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Analyzing the Impact of Causal Factors on Political Management to Determine Sustainability Policy under Environmental Law: Enriching the Covariance-based SEMxi Model

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ABSTRACT

This research aims to develop a causal relationship model on political management for sustainability policy formation under Thai environmental law by applying the best and valid model with a non-spurious property called the Covariance-based on Structural Equation Model with exogenous variables (Covariance-based SEMxi Model). This newly-developed model is in distinction with any past models as it is made effectively applicable to any sectors across areas. The model can also be utilized to design a long-term forecasting model with the ability to determine appropriate future scenarios. When assessing the covariance-based SEMxi model performance, the mean absolute percentage error (MAPE) and the root mean square error (RMSE) are estimated at 1.19% and 1.30%, respectively, in comparison of other models, including Gray-Autoregressive Integrated Moving Average Model (GM-ARIMA), Gray Model (GM), Back Propagation Neural Network (BP), Artificial Neural Natural Model (ANN), and Multiple Regression Model (MR). As for the results, this research reveals a direct impact of economic factors on environmental and social factors. In the meanwhile, social factors have a direct impact on environmental and economic factors. The research also indicates a direct effect on the environment with a maximal magnitude of 67%. Whereas a direct effect of social factors on the environment is detected at the magnitude of 55%. These effects are perceived to exceed the specified carrying capacity set by Thailand. In addition, a causal relationship is observed between economic and social factors, where the environment is found with the lowest error correction capability of only 5%. At the same time, economic and social factors are noticed with greater correction capability of 59% and 31%, respectively. This finding implies that the ecosystem will experience slow recovery whenever it deteriorates. Hence, the government must place a higher concentration on the environment, while different measures on environmental legislation should be closely controlled to contain any future damage. Besides, energy consumption must be managed not to exceed the established carrying capacity by simultaneously implementing both proactive and reactive measures. This process can be strengthened by optimizing the newly-introduced model produced by this work for a scenario design in policy management to attain sustainability.

Keywords: sustainability policy, causal factors, energy cost, environmental law, latent variables, political policy.
JEL Classifications: P28, Q42, Q43, Q47, Q48

1. INTRODUCTION

Global warming is a common issue for all countries around the world. Many countries are constantly putting effort to cope with this concern (The World Bank: Energy Use (Kg of Oil Equivalent Per Capita) Home Page, 2021). In particular, the Conference of the Parties is a leadership summit on the issue of climate change by the United Nations. The first meeting was held in 1995 in Berlin. However, the past 20 meetings fail to bring concrete outcomes except for the Kyoto Protocol. This phenomenon is perceived as a failure in terms of carbon dioxide emission reduction. In fact, many have highly expected the 21st meeting as the last defensive shield before climate change becomes more severe, which it may be difficult to restore the environment back to normal (Office of the National Economic and Social Development Council (NESDC), 2021).

It is the same case for Thailand as it is constantly facing the same issue of climate change. This issue is noticed to affect all sectors of the world; be it human lifestyle, production and consumption, resources, health, and agriculture. From the past to the present (1990–2020), Thailand has established a policy embedded into the national strategy for short-term (1–5 years), medium-term (1–10 years), and long-term (1–20 years). This referred policy is nationally perceived as a sustainability policy. Whereby this policy focuses on promoting simultaneous growth in the national economy, society, and environment (National Statistic Office Ministry of Information and Communication Technology, 2021; Savaresi, 2018; Mizan, 2015). Thailand has been committed to adhering to the Kyoto Protocol of August 2002. When the Kyoto Protocol came into effect on February 16, 2005, Thailand started participating in the project of Clean Development Mechanism (CDM). Thailand has given the interest in implementing the mechanism ever since in the promotion of human potential and development, as well as related agencies in greenhouse gas management (National Statistic Office Ministry of Information and Communication Technology, 2021; Department of Alternative Energy Development and Efficiency, 2021). This effort is considered as part of proactive actions to enhance the knowledge and skills of personnel in Thailand, strengthen understanding, and improve other skills in advancing clean development mechanism projects. Undoubtedly, this action shows an endless responsibility and role of Thailand in reducing greenhouse gas emission, as well as supporting the sustainable development plans of the country, be it economic, social, and environmental, for its future Thailand to continue (Thailand Greenhouse Gas Management Organization (public organization), 2021).

As for determining a sustainability policy under Thai environmental law, it directly connects to the Enhancement and Conservation of National Environmental Quality Act, B.E. 2535, and its Amended Version (2nd Edition), B.E. 2550, where several measures have been placed to promote economic growth (NESDC, 2021). The promotion includes encouragement of foreign direct investment to land investments in Thailand, particularly places across heavy industries, increment in exports and local investments, new markets expansion, tourism advancement to tourists from various countries across the world via all forms of tourism, various tax exemption from investment, funding for private investment, loans facilities for national investment, and many more. As a result of such promotion, it has continuously improved Thailand's economic growth (NESDC, 2021; United Nations Framework Convention on Climate Change, UNFCCC, Bonn, Germany, 2016). As can be observed, there is a growth in the Thai gross domestic product (GDP), Thai gross national product (GNP) of Thailand, and income, and the GDP has been indulged in an increased rate of 7.0% in 2020. The exports were valued at more than 263 billion dollars with an 8.5% increase compared to 2019. The local exports from local businesses rose by 18.1%, which was higher than the growth rate of the 4.0% direct investment sector (FDI). In terms of trade surplus, Thailand contains a high value of 9.5 billion dollars in surplus, and this figure is the highest value in 4 years. In fact, the high GDP growth is accompanied by macroeconomic stability, where the inflation rate has a little increase of 2.70%, while foreign exchange reserve is increased to 81 billion dollars. The public debt ratio gradually declines to 53% of the GDP. Surprisingly, a significant increase in public annual income goes up to nearly 2,800 dollars per capita. The percentage of poor households is found to fall by 1.40% as per recognition made by the United Nations Development Program (UNDP) (Thailand Greenhouse Gas Management Organization (public organization), 2021; Pollution Control Department Ministry of Natural Resources and Environment. Enhancement and Conservation of National Environmental Quality Act, B.E. 2535, 2021). In addition, Thailand has also made a commitment to enhancing social promotion by reducing poverty. The Human Development Index (HDI) indicates that Thailand has made a progress in poverty reduction with an HDI point of 0.50 in 2020 in terms of strategy, policy, and action, while labor productivity in 2020 is shown an increase by 6.0% illustrated by the statistics of 2016–2019. Besides, the Incremental Capital Output Ratio (ICOR) is also increased to 6.05 times. In terms of literacy, the population is constantly receiving more education, whereas the unemployment rate continues to decline. More people have good access to good public healthcare with future development to better direction (Pollution Control Department Ministry of Natural Resources and Environment. Navigation of Thai Waterways Act, B.E. 2546, 2021). People have comprehensive access to medical and public health, while the government is constantly monitoring the health and illness of the people. When it comes to social security, various policies have been put to safeguard society with continuous monitoring effort (Pollution Control Department Ministry of Natural Resources and Environment. Principle 4: In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it, 2021). The government also implements a consumer protection policy in which follow-ups and checks are made to ensure that consumption gaps are kept to a minimum (United Nations Framework Convention on Climate Change, UNFCCC, Bonn, Germany, "The Paris Agreement: An Early Assessment, 2014).

Considering the government's effort to accelerate economic growth, along with the development of social growth from the past (1990) to the present (2020), Thailand has been successful with effective and efficient implementing policies. As a result, the population has enjoyed an increase in incomes and per capita GDP (NESDC, 2021) and experienced in standardized quality of domestic society across all areas of the nation Department of Alternative Energy Development and Efficiency, 2021). Upon articulating on the environment, it shows that the environment is growing at a continually declining rate (National Statistic Office Ministry of Information and Communication Technology, 2021) where energy consumption and greenhouse gas emission are gradually increasing. Particularly in electronic and industrial sectors, CO_2 emission has been found with a growth rate of up to 69.52% (2020/1990) (NESDC, 2021; Pollution Control Department Ministry of Natural Resources and Environment.

Enhancement and Conservation of National Environmental Quality Act, B.E. 2535, 2021). Such a rise in great volume in these sectors will have a massive impact on current and future ecosystems.

Therefore, the implementation of the sustainable development policy under Thai environmental law has been continuously executed in order to achieve sustainability by progressing in all possible forms, especially participating in international policy cooperation since 1995 through a conference in Italy on Human and Environment, and other meetings as to martialize sustainability from policies implementation in the present and the future. In line with the above data, the implementation is insufficient until the present day (2020), because the environment gradually deteriorates day by day. One of the key reasons is, since the past till today (1990–2020), lacking essential tools for sustainability management in policy implementation. Additionally, the negligence of model validity and BLUE property is often made obvious resulting in obtaining true influence of the factors; be it direct and indirect. Therefore, this research has seen it as a gap, which is aimed to fulfill by this work in developing a management model to achieve sustainability for Thailand in the long run. This research has reviewed relevant literature from the past to the present exploring the modeling of various models from both domestic and international space. It is also expected to create knowledge in modeling and guideline in policy and planning formulation.

2. LITERATURE REVIEW

Under this section, it reviews various studies and relevant literatures on variables linkage by highlighting existing works and findings. There are a number of streamline studies investigating the causality and relationship of diverse factors relating energy, economy, and environment by using different research and statistical tools. Among many streamline studies, Alonso and Roque (2021) examined the causal relationship between production cost and oil prices based on Granger's causality and the Toda and Yamamoto approach. Their study has found unclear connection yet its implication explains that higher prices incentivize greater production. Khobai et al. (2021) examined the long run-and-causal relationship between energy consumption and economic growth within the BRICS nations from 1990 to 2018 by applying Pedroni panel co-integration approach and Pair-wise Granger-causality method. As for their findings, a long run relationship is detected between economic growth, energy consumption, employment and trade openness in those nations. In addition, a unidirectional causality has also been confirmed running from economic growth to energy consumption. In Argentina, Khobai (2021) investigated both relationship and direction of causality between the same factors by deploying the Autoregressive Distributed Lag (ARDL) bounds testing method and the Vector Error Correction Model (VECM) approach for the period of 1990 to 2018. Upon analysis, both testing approaches depict unidirectional causality running from economic growth to renewable energy consumption. In contrast, Muse (2021) explored both economic growth and carbon emission in determining renewable energy demand in Nigeria by using the same ARDL approach. As far as the demand of renewable energy is concerned, his study confirms that climate change leads to the increasing needs in renewable energy while economic growth can be viable to understand such a demand. Iwaszczuk et al. (2021) analyzed the causal relationship between foreign direct investment (FDI) and gross domestic product (GDP) from 1995 to 2018 by applying the Toda–Yamamoto approach for Vector Autoregression (VAR) model. Their study shows that there is a statistically significant one-way causal relationship ranging from GDP to FDI implying that economic growth may urge the FDI inflow although it has not been found a clear connection with GDP. Whereas Grabara et al. (2021) extended further by adding renewable energy consumption into their investigation in addition to the above two factors within the context of Kazakhstan and Uzbekistan and economic growth and from 1992 to 2018. Their analysis has confirmed a two-way connection between variables with the presence of co-integration between the series.

Considering some countries in ASEAN region, Chontanawat (2020) analyzed the causal relationship between energy consumption with economic growth and CO_2 emissions during 1971 to 2017 by utilizing Johansen cointegration with Granger causality. As for the outcome, a long-run link is presented between energy consumption, economy and pollution. In addition to this finding, a unidirectional causality is found ranging from economic growth to energy consumption in three countries, namely Indonesia, Malaysia, and Thailand. Within this specific ASEAN-5 countries, Batool et al. (2021) also examined the causal relationship between the above factors and additional factor of urbanization by extending the same casualty model with data set ranging from 1980 to 2018. Upon extensive analysis, only energy consumption and urbanization are shown to deteriorate the quality of environment indicated by the increment of CO_2 emission in the concerned regions. Sadath and Acharya (2021) explored the linkage between energy services and human development in India by approximating different indices, including human development, multidimensional energy poverty, and confidence. Upon analysis, their study depicts a clear negative correlation between the variables. At the same time, energy poverty is discovered to have a great impact on Gross State Domestic Product (GSDP) per capita. In addition, the confidence index indicates a positive connection with human development index, whereas negative connection with energy poverty. While Hadi et al. (2021) explored the impact of electricity distribution and energy consumption on industrial development taking place across regions in Indonesia for the period 2012 to 2019 by deploying static panel regression (fixed effect) and dynamic Generalized Method of Moments (GMM) approach. As part of their discovery, both significant positive and negative impacts are detected over industrial development. The positive effect is caused by distribution of electricity and investment, whereas the negative effect is caused by inflation, electricity distribution, and energy consumption. As for Ampofo et al. (2021), they analyzed the cointegration and causal relationships between economic growth, carbon emissions, and energy consumption of the eleven (11) countries over the year 1972 to 2013 by optimizing on the nonlinear autoregressive distributed lag (NARDL) bounds testing method and nonpragmatic Granger causality tests. Their study indicates variety of results across the countries, including nonlinear cointegration and long-run asymmetric effect, among the variables.

Upon exploring different regions across the world, Ali et al. (2021) analyzed the key factors of household electricity consumption by considering the patterns and flows of consumption of households in Malaysia. Their findings indicate that the average urban household electricity consumption is about 648.31 kWh/month. This consumption is expected to grow due to the rise of household monthly income and quality of life. In Sri Lanka, Murshed et al. (2020) investigated the impacts of energy consumption, energy prices and imported energy-dependency on both gross and sectoral value addition. Overall, their study depicts the changes in gross, agricultural, industrial and services value additions due to the contribution of energy consumption. In South Korea, Kim (2020) considered the relationship between electricity consumption and other factors; income, number of household members, and age, using correlation and multiple regression. A significant correlation is demonstrated in the study while confirming that only income and the number of household members affecting on electricity consumption. In China, Qiang et al. (2019) studied the urban passenger transportation (UPT) development using data set from 2000 to 2014. Their study has found the key development growth in private vehicles while the total and per-capita UPT CO_2 emissions are increasing. Thus, the portion of such development emission to the total UPT CO_2 emission is indicated to increase as well. While Yi and Le-Le (2014) investigated the impact of energy consumptions, coal consumptions, and relating emissions on GDP by structuring a Chinese inter-regional general equilibrium model. Upon imposing policies on structure adjustment, their study has found a decrease in both coal proportion and CO_2 emissions by 5% and 11.3% from the baseline scenario, respectively, in 2030. Whereas Xiao-Yu and A-Lun (2020) put forth a study on the impact of household consumption on energy use and CO_2 emissions with the use of the input-output model. Their study detects an increase in total household energy consumption and total CO_2 emissions accounting nearly 30% and 66.3% of total energy consumption and total household emissions, respectively, in 2012. Interestingly, Zhen (2016) examined the role of nuclear power in China on emission reduction. By accounting other renewable energy sources, the nuclear power is confirmed with very low greenhouse gas emission enabling China to shift its concern to low-carbon economy of China.

Moreover, there are studies and research highlighting legal frameworks on energy and environment. Krzykowski et al. (2021) claimed that the effective investment process requires a stable and predictable legal environment upon investigating the concept of reasonable and legitimate expectations in the international law framework. While Schmeier and Gupta (2020) looked another principle of no significant harm in international water law. In addition, Rimmer (2019) explored in different lens of legal frameworks by focusing on climate law, Paris Agreement 2015, and justice needs in order to discuss different topics across climate change issue. With the given global treaty, an intellectual property mechanism is presented with necessity in research, development, and clean technologies deployment in order to combat with climate change. Whereas Sevaresi (2018) reviewed the role of the same treaty on traditional knowledge within environmental and human rights law under the context of the climate change. In terms of China's context, Switzer et al. (2015) examined the impact of the law and policy of China's export restrictions of minerals on the global renewables energy industry though the World Trade Organization (WTO) rule of law. As for the result, such legality on export restrictions imposed by China is confirmed with a threat to the legitimacy of the WTO. However, Khan (2015) complemented the evolution of polluter-pays-principle (PPP) with the Caney's proposal driving polluters to play the social and environmental costs upon any pollutions made so that fundamental principles of justice and responsibility can be observed.

As far as relationship and legality are concerned, this research is developed with best quality and beneficial result for future use by any interested parties. The above studies have confirmed the connections and relevancy between studied variables, as so the findings can be validated and processed for future application in different contexts across various regions. Through a revision of relevant research, it reveals that past researches both in Thailand and abroad consider different management modeling with different analytical areas. Thus, different methods for conducting research are made somehow insignificant. Some models are perceived to neglect the spuriousness and validity of their models. Whereas some remain focused on analyzing causal factors using path analysis while neglecting the direct-and-indirect effect. This negligence has formed research gaps. This is when this research is motivated to develop and improve in order to close these gaps. Moreover, this research is made applicable for optimization in different policy contexts appropriating particular countries upon application. This research focuses on structuring the covariance-based SEMxi model by utilizing various information sources from different agencies across Thailand. To identify the entire research indicators, data and information resources are retrieved from the Office of the National Economic and Social Development Board (NESDB), the National Statistic Office Ministry of Information and Communication Technology, the Office of Natural Resources and Environmental Policy and Planning, and the Department of Alternative Energy Development and Efficiency. The indicators are expressed in terms of urbanization rate, industrial structure, net exports, in-direct foreign investment, and foreign tourists, as economic indicators. While the components of employment, health and illness, and technology rate, are perceived as social indicators. In the meanwhile, energy consumption, energy intensity, carbon dioxide emission rate, and green technology rate, are presented as environmental indicators. This research takes secondary data into account for the duration period of the year 1990–2020. The research steps are discussed below.

1) Specifying the covariance-based SEMxi model by identifying latent variables and observed variables;
2) Evaluating a stationary property of the observed variables using the concept of Augment Dickey and Fuller (1981);
3) Analyzing the co-integration at the same level, which is level I(0) or level I(1) only, utilizing the theory of Johansen and Juselius (1990);
4) Constructing the covariance-based SEMxi model reflecting a causal factor relationship in both long-and-short term;
5) Checking validity and BLUE property of the covariance-based SEMxi model, and;
6) Assessing performance using MAPE and RMSE to verify the covariance-based SEMxi model with other models, namely

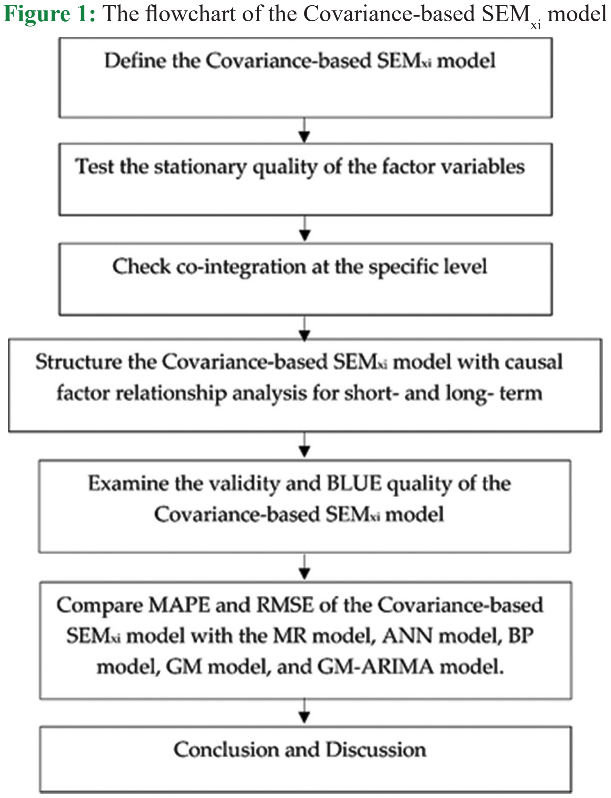
MR model, ANN model, BP model, GM model, and GM-ARIMA model, as shown in Figure 1.

3. THE MATERIAL AND METHOD

The covariance-based SEM_{xi} model consists of two sub-models: Structural model and Measurement model. The discussion of each model is made as follows (MacKinnon, 1991; Johansen, 1995; Enders, 2010).

1. Structural Model is a model presenting a causal relationship and stochastic relationship. The variables presented in the model are retrieved from subject analysis that a study is done. In other words, they are hypothetical variables corresponding to theories used as a study framework. However, these are variables that cannot be measured or observed, and they are referred as latent variables by analytical language of the structural model. The latent variables are divided into two groups: endogenous variables and exogenous variables (Harvey, 1989). This concerned model is perceived as simultaneous-equation models in econometrics analysis, but the difference remains where endogenous variables and exogenous variables of simultaneous-equation models are either measurable or directly observable. Therefore, the correlation estimation of endogenous variables and exogenous variables of structural model and simultaneous-equation models is similar. This valuation can be performed through various methods, including Instrument Variable, Two-Stage Least Squares, Generalized Least Squares, Maximum Likelihood, and many more (Sims, 1980).
2. Measurement Model is a model built to facilitate the structural model, because the variables defined in the structural model are non-observable or non-measurable, or also known as latent variables. It is then impossible to estimate the correlation of the model. Hence, it is necessary to measure or indirectly determine the latent variables by observing or measuring from other variables reflected as latent variables in the structural model. These specific variables are often referred by the language of structural equation model as manifest variables, reflective variables, observed variables, or even indicative variables. To this specific study, it reserves the term as observed variables in discussion. These variables are indicators of the latent variables that the study aims for. In optimizing observed variables to structure as latent variables, it is possibly done by applying a confirmatory factor analysis method (Byrne, 2009).

Figure 1: The flowchart of the Covariance-based SEM_{xi} model



The Factor Analysis (FA) is divided into two categories: Explanatory FA and Confirmatory FA. The main difference between the two types holds between element variables of the FAs. The confirmatory FA is the FA in which its element variable has been pre-defined for the FA (measurement variables), whereas the explanatory FA generates FA variables from measurement variable groups without variable specification (Sutthichaimethee and Ariyasajjakorn, 2020).

The composition and relationship of the two models are shown in Figure 2. As per illustration of the above figure, the structural model is built with two latent variables; 1 exogenous variable (LT1) and 1 endogenous variable (LT2), together with an error term or disturbance term. This term reflects other possible factors impacting the endogenous variable. Thus, the relationship between the two latent variables become either random or uncertain. As for the observed variables in the measurement model, there are four variables altogether; the first two variables are OV 1 and OV 2 reflecting exogenous variables (LT1), and another two observed variables are OV3 and OV4 reflecting endogenous variables (LT2). Each observed variable contains an error term explaining the measurement error (Sutthichaimethee et al., 2019).

3.1. Analysis Procedure of Structural Equation Model

The analysis process under the structural equation model is similar to that of general econometric analysis carrying out 5 main steps: Model Specification, Data Collection, Model Estimation, Model Assessment, and Model Modification. Details of each step are briefly described as follows.

3.2. Model Specification

Since the structural equation model consists of two sub-models; structural model and measurement model. Therefore, the two models should be structurally specified. The structural equation model indicates the relationship between endogenous variables and exogenous variables. As for the measurement model, it connects latent variables with observed variables as reflective variables. When the two models are completely constructed, they may be presented in the form of equation or path diagram for better comprehension and validation. Under this step, Model Identification is extended as another significant consideration lying out important properties as follows (Sutthichaimethee, 2018).

The Model Identification is the procedure or process evaluating the properties of the model whether it is able to estimate specified parameters or otherwise. This identification implies that the developed model is capable to calculate the parameters with unique and non-redundant elements. This description can be better written in an equation as below (Sutthichaimethee, 2016; Sutthichaimethee, 2018).

$$t \leq \frac{s}{2} \quad (1)$$

Where t = number of parameters for estimation; S = number of variance and covariance of the observed variables for estimation, and this is equivalent to (p + q) (p + q + 1); p = number of observed variables representing endogenous variables; q = number of observed variables representing exogenous variables (Sutthichaimethee, 2017).

In case of $t \leq \frac{s}{2}$, the specified model is unidentified or under identified, and it is not capable to estimate clear parameters. Thus, the model modification is required to correct the model enabling it to estimate an exact value of each parameter by accounting on certain conditions into the mode.

In the event of $t \leq \frac{s}{2}$, the specified model is exactly identified or just-identified allowing the model to estimate exact parameters. Under this circumstance, the degree of freedom is equivalent to zero (0).

In case of $t \leq \frac{s}{2}$, the specified model is over identified, and it is the condition which each estimated parameter can be drawn from multiple values. The degree of freedom is a positive value, and it equals to (s/2)-t.

In summary, the structural equation model must be built from different qualities and properties, such as exact identification or over identification, enabling the parameters of the structural equation model for valuation. If the model is unidentified, exact parameters are impossibly estimated from collected data, unless the model is modified. Hence, when the structural equation model is identified, testing variables must be performed accordingly before proceeding to the model estimation (Sutthichaimethee and Ariyasajjakorn, 2017).

3.3. Data Collection

The key objective of the structural equation model is to study the causal relationship of a group of factors. However, the factors or variables cannot be directly measured or observed, or also known as latent variables. These specific variables are qualitative in nature. Thus, they are initially required for conversion into quantitative quality. This process can be done in numerous ways. Under the SEM model, it is done by deriving from observed variables reflecting latent variables, and estimating them by utilizing the factor analysis method. Data collection of observed variables is mainly obtained from a survey or interview. Thus, acquired information under this model consideration is acted as cross-section data and primary data (Sutthichaimethee and Ariyasajjakorn, 2018).

3.4. Estimation

There are two approaches for SEM estimation: Covariance-based SEM and Variance-based SEM. However, this paper explains only the method of Covariance-based SEM as for its scope focus. The Covariance-based SEM is designed to compute a parameter with covariance matrix quality of the manifest variables or known as estimated covariance matrix developed from the implied covariance matrix as close as covariance matrix from actual or observed covariance matrix. This function of difference evaluation is called the fitting function. The above concept can be written in an equation form as follows (Sutthichaimethee and Ariyasajjakorn, 2017; Sutthichaimethee and Dockthaisong, 2018).

$$\sum = \sum(\theta) \quad (2)$$

Where $\sum$ is the population variance matrix of the endogenous observed variable (y), and exogenous latent variable (x). As for $\sum(\theta)$, it is the population variance matrix of the observed variables, written as a function to the parameter as (θ). This function means that each value of the covariance matrix depends on one or more parameters, because population parameter (θ) is not known. The estimated variance matrix is also called as the implied covariance matrix, or written in a symbol as (Sutthichaimethee and Kubaha, 2018):

$$\widehat{\sum} = \sum(\widehat{\theta}) \quad (3)$$

The principle of the structural equation model estimation lies within a parameter estimator pushing $\widehat{\sum}$ close to the variance of the observed sample (s). In other words, it is to estimate $(\widehat{\theta})$ that makes

$$(S - \widehat{\sum}) \text{ with the lowest value} \quad (4)$$

In calculating a parameter of the covariance-based SEM, it can be done via different approaches, including Maximum Likelihood, Unweighted Least Squares (ULS), Generalized Least Squares (GSL), Generally Weighted Least Squares (GWLS) and Diagonally Weighted Least Squares (DWLS).

3.5. Model Assessment

In the assessment of developed structural equation model in terms of its model fit, these three key considerations play a role in the model evaluation matter, namely overall goodness of fit assessment, measurement model assessment, and structural model assessment. In this research, it only discusses about the overall goodness of fit evaluation. The further discussion is written below. The assessment of overall goodness of fit establishes several statistical values for the overall evaluation. Each value has its own advantages and disadvantages depending research facts and frameworks. A summary of the statistics optimized to assess the overall goodness of the model is reported as follows (Sutthichaimethee and Kubaha, 2018; Sutthichaimethee et al., 2015).

1. Chi-square statistics: Under the estimation of the structural equation model, this specific method is called minimum fit function chi-square. This statistical value is applied to assess the goodness of the covariance analaysis model, where a null hypothesis is determined.

Chi-square Evaluation Formula χ^2.

$$\chi^2 = (N-1)F_{\min} \quad (5)$$

Where N = sample size; Fmin = the value of fitted function

As of the variance of a sample with a variance matrix from an estimated parameter, the degree of freedom for the chi-square is equal to

$$\frac{1}{2k(k+1)} - t \quad (6)$$

Where k = number of observed variables; t = number of parameters for estimation

The higher the calculated chi-square value is, the lower chance of accepting the hypothesis would be. This description implies that estimated model cannot be used to explain facts.

2. Root Mean Square Error of Approximation: It is a statistical value that is similar to Non-Centrality Parameter (NCP). This value can be obtained by using the following formula.

$$\frac{F_0{}^{1/2}}{DF} \quad (7)$$

Where F_0 is the difference between functions; DF denotes as the degree of freedom. If the RMSEA value is equal to zero, it indicates that the estimated model is at exact fit.

3. Goodness-of-Fit Index (GFI): It is the ratio of the difference in goodness function pre-and-post model modification of GFI model. The value lies between 0 and 1. If GFI value approaches 1, it shows that the model is fit with data. If GFI value is >0.90, the model is fit with the empirical data.
4. Adapted Goodness-of-Fit Index (AGFI): It is the use of GFI modifying and considering variables size and sample groups. The meaning of this value is similar to the GFI value. If the AGFI is close to 1, it explains that the model is in perfect fit with the empirical data.
5. Root Mean Square Residual (RMR): It is a measure of the residual mean by comparing the magnitude of covariance between population variable and estimated RMR. The RMR works well when all observed variables are standardized variables. If the RMR approaches 0, the model is as fit as the empirical data.
6. Critical N (CN): In order to ensure the goodness of fit of the model with the empirical data, where sample size sustains the chi-square significant, the CN should be >200.
7. Largest Standardized Residual: It is the highest value of residual between the analyzed correlation matrix and the assessable matrix. If the residual approaches 0, the model is likely to fir with the empirical data, where the appropriate residual lies between +2 and -2.

3.6. Model Modification

The results of the model assessment hold on two possibilities: passing or failing. Based on both cases, the model can be enhanced. However, this model modification generally applies to those failed models, which do not meet evaluation criteria. There is a number of reasons why the variables cannot explain the facts. Those reasons may be due to incomplete and improper analysis process at any research stages. Hence, the failure may be contributed by various conditions, for instance (Sutthichaimethee et al., 2015);

- Modeling Procedure Error
- Improper Data Collection
- Inadequate Choices of Estimation Methods.

Thus, this model modification depends on certain causes, and that requires the researchers' observations and revision. However, diagnosing the need of model modification for structural equation model can partially consider the statistic outcomes retrieved from the model evaluation.

4. EMPIRICAL ANALYSIS

4.1. Screening of Influencing Factors for Model Input

In this paper, the covariance-based SEM_{xi} model is constructed with three latent variables, namely Economic (*Econi*) factor, Social (*Socia*) factor, and Environmental (*Envir*) factor. The observed variables consist of 15 factors variables, including per capita GDP (*GDP*) urbanization rate (*Urr*), industrial structure (*Ind*), total exports (*E−M*), indirect foreign investment (*Ife*), foreign tourist rate (*Ftr*), expenditure government rate (*Ger*), employment (*Esr*), health and illness (*Hri*), social security (*Scs*), consumer protection (*Scr*), total energy consumption (*Eer*), energy intensity (*Eir*),Green technology (*Egt*), and Carbon Dioxide emission (ECO_2).

The covariance-based SEM_{xi} model selects 15 factors variables in total for Unit root test at the level I(0) and the first level I(1) in accordance of Augment Dickey-Fuller theory (ADF-test) per illustrated in Table 1.

According to Table 1, all factors are seen as non-stationary at Level I (0) except only Green technology (*Egt*) with the stationary property at Level I (0). For this particular research, it selects and uses only stationary variables at the same level. Therefore, the stationary property at the first level I (1) is calculated. This research confirms that all factors are stationary at Level I (1) because every Tau-test is valued greater than the MacKinnon Critical Value. This finding explains that all factors are at a significant level of $\alpha = 0.01$, $\alpha = 0.05$, and $\alpha = 0.1$. All such factors at the first difference, Level I (1), are taken for co-integration analysis using Johansen and Juselius theory as shown in Table 2.

In this part of the analysis, only stationary factors are selected at the same level, Level I (1). Especially, the analysis of co-integration, it adapts the theory of Johansen and Juselius to facilitate the analysis, and the analysis results are shown in Table 2.

4.2. Analysis of Co-Integration

Table 2 demonstrates that all factor variables are co-integrated. The trace test values are estimated at 205.05 and 90.00, which are higher than the MacKinnon critical values at a significance level of 1% and 5%. By considering the maximum eigenvalue test results, they are calculated at 218.09 and 86.25, going greater than the MacKinnon critical values with a significance level of 1% and

Table 1: Unit root test at level I(0) and first difference I (1)

Tau Test				MacKinnon Critical Value		
Variables	Level I(0) Value	Variables	First Difference I(1) Value	1%	5%	10%
ln (*GDP*)	−4.21	ln (*GDP*)	−5.10***	−4.55	−3.05	−2.25
ln (*Urr*)	−3.78	ln (*Urr*)	−5.05***	−4.55	−3.05	−2.25
ln (*Ind*)	−4.50	ln (*Ind*)	−4.70***	−4.55	−3.05	−2.25
ln (*E−M*)	−3.95	ln (*E−M*)	−5.05***	−4.55	−3.05	−2.25
ln (*Ife*)	−4.10	ln (*Ife*)	−4.70***	−4.55	−3.05	−2.25
ln (*Ftr*)	−3.40	ln (*Ftr*)	−4.55***	−4.55	−3.05	−2.25
ln (*Ger*)	−3.25	ln (*Ger*)	−4.90***	−4.55	−3.05	−2.25
ln (*Esr*)	−3.60	ln (*Esr*)	−5.15***	−4.55	−3.05	−2.25
ln (*Hri*)	−4.15	ln (*Hri*)	−4.60***	−4.55	−3.05	−2.25
ln (*Scs*)	−3.15	ln (*Scs*)	−4.70***	−4.55	−3.05	−2.25
ln (*Scr*)	−3.05	ln (*Scr*)	−5.65***	−4.55	−3.05	−2.25
ln (*Eer*)	−3.20	ln (*Eer*)	−5.00***	−4.55	−3.05	−2.25
ln (*Eir*)	−3.75	ln (*Eir*)	-5.25***	−4.55	−3.05	−2.25
ln (*Egt*)	−5.20	ln (*Egt*)	-6.55***	−4.55	−3.05	−2.25
ln (ECO_2)	−3.95	ln (ECO_2)	-4.70***	−4.55	−3.05	−2.25

Note: *GDP* is the per capita GDP, *Urr* is the urbanization rate, *Ind* is the industrial structure, *E−M* is the total exports, *Ife* is the indirect foreign investment, *Ftr* is the foreign tourist rate, *Ger* is the expenditure government rate, *Esr* is the employment, *Hri* is the health and illness, *Scs* is the social security, *Scr* is the consumer protection, *Eer* is the total energy consumption, *Eir* is the energy intensity, *Egt* is the Green technology, and ECO_2 is the Carbon Dioxide emission. *** denotes a significance, α = 0.01, compared to the Tau test with the MacKinnon Critical Value, Δ is the first difference, and ln is the natural logarithm.

Table 2: Co-integration test by Johansen and Juselius

Variables	Hypothesized No of CE(S)	Trace statistic test	Max-Eigen statistic test	MacKinnon critical value	
				1%	5%
ln (*GDP*), ln (*Urr*), ln (*Ind*), ln (*E−M*), ln (*Ife*), ln (*Ftr*), ln (*Ger*), ln (*Esr*), ln (*Hri*), ln (*Scs*), ln (*Scr*), ln (*Eer*), ln (*Eir*), ln (*Egt*), ln (ECO_2)	None***	205.05***	218.09***	12.25	10.55
	At Most 1***	90.00***	86.25***	10.55	7.05

*** denotes significance α=0.01

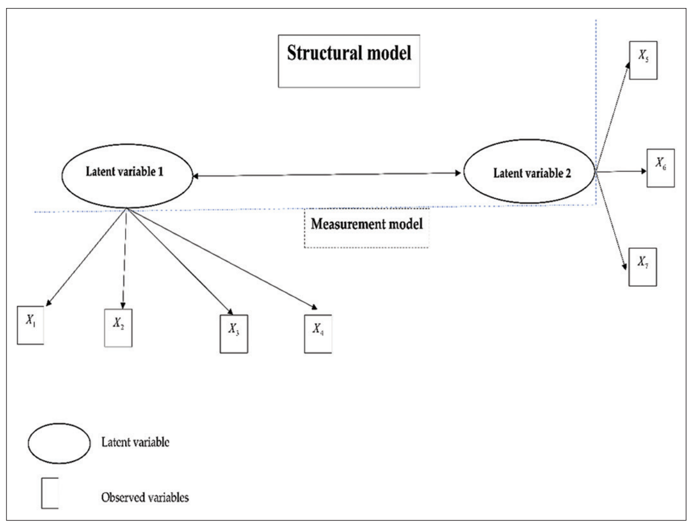
5%. This finding allows this research to construct the covariance-based SEMxi model, and further proceed with error correction.

4.3. Formation of Analysis Modeling with the Covariance-based SEMxi Model

To develop a model, this research utilizes latent variables in three different areas: economic dimension, social dimension, and environmental dimension, expressing a causal relationship to create the covariance-based SEMxi model. This model contains all 15 factors variables, which are characterized as co-integration at the same level, first difference level I (1). This outcome allows the research to estimate the error correction mechanism detailed in Figure 3.

From Figure 3, it shows that latent variables are related to causally-direct- and-indirect effect. In the meanwhile, the covariance-based

Figure 2: Structure of the Structural Equation Model (Sutthichaimethee and Ariyasajjakorn, 2020)



SEMxi model has passed the model validity testing estimated at the following outcomes; χ^2/df is 1.50, RMSEA is 0.01, RMR is 0.001, GFI is 0.95, AGFI is 0.96, R-squared is 0.93, F-statistic is 125.50 (probability is 0.00), the ARCH test is 23.25 (probability is 0.1), and LM test is 1.21 (probability is 0.10). The covariance-based SEMxi model is completely BLUE. This covariance-based SEMxi model can express the relationship of causal factors, direct effect, causal effect, and indirect effect with different magnitudes of impact per illustration in Table 3.

Table 3 explains the outputs of the covariance-based SEMxi model after assessing its goodness of fit. Through analysis, the covariance-based SEMxi model has been found to pass all the criteria of goodness of fit, where RMSEA and RMR approach 0, and GFI and AGFI are closer to 1. In addition, no heteroskedasticity, multicollinearity, and autocorrelation have been detected. This can be affirmed by the R-square of 93%, and the greater F-test

Figure 3: The relationship analysis result of the covariance-based SEM_{xi} model

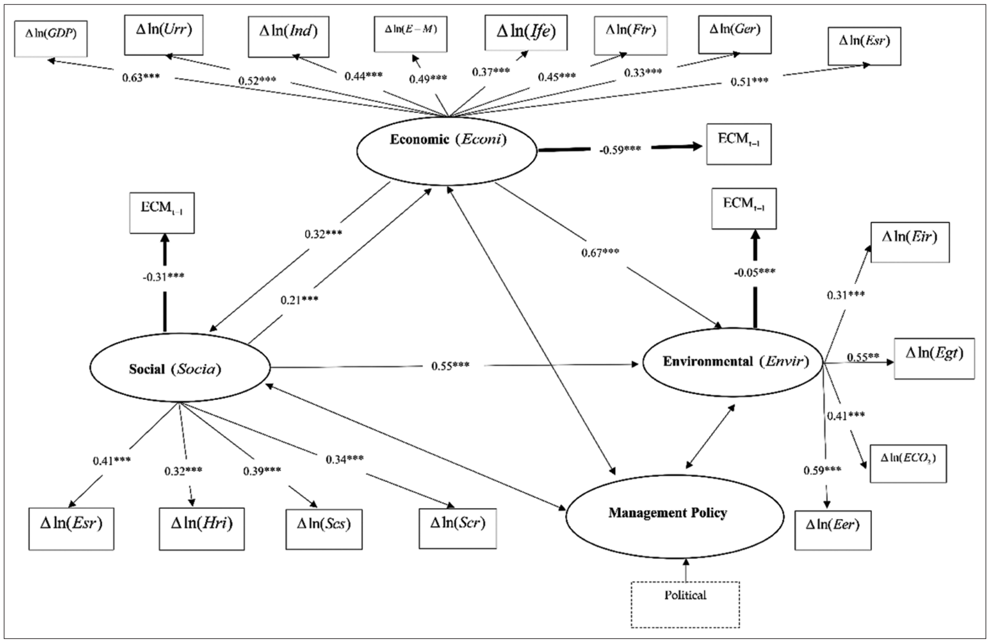


Table 3: Results of relationship size analysis of the Covariance-based SEM_{xi} model

Dependent Variables	Type of effect	Independent Variables			
		Economic (*Econi*)	Social (*Socia*)	Environmental (*Envir*)	Error Correction Mechanism (ECM_{t-1})
Economic (*Econi*)	DE	-	0.21***	-	−0.59***
	IE	-	-	-	-
Social (*Socia*)	DE	0.32***	-	-	−0.31***
	IE	-	-	-	-
Environmental (*Envir*)	DE	0.67***	0.55***	-	−0.05**
	IE	0.12***	0.09***	-	-

In the above, *** denotes significance α=0.01, ** denotes significance α=0.05, DE is direct effect and IE is indirect effect

compared to the F-critical at a significant level of 1%. Therefore, the covariance-based SEMxi model can be used to analyze the magnitude of the impact of the causal factor relationship in both direct effect and indirect effect. As for the findings, the Economic (*Econi*) factor has a direct effect on the Social (*Socia*) factor by 32% at a significance level of 1%. This result implies that when the Economic (*Econi*) factor is changed by 1%, it causes the change in the Social (*Socia*) factor by 32%. Besides, the change in the Social (*Socia*) factor has a direct effect on Economic (*Econi*) by 21% at a significance level of 1%, indicating that when the Social (*Socia*) factor is changed by 1%, it causes the change in the Economic (*Econi*) factor by 21%. In terms of their relationship, this research confirms a causal relationship between the Economic (*Econi*) factor and the Social (*Socia*) factor showing that each factor is influential over one another. Moreover, this research has also found that the Economic (*Econi*) factor has a direct effect on the Environmental (*Envir*) factor by 67% at a significance level of 1% showing that when the Economic (*Econi*) factor is changed by 1%, it causes a change in the Environmental (*Envir*) factor by 67%. While the Social (*Socia*) factor is also found with indirect effect on the Environmental (*Envir*) factor by 55% at a significance level of 1% depicting when the Social (*Socia*) factor is changed by 1%, it causes a change in the Environmental (*Envir*) factor by 55%. The result of such direct effect has a great influence over the changes.

In case of indirect effect, this research shows that the Economic (*Econi*) factor has an indirect effect on the Environmental (*Envir*) factor by 12% at a significance level of 1% though the Social (*Socia*) factor. The Social (*Socia*) factor has been found with indirect effect on the Environmental (*Envir*) factor by 9% at a significance level of 1% through the Economic (*Econi*) factor. By considering further about error correction mechanism, this research illustrates that the ECM_{t-1} has a direct effect on the Economic (*Econi*) factor, where its parameter is equivalent to -0.59 at a significance level of 1%. This finding informs that the error correction of the Economic (*Econi*) factor in the covariance-based SEM_{xi} model comes with the equilibrium-adjustment ability at the rate of 59%. The ECM_{t-1} also has a direct effect on the Social (*Socia*) factor, where its parameter is equivalent to -0.31 at a significance level of 1% showing the error correction of the Social (*Socia*) factor with the equilibrium-adjustment ability of 31%. At the same time, the ECM_{t-1} has another direct effect on the Environmental (*Envir*) factor, where its parameter is equivalent to -0.05 at a significance level of 5%. This output has explained that the error correction of the Environmental (*Envir*) factor comes with the equilibrium-adjustment ability at the rate of 5%. This specific result further portrays that the Environmental (*Envir*) factor comes with the lowest equilibrium-adjustment ability compared to other factors

Table 4: The performance monitoring of the forecasting model

Forecasting Model	MAPE (%)	RMSE (%)
MR model	16.52	20.14
ANN model	15.11	16.69
BP model	10.09	12.38
GM model	5.45	7.11
GM-ARIMA model	4.10	3.05
Covariance-based SEM_{xi} model	1.19	1.30

For this research, the performance of the covariance-based SEMxi model is examined with MAPE and RMSE values in comparison with other models; MR model, ANN model, BP model, GM model, and GM-ARIMA model. The details are described as follows.

Table 4 compares the performance between the covariance-based SEM_{xi} model and other existing models. The covariance-based SEM_{xi} model is estimated with the lowest MAPE and RMSE compared to other models. The covariance-based SEM_{xi} model comes with MAPE and RMSE of 1.19% and 1.30%, respectively. Whereas other models, such as GM-ARIMA model is estimated with MAPE and RMSE of 4.10% and 3.05%, respectively. In addition, the GM model is provided with MAPE and RMSE of 5.45% and 7.11%, respectively. In the meanwhile, the BP model is generated with MAPE and RMSE of 10.09% and 12.38%, respectively. The ANN model comes with MAPE and RMSE of 15.11% and 16.69%, respectively. Lastly, the MR model is provided with MAPE and RMSE of 16.52% and 20.14%, respectively. However, the finding from this performance of the covariance-based SEM_{xi} model allows drawing a conclusion of which the developed model is appropriate for future use in policy and planning determination.

5. CONCLUSIONS AND DISCUSSION

This research is mainly developed a model standing district from the previous works. The covariance-based SEMxi model is a model presenting the relationship of latent variables in three key elements: economic factor, social factor, and environmental factor, with observed variables used as factors variables in each dimension. Economic factor (*Econi*) comprises of per capita GDP (*GDP*), urbanization rate *Urr*, industrial structure (*Ind*), total exports (*E−M*), indirect foreign investment (*Ife*), foreign tourist rate (*Ftr*) and expenditure government rate (*Ger*), while Social (*Socia*) factor contains employment (*Esr*), health and illness (*Hri*), social security (*Scs*), and consumer protection (*Scr*). Whereas Environmental factor (*Envir*) consists of total energy consumption (*Eer*), energy intensity (*Eir*), Green technology (*Egt*), and Carbon Dioxide emission (ECO_2). As for the findings, this research depicts that the covariance-based SEMxi model is the best model with reasonable validity and goodness of fit. The model is confirmed with a non-spurious standard eliminating heteroskedasticity, multicollinearity, and autocorrelation. When testing the model performance in comparison to past models, the covariance-based SEMxi model is found with the higher performance than any other models, namely GM-ARIMA model, GM model, BP model, ANN model, and MR model, respectively, allowing this research aware of the true size of direct effect and indirect effect.

Therefore, the model is found appropriate for the determination of national policy in order to achieve sustainability under the environmental law of Thailand. However, when applying the covariance-based SEMxi model to analyze both a direct effect and indirect effect. It is presented that economic factor has a strong direct effect on the environment, while the impact size is greater than the environmental carrying capacity set by Thailand. Another finding shows that social factor has the same change over the environment with the value of the direct effect is slightly-doubled. This case indicates that the economic and social growth is expected to increase while imposing a tremendous impact on environmental change. Besides, it is demonstrated that the environment has the lowest error correction ability compared to economic factor and social factor, respectively. This result further implies that Thailand should set a new national policy for sustainable development under environmental law. This is due to existing policies that would place the environment in danger, and it would be threatening to revive it in the future. In addition, the environment has shown a very slow equilibrium adjustment ability signaling destructive and irreversible impact on the environment if it is not provided with top priority action. This signal has also indicated its impact beyond the carrying capacity when the ecosystem is disrupted.

From relevant research reviews, it allows this research to distinguish from past research by proposing the covariance-based SEMxi model with an integration of various concepts and theories while aiming to strengthen any shortcomings of past models, so that the covariance-based SEMxi model is maximized by reducing errors and inaccuracies. This research has deployed the LISREL software in order to generate the covariance-based SEMxi model with suitable capability for future use across the regions. It is expected to continually benefit short-term, medium-term, and long-term predictions with the property of BLUE and model validity. This strength has made it one of the non-spurious models in the future development of the country.

As part of suggestions in this research application, the factor variables should be selected in the correct and most appropriate manner and ensured that these variables entirely cover any latent variables. This assurance is made to confirm the accuracy of parameter estimation. In addition, advanced statistics should be optimized for maximum effectiveness in outputs. This research applies an iterative procedure estimation enabling to narrow down past research gaps, partially about the deployment of the Ordinary Least Square method, where errors are usually detected, as well as ineffective use of the BLUE test. Nonetheless, this research is ensured to effectively apply the Error Correction Mechanism Test for equilibrium adjustment of each factor to better support research planning in the future.

The limitation of this research is realized within the sustainability policy under Thailand's environmental law. In this policy framework, Thailand does not make use of scenarios in planning. Whereas the covariance-based SEM_{xi} model should be configured with scenarios. In fact, scenarios should be structured for forecasting purposes. In addition, some important variables do not go as the free market, because the government still intervenes in control of market prices. As a result, these variables are excluded from the model. For instance, the price of diesel fuel is not considered in the modeling, while it is observed as an important indicator to create appropriate policy-making in the future.

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