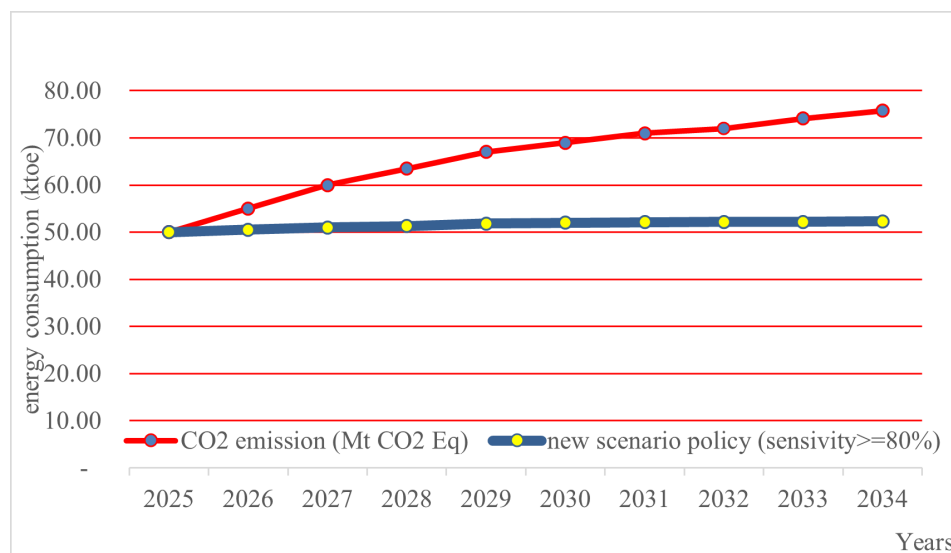


Figure 2: Forecast of CO₂ emissions for 2025–2034 using the SEM-SAM model.

From Figure 2, it is observed that CO₂ emissions will continuously increase due to rising energy consumption in the industrial sector, exceeding the carrying capacity threshold set at no more than 65.05 Mt CO₂ Eq. for the period 2025–2034. The emissions are projected to grow by 30.45%, reaching 75.01 Mt CO₂ Eq. during this period. Therefore, this research proposes a new scenario policy where the increased use of biodiesel fuel and clean technology helps reduce the growth rate of CO₂ emissions to only 45.01 Mt CO₂ Eq. (2025–2034). This demonstrates that the SEM-SAM model developed in this study is suitable for application in national decision-making to achieve the carbon neutrality target in the future.

4 Discussion and Conclusion

This research developed a model to determine the causal relationships of factors affecting future energy consumption in Thailand's industrial sector, aligned with the country's sustainable development goals. The model, referred to as the SEM-SAM model, serves as an important tool for supporting effective national governance toward achieving the carbon neutrality target by 2050. The model incorporates 14 indicators across three dimensions; economic, social, and environmental. The study found that these 14 variables were appropriate at the first-difference level I(1), showing statistical significance at $\alpha = 1$. Therefore, these indicators were designated as observed variables to explain changes in each latent variable, namely: urbanization rate (X_1), industrial structure rate (X_2), foreign investment rate (X_3), total export rate (X_4), expenditure rate (X_5), employment rate (w_1), health and illness rate (w_2), education rate (w_3), protection rate (w_4), biodiesel rate (M_1), Clean technology rate (M_2), total energy consumption (Z_1), energy intensity rate (Z_2), and Carbon dioxide emissions (Z_3). The variables also demonstrated full cointegration properties, indicating the system's ability to adjust toward equilibrium when impacted by government policies. However, the adjustment speeds differ across sectors, with the environmental sector showing the slowest return to equilibrium. Further analysis of relational influences revealed that the SEM-SAM model can forecast CO₂ emissions from industrial energy consumption exceeding the defined carrying capacity of 65.05 Mt CO₂ Eq. (2025–2034). The growth rate between 2025 and 2034 is projected to increase by 30.45%, reaching 75.01 Mt CO₂ Eq. This study, therefore, identifies a new scenario policy, highlighting that increasing the biodiesel usage rate and the clean technology adoption rate can mitigate the rise in CO₂ emissions, limiting it to only 45.05 Mt CO₂ Eq. (2025–2034). Consequently, the model proves highly suitable as a decision-making tool for the government in formulating future national policies and management plans.

This research developed the SEM-SAM model, which demonstrated strong validity. The estimation results showed the presence of white noise, as there were no issues with autocorrelation, multicollinearity, or heteroscedasticity. When analyzing the causal relationships among factors, the model was able to explain their influences accurately and appropriately. Therefore,

the SEM-SAM model is highly suitable for long-term forecasting (2025–2034). The findings indicate that SEM-SAM can serve as an important tool for decision-making, impact analysis, and as an early warning system for the government to ensure proper actions aligned with sustainable development plans.

From the study, the researcher discovered that the government must simultaneously manage development policies across three dimensions: Increasing sustainable productivity and income, adapting to climate change, and reducing greenhouse gas emissions. So far, the country's management has succeeded mainly in only one aspect: increasing sustainable productivity and income. This achievement is directly related to economic management but lacks effective environmental governance, which has led to climate change. Research shows that greenhouse gas emissions have been rising rapidly and continuously, and Thailand currently lacks a clear plan or effective tools to address this issue. Furthermore, to meet the carbon neutrality target by 2050, all production sectors must reduce greenhouse gas emissions by at least 20–40%, with the remaining emissions needing to be offset by carbon sequestration to achieve balance. However, if the electricity sector continues to emit CO₂ at an increasing rate, this target will be unattainable, leading to serious future damage to ecosystems. This highlights that all production sectors must take concrete actions urgently before it becomes too late to reverse the damage.

For this research, the analysis to develop new scenario policies using the SEM-SAM model revealed that these new policies serve as an important tool to support decision-making in formulating national management strategies with appropriate direction and real effectiveness. The findings show that the model can reduce the growth rate of CO₂ emissions continuously. These results align with the hypotheses and theoretical frameworks established.

As for the recommendations, the SEM-SAM model is highly valuable for implementing future sustainability policies. It serves as a crucial tool for Thailand's policy and planning processes, especially in managing the country's development toward becoming a new industrial nation. The SEM-SAM model is well-suited for forecasting CO₂ emissions from energy consumption in the industrial sector and can be adapted for other sectors due to its high validity and suitability, being recognized as the best model. Additionally, this model has not shown any issues compromising its reliability. Historically, Thailand's policies have been developed through fragmented administrative analyses without an integrated model suitable for practical application, which has led to errors and unsustainable policy and planning. Therefore, the government must emphasize adopting high-quality models as essential tools to set accurate policies and properly guide future actions.

In terms of limitations, this research identified that Thailand's sustainable development planning has been conducted without simultaneously considering causal factors across economic, social, and environmental dimensions. Additionally, some crucial indicators are missing, such as oil prices, heavy industrial production for government use, and electric vehicle adoption, which could be important indicators for government policy. Consequently, the new scenario policies may not fully cover all important indicators. Furthermore, government-disclosed data may contain certain distortions or lack sufficient timeliness, which limits its potential for comprehensive long-term analysis. In addition, research in the social sciences requires more in-depth data to ensure that the analysis is as comprehensive as possible, particularly with regard to measuring the distribution and concentration of income across Thailand.

References

- [1] P. Sutthichaimethee, W. Sa-Ngiamvibool, P. Thanarak, J. Luo, and S. Wattana, "A long-term CO₂ emission forecasting under sustainability policy using an advanced model complementing the paarimax framework," *Agriculture*, vol. 14, no. 12, p. 2342, 2024.
- [2] W. Bardi, S. Ayouni, and M. Hamdaoui, "Are structural policies in countries bordering mediterranean appropriate to economic convergence: Panel ardl application," *Cogent Economics & Finance*, vol. 7, no. 1, pp. 2–20, 2019.
- [3] P. Sutthichaimethee, P. Saraphirom, and C. Junsiri, "An advanced model for greenhouse gas emission reduction in the agricultural sector to achieve sustainability for thailand's future," *Applied Sciences*, vol. 15, no. 4, p. 2160, 2025.
- [4] P. Sutthichaimethee, W. Sa-Ngiamvibool, B. Wattana, J. Luo, and S. Wattana, "Enhancing sustainable strategic governance for energy-consumption reduction towards carbon neutrality in the energy and transportation sectors," *Sustainability*, vol. 17, no. 6, p. 2659, 2025.
- [5] Office of the National Economic and Social Development Council (NESDB), "March 2025," http://www.nesdb.go.th/nesdb_en/more_news.php?cid=154&filename=index, 2025, accessed March 2025.
- [6] National Statistic Office Ministry of Information and Communication Technology, "March 2025," <http://web.nso.go.th/index.htm>, 2025, accessed March 2025.
- [7] P. Sutthichaimethee, G. Mentel, V. Voloshyn, H. Mishchuk, and Y. Bilan, "Modeling the efficiency of resource consumption management in construction under sustainability policy: Enriching the dsem-arima model," *Sustainability*, vol. 16, no. 24, p. 10945, 2024.

- [8] P. Sutthichaimethee, P. Saraphirom, and C. Junsiri, "Long-term strategy for determining the potential of climate-smart agriculture to maximize efficiency under sustainability in thailand," *Sustainability*, vol. 17, no. 8, p. 3635, 2025.
- [9] Department of Alternative Energy Development and Efficiency, "January 2025," http://www.dede.go.th/ewtadmin/ewtdede_web/ewt_news.php?nid=47140, 2025, accessed January 2025.
- [10] P. Sutthichaimethee, "Forecasting economic, social and environmental growth in the sanitary and service sector based on thailand's sustainable development policy," *Journal of Ecological Engineering*, vol. 19, no. 1, pp. 205–210, 2018.
- [11] United Nations Framework Convention on Climate Change, UNFCCC, "Global progress in environmental law," *Environmental Policy and Law*, vol. 46, no. 1, pp. 23–27, 2016.
- [12] P. Sutthichaimethee, P. Saraphirom, and C. Junsiri, "Efficiency of national governance in managing long-term greenhouse gas emission reduction in the agricultural sector towards the thailand 5.0 goal," *Sustainability*, vol. 17, no. 9, p. 3959, 2025.
- [13] United Nations. University of Oslo, "Walter wallace wheel," http://www.uio.no/studier/emner/matnat/ifi/INF5180/v10/undervisningsmateriale/handouts/09_WWHEEL315.pdf, 2015, accessed March 2025.
- [14] Pollution Control Department Ministry of Natural Resources and Environment, "Enhancement and conservation of national environmental quality act, b.e. 2535," http://www.pcd.go.th/info_serv/reg_envi.html, 2023, accessed December 2023.
- [15] The World Bank, "Energy use (kg of oil equivalent per capita)," <https://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE>, 2025, accessed March 2025.
- [16] DEPA Thailand, "Smart city manual," <https://www.depa.or.th/en/digitalservice/smartcity/smart%20city%20manual>, 2025, accessed January 2025.
- [17] Thailand Greenhouse Gas Management Organization, "Net zero ghg emissions," <https://thaicarbonlabel.tgo.or.th/tools/files.php?mod=YjNKblIXNXBlbUYwYVc5dVgyUnZkMjVzYjJGaw&type=WDBaSIRFVlQ&files=TkRrPQ>, 2025, accessed March 2025.
- [18] National Statistical Office Ministry of Information and Communication Technology, "March 2025," <http://web.nso.go.th/index.htm>, 2025.
- [19] C. Junsiri, P. Sutthichaimethee, and N. P. a ran, "Efficiency of national governance in managing long-term greenhouse gas emission reduction in the agricultural sector towards the thailand 5.0 goal," *Forecasting*, vol. 6, no. 3, pp. 485–501, 2024.
- [20] D. Dickey and W. Fuller, "Likelihood ratio statistics for autoregressive time series with a unit root," *Econometrica*, vol. 49, pp. 1057–1072, 1981.
- [21] S. Johansen and K. Juselius, "Maximum likelihood estimation and inference on cointegration with applications to the demand for money," *Oxford Bulletin of Economics and Statistics*, vol. 52, pp. 169–210, 1990.
- [22] P. Sutthichaimethee, P. Saraphirom, and C. Junsiri, "A path analysis—generalized method of moments based on a nearest-neighbor with observed variable model for developing new scenario policies to reduce greenhouse gas emissions from agricultural waste towards sustainability," *Applied Sciences*, vol. 15, no. 4, p. 2160, 2025.
- [23] S. Johansen, *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*. New York: Oxford University Press, 1995.
- [24] W. Enders, *Applied Econometrics Time Series; Wiley Series in Probability and Statistics*. Tuscaloosa: University of Alabama, 2010.
- [25] A. Harvey, *Forecasting, Structural Time Series Models and the Kalman Filter*. Cambridge: Cambridge University Press, 1989.
- [26] C. A. Sims, "Macroeconomics and reality," *Econometrica*, vol. 48, pp. 1–48, 1980.
- [27] B. Byrne, *Structural Equation Modeling with AMOS: Basic Concepts, Applications, and Programming*. London: Routledge, 2009.
- [28] P. Sutthichaimethee and B. Dockthaisong, "A relationship of causal factors in the economic, social, and environmental aspects affecting the implementation of sustainability policy in Thailand: Enriching the path analysis based on a GMM model," *Resources*, vol. 7, no. 4, p. 87, 2018.

- [29] P. Sutthichaimethee and D. Ariyasajjakorn, "Forecasting model of GHG emission in manufacturing sectors of thailand," *Journal of Ecological Engineering*, vol. 18, no. 1, pp. 18–24, 2018.
- [30] —, "Forecast of carbon dioxide emissions from energy consumption in industry sectors in thailand," *Environmental and Climate Technologies*, vol. 22, no. 1, pp. 107–117, 2018.