THE EFFICIENCY OF SUSTAINABLE DEVELOPMENT POLICY FOR ENERGY CONSUMPTION UNDER ENVIRONMENTAL LAW IN THAILAND: ADAPTING THE SEM-VARIMAX MODEL

BY

MR. PRUETHSAN SUTTHICHAIMETHEE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
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Thesis Title	:	The Efficiency of Sustainable Development Policy for Energy Consumption under Environmental Law in Thailand: Adapting the SEM-VARIMAX Model
Author Name	:	Mr. Pruethsan Sutthichaimethee
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ABSTRACT

This research is incorporated as a mixed methods research aimed; 1) To establish a causal factor model for sustainable development policy in energy consumption under environmental law in Thailand. 2) To analyze the direction impact of the model and evaluate the future trends of policy efficiency in sustainable development for the next seventeen years (2020-2036) and 3) To examine future environmental management using quantitative and qualitative methods laid upon the environmental laws for sustainability. To this extent, quantitative research is carried out by applying a structural equation modeling/vector autoregressive model with exogenous variables (SEM-VARIMAX Model). The result of such research is used to build regulatory measures for the environmental law. Furthermore, this model ensures the absence of heteroskedasticity, multicollinearity, and autocorrelation. In fact, it meets all the standards of goodness of fit. With the implementation of the sustainable development policy for energy consumption under environmental law $(S.D.EL)$, the forecast results derived from the SEM-VARIMAX Model indicate a continuously high change in energy consumption from 2020 to 2036the change exceeds the rate determined by the government. In addition, energy consumption is predicted to have an increased growth rate of up to 185.66% (2036/2020), which is about 397.08 ktoe (2036). The change is primarily influenced by a causal relationship that contains latent variables, namely, the economic factor $(ECON)$, social factor $(SOCI)$, and environmental factor $(ENVI)$. The performance of the SEM-VARIMAX Model was tested, and the model produced a mean absolute percentage error (MAPE) of 1.06% and a root-mean-square error (RMSE) of 1.19%. A comparison of these results with those of other models, including the multiple linear regression model (MLR), back-propagation neural network (BP model), grey model, artificial neural natural model (ANN model), and the autoregressive integrated moving

average model (ARIMA model), indicates that the SEM-VARIMAX model fits and is appropriate for long-term national policy formulation in various contexts in Thailand. This study's results further indicate the low efficiency of Sustainable Development Policy for Energy Consumption under Environmental Law in Thailand. The predicted result for energy consumption in 2036 is greater than the government-established goal for consumption of no greater than 251.05 ktoe.

Hence, the findings are analyzed within a context of new policies scenario in enforcing the law to control the energy consumption, and that results with an estimated future growth rate up to 88.19% (2036/2020). Besides, qualitative research is also analyzed by using economic measures under the law in Thailand. Those measures are seen most suitable in the national planning of Thailand. Therefore, a determination of policies and planning of Thailand should be highly accounted for both law enforcement and economic measures in order to create a sustainability in the future.

ACKNOWLEGEMENTS

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The author is indebted to many people who provided valuable data, suggestions and help.

Pruethsan Sutthichaimethee

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Chapter 1

Introduction

1.1 Background and General Statement of the Problems

Sustainable Development Policy is a policy that has been given a serious attention around the world. It is used side by side to define national strategies of various countries for different time scale, short-term, medium-term and long-term [123]. On the area of environmental law specifically, it is part of driving mechanisms to run such a policy for economic, social and environmental sustainability. [456] In order to make national development more sustainable, it requires a mutual coordination between the national management policy and legislation, especially integrating and incorporating environment law in order to achieve a long-run sustainability. [678] For Thailand, the main goal of sustainable development policy is to play a core role in creating sustainability, as stated in the constitution of the Kingdom of Thailand B.E. 2560, with the say of government policy under Article 72. In addition, the government is given the role of managing the environment under Article 57, and protecting it under Article 58.

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[1] EfstathiaLaina, "Sustainable Development in Operation," Environmental Policy and Law 46 No. 1 (February 2016): 47-49.

[2] United Nations Framework Convention on Climate Change, UNFCCC, Bonn, Germany, "The Paris Agreement: An Early Assessment," Environmental Policy and Law 44 No. 5 (October 2014): 485-488.

[3] Annalisa Savaresi, "The Paris Agreement: An Early Assessment," Environmental Policy and Law 46 No. 1 (February2016): 14-18.

[4] Reinhard Krapp, "Sustainable Development in the Second Committee," Environmental Policy and Law 46 No. 1 (February 2016): 10-13.

[5] Md. Kamal Uddin, "Climate Change and Global Environmental Politics: North-South Divide," Environmental Policy and Law 46 No. 2-4 (June 2017): 106-114.

[6] Patricia Moore, Eliana Silva Pereira and Gillian Duggin, "Developing Environmental Law for All Citizens," Environmental Policy and Law 45 No. 2 (April 2015): 88-98.

[7] United Nations Framework Convention on Climate Change, UNFCCC, Bonn, Germany, "Global Progress in Environmental Law," Environmental Policy and Law 46 No. 1 (February 2016): 23-27.

[8] Annalisa Savaresi, "Developments in Environmental Law," Environmental Policy and Law 42 No.6 (January 2012): 365-369.

Furthermore, this version of the constitution provides a new provision to guarantee the rights of the people and community toward the environment under Article 43, as well as grant the right to charge the government or government agencies with the responsibility for protecting the environment under Article 41. While the National Environmental Quality Promotion and Preservation Act (Version 2) B.E. 2561 [9] comes with a significant focus on the formulation of environmental protection policies, as follows: 1) promoting the participation of people and NGOs in protecting the environment, particularly Articles 6 to 8; 2) establishing an Environmental Committee under Articles 12 to 21; 3) establishing a Pollution Control Committee under Articles 52 to 54 as the main organization to determine pollution control policy; 4) establishing the Environment Fund under Articles 22 to 31; 5) overseeing the environmental quality management short-term plans of 5 and 20 years under Articles 35 to 41, which is deemed significant, especially the sustainable development policy for energy consumption under environmental law; 6) establishing environmental standards under Articles 32 to 34; 7) establishing environmental protection zones under Articles 42 to 45; 8) establishing pollution control zones under Articles 59 to 63; 9) assessing environmental impact under Articles 46 to 51/7 and 101/1 to 101/2; and 10) determining the civil responsibility of polluters under Articles 96 to 111.

In fact, from 1995 to 2018, Thailand has tremendously improved its economic development, when gross domestic product (GDP) of Thailand improves with an increasing growth rate [9]. The Thai government has continuously established policies to increase in national revenues. The main revenue-generated bases the government has attended to are the continuation of export activities to major trading partners, while increasing the diversification of exported goods with good quality and strong marketability. This is done together with establishing various measures to broadening market shares[910]. In addition, it can be observed that the government has adopted certain strategies by allowing others countries engaging in local investments in various industrial projects. Besides, the government allows joint investments together with other foreign countries within the main industries of Thailand, as well as promotes Thailand as a strategically important production base. These strategies are from both proactive and receptive approaches, including tax exemption for foreigners to

[9] Office of the National Economic and Social Development Board (NESDB), National Income of Thailand, at http://www.nesdb.go.th/nesdb_en/more_news.php?cid=154&filename=index, (last visited 1 April 2019).

[10] National Statistic Office Ministry of Information and Communication Technology, Economic and social, at http://web.nso.go.th/index.htm, (last visited1 April 2019).

land production bases in Thailand, and the promotion of international tourism, for instance [11]. Besides, the government seeks to promote and implement social policies at the same time. This has resulted in development and an increased growth rate. In general, the government has played a significant role in formulating different policies, such as the promotion in employment opportunities, health and illness, social security, consumer protection, as well as monitoring and follow-up programs[12]. However, with robust development in economic and social development, it has simultaneously led to the environmental change as well. By noting from the past (1995) until today (2018), the greenhouse gas rate has increased continuously, especially the increment of CO_2 emission from the energy-based sector. This cause of energy consumption tends to rise continuously in all sectors. The most sectors are the electronic sector, transportation sector and industrial sector, generating greenhouse gas up to 90.05 percent (2018). [13] From the above discussion, it can be noticed that Thailand has succeeded with economic and social policy, yet environmental policy is not much given serious attention in development; resulting in the reduction of carrying capacity in the ecosystem. One of major reasons is that the inefficiency and weak enforcement of environmental law.[914] Moreover, there is still a lack of tools in the implementation of the sustainable development policy in energy consumption under environmental law in Thailand to drive the nation towards the sustainability.

Establishing a sustainable development policy for Thailand is considered to be an important strategy for driving the country toward sustainability. This requires a powerful tool for ensuring that the outcomes of national policies and plans have the highest possible efficiency and effectiveness over short- and long-term periods. Meanwhile, the government can aim to mitigate or solve problems, particularly during the formulation process of the sustainable development policy in energy

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[11] Department of Alternative Energy Development and Efficiency,Energy Consumption, at http://www.dede.go.th/ewtadmin/ewt/dede_web/ewt_news.php?nid=47140, (last visited2 April 2019).

[12] Thailand Greenhouse Gas Management Organization (Public Organization),Greenhouse Gas emission, at http://www.tgo.or.th/2015/thai/content.php?s1=7&s2=16&sub3=sub3, (last visited 2 April 2019).

[13] Achawangkul Yaowateera, Thailand's Alternative Energy Development Plan, at http:// www.unescap.org/sites/default/files/MoE%20_%20AE%20policies.pdf, (last visited 3 April 2019).

[14] Gabriela Wuelser, Christian Pohl and Gertrude Hirsch Hadorn, "Structuring complexity for tailoring research contributions to sustainable development: a framework," Sustainability Science7 (26 October 2011): 81–93.

consumption under environmental law. This is also seen as a necessity for national development under the national strategic plan because of its effects on economic, social, and environmental dimensions, which constitute part of a holistic approach to developing the nation. Any country that is able to strategize such an approach and turn it into reality will benefit by attaining sustainability in both the short term and long term. In the long run, there is a high possibility that problems and hurdles will occur within and outside the nation, and these challenges are usually difficult to control or even monitor. Thus, strategic planning must evolve from strong knowledge, capacities, and resources, since the output of this action will determine the future of the nation. To date, the implementation of Thailand's sustainable development policy in energy consumption under environmental law is still weak and poorly planned. Moreover, there is still no single tool to facilitate a solution to this matter, which affects economic, social, and environmental systems.

1.2 Literature Review

Upon reviewing relevant literatures across available resources, many streamline studies highlight the evolving concept of sustainable development that has made a significant contribution in different areas across the globe. Zhou et al. [15] investigated the evolution of sustainable development-related politics and laws in China, and they found that ecological civilization tends to broadly tackle problems, focus on public participation, as well as fill the gap in environmental legislation. In their review of the historical experience of successful development in the Su-style furniture industry in the Ming Dynasty using a diamond model, Fan and Feng [16] found that style, material, skill, and government contributions, as well as consumer demand, had significant roles in gaining competitive advantages during that period. In fact, Boyd et al. [17] reviewed 10 Clean Development Mechanism (CDM) projects according to their sustainability privileges. The study later illustrated that sustainable

[15] Zhou Ke et al., "The Evolution of Policy and Law for Sustainable Development in China," Frontiers of Law in China 9 No. 3 (September 2014): 389-402.

[16] Kuo-Kuang Fan and Ting-Ting Feng, "Discussion on Sustainable Development Strategies of the Traditional Handicraft Industry Based on Su-Style Furniture in the Ming Dynasty," Sustainability 11 No. 7 (4 April 2019): 1-24.

[17] Boyd Emilyet al., "Reforming the CDM for sustainable development: lessons learned and policy futures," Environmental Science & Policy 12 No. 7 (November 2009): 280-831.

development concerns have been marginalized in some countries. Joseph [18] has observed that, most Malaysian local authorities' personnel do not understand the concept of sustainable development and sustainability reporting. In Bangladesh, Bahauddin[19] revisited the environmental protection history and other relevant interests. This visit has made a new initiative possible by paving core best practices. Strengthening and restructuring key environmental organizations are of few guidelines that must be done. As of understanding the concept of sustainable development, Rivera [20] studied sustainable development goals (SDGs), and investigated whether any work has been done between science and policy. The study pointed out the failure to fulfill some set criterion. Ali, Bibi and Rabbi [21] have investigated the connection between environmental degradation and economic growth in Pakistan through a test of Environmental Kuznets Curve along with Autoregressive Distributed Lag (ARDL) model. There comes the result of which inverted U-shaped relationship exists between those two spaces, implying the positive impact of population density on per capita carbon emission. In addition, the rise of energy consumption tends to degrade the environmental aspect. However, the role of multi-stakeholder partnerships dealing with climate change and sustainable development for developing countries was examined by Pinkse and Kolk [22]. Upon analysis, it revealed the participation of all parties in the creation of linkage between issues. To Choi and Ng [23], they attempted to understand consumers' responses on two sustainability concepts in terms of environmental and

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[18] Corina Joseph, "Understanding sustainable development concept in Malaysia," Social Responsibility Journal9 No. 3 (26 July 2013): 441-453.

[19] Khalid Md. Bahauddin, "Environmental system management and governance needs in a developing country," Environment Systems and Decisions 34 No. 2 (18 September 2013): 342-357.

[20] Manuel Rivera, "Political Criteria for Sustainable Development Goal (SDG) Selection and the Role of the Urban Dimension," Sustainability 5 No. 12 (28 November 2013): 5034-5051.

[21] Shahid Ali, Maryam Bibi and Fazli Rabbi, "A New Economic Dimension to the Environmental Kuznets Curve: Estimation of Environmental Efficiency in Case of Pakistan," Asian Economic and Financial Review 4 No. 1 (January 2014): 68-79.

[22] Jonatan Pinkse and Ans Kolk, "Addressing the Climate Change—Sustainable Development Nexus: The Role of Multistakeholder Partnerships," Business & Society 51 No. 1 (23 November 2011): 176-210.

[23] Sungchul Choi and Alex Ng, "Environmental and Economic Dimensions of Sustainability and Price Effects on Consumer Responses," Journal of Business Ethics 104 No. 2 (26 May 2011): 269-282.

economic aspects, along with price. The study explained a positive consumer behavior on two-sustainability-focused companies, while there was no in favor of low price reaction when the consumers are aware of the firm with poor environmental sustainability. Amesheva[24] touched upon the environmental impact on development and social inequality along with recent legislative measures. As of a result, it revealed the need of reformation due to governance challenge. In the meanwhile, Bakari [25] shad some highlights on the challenges of sustainable development implementation in term of global governance, confirming less impact on the whole global governance system. While the need of economy and environment was found by Martin [26] with the affirmation of the assessment of environmental and welfare policies. The main aim of all the relevant studies in the review was to address the concept of sustainability in economic, social, and environmental aspects.

However, the UN Secretariat [27] reported the possible continuation of Urban development, and this aspect can be further improved by adopting the New Urban Agenda at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III). Khalifa and Connelly [28] has found advantages to decision makers after the introduction of sustainable development indicators along with an index appropriate as compared to the current method of locally calculated Human Development Indices (HDI). In addition, Wuelser, Pohl and Hadorn[29] proposed an analytical framework assisting research on sustainable development by using theoretical conceptions and in-

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[24] Inna Amesheva, "Environmental Degradation and Economic Development in China: An Interrelated Governance Challenge," Law and Development Review 10 No. 2 (July 2017): 425-450.

[25] Mohamed El-Kamel Bakari, "Sustainable Development in a Global Context: A Success or a Nuisance?," New Global Studies 9 No. 1 (April 2015): 27-56.

[26] Edward J. Martin, "Economic rights, sustainable development, andenvironmental management," Public Administration and Management 16 No. 2 (2011): 121–144.

[27] United Nations, Urbanization and sustainable development in Asia and the Pacific: linkages and policy implications, at https://www.unescap.org/commission/73/document/E73_16E.pdf, (last visited1 April 2019).

[28] Marwa A. Khalifa and Stephen Connelly, "Monitoring and guiding development in rural Egypt: local sustainable development indicators and local Human Development Indices," Environment Development and Sustainability 11 No. 6 (December 2009): 1175–1196.

[29] Gabriela Wuelser, Christian Pohl and Gertrude Hirsch Hadorn, "Structuring complexity for tailoring research contributions to sustainable development: a framework," Sustainability Science 7 (26 October 2011): 81–93.

depth analysis by paving the setting of joint learning in policy making, shared visions and knowledge creation which in line with sustainable development's objectives. While Mueller, Santos and Seuring[30] discussed four different standards (ISO 14001, SA 8000, FSC and FLA), and revealed basic conditions for stakeholders to uphold, like CSR in supply chains, for instance. Based on other existing studies, Zhang et al. [31] evaluated the overall robustness of Ecological Footprint (EF) for decision-making on sustainability, while seeking ways to improve the EF. The new three methods were proposed, a correction factor for bio-capacity measurement, three-dimensional ecological footprint model and modified carbon footprint measurement. To add on, Wang et al. [32] introduced the ecological carrying capacity intensity (EC Intensity) according to the revised version of three-dimensional ecological footprint (3DEF) model. The findings of the study disclosed that EC Intensity has raised slowly with stronger capacity for regional development. Singh and Debnath [33] did a study to comprehend the Clean Development Mechanism (CDM). The finding gave them the fact that sustainable development is reachable if there is an emphasis on strategic goals and mission.

On the other hand, Giddings, Hopwood and O'Brien [34] integrated environment, economy, and society to sustainable development and this required more than technical changes and a shift in human worldview. With the investigation of Sapukotanage, Warnakulasuriya and Yapa[35] on the

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[30] Martin Mueller, Virginia Gomes dos Santos and Stefan Seuring, "The Contribution of Environmental and Social Standards towards Ensuring Legitimacy in Supply Chain Governance," Journal of Business Ethics 89 No. 4 (November 2009): 509–523.

[31] Lu Zhang et al., "Validity and utility of ecological footprint accounting: A state-of-the-art review," Sustainable Cities and Society 32 (27 April 2017): 411-416.

[32] Yening Wan, et al. "Assessing the Ecological Carrying Capacity Based on Revised Three-Dimensional Ecological Footprint Model in Inner Mongolia, China," Sustainability 11 No. 7 (4 April 2019): 1-18.

[33] Rajul Singh and Roma Mitra Debnath, "Modeling sustainable development: India's strategy for the future," World Journal of Science, Technology and Sustainable Development 9 No. 2 (31 May 2012): 120-135.

[34]Giddings Bob, Hopwood Bill and O'Brien Geoff, "Environment, economy and society: fitting them together into sustainable development," Sustainable Development 10 No.4 (30 October 2002): 187-196.

[35] Sapukotanage, B.N.F. Warnakulasuriya and S.T.W.S. Yapa., "Outcomes of Sustainable Practices: A Triple Bottom Line Approach to Evaluating Sustainable Performance of Manufacturing

sustainable practices of the manufacturing firms in a developing nation in South Asia, there was evidence of such sustainable practices leading towards sustainable performance. Sutthichaimethee [36] predicted the sustainable development policy implementation in the sanitary and service sectors of Thailand by 2045 with the result of potential growth of Thai economy system by 25.76% along with changes. Gradually, the Greenhouse gas emissions are found to increase by 49.65%. To Greaker et al. [37] , they established a benchmark for climate policy at a national level. The greenhouse gas mitigation projects at certain cost and acquisitions of emission permits were part of the benchmark, as discussed in the study. It is also worth noting that many studies have shown the significance of why the concept comes into existence. Cetindamar and Husoy[38] understood why companies act environmentally responsible and that came with more than one reason, while ethical and economic reasons are found to be among the reasons. Bedore[39] further investigated the impact of new Canadian legislation, Federal sustainable development Act in 2008 on sustainable development. The result of this investigation pointed out the improvement of Canadian sustainable development planning systems due to this Act. Lee, Park and Park [40] looked at Korea's official development assistance (ODA) projects in Sri Lanka as the basis of identifying policy issues on the sustainable development of

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Firms in a Developing Nation in South Asia," International Business Research 11 No.12 (29 November 2018): 89-104.

[36] Pruethsan Sutthichaimethee, "Forecasting Economic, Social and Environmental Growth in the Sanitary and Service Sector Based on Thailand's Sustainable Development Policy," Journal of Ecological Engineering 19 No. 1 (1 January 2018): 205-210.

[37] Mads Greaker et al., "A Kantian approach to sustainable development indicators for climate change," Ecological Economics91 (29 April 2013): 10-18.

[38] Cetindamar, D. and Husoy, K, "Corporate Social Responsibility Practices and Environmentally Responsible Behavior: The Case of The United Nations Global Compact," Journal of Business Ethics 76 No. 2 (December 2007): 163–176.

[39] Jenna Bedore, "An Evaluation of Canada's Environmental Sustainability Planning System and the Federal Sustainable Development," (Master's Thesis, Department of Resource Management, School of Resource and Environmental Management Faculty of Environment., Queen's University, 2008).

[40] Dayoung Lee, Hyeyun Park, and Sun Kyoung Park, "Policy Issues for Contributing ODA to Sustainable Development in Developing Countries: An Analysis of Korea's ODA and Sri Lankan Practices," Asian Perspective 42 No. 4 (October-December 2018): 623-646.

developing countries, and the observation has shown the improvement made by the projects in term of environmental policy enhancement, public awareness, increased communication and cooperation between participating countries and follow-up management. While Caracuel et al. [41] sought to see the impact of institutional distance between the home and the host country, and the headquarters' financial performance on the environmental standardization decision among multinational companies. The finding showed that when an environmental institutional distance is high, it would slow down the standardization of environmental practices, while high-profit headquarters are ready to take part. Pires, Fidelis and Ramos [42] measured and compared local sustainable development based on common indicators by seeing through some constraints and achievements. As of their finding, it revealed that the communication, limited political support, and application of such indicators are the main issues, and these limit indicators' capacity towards sustainable development.

Giannetti et al. [43] later diagnosed an environmental energy of Brazil compared to Russia, India, China, South Africa and United States. The study concluded what actions may be put in place; reducing total energy use in developed economies and decreasing exportation of indigenous resources in developing economies. Wysokinska[44] analyzed the impact of eight UN Millennium Development Goals implementation, drawing a further implication that triggers the fight against poverty, hunger, disease, and environmental destruction, rather than mitigate the risk of climate change, global hunger, and the economic fallout. Panzaru and Dragomir [45] firmly stood with high importance of managers'

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[41] Javier Aguilera-Caracuel et al., "The Effects of Institutional Distance and Headquarters' Financial Performance on the Generation of Environmental Standards in Multinational Companies," Journal of Business Ethics 105 No. 4 (July 2012): 461-474.

[42] Sara Moreno Pires, Teresa Fidélis and Tomás B. Ramos, "Measuring and comparing local sustainable development through common indicators: Constraints and achievements in practice," Cities 39 (August 2014): 1-9.

[43] Biagio F. Giannetti et al., "Emergy diagnosis and reflections towards Brazilian sustainable development," Energy Policy 63 (December 2013): 1002-1012.

[44] ZofiaWysokiński, "Millenium Development Goals/UN and Sustainable Development Goals/UN as Instruments for Realising Sustainable Development Concept in The Global Economy," Comparative Economic Research 20 No. 1 (9 March 2017): 101-118.

[45] StelianPânzaru, and Camelia Dragomir, "The Considerations of the Sustainable Development and Eco-Development in National and Zonal Context," Review of International Comparative Management 13 No.5 (December 2012): 823-831.

involvement in predicting economic growth for sustainable and economic development. Byrch et al. [46] have found the participant maps in promoting business, and accommodating economic growth and development, as the key player in the sustainable development after they revisited the meaning of sustainable development held by New Zealand. In addition, Casey and Galor[47] examined the carbon emissions in terms of their effect of lower fertility. Regardless of its complexity, population policies were found to be part of the approach to tackling global climate change. Also, Ramakrishnan et al. [48] have established an environmental model for economic growth by integrating sustainability principles. The model produced a number of outcomes, showing the energy demand would decrease when the regional agricultural share rises.

However, another exploration on the engagement of sustainable development with legislation gives a better understanding of how such development can be enforced. Ladan[49] tried to establish a significant nexus between the SDGs, human rights and climate change. This study has concluded that national law must come into play in order to archive the above objective. Craig et al. [50] sought to study the flexibility and stability in governance. They came into a conclusion of which an attention to process and procedure along with increased use of substantive standards would improve and better the substantive flexibility level to operate with legitimacy and fairness. Whereas, Wang [51] reviewed

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[46] Christine Byrch et al, "Sustainable "what"? A cognitive approach to understanding sustainable development," Qualitative Research in Accounting & Management 4 No.1 (December 2007): 26-52.

[47] Gregory Casey and Oded Galor, Population Growth and Carbon Emissions, at https://www.brown.edu/academics/economics/sites/brown.edu.academics.economics/files/uploads/2016-8_paper_0.pdf, (last visited 1 April 2019).

[48] Suresh Ramakrishnan, et al., "An interactive environmental model for economic growth: evidence from a panel of countries," Environmental Science and Pollution Research 23 No.14 (12 April 2016): 14567–14579.

[49] Muhammed TawfiqLadan, "Achieving Sustainable Development Goals Through Effective Domestic Laws and Policies on Environment and Climate Change," Environmental Policy and Law 48 No.1 (February 2018): 42-63.

[50] Robin Kundis Craiget al., "Balancing stability and flexibility in adaptive governance: an analysis of tools available in U.S. environmental law," Ecology and Society 22 No.2 (June2017): 3.

[51] Alex L. Wang, "The Search for Sustainable Legitimacy: Environmental Law and Bureaucracy in China," Harvard Environmental Law Review 37 No. 2 (2013): 365–440.

ongoing debates pertaining to environmental regulation in developing countries and other aspects. During this exploration, China has been found to face environmental problems, yet China has made a serious long-term campaign to confront these issues. Furthermore, Bartel and Barclay [52] have applied Motivational Posture Theory to examine motivational attitudes on relevant areas, including government, environmental problems, environmental laws and regulations and farm management behaviors in the context of Australian agriculture and environmental regulation. Here, the compliance was found and supported both government and regulations. At the same arena, Kim and Mackey [53] exhibited the international environmental law and found it to be a complex network of treaties and institutions. Huber[54] visited the recurrent political challenge for environmental policymakers, and has found the matter of regulatory cost and change-resistant legal and institutional policy arrangements becomes the main challenge. Alongside, Tecklin, Bauer and Prieto[55] explored the environmental policymaking process while examining the character and impact of the environmental governance. Here, the study was evident of the strongly market-enabling quality for the governance instead of the market-regulating one. In addition, Zeben[56] managed to introduce additional criteria for competence allocation, and this further expanded its application in the regulatory process, be it norm setting, implementation or enforcement.

If other studies are put further into the discussion, Bodansky[57] clarified the nature of the legitimacy challenge on environmental problem with the claim of decision-making deficit for both

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[52] RobynBartel and ElaineBarclay, "Motivational postures and compliance with environmental law in Australian agriculture," Journal of Rural Studies 27 No. 2 (April 2011): 153-170.

[53] Rakhyun E. Kim and Brendan Mackey, "International environmental law as a complex adaptive system," International Environmental Agreements 14 No. 1 (22 September 2013): 5-23.

[54] Bruce R. Huber, "Transition Policy in Environmental Law," Harvard Environmental Law Review 35 No.1 (2011): 91-130.

[55] David Tecklin, Carl Bauer and Manuel Prieto, "Making environmental law for the market: the emergence, character, and implications of Chile's environmental regime," Environmental Politics 20 No.6 (2 November 2011): 879–898.

[56] Josephine van Zeben, "Subsidiarity in European Environmental Law:A Competence Allocation Approach," The Harvard environmental law review 38 No.2 (5 August 2014): 415-464.

[57] Daniel Bodansky, "The Legitimacy of International Governance: A Coming Challenge for International Environmental Law?," The American Journal of International Law 93 No.3 (July 1999): 596-624.

individual states and international institutions. With his study of the European Union, it demonstrated that the magnitude of legitimacy positively depends on the strength of the institution. Heinzerling[58] encouraged the lawyers furthering their efforts to attain proper laws and institutions that can reduce the effect of the polluting state. In China, Chang and Wang [59] began to tap on climate change, including most environmental governance system. However, the results showed that pollution discharge permit system is built upon insufficient resources, leading to differing standards for different places in China. Nonetheless, Periconi and Jokajtys[60] pointed out the importance of modern environmental laws in New York restricting on certain harmful practices for the environment, and those laws shall be continued for the current applications. Latham, Schwartz and Appel [61] investigated the intersection of tort and environmental law, and later found that such intersection should be narrowed in order to harmonize both statutory and common law. To this extent, Wood [62] addressed the failure of environmental law in the United States as all juristic agencies allowed so. In order to reduce such failure, the study suggested that all government institutions shall be held accountable for their discretions. While Gibson [63] put 10 basic design principles as part of environmental assessment consideration in Canada, triggering a new trend of global attention for the future version of

[58] Lisa Heinzerling, "New directions in environmental law: A climate of possibility." The Harvard environmental law review 35 No.2 (January 2011): 263-273.

[59] Yen-Chiang Changand Nannan Wang, "Environmental regulations and emissions trading in China," Energy Policy 38 No. 7 (July 2010): 3356-3364.

[60] James J. Periconi and Matthew R. Jokajtys, "Shining Some Light Back on the Dark Ages: New York State's Early Environmental Law and Its Implications for Today's Environmental Insurance Coverage Disputes," Environmental Claims Journal 26 No.4 (October 2014): 287-300.

[61] MarkLatham, Victor E. Schwartz and Christopher E. Appel, "The intersection of tort and environmental law: where the twains should meet and depart," Fordham Law Review 80 No. 2 (11 August 2013): 737-773.

[62] Mary Christina Wood, "You Can't Negotiate with a Beetle" : Environmental Law for a New Ecological Age," Natural Resources Journal 50 No. 1 (Winter 2010): 167-210.

[63] Robert B. Gibson, "In full retreat: the Canadian government's new environmental assessment law undoes decades of progress," Impact Assessment and Project Appraisal 30 No.3 (11 September 2012): 179-188.

environmental assessment. In particular, Fast and Fitzpatrick[64] explored the Environmental Rights Act of the Government of Manitoba in Bill 20, indicating the importance of the Environmental Bill of Rights in the legislation, and it must be placed in the on-going efforts to restructure the provincial environmental protection system. De Moerloose[65] has further compiled papers for the "2016 Law and Development Conference: From the Global South Perspectives." This compilation exhibited the disconnection between law and development, and that leads to further action on reconnecting law with development.

Nevertheless, Tania[66] has reviewed the trade–sustainable development debate in the view of Rio+20 and its relevant green economic policy. Here, the market access barriers for least developed country (LDC) is turned out to be the main concern for developed countries towards the sustainable development. Whereas Chepaitis and Panagakis[67] engaged legal philosophy in bridging individual capacity and environmental degradation, and this justified the return of greenhouse gases in the atmosphere with the absence of individual responsibility. Miao[68] analyzed the situations of the right to justice in environmental matters in China from a legal perspective. The study's findings have shown three main focuses in order to protect such right; engaging, effectiveness, and efficiency. To a broader aspect, Pourhashemi et al.[69] examined the international treaties and the United Nations framework on climate change convention in particular, as well as to evaluate the existing forms of legal and

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[64] Heather Fast and Patricia Fitzpatrick, "Modernizing environmental protection in Manitoba: The environmental bill of rights as one component of environmental reform," Journal of Environmental Law and Practice 30 No.3 (August 2017): 295-320.

[65] Stéphanie de Moerloose, "Law and Development as a Field of Study: Connecting Law with Development," Law and Development Review 10 No.2 (October2017): 179-186.

[66] Sharmin Jahan Tania, "Is There a Linkage Between Sustainable Development and Market Access of LDCs?," Law and Development Review 6 No.1 (July 2013): 143-223.

[67] Daniel J. Chepaitis andAndrea K. Panagakis, "Individualism Submerged: Climate Change and the Perils of an Engineered Environment," UCLA Journal of Environmental Law and Policy 28 No. 2 (January 2010): 291-342.

[68] Miao He, "Sustainable Development through the Right to Access to Justice in Environmental Matters in China," Sustainability 11 No.3 (10 February 2019): 900.

[69] S. A. Pourhashemi et al., "Analyzing the individual and social rights condition of climate refugees from the international environmental law perspective," International Journal of Environmental Science and Technology 9 No.2 (November 2012): 57-67.

operational protection in relation with climate change. From this study, they have found many issues, and a failure to protect the rights of refugees and immigrants comes before hand. By tackling the above issues, it could actually result in efficient management of this crisis and stop the possible chaos across the globe. While Ruhl [70] investigated the context and policy dynamics of climate change and its trends while exploring normative and structural impacts on how environmental law fits in. The study has illustrated three main areas that environmental law plays: pollution control and ecological conservation, climate change mitigation, and its adaptation.

The structural equation model is a forecasting method commonly used in studies in a variety of contexts and for various objectives. Moreno et al.[71] applied a structural equation model (SEM) and confirmatory factor analysis (CFA) to understand the nature of classroom conflict in schools in Spain. Boccia and Sarnacchiaro[72] examined consumer attitudes pertaining to companies' corporate social responsibility initiatives by applying a structural equation model. Baumgartner and Homburg [73] assessed the applications of structural equation modeling in marketing and consumer research in three aspects, examining problematic issues and suggesting ways to improve them. Furthermore, Mai, Zhang, and Wen[74] analyzed latent variables by comparing exploratory structural equation modeling (ESEM) with structural equation modeling (SEM) and manifest regression analysis (MRA). In their study, ESEM was determined to provide the least biased estimation of regression coefficient. Ryu and

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[70] J.B. Ruhl, "Climate Change Adaptation and the Structural Transformation of Environmental Law," Environmental law (Northwestern School of Law) 40 (November 2009): 363- 431.

[71] Eva María Olmedo Moreno et al., "Structural EquationsModel (SEM) of aquestionnaire on the evaluation of intercultur al secondary education classrooms," Suma Psicologica 21 No. 2 (June 2014): 107–115.

[72] Flavio Boccia and Pasquale Sarnacchiaro, "Structural Equation Model for the Evaluation of Social Initiatives on Customer Behaviour," Procedia Economics and Finance 17 (November 2014): 211–220.

[73] Johann Baumgartner and Christian Homburg," Applications of Structural equation modelinginmar keting and consumer research: Areview," International Journal of Research in Marketing 13 No.2 (January1996):139–161.

[74] Yujiao Mai, Zhiyong Zhang and Zhonglin Wen, "Comparing Exploratory Structural Equation Modeling and Existing Approaches for Multiple Regression with Latent Variables," Structural Equation Modeling: A Multidisciplinary Journal 25 No.5 (26 March 2018): 737–749.

Mehta [75] examined multilevel factorial invariance in n-level structural equation modeling (nSEM) by optimizing a multigroup multilevel confirmatory factor analysis. Lei and Lomax [76] examined structural equation modeling under nonnormality conditions using two different estimation methods. Significantly, the study showed no effect of estimation methods and nonnormality conditions on the standards errors of parameter estimates. Cugnata,Kenett,and Salini[77] used bayesiannetworks (BN) to investigate factors regarding overall customer satisfaction to determine appropriate actions to improve customer satisfaction. Nylund,Asparouhov,and Muthen[78] simulated a study on the performance of latent class analysis (LCA), factor mixture model (FMA) and growth mixture model (GMM) to identify the number of classes in different sample sizes. In Japan, Saito,Kato,and Tang[79] estimated the effects of daily CO_2 exchange on environmental variables by using a path analysis, which showed soil temperature having a significant impact on ecosystem CO_2 exchange throughout the year. Yang and Yuan [80] proposed ridge generalized least squares (RGLS) as part of a structural equation modeling procedure for the development of formulas. Here, RGLS were found beneficial for enhancing parameter estimate efficiency.

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[75] Ehri Ryu and Paras Mehta, "Multilevel Factorial Invariance in n-Level Structural Equation Modeling (NSEM)," Structural Equation Modeling: A Multidisciplinary Journal 24 No.6 (January 2017): 936–959.

[76] Ming Lei and Richard G. Lomax, "The Effect of Varying Degrees of Nonnormality in Structural Equation Modeling," Structural Equation Modeling: A Multidisciplinary Journal 12 No.1 (January 2005): 1–27.

[77] Federica Cugnata, Ron Kenett and Silvia Salini, "Bayesian Network Applications to Customer Surveys and InfoQ," Procedia Economics and Finance 17 (December 2014): 3–9.

[78] Karen L. Nylund, TihomirAsparouhov and Bengt O. Muthen, "Deciding on the Number of classes in Latent Class Analysis and Growth Mixture Modeling: A Monte Carlo Simulation Study,"Structural Equation Modeling: A Multidisciplinary Journal 14 No.4 (October 2007): 535–569.

[79] Makoto Saito, Tomomichi Kato and Yanhong Tang "Temperature controls ecosystem CO_2 exchange of an alpine meadow on the northeastern Tibetan Plateau," Global Change Biology 15 No.1 (8 January 2009): 221-228.

[80] Miao Yang and Ke-Hai Yuan, "Optimizing Ridge Generalized Least Squares for Structural Equation Modeling," Structural Equation Modeling: A Multidisciplinary Journal 26 No.1 (12 June 2018): 24–38.

A number of studies in various countries have attempted to optimize different forecasting models. In China, Chang et al. [81] deployed a fuzzy-based grey modeling (GM) procedure in the estimation of sulfur dioxide emissions. The study showed the effectiveness of the model and the forecasting indicated a decline in such emissions. Wang et al.[82] predicted air temperature by introducing a new integrated model, the Variational Mode Decomposition-Autoregressive Integrated Moving Average (VMD-ARIMA), which was found to be effective in providing accurate temperature forecasting. Ma et al.[83] predicted provincial vehicle ownership utilizing the Gompertz model, estimating a rapid growth in vehicle ownership in each province by 2050. Zhao et al.[84] used a giant information history simulation to estimate the value-at-risk (VaR) of oil prices, analyzing how various VaR factors from online news sources can most accurately measure crude oil VaR.Xiong et al. [85] incorporated a novel linear time-varying grey model (1,N) to predict haze while comparing it with the original GM model, finding that the novellinear time-varying GM model outperformed the original model. In New Zealand, Zhao, Liu, and Mbachu[86] explored the connection between household energy use and residential building costs by using time series methods, the exponential smoothing method, the autoregressive integrated moving average (ARIMA) model and the artificial neutral networks (ANNs) model. In the study, the ANNs model was proven to be the most accurate

[81] Che-Jung Chang et al., "Employing a Fuzzy-Based Grey Modeling Procedure to Forecast China's Sulfur Dioxide Emissions,"International Journal of Environmental Research and Public Health 16 No.14 (13 July 2019): 2504.

[82] Huan Wang et al., "An Integrated Variational Mode Decomposition and ARIMA Model to Forecast Air Temperature,"Sustainability 11No.15 (25 July 2019): 4018.

[83] Lin Ma et al., "China's Provincial Vehicle Ownership Forecast and Analysis of the Causes Influencing the Trend,"Sustainability 11No.14 (19 July 2019): 3928.

[84] Lu-Tao Zhao et al., "Forecasting Oil Price Volatility in the Era of Big Data: A Text Mining for VaR Approach,"Sustainability 11 No.14 (17 July 2019): 3892.

[85] PingpingXiong et al., "A Novel Linear Time-Varying GM(1,N) Model for Forecasting Haze: A Case Study of Beijing, China,"Sustainability 11 No.14 (13 July 2019): 3832.

[86] Linlin Zhao, Zhansheng Liu and Jasper Mbachu, "Energy Management through Cost Forecasting for Residential Buildings in New Zealand," Energies 12 No.15 (26 July 2019): 2888.

for cost forecasting. In the U.S., Barari and Kundu[87] revisited the role of the U.S. Federal Reserve in triggering the recent housing crisis by using a VAR model and found that federal funds rate did not lead to house price increases. Looking at the European Union, Tucki et al.[88] proposed a new method to investigate the development of the electromobility sector in Poland and the EU states. Their study concluded that Poland and the EU states require new approaches in terms of energy management and vehicle operation management. In Africa, Ahmed et al.[89] applied the ANNs model to forecast GRACE data of African watersheds and found that the model provided the most accurate forecast. Ramsauer, Min, and Lingauer[90] adapted a Factor-Augmented Vector Autoregression Model (FAVAR) with an extension of a Kalman Filter for Factors to measure the impact of monetary policy in a case study.

Upon reviewing all the relevant literature, it was found there was no research utilising the mixed methods research. This research, therefore, intended to explore such research, aiming to fill the gap in both quantitative and qualitative research while optimizing the synergy value of those dimensions to support in decision-making and achieve sustainability. Hence, determining the relationship among the factors by developing a causal model that integrates economic, social, and environmental aspects, as well as enforcing the environmental law, has become crucial. In addition, studying the relevant research (discussed in the literature review section) reveals a gap that no other studies have focused on when proposing models for different contexts in various sectors. In fact, the previous studies have applied the same research methodologies, leading to insufficient analysis in different contexts and sectors. Therefore, this paper has identified the gap and problem, and has introduced the SEM-VARIMAX model as a tool for national policy formulation and future planning in all short-, medium- term and long-term policies. Upon obtaining the quantitative results, the

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[87] Mahua Barari and Srikanta Kundu, "The Role of the Federal Reserve in the U.S. Housing Crisis: A VAR Analysis with Endogenous Structural Breaks,"Journal of Risk and Financial Management, 12 No.3 (23 July 2019): 125.

[88] Karol Tucki et al., "The Development of Electromobility in Poland and EU States as a Tool for Management of CO_2 Emissions," Energies 12 No.15 (31 July 2019): 2942.

[89] Mohamed Ahmed et al., "Forecasting GRACE Data over the African Watersheds Using Artificial Neural Networks," Remote Sensing 12 No.15 (27 July 2019): 1769.

[90] Franz Ramsauer, Aleksey Min and Michael Lingauer, "Estimation of FAVAR Models for Incomplete Data with a Kalman Filter for Factors with Observable Components," Econometrics 7 No.3 (15 July 2019): 31.

research integrates them with the qualitative outcomes, which are analyzed by various economic measures to further apply in the environmental laws.

1.3 Hypotheses of the Study

1.3.1 Each latent variable has both direct and indirect relationships.

1.3.2 Latent variables have direct and indirect impacts over one another, and they have the same impact on sustainable development policy for energy consumption under environmental law in Thailand with different magnitudes derived from the observed variables.

1.3.3 Future environmental management using quantitative and qualitative methods based on the environmental laws is appropriate and able to create measures in enforcing the environmental law.

1.4 Objectives of the Study

1.4.1 To establish a causal factor model for sustainable development policy in energy consumption under environmental law in Thailand.

1.4.2 To analyze the direction impact of the model and evaluate the future trends of policy efficiency in sustainable development for the next seventeen years (2020-2036).

1.4.3 To examine future environmental management using quantitative and qualitative methods laid upon the environmental laws forsustainability.

1.5 Research Methodology

As of this study, it is structured to be mix methodsresearch. It employs quantitative analysis with the use of secondary data during 1990-2018 to construct a relationship model for sustainable development policy in energy consumption under environmental law of Thailand. In the quantitative research, the research applies advanced statistics within proper context, as to make the model applicable for different sectors. This entire built-up concept is called “Structural Equation Modelling-Vector Autoregressive with Exogeneous Variables Model or SEM-VARIMAX Model in short. The

research also utilizes Linear Structural Relations (LISREL) [91] software along with Econometric Views (EVIEWS)[9293]. The above mentioned model is assessed in term of its Model Validity and Best Modelling, as well as "best linear unbiased estimated (BLUE) assessment. This is to ensure that there will be no issues of heteroskedasticity, multicollinearity, and autocorrelation. Once the complete model is obtained,it is then deployed to analyze the future trend together with qualitative analysis together with analyzing,the qualitative research can be done using various economic measures in the environmental laws for future management based on the adaptation of European economic measures. In addition to this analysis, this work observes the documentary research approach from academic journals, theories, regulations and relevant studies. The model validity test is done through triangulation, and the research flow is explained below, as illustrated in figure 1.1.

1.5.1 Determine a variable framework based on the SEM-VARIMAX model, which contains both latent variables of Sustainable Development Policy under Environmental Law $(S.D.EL)$, economic $(ECON)$, social $(SOCI)$, and environmental $(ENVI)$, while the observed variables contain of 14 factors, which are Sustainable Development Policy under Environmental Law indicators, Error Correction Mechanism (ECM_{t-1}) and Carbon Dioxide Emissions (CO_2). The data of such economical indicators is retreived from the Office of the National Economic and Social Development Board (NESDB), National Statistic Office Ministry of Information and Communication Technology and the Office of Natural Resources and Environmental Policy and Planning. As of the economic indicators, there are percapitaGDP (GDP), urbanizationrate (UR),industrialstructure (IS), net exports $(X-E)$, indirect foreign investment (IF), foreign tourists (FT). These economical indicators data are also retrieved from the Office of the National Economic and Social Development Board (NESDB), National Statistic Office Ministry of Information and Communication Technology and the Office of Natural Resources and Environmental Policy and Planning. The social indicators are employment (EM), health and

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[91] Karl Gustav Jöreskog and Dag Sörbom, New Features in LISREL 8 (Chicago: Chicago Scientific Software International, 1993), pp.101-169.

[92] Michael D. Hunter, State Space Modeling in an Open Source, Modular. Structural Equation Modeling: A Multidisciplinary Journal 25 No.2 (23 October 2017): 304–324.

[93] Pruethsan Sutthichaimethee and Boonton 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 7 No. 4 (18 December 2018): 87.

illness (HI), social security (SS), consumer protection (CP). The authors have found the data from the Office of the National Economic and Social Development Board (NESDB), the Office of Natural Resources and Environmental Policy and Planning, and National Statistic Office Ministry of Information and Communication Technology. The environmental indicators include energy consumption (EC) and energy intensity (EI), and the data is retrieved from Department of Alternative Energy Development and Efficiency.

1.5.2 Examine and check the stationarity of observed variables with a unit root test based on the concept of the Augmented Dickey–Fuller [94].

1.5.3 Test the co-integration of observed variables at the same level [9596].

1.5.4 Construct a causal factor relationship model and estimate its relationship with the SEM-VARIMAX model along with other test of BLUE characteristic and its goodness of fit [97].

1.5.5 Compare the effectiveness of the SEM-VARIMAX model with other models, including multiple regression, the grey model, ANN model, BP model, ARMA model and ARIMA model through a performance measure of MAPE and RMSE [9899100].

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[94] David A. Dickey and Wayne A. Fuller, "Likelihood ratio statistics for autoregressive time series with a unit root," Econometrica 49 No.4 (July 1981): 1057-1072.

[95] Søren Johansen and Katarina Juselius, "Maximum likelihood estimation and inference on cointegration with applications to the demand for money,"Oxford Bullectin of Economics and Statistic 52 No.2 (May 1990): 169–210.

[96] Søren Johansen,Likelihood-based inference in cointegrated vector autoregressive models (New York: Oxford University Press, 1995), pp. 81-124.

[97] James G. MacKinnon, Long Run Economic Relationships (Oxford: Oxford University Press, 1991), pp. 267-276.

[98] Melanie M. Wall and Ruifeng Li., "Comparison of multiple regression to two latent variable techniques for estimation and prediction,"Statistics in medicine 22 No.23 (14 November 2003): 3671–3685.

[99] Walter Enders, Applied econometrics time series (United States of America: Wiley, 2004), pp.319-372.

[100]Andrea C. Harvey, Forecasting, structural time series models and the Kalman Filter (Cambridge: Cambridge University Press,1989), p. 145.

1.5.6 Forecast the future sustainable development policy for energy consumption under environmental law with the use of a sample indicator, which is CO_2 emissions, by deploying the SEM-VARIMAX model for the year of 2020 to 2036, totaling 17 years.

1.5.7 Analyze the implementation of both government and economic measures based on the environmental law for the sustainable development of Thailand.

1.5.8 Discuss and draw conclusions on the research's results.

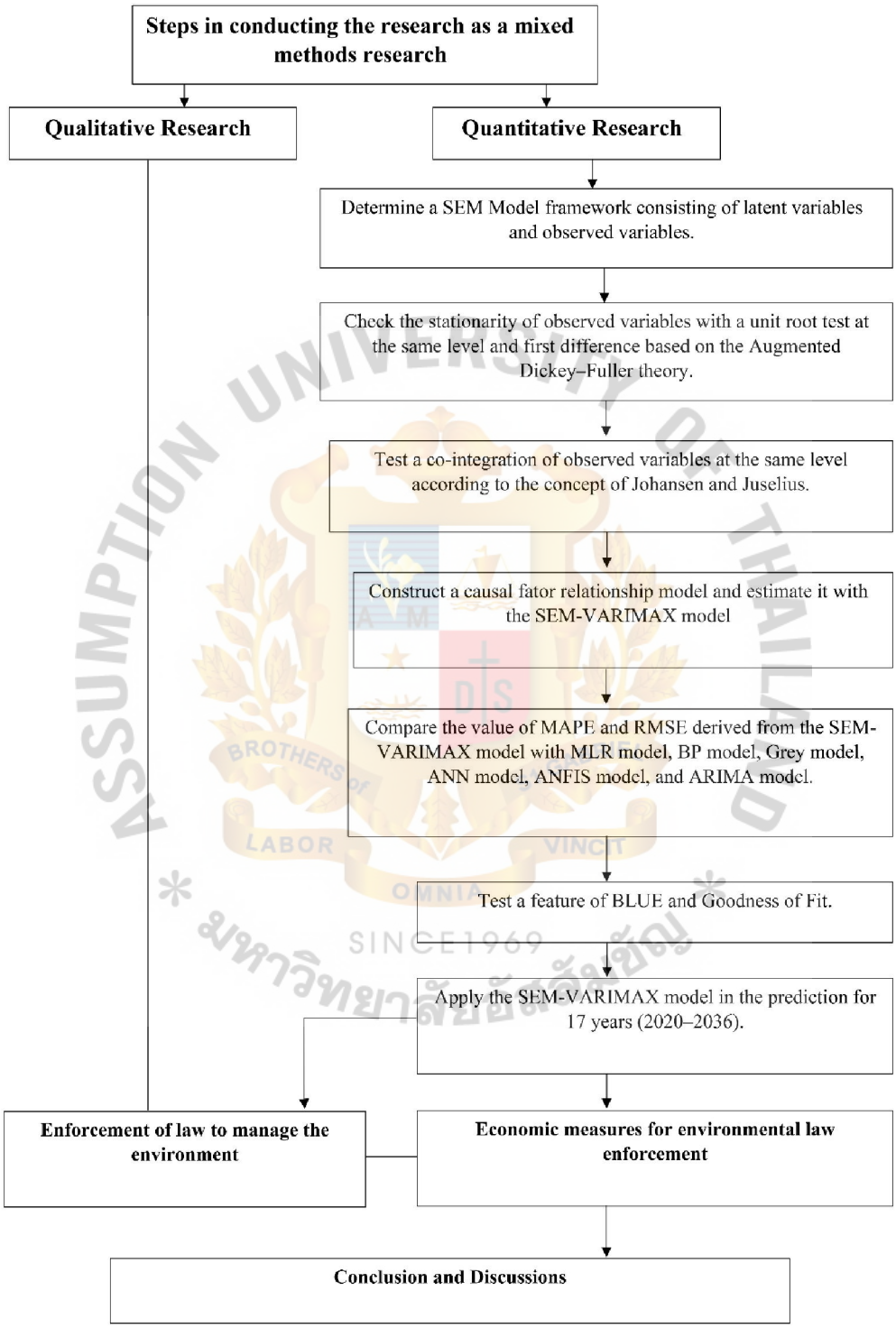

Figure 1.1 The research process in sequence

1.6 The Scope of Study

1.6.1 The Scope of Content

This research is conducted as a mix methods research by integrating quantitative research with qualitative research, and this leads to the construction of quantitative research-based analytical model. Later, the model is put to further do the qualitative research analysis. In the case of quantitative research aspect, there is the application of secondary data from 1990 to 2018 of Thailand to structure the observed variables by applying advanced statistics. This newly developed model is known as "SEM-VARIMAX Model", which is made applicable for any context while producing a high level of efficiency upon used. The main sources of information are contributed by the Office of the National Economic and Social Development Board (NESDB), National Statistic Office Ministry of Information and Communication Technology, Department of Alternative Energy Development and Efficiency, Thailand Greenhouse Gas Management Organization (public organization), and the Office of Natural Resources and Environmental Policy and Planning. Whereas qualitative research is retrieved from a compilation of various sources and documentations supported by both public and private organizations in Thailand, including the aforementioned bodies. Moreover, the academic theses and research articles are used to analyze the future trends of changes over the next seventeen years (2020-2036).In addition, theresearch accounts some economic measures based on the environmental law in Thailand adapted from the European economic measures available in terms theregulatory framework, theories and relevant studies. In fact, this research incorporates both quantitative and qualitative analysis, where the quantitative analysis controls and limits the government power in creating a new policies scenariowhile taking into account the qualitative research, so as to draw conclusions and engage in discussions, respectively.

1.6.2 The Scope of Variables

1. As of the quantitative research, it determines two main variables; latent variables and observed variables.

1) Latent variables consist of sustainable development policy under environmental law $(S.D.EL)$, economic $(ECON)$, social $(SOCI)$, and environmental $(ENVI)$

2) Observed variables includes percapitaGDP (GDP), urbanizationrate (UR),industrialstructure (IS), net exports $(X-E)$, indirect foreign investment (IF), foreign

tourists (FT), employment (EM), health and illness (HI), social security (SS), consumer protection (CP), energy consumption (EC), energy intensity (EI),and carbon dioxide emissions (CO_2)

2. In contrast, the qualitative research is analyzed using economic measures in the environmental law attempting to provide policy recommendations and suggestions for sustainable development.

1.6.3 The Scope of Study Place

This research is conducted tostudy within the Kingdom of Thailand.

1.6.4 The Duration of the Study

This research takes up for sixmonths to complete.

1.7 Conceptual Framework

A formation of conceptual framework for this research is optimized upon theories and advanced statistics, namely Structural Equation Modeling and Vector Autoregressive, and this is part of existing contributions of previous researches. Such a compilation allows us to come up with the conceptual framework as demonstrated in the figure 1.2.

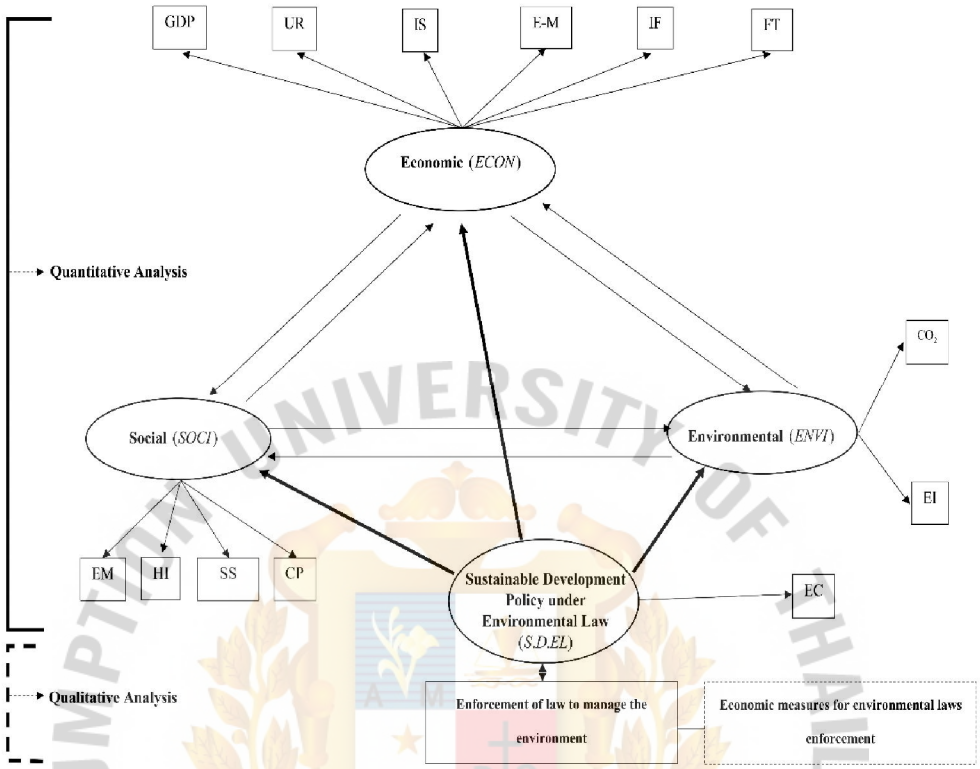

Figure 1.2 Conceptual Framework

Figure 1.2 illustrates the conceptual framework in the form of mix methods rerearch, consisting of quantitative analysis and qualitative analysis. The quantitative reserearch shows the impact of the causal factor relationship in the SEM-VARIMAX modeldetermined by Sustainable development policy under environmental law $(S.D.EL)$, where thelatent variables are: economic $(ECON)$, social $(SOCI)$, and environmental $(ENVI)$; the observed variables consist of energy consumption (EC), percapitaGDP (GDP), urbanizationrate (UR),industrialstructure (IS), net exports $(E-M)$, indirect foreign investment (IF), foreign tourists (FT), employment (EM), health and illness (HI), social security (SS), consumer protection (CP), Carbon dioxide emissions (CO_2), energy intensity (EI). In terms of qualitative analysis, this applies economic measures to enforcement of the environmental laws for future sustainable development. However, since this research is mixed methods research, the results are further absorbed to form a new policies scenario using economic measures in the environmental laws, to produce policy recommendations, as well as to support future national strategies.

1.8 Expectations of the Study

1.8.1 It acts as a guideline in formulating policies and plans to attain the sustainable development in Thailand.

1.8.2 It is to serve as a knowledge discovery for the future researches.

1.8.3 It is to guide in the future application in terms of research synergy and development for different sectors.

1.8.4 It is to enhance the future development though the maximal optimization of the environment law for Thailand to be benefitted most.

1.8.5 It is to pave a guideline in analyzing other areas of policies under different legislative laws for particular context.

Chapter 2

Concept, Theory, Materials and Method

In this chapter, we will discuss about the concept, theory, materials and methods used in the work. The research is developed based on knowledge and contents optimized from various concepts and theories. This discussion is organized under materials and methods which are arranged as follows.

2.1 Environmental Laws Issues

2.2 The 20-Year National Strategy Framework (2017–2036)

2.3 Model Simulation and Spurious Correlation

2.4 Problems arising from Model Simulation

2.5 Stationary

2.6 Co-integration

2.7 Forecasting Models and Their Application

As for this research, it, however, is made available to form as knowledge and academic guideline for further and future research. The said details are given below.

2.1 Environmental Laws Issues

2.1.1 Market Failures

It is an economic term. This does not mean the market collapse, but it reflects that many things do not go as they are supposed to. This makes the market mechanism in term of supply and demand malfunction and does not produce the most benefit[101].

The causes of market failure can be understood as follows.

1. It is normally caused by the use of property or public goods, like fresh air. Everyone has the right to utilize its benefit. It is not owned by anybody, and no one can prevent anybody from using it. People breathe in and out the air with zero market price. This affects the environment is devastating. Something vanishes after use while some can be reused within an appropriate environment.

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[101] Pollution Control Department Ministry of Natural Resources and Environment, Enhancement and Conservation of National Environmental Quality Act, B.E. 2535, at http:// www.pcd.go.th/info_serv/reg_envi.html, (last visited1 July 2019).

2. It is caused by a behavior called “Tragedy of the common.” It is a phenomenon where every person takes advantage out of nature, and everyone thinks the same way. Nature, therefore, can be deteriorated.

3. It is about a collective action and free riders resulted from the above behavior. Given a situation where the shepherds are asked to preserve the nature. This can be done if those shepherds come from the same group and village. However, it will be even difficult if the number of them become bigger and they come from different places and cultures. This scenario is called a collective action problem and involves a transaction cost to conclude a case. If there are more parties involved, the cost is even higher. In some cases, people will witness free riders along the way.

4. It is caused by externalities. The factory owners do not give a serious attention of the waste, like smokes released into the air. Such waste is not a cost to the factory owners. If those owners pay the cost to eliminate the waste, then the pollution will be dramatically reduced. However, the owners attempt to do anything to reduce their costs. The process pressuring the owners to observe environmental or social cost is called “internalizing externalities.” Based on an assumption of Economics, if one needs to trade an object with money, the paid object will be less needed than what is free.

2.1.2 Mismatched Scale

The problem of environmental law does not depend on geographical boundaries, natural structure or territory. A national border is not under a jurisdiction of environmental law. The acid rain control in 80s and 90s was a difficult task due to the affected group is not the initiator. In the context of Thailand, smokes from burning forests produced by other countries is an obvious case that could be observed. The economists call it as "Geographical spillovers." (the word “spillover” is a fantasy term referring as a pollen is blown away to nowhere. Lacking of boundaries in environmental law is a political matter, and an analysis of optimization of political and economic scales can be done by controlling a pollution level not affecting the neighboring states based on international standards of particular country. Otherwise, the production base will be moved. This is, therefore, a reason why many international conventions and protocols put in place to reduce any potential issue of the environment[102].

Looking at international agreements, if we have to implement internal laws and best practices along with advices and practices the states must adhere, this sense of adherence is known as a soft law by the language of international law. To the state councilors, this set of order is not an

[102] Department of Alternative Energy Development and Efficiency,Energy Consumption, at http://www.dede.go.th/ewtadmin/ewt/dede_web/ewt_news.php?nid=47140, (last visited 2 April 2019).

internal law, because it must be translated and cannot be transformed into internal law (it is a hard law). This is due to that the best practices are not a command while the practices are a lot in numbers. This complexity is very technical. Besides, those best practices are also changing quickly based on the social progress. To the lawyers, such practices must be certified by Thai law, and written or transmitted in Thai language only. This is because the practices are applicable to Thai people. For instance, this discussion puts the Convention for the Protection of Pollution from Ships – MAPOL 73/78 Annex III ofInternational Maritime Organization in review. It is excellent if such practice is correctly translated and deployed in time of the international maritime trade.

There is a book about Soft law recommended for reading, and it is "Soft Law in European Community Law written by Linda Sender published by Oxford and Portland Oregon 2004. It is available as an e-book. The other book in recommendation is "a soft law of international financial law."

2.1.3 Cognitive Biases

In this part of the issue, it happens due to the perception and prejudice of people about the environment. In most cases, people are enthusiastic to tackle the environmental problem as suggested by the economists. The economists claim that such method is rational, but people are prejudiced, making them refuse to support and stand for objection. This is because people are not familiar with numbers, especially the number of possibilities. The economists conclude that people often calculate tradeoffs wrongly while their perception is a partial factor for environmental law enforcement.

2.1.4 Protection Laws for Individuals

The environmental law involves benefits and interest for all parties. In most cases, those interests are always in conflict. Therefore, such law is often problematic. For example, a protection of wildlife in nature is admirable. Everyone is aware and accepts such idea. However, when people find a viper in their house, it would be beaten to death. This is because people see that danger that might come near. In examining the draft law on the prevention of cruelty to animals and the use of animals for experiment, it becomes a difficult task and challenging because of the subject is not identified for a protection. Therefore, it is unknown to whom shall receive the protection[103].

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[103] Thailand Greenhouse Gas Management Organization (Public Organization),Greenhouse Gas emission, at http://www.tgo.or.th/2015/thai/content.php?s1=7&s2=16&sub3=sub3, (last visited 2 April 2019).

2.1.5 Three Analytical Frameworks

Suppose there is someone needs to make policy decisions. What reason would the person use as a criterion for that problem? Here is the framework used for making decisions of environmental issue. There are three major concepts. In fact, the society argues about the decision-making framework rather than methods to use, and this always go opposite[104].

1. Basic Rights-Based Reasoning (Ethical Rights)

This reason can be used as an excuse for most cases, because it does not need measuring instruments. This framework will claim the environmental rights in a way that every human being has the basic right to live happily in the environment, and they also have the right to protect themselves from pollution. The state is obliged to ensure this basic right through the Declaration of Stockholm Declaration of the United Nations Conference on the Environment, for instance. The declaration guarantees individuals with "fundamental right to freedom, equality, and adequate condition of life, in environment of a quality that permits a life of a dignity and wellbeing." The state must promote every single part of this right. Otherwise, it will be condemned by other parties, because they have the right to claim basic rights as well as other rights, such as rights of employment and rights of local community to determine its own future.

2. Utilitarianism and Cost-Benefit Analysis

In the opinion of economists, the environmental problem or issue comes from market failures. The law should come to rectify this issue, as no one wants to get expensive items. stuff. If the regulation cost is cheaper than the issue, the state should interfere and control the market while maintaining the market mechanism. The state will conduct a cost-profit analysis. The U.S. government often uses this method. The Environmental Protection Agency (EPA), which is an independent agency, has a duty to carry out the analysis. Although the scientific figure is provided, people still do not believe it for many reasons. Since it involves scientific uncertainty, it becomes harder to make decisions.

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[104] 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, at http://infofile.pcd.go.th/law/Environmental%20law55_1.pdf?CFID=1741861&CFTOKEN=32274043, (last visited1 November 2019).

3. Environmental Justice

This framework accounts different groups in society responsible for the environment. This view is seen as a distributive justice. For better understanding, one example is explained in the following. In 1978 in the United States, when Governor James Hunt encountered an environmental problem in Warren County, a crowded city. The residents were poor, and more than half of its population were black people and local Americans. This city was selected as a dump site, because people here had no political voices. Fortunately, the decision changed due to the public protest. The above story shows that communities in some areas bear a disproportionate share of environmental burden. Simply put, it is a question of why some communities should bear the pollution on behalf of other people.The story of the United States of America does not come to an end yet. In 1994, the President Bill Clinton issued an executive order (a secondary law issued by the President under the Constitution), that is currently in force to establish guidelines for government agencies to consider the phrase "by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effect."The story arose in Warren County is an example the West uses a stronger term rather than "environmental racism."

The environmental justice is not taken into account only for the distribution of environmental burden, but it is also for the decision process of environmental problem. Thus, listening to opinions on environmental issue is constructed from the above principle.

2.1.6 Sustainable Development and International Agreements on Environment

1. Sustainable Development

Creating economic growth is the core objective of every government. The government must reduce poverty and improve the quality of life. Here, there is a conflict between economic development and environmental quality (Development vs Environment). In 1992, the Earth Summit meeting in Rio de Janeiro compromised on two aspects under the concept of sustainable development along with its definition of "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[105]

[105] Thailand Greenhouse Gas Management Organization (Public Organization),Greenhouse Gas emission, at http://www.tgo.or.th/2015/thai/content.php?s1=7&s2=16&sub3=sub3, (last visited 2 April 2019).

2. Environmental Principles

It discusses about international agreement between countries, which they need to adhere and transmit them as internal laws. The principles include many core contents on environments, as pointed below.

1) Principe de gestion écologiquement rationnelle et efficace (Principle of Ecosystem Maintenance with Rationales and Efficiency: from La déclaration de principe sur les forêt de Rio)

2) Principe d' anticipation (Principle of Anticipation: from point 8 du préambule de la Convention de Rio on biodiversity)

3) Principe de précaution (Precautionary Principle: from principe 15 de la déclaration de Rio)

4) Principe de participation (Participation Principle in Decision-Making, Protection, Benefit Reservation on Biodiversity: from point 12 de la Convention sur la diversité biologique)

5) Principe de l'indepentance entre développement et de protection de l'environement (Principle of Independence between Development and Environment Protection: from paragaphe 21 du préambule de la Convention de Rio)

2.1.7 The Practice of Environmental Protection

As it has been mentioned, the environment and economic growth often cannot go together. Many countries have to choose ways to fix or methods to develop. Every country has different options. The decision of selecting one method over the other is often called by the West as "choice between guns and butter." In fact, the scientists tell us only scientific information or facts. Whereas the economists can only tell about costs and benefits. There is no one telling us what environmental laws should be (correct level of regulation) and how environmental issue should be dealt (choosing the right level of environmental protection). All these questions are to be dealt politically by recognizing the scarcity of resources. In drafting the environmental law, the draft should determine a mechanism of decision-making with the responsibility of the responsible policy makers[106].

In solving this environmental problem, the economists refer to "Tragedy of the

[106] Office of the National Economic and Social Development Board (NESDB),National Income of Thailand, at http://www.nesdb.go.th/nesdb_en/more_news.php?cid=154&filename=index, (last visited 1April 2019).

Common." Suppose there is a pasture, and it is for the public. Here, everyone can feed animals as many as they wish to for the public interest, because there is a plenty of grass. In addition, there is no control over anything, as well as zero scarcity in economics. When time passes, more people come to use the area, and the number of animals is increasing. The question arises as to what shall be done. Originally, the common laws countries used the trespass and nuisance laws. While the civil laws countries used violation laws. The limitation of using such laws is that, firstly, the prosecution is the case between the plaintiff and the defendant who have been suffered. This case used the original law. Currently, there is a class action for the support. Secondly, the use of the old law asked a compensation only in the past, even if a court considers future damage (permanent damage). Thirdly, pollution may not be caused by a single factory in that particular area. Fourthly, it comes with a question of how to recover back other damages occur in the nature, such died fishes and burnt nature, except suing under public nuisance, but the victim is that state government itself. The modern environmental law must come and able to fill the above gap. Reviewing foreign environmental laws, it has found that the same version of the law is not a single issue. The United States has many laws, and does France.

The environmental law should have three components. Firstly, it is a law that prevents damages. Secondly, there is no causation examination for a violation. The environmental law textbook says that there shall be no investigation of who owns downwind or downstream properties. Lastly, the law neglects whether it is an attempt or due care. Since the common law and civil law have such restrictions, a specific law was, therefore, enacted to solve and prevent the environmental problem. This method is called "Prescriptive Regulation or Command and Control." The newly enacted environmental law still does not solve some fundamental problems, like what has been discussed about the Tragedy of the commons.

In the environmental law's textbook, there is a term of "Regulatory Toolkit," referring to the mechanic's toolbox containing a number of tools for the mechanic. The same phenomenon goes to solving the environmental problem. There are various tools available for the problem as illustrated below[107].

1. Prescriptive Regulation

Using the law of Command and Control, it is a method of structuring rules in

[107]Pollution Control Department Ministry of Natural Resources and Environment. Enhancement and Conservation of National Environmental Quality Act, B.E. 2535, at http://www.pcd.go.th/info_serv/reg_envi.html, (last visited1 July 2019).

using property and restricting actions affecting the environment. In case of Tragedy of the common, its principle constructs the law of using grassland, determining the number of users and animals, and keeping some areas for maintenance. In addition, some other cases, the principle limits the release of toxic substances into water or air based on a technical standard (technology-based standard) or the scope of action (performance-based standard) or the required processes (procedure-based standard) through a consideration of time while enforcing only the industrial sector. This includes waste discharge and other unwanted waste.

In some countries, instead of using the law, they instead deploy a contract system between the operators and the state called "environmental covenants" or another name as "voluntary agreements." The advantages of this command and control measure are clear in which it defines some punishments if violated and informs a clear duty of lawgivers. If a community agrees with this regulation, the enforcement of pollution control laws becomes more effective and workable, without reviewing it as only right for the community. Whereas its drawback is that the lawgivers might not be aware of the limitations of the production process, leading to malfunction of the industry. Besides, they do not consider the techniques that have better alternatives in the future. In some cases, the same rules are to apply in all industries, and this action has been criticized by economists. This is because each industry has different pollution control costs. However, the said measure may discourage the operators to perform better than the standards set by the regulations.

2. Economic measures

The making of economic tools is due to the drawback of the mentioned prescriptive regulation. Thus, it is better to seek for other market mechanism or deploy a Free Market Environmental system.

The following are economic tools and their benefits:

1) In Economics, there is an assumption that a price or property system affects behavior.

2) The economic methods will encourage people to look for the most cost-effective method, including new innovations.

3) If a person is well-informed to solve a problem, it is better than an issuance of regulations by the state.

4) Reduces a burden of enforcing state laws, as well as allows resource users to perform as much of their costs are acceptable.

5) Motivate resource users to preserve the environment in better ways.

However, there is no guarantee that such tools are the best tools. This is because of inability to self-enforcing, and that may become more burdensome in monitoring for the state. Also, they might not be acceptable by the community or workable as the market mechanism[108].

1) Property Rights

In this case, it must create a strong and well-informed market. For instance, as the Tragedy of the Common, if the grassland and the right to feed animals are given an ownership, the owners will take care of their right. Giving out the ownership to this property is actually giving a right to the community. The owners will not be in hurry to use the property, because they are afraid of others to use it. Thus, the property will be maintained. This method is called a sustainable managed, as it does not cost an expense to the government. While the academicians call it as "Free Market Environmentalism," because the owners will take care of their own property while the community can benefit it.

Other example goes when the state gives a rent of forestry to private organizations for the benefit of the private sector, but this should not limit the access of the existing community around the area. The organizations have a duty to preserve the wildlife. Therefore, the sector will use this right to protect other rights and comply with the agreement, or the state leases private lands to preserve wildlife.

The state determines the right to catch fish in a river. It will protect its rights by using a tort liability. If an upstream factory causes sewage and destroys ecosystem in the river, it will sue the factory. In fact, the state does not need money. Rather, it wants people to preserve the river.

2) Tradable permit

When the ownership is made, a trade is what can be done in the market. The state must create products and markets, allowing what is outside the market turn in to the market. As for a better understanding, like the previous scenario, it is to give a right to feed the animals in the grassland, or a right to release Sulfur dioxide. In order to have those rights, there should be a law to determine those rights with price.

The hassle of this method is as follows.

(1) it is difficult to determine the level of license, though considering the history, usage, equality or personal rights.

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[108]Department of Alternative Energy Development and Efficiency, Energy Consumption, at http://www.dede.go.th/ewtadmin/ewt/dede_web/ewt_news.php?nid=47140, (last visited2 April 2019).

(2) the existing operators, that cause environmental problem, and new operators must come and buy the permit in the market.

(3) it is possible to monopolize license trading.

(4) it is difficult to monitor small enterprises or pollution sources.

(5) It is difficult to take care of if it is polluted across the boundary, which leads to the landscape problem.

(6) It is difficult to issue a license with the same format if it is a mixed pollution.

A successful example is illustrated by an acid rain tradable program in the United States, but it failed due to the following.

(1) There are few traders in the market, resulting in less competition, and may lead to monopoly in some cases.

(2) There are highly regulated, making the trading expensive.

(3) The technology for reducing pollution or eliminating pollution has been slowly developed.

(4) When issuing a license, there are a number of permits, making it feel worthless. Therefore, it creates no incentive for trading.

(5) There is a barrier to new manufacturers or a limited number of them.

This can be concluded that this method requires products and sellers. The challenges here are how to determine an initial price per unit and how to do a fair distribution.

3) The Use of Financial Instruments

(1) The revolving funds or green funds are for spending to conserve and preserve the environment. This type of fund is prepared by the central government to finance local businesses, small enterprises or other organizations or agencies in activities related to environmental conservation, waste management or forest restoration.

In the draft of the Forest Act (no...) BE ...., it attempted to create a revolving fund, but all parties disagreed on the draft.

This tool also works as a loan, lending and circulating to other people. This allows people to buy a land and sell it. Later, people will have to buy another land on loan with a low interest rate according to a scheme of environmental revival. The weakness of this tool is to use it in abused ways, such as to expand the industrial area without any measures to prevent and solve environmental problem.

(2) Performance bonds

The entrepreneurs agree to be self-insured in the security, promising to carry out a duty per say. After that, he can withdraw their collateral back. In the event of seized collateral, it will be utilized to solve the environmental problem. For example, the collateral of a mining operator that promises to restore back the mining area and rebuild the natural diversity. If unable to do so, this collateral will be confiscated, and later used in the restoration of the said environment.

(3) Deposit refund system

It is similar to the performance bonds. It is a deposit the traders leave with the financial institution, and that deposit can be withdrawn when the risk is eliminated.

(4) Financial penalties - Fiscal instruments and charges system

This method creates fiscal measures affecting the price of products and services. It is done by determining the price through a collection of charges, taxes or liability.

According to economists, they claim that the taxes or liability must be equivalent to the marginal environment damage. This tax is called the Pigouvian tax, which is a tax collection from those wrong doers. Such tax is also known by the principle of "Polluter Pays" or "User Pays." The economists see it as a more effective method than government regulation. In fact, this tax measure does not tell in detail what operators will do to reduce pollution like any other rules set, but they will do anything by any means to reduce the tax and liability.

This measure is not a measure that focuses on solving environmental problem, but it is the introduction or policy of the state that will allow operators and entrepreneurs to cooperate. Therefore, taxes or fees are not set very high, and will be incorporated with other methods.

The parties who disagree on the use of tax or fee measures are based on the reasons as follows: (1) how to determine a fair tax burden, (2) taxes or costs will be shifted to consumers who are not directly involved in solving environmental problem at all. Sometimes, they cause high costs in products and services, (3) taxes and fees will become acceptable to the destruction of the environment due to paid taxes and fees. People may see and heard of Carbon tax, Oil tax, Coal tax or even a car tax calculated based on smoke emissions. This tax has to be a price right. If this method is used, a question of how much should be answered. By giving a financial subsidyis another method used to lower tax payers who bear a cost related to reducing environmental problem or any activities aim to solve the problem.

3. Promoting a Voluntarism

It is voluntary spirit used to encourage people participating to solve the environmental problem. This is the case that the entrepreneurs and operators themselves agree to do

without being forced. Initiatives may come from the state that plays as a coordinator role while providing an assistance between entrepreneurs with equal capabilities (non-mandatory). For instance, in Australia, there is a mutual agreement of landowners and communities to use the land to protect wildlife through the Australian Land Care programme. This scheme plays the same role to preserve and protect biodiversity[109].

The good side behind this idea is that there is no interference from the state, and that can create ethic of environmental stewardship. This later can be developed into a community norm. however, it is difficult, especially some people do not see the economic benefits.

In the creation of volunteerism, it makes the society aware of the problem by providing education and information instruments, including the following trends.

1) Education and training

This is to change attitudes and behaviors. The state may host education and training to help fill the gap between existing understanding.

2) Corporate environmental reports

The company's environmental reports may be annual reports or separate reports.

3) Community right to know and pollution inventories

Accessing to information is the first gateway before discussing the environmental issue. In many countries, there are laws that require the disclosure of pollution from chemical use as part of the community right to know. For instance, a law is enforced for the community to know about the environmental impact of the factories and ways to prevent such impact. This includes Emergency Planning and Community Right to Know Act 1986 (USA).

4) Product certification

This certification is about eco-labelling schemes for the consumers to select on the products.

5) Award schemes

This is to awardEuropean Better Environmental Awards for Industry.

At this point of drafting the environmental law, there should be viewed as a triangle. This is due to the characters in three roles, law, entrepreneurs and society. The state can draw collective benefit for the society (Entrepreneurs and people in the society) used as tools for enforcing

[109] Department of Alternative Energy Development and Efficiency, Energy Consumption, at http://www.dede.go.th/ewtadmin/ewt/dede_web/ewt_news.php?nid=47140, (last visited2 April 2019).

environmental laws as an informal role in the society

The role of collective groups is as follows.

(1) Providing information to the community.

(2) Providing information to government agencies that are regulating and issuing rules and regulations.

(3) Acting as a watchdog role in which political science constitutes a share of power in law enforcement

(4) Being a helper for prevention and compensation, such as class action law. The is hoped to constructive engagement. In fact, this idea comes from Environmental Justice.

2.1.8 Environmental Litigation

Citizen Suit Provisions Process

This process is for individual citizens and environmental organizations act as a private prosecutor[110].

There are two cases that can be sued.

1. any person or organization can be sued, and that is whether public or private organizations that act and violate environmental law by acting like a lawyer. The environmental organizations will be the case in the event of the government agency lacks the power to prosecute or the government agency ignores the action.

2. EPA, other officials or agencies are sued if they are found to violate the set regulation or provide in accordance with the law model.

Giving a power to prosecute is not intended to claim compensation, but rather to enforce the law. This is not to transform citizen suites to profit-making opportunities.

In summary, a suing is a process to end the action while requesting a compensation for environmental organizations or other organizations as to implement measures to solve problems for environmental benefits. The citizen suites do not authorize the private sector to sue or violate the environmental law in all respects. In case of Clean Air Act, it firstly does not aim to sue car owners who emit toxic fumes to the atmosphere. Secondly, seeking monetary penalties is not allowed, even if suing as injunctive actions. Thirdly, it is allowed to sue only “the person who violates the law”

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[110] Thailand Greenhouse Gas Management Organization (Public Organization), Greenhouse Gas emission, at http://www.tgo.or.th/2015/thai/content.php?s1=7&s2=16&sub3=sub3, (last visited 2 April 2019).

(alleged to be in violation of the underling act). This last phase has a problem in interpreting a case, like Gwaltney of Smithfield, Ltd. V. Chesapeake Bay Foundation, 484 U.S. 49 (1987). The case was concluded that suing is not for the past violation, but it is that the plaintiff wishes to demonstrate. In the event of both public and private agencies sue for the same offense in this case, the citizen suite cannot be done if the government agency is "diligently prosecuting" whether civil or criminal cases.

2.1.9 Sanction of Environmental Law[111]

1. Civil Liability

Determining civil liability for the cause of environmental damage and penalties may motivate entrepreneurs to manage environmental damage risks. The risk management here is to shift the risk to another person, and insurance is for instance. This measure seems to be the solution when the damage has already occurred (ex post). In fact, it is that the entrepreneurs plan in advance (ex ante) from the risk management.

2. Determination of Criminal Liability

It focuses on deterrence. People will obey the law when it is calculated that it is not worth it if violated. This thinking is a profit-maximization approach, which is the basic principle of economics and named after the proponent of Baker's deterrence framework.

$B < cD$

When B is the benefit the person who will receive.

c is the possibility of being arrested, prosecuted and convicted.

D is to pay the fine, including the cost of defending the case and loss of commercial interests, like other expenses are ordered by a court.

How much the fine set by the law can be calculated based on the following equation.

$D > B \div c$

When looking at the price of the damages, it must encourage the offenders think that it is not worth by estimating through the below equation.

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[111] Pollution Control Department Ministry of Natural Resources and Environment. Enhancement and Conservation of National Environmental Quality Act, B.E. 2535, at http://www.pcd.go.th/info_serv/reg_envi.html, (last visited1 July 2019).

B> c x H ÷ c

When c is the price of the damage occurred

The summary of Toolkit.

The environmental law shifts itself from general civil and criminal laws to the so-called command and control. There is also an integration of marketing tools in this command and control. In fact, the promotion of education and provision of information on environmental awareness are a modern environmental law. However, the environmental law is still not effective. One of the reasons comes from what the West call it as "management by crisis." The second reason comes from writing the law. The more written, the more complicated it is. Let's look at each pollution control law. Regardless of waste water, polluted air or garbage, the third cause of unintended consequences is that there are often unexpected events. This phenomenon is called "everything goes somewhere", solving one issue, and other issue emerges, especially in the work of garbage management. At first sight, a cleanliness occurs, but other issues happen to emerge, issue of infection and fairness.

2.1.10 Government Agencies with Environmental Duties[112]

1. Organizing government agencies to manage the environmental problem is also a matter of environmental law, but it is overlapping with the law in the Government Administration Department. In the National Environmental Quality Promotion and Preservation Act 1992, it grants an authority to the Prime Minister, the National Environment Board, Pollution Control Committee, Environment Fund Committee, as well as local government organizations to oversee the environmental matter.

In reality, the environment concern of Map Ta Phut, for instance, was not taken care of by Thai government agencies. In fact, the environment is not an only task of the Ministry of Natural Resources and Environment, but it is also the work of the Ministry of Agriculture and Cooperatives, the Ministry of Public Health, the Ministry of Energy, the Ministry of Interior (Department of Land), and many other public organizations. In international arena, the environment has been the main concern to many foreign countries, as compared to Thailand.

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[112] 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, at http://infofile.pcd.go.th/law/Environmental%20law55_1.pdf?CFID=1741861&CFTOKEN=32274043, (last visited 1 November 2019).

As of the United States, only state, treasury and wars agencies were originally present. Due to the current climate change, pollution, forestry, biodiversity, fisheries, wildlife, land, mineral, oil, public health, toxic substances and benefits and care for the marine have been become its national concern. Therefore, there are many more agencies emerged within the states as to oversee and control. In Thailand, it is too fast to conclude what would be in term of those agencies in place, because it depends on how Thailand interprets the term of environment. This chain of work in the United States is called as a soup of government agencies.

2. Administrative Procedure Law

Administrative procedure law is a law that involves actions, which government agencies should or should not do, and it is a law that makes administrative proceedings transparent. The administrative authorities are responsible for their actions. In environmental law, it imposes the regulations, approve requests, investigate facts, listens to opinions, grant subsidies, reward the works, and give an order to those officials. All of these powers are granted by the law.

In the past, there were discussions with the Council of state and the administrative procedure committee regarding the implementation of environmental law, the authority action of the officials, and other concern. The National Environmental Quality Promotion and Preservation Act of 1992, although written briefly and quickly, was present before the Administrative Procedure Act B.E 2539 (1996). It also takes into account the procedure for the authorities, as official orders and environmental law cannot be separated. Often, the agency forgets that its own duty. When there is a law, it is its role as the government officials, to implement (legal authority), prescribe (legal measures) and interpret (interpretation).

3. Auxiliary Environmental Laws and Regulations

Thailand has enacted laws and announced numerous environmental regulations, many of which contain permit requirements, or are relevant to business operations. These include, among others:

1) The National Environmental Quality Act (NEQA) of B.E. 2535 (1992) deals with wide ranging issues related to the enhancement and conservation of Thailand's environment.

2) ONEP's "Policy and Prospective Plan for Enhancement and Conservation of National Environmental Quality, 1997-2016"that involves a series of governmental guidelines stemming from the NEQA and deals specifically with water pollution, air pollution, noise and vibration pollution, pollution from solid waste and night soil, pollution from hazardous materials, and

pollution from hazardous waste.

3) Soil Quality Standards (2004)

4) Air Quality and Noise Standards (2007)

5) Water Quality Standards (2009)

6) The Factory Act of B.E. 2535 (1992) delineates the rules for operating factories in Thailand and the regulations relative to the location of factories, the type and quality of machinery that is to be used, and the standards for measuring emissions that have a potential impact on the surrounding environment.

7) Regulations issued by the Ministry of Industry state the permissible amounts of adulterated substances in factory air emissions and in the wastewater released by the factory.

8) Announcements of the National Environment Board stipulate the zones that are specifically pollution control areas, including Pattaya and Phuket.

9) Announcements of the former Ministry of Science, Technology and Environment list specific protected areas and measures to ensure protection of the environment, particularly in Pattaya, the Phi Phi Islands and Phuket.

10) Sanitary regulations issued either by the Department of Industrial Works or the Pollution Control Department define the procedures for the disposal of refuse and garbage.

11) Announcements of the National Environment Board Announcements specify the standard of quality for seawater, surface water and underground water; and

12) Announcements of the Ministry of Natural Resources and Environment deal with standards for controlling wastewater drainage from development sites, from coastal fish hatcheries, and others.

The degree of government control required varies depending on the type of business. To ensure environmental safety, certain regulations are utilized on industrial sites likely to emit pollution. To find out which factory type requires licensing or notification read the Factory Act B.E. 2535 (1992)

Business activities in Thailand must comply with environmental management criteria and conditions as set by the Thai government and its associated agencies. Strict compliance is enforced, particularly for companies operating in the following sectors: oil refinery, natural gas separation, power generation, chemicals and petrochemicals, minerals and base metals, etc. For more information on environmental regulations, please refer to the Pollution Control Department

Other key legislation that deals with issues pertaining to the environment, pollution, and/or waste are as follows:

1) Navigationof Thai Waterways Act, B.E. 2546(2003)[113]

This Act appertains to control of internal water navigation, however, the 14th Amendment of this Act was introduced in B.E. 2535 (1992). Prohibits dumping of any refuse, including oil and chemicals, into rivers, canals, lakes or waterways that may pollute the environment or disrupt navigation in internationally recognized Thai waterways.

2) Fisheries Act, B.E. 2490 (1947) (amended in 1953 and 1985)

This Act appertains to fishing control and marine life conservation. Prohibits dumping or discharging of hazardous chemicals into water resources reserved for fishing.

3) National Executive Council Announcement No. 103, B.E. 2515 (1972)

This decree appertains to land allocation control. The Land Allocation Control Board has the power and authority to issue regulations involving land allocation. Under the amended directive involving land allocation (1992), drainage systems and wastewater treatment facilities have to be constructed by the applicant, on any plot that is to be developed for commercial use, for a land allocation license to be issued.

4) Building Control Act, B.E. 2522 (1979)

This Act appertains to building control. This Act authorizes the Minister of Interior and local officials to regulate building construction, alteration, removal, and usage. Under Ministerial Regulation No.3 (B.E. 2535), high rise buildings or spacious buildings must have both drainage and wastewater treatment systems.

5) Bangkok Metropolis Regulation on Drainage Control, B.E. 2534 (1991)

This decree appertains to effluence (solid and liquid) from buildings into drainage pipes and public waterworks. Buildings to be constructed must have both a drainage and wastewater treatment system in place.

6) Public Cleanliness and Orderliness Act, B.E. 2535 (1992)

This Act appertains to the control of public sanitation measures and garbage disposal throughout the country. It prohibits the dumping of refuse in public surface areas or waterways.

(1) Water

Water contamination has taken a toll on all the species of the earth.

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[113] Pollution Control Department Ministry of Natural Resources and Environment, Navigationof Thai Waterways Act, B.E. 2546, at http://www.pcd.go.th/info_serv/reg_envi.html, (last visited5 July 2019).

Almost 60% of the planet's species live in bodies of water. It occurs due to several factors. Industrial waste dumped into rivers and oceans cause an imbalance in the water leading to its severe contamination and death of aquatic species. Also, spraying insecticides and pesticides on fields, crops, and plants pollutes the ground water system. Eutrophication is another big source; it occurs due to the washing of clothes or household utensils with heavy detergents in lakes, ponds or rivers. And lastly, water pollution not only harms aquatic life but it also contaminates the entire food chain thereby severely affecting human health.

(2) Soil

Soil contamination is caused by the presence of human-made chemical agents or waste in the earth. Typically, soil pollution is the result of industrial activity, agricultural production, or the improper disposal of waste. The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, lead, and other heavy metals. Indeed, there is a correlation between soil contamination with the degree of industrialization and the intensity of chemical usage by the general population. Polluted soil does affect human health through direct contact with the soil or via inhalation of contaminants that have vaporized; potentially greater threats are posed by the infiltration of soil pollutants into underground water supplies.

(3) Air

Air contamination is the most prominent and dangerous form of pollution. It occurs due to many reasons. Excessive burning of fuel, which is a necessity in the daily lives of almost every single inhabitant on this planet for cooking, driving and other industrial activities; releases a huge amount of chemical substances in the environment everyday; making the air toxic to breathe. In fact, manufacturing plants release large amount of carbon monoxide, hydrocarbons, organic compounds, and chemicals into the air thereby depleting the quality of air. The release of Sulphur dioxide and hazardous gases into the atmosphere causes damage to the planet's ecosystem as well as to the human body.

(4) Odors

Air quality is affected not only by conventional air pollutants but also by unpleasant odors. Usually, bad odors are considered a nuisance, but in cases that are more serious it may lead to feelings of nausea, the onset of chronic headaches, or to other symptoms that can impair normal bodily functions. With the pressures of population growth, industrialization and urbanization, the existence of foul odors in both public and private living spaces has been assuming greater importance for government authorities to take corrective measures. Indeed, the presence of unhealthy odors contributes to air quality concerns and affects daily human activity. According to a

ministerial regulation issued by the Ministry of Industry in 2005, “odor” is defined as air contaminants that can be detected by the human nose or analytical equipment. Meanwhile, “odor sample” means an air sample that is odorous at the source.“Odor concentration” refers to the value indicating the dilution ratio of odorous air samples with fresh air.“Industrial Zone” means the area where the land use is defined as industrial land under the town and country planning law; or an industrial estate under the Industrial Estate Authority of Thailand regulation; or an industrial land under the Factory Act.“Off the industrial zone” refers to areas other than the industrial zone. No factories shall discharge smelling air from the factories, unless a particular act or several acts have been committed. The method of diluting must not be used.

(5) Noise

Like most fast-developing Southeast Asian countries, there is plenty of noise contamination in several of Thailand’s urban centers due to traffic and construction. Past certain baseline decibel levels, many kinds of noise tend to cause adverse health effects amongst the general population. These impairments include hearing loss and a range of stress-related ailments, such as sleep deprivation, aggressiveness, diminished cognitive performance, heart problems, etc. For these reasons, ambient noise is a significant public health risk that can affect a population’s productivity and quality of life. In fact, the Pollution Control Department establishes general noise guidelines of less than 55 decibels as “good,” 55-70 decibels as “moderate,” and above 70 decibels as “unhealthful”.

(6) Waste &Hazardous Waste

As defined by the Enhancement and Conservation of National Environmental Quality Act B.E. 2535 (1992), waste refers to “refuse, garbage, filth, dirt, wastewater, polluted air, polluting substances or any other hazardous substances which are discharged or originated from point sources of pollution, including residues, sediments or remainders of such matters, either in the state of solid, liquid or gas”. There are several classifications of waste, such as municipal solid waste, industrial waste, e-waste, healthcare waste, and organic waste.

As an example, municipal solid waste (MSW) refers to the stream of garbage collected through community sanitation services. It includes wastes such as durable goods (e.g. tires, furniture), nondurable goods (e.g. newspapers, plastic plates/cups), containers and packaging (e.g. milk cartons, plastic wrap), and other wastes (e.g. yard trimmings, food). This category of waste generally refers to common household waste, as well as office and retail wastes, but excludes industrial, hazardous, and construction wastes.

Meanwhile, industrial wastemeans solid waste generated by manufacturing or industrial processes that is not considered to be hazardous waste under existing

regulations. Such waste may include, but is not limited to, electric power generation; fertilizer/agricultural chemicals; food and related products/by-products; inorganic chemicals; iron and steel manufacturing; leather and leather products; nonferrous metals manufacturing/foundries; organic chemicals; plastics and resins manufacturing; pulp and paper industry; rubber and transportation equipment; and water treatment.

Regarding the category of hazardous waste, it is waste that is recognized as being dangerous or potentially harmful to human health or the environment. Such waste can be classified as liquids, solids, gases, or sludges. They can be discarded commercial products, like cleaning fluids or pesticides, or the by-products of manufacturing processes.

According to the Notification of the Ministry of Industry B.E. 2548 (2005) issued pursuant to the Factory Act B.E. 2535 (1992) on the Disposal of Wastes or Unusable Materials, factory operators having hazardous wastes which have such characteristics and properties as defined in the Notification must carry out the disposal of the wastes or unusable materials as follows:

- Wastes and unusable materials shall not be stored in the factory longer than 90 days without prior approval by the Department of Industrial Works (DIW). The storage of wastes and unusable materials in the factory shall comply with the provisions in the Notification of the Ministry of Industry B.E. 2547 (2004) on Manifest System.

- Wastes and unusable materials shall not be taken out of the factory except with prior approval from the Director-General of DIW or the person assigned by the Director-General to take them out to disposal or recovery by method and at the place according to the criterion and the method defined in Annex 4 of the Notification and only by the permitted waste collector, transporter, and processor. If the treatment and disposal of wastes and unusable materials within the factory shall comply with the provisions provided in Section 4, Article 17 and Articles 21 to 24 of the Notification; and

- Details on type, quantity, characteristics, properties and storing place of such hazardous wastes or unusable materials concerned as well as method of storage, detoxification, disposal, discarding, landfilling and transport according to "Form Sor Kor 3", attached to the notification must be yearly notified to the Department of Industrial Works by the third of March of the next calendar year.

Additionally, the separation, collection, transportation, treatment and disposal of infectious wastes generated from hospitals, clinics and health care service centers have been complied with the Regulation of the Ministry of Health on the Disposal of Infectious Waste B.E. 2545 (2002).

(7) Indicators of Pollution

The National Environment Board, which operates with the Prime Minister as chair, is the government entity that considers whether a given site in Thailand should be characterized as a "Pollution Control Area". Presently, nine locations fall under the aforementioned designation. To be specific, they are Pattaya, Phuket, Hat Yai, Songkhla, Koh Phi Phi/Ao Nang/Mueang Krabi, Samut Prakan, BMA vicinity (Pathum Thani, Nonthaburi, Samut Sakhon, and Nakhon Pathom), Phetchaburi/Phrachuap Khiri Khan, and Na Phralan Chaloem Phra Kiat (in Saraburi). Key pollution markers to be utilized when determining a pollution control area should be detectable or measurable with their quantifiable results able to identify the locale's pollution level. Those indicators include surface water, air pollution, noise, solid waste, hazardous waste and contamination in the soil and groundwater. All of the aforementioned markers should be evaluated and scored according to the level of the problem.

For any place in Thailand where all six indicators are present and a total score equals to or results in more than 25 points, that locality is to be recognized as a pollution control area. However, in those localities where groundwater is not utilized, groundwater quality should not be taken into consideration. In such cases, the 8-points indicator score should concern only soil contamination and the weight score of 2 points should be maintained with the same distribution of total scores. Additionally, surface water in some locations may be related to both coastal water and river water. In these cases, a water quality survey should be conducted for both sources and a weight score equally divided into 4 points for surface water that is affiliated with coastal and river waters.

(8) Regulations of Industrial Pollution Control Facilities

In reference to Section 70 of the National Environmental Quality Act (1992), "The owner or possessor of the point source of pollution under Section 69 has the duty to construct, install or bring into operation an on-site facility for wastewater treatment or waste disposal as determined by the pollution control official. For this purpose, the pollution control official may also require that such owner or possessor commission a Monitoring Control Operator to control the wastewater treatment or waste disposal facility that shall be constructed, installed or brought into operation accordingly".

An air or water pollution control facility covers any system, treatment works, or appliance used or placed in operation primarily for the purpose of reducing, controlling, or eliminating both air or water pollution caused by either industrial or agricultural waste. Technology can prevent or limit the escape of pollution from industrial and commercial facilities. Regulatory agencies, like the Department of Industrial Works, have the authority to require facilities to install

pollution control technologies or to change operating practices that contaminate the environment. Moreover, municipalities are encouraged to set up their own waste management action plans in line with the National Environmental Quality Act (1992) and the Decentralization Act (1999). Areas declared as environmental conservation or pollution control zones are managed rigorously.

2.2 The 20-YearNational Strategy Framework (2017–2036)

The 20-Year National Strategy Framework released by Prime Minister General Prayut Chan-o-cha is crucial to providing Thailand with a clear long-term direction for sustainable development. Referred to as the 6-6-4 plan, it consists of six areas, six primary strategies, and four supporting strategies[114].

The six areas are: security, competitiveness enhancement, human resource development, social equality, green growth and rebalancing, and public sector development.The six primary strategies seek to:

1. enhance and develop the potential of human capital
2. ensure justice and reduce social disparities
3. strengthen the economy and enhance competitiveness on a sustainable basis
4. promote green growth for sustainable development
5. bring about national stability for national development toward prosperity and sustainability
6. enhance the efficiency of public sector management and promote good governance.

The four supporting strategies for efficient national development involve infrastructure development and a logistics system; science and technology, research, and innovation; urban, regional, and economic zone development; and international cooperation for development.

[114] Office of the National Economic and Social Development Board (NESDB), National Income of Thailand, at http://www.nesdb.go.th/nesdb_en/more_news.php?cid=154&filename=index, (last visited 1April 2019).

2.2.1 The 12th National Economic and Social Development Plan (2017–2021)[115]

The 12th NESDP was mapped out in line with the national strategy. This plan places an emphasis on socio-economic development derived from the use of knowledge, skill and the application of science, technology, innovation and research and development. It also stresses a balance with environmental sustainability. This plan will continue to focus on the SEP and its three principles of moderation, reasonableness and prudence.

2.2.2 Thailand 4.0 policy

Thailand 4.0 reflects the integration of SEP's focus on designing a value-based economy by building on the emerging technology breakthroughs while ensuring environmentally-friendly practices. It has the ultimate goal of pulling Thailand out of the middle-income trap and pushing the country into the high-income range[116].

The Thailand 4.0 policy will be achieved by reforming Thailand's existing five industries, or the 'First S-Curve', including automotive, electronics, affluent medical and wellness tourism, agriculture and biotechnology, and food. It will also promote five new industries, or the 'New S-Curve', including robotics, aviation and logistics, biofuels and biochemicals, the digital industry, and the medical hub, in which Thailand has the potential to succeed.

Thailand needs to deal effectively with disparities and the imbalance between the environment and society. With the same overall target as the SDGs, the Thailand 4.0 policy is a government tool to gear up the country's economy and production to become a high-income nation, move toward an inclusive economy and focus on sustainable growth and development. Thailand 4.0 is an economic model that endeavors to change traditional farming to smart farming, traditional SMEs to smart enterprises, traditional services to high-value services, and transform the economy so that it is driven by innovation, creativity, research and development, and green industries.

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[115] Office of the National Economic and Social Development Board (NESDB), National Income of Thailand, at http://www.nesdb.go.th/nesdb_en/more_news.php?cid=154&filename=index. (last visited 1April 2019).

[116] Thailand Greenhouse Gas Management Organization (Public Organization),Greenhouse Gas emission, at http://www.tgo.or.th/2015/thai/content.php?s1=7&s2=16&sub3=sub3, (last visited 2 April 2019).

2.2.3 National means of implementation for the SDGs

Thailand's government has formed the National Committee for Sustainable Development (CSD), headed by the Prime Minister. It has 37 members from the public, private academia and civil society, with the Secretary-General of National Economic and Social Development Board (NESDB) as the secretariat. The National Committee for Sustainable Development and other policy bodies and frameworks have placed particular emphasis on cooperation between the public and private sectors and civil society organizations based on the partnership for development principle.[117]

However, the implementation structure still has fewer representatives from civil society organizations than many civil society groups anticipated. Only 4 out of 38 CSD members are representatives of civil society. Therefore, the public sector largely determines the processes of CSO involvement and the content of key technical outputs such as roadmaps for each SDG. This has led to complaints that CSOs/NGOs less critical of the government are being invited to contribute to SDG planning, while those groups who are more critical or who are operating at the grassroots, or in remote areas, are excluded.

The public sector mainly uses the budget that the Government has allocated to agencies for working towards the SDGs. These funds serve as foundations for the government's integrated action plans in line with the 20-Year National Strategy Framework and the 12th National Economic and Social Development Plan.

The government has created a structure for inter-agency coordination in their efforts to achieve the SDGs. When SDG's goals, targets and indicators require coordination between at least two agencies and the work is considered as an important issue in accordance with key development policies, national security policies, other key government policies and SEP, agencies can request a strategically integrated budget from the central budget. This provides opportunities for program implementation to be connected, harmonized and mutually supportive in an efficient, cost-effective and non-duplicative manner. Evidence that this process is actually occurring on a regular basis is currently sparse.

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[117] Office of the National Economic and Social Development Board (NESDB), National Income of Thailand, at http://www.nesdb.go.th/nesdb_en/more_news.php?cid=154&filename=index, (last visited 1April 2019).

2.2.4 Monitoring and evaluation

The Thai Government's roadmap for reaching the SDGs consists of three parts[118]:

1. The strategic part will deal with ways to apply SEP to achieve national targets.
2. The project part will cover action plans with implementation timeframes.
3. The follow-up part can apply key performance indicators of the UN, and the SEP-based indicators that organizations have developed or are developing, in assessing Thailand's results and showing whether further action is required for success in achieving the 17 SDGs.

The Government has said it believes the review of the implementation of the 2030 Agenda for Sustainable Development is not simply a reporting process or an opportunity to exchange good practices and challenges among countries. It is also an opportunity for relevant agencies to understand the current situation and plans as well as raising awareness and promoting understanding of SDGs among public and private agencies, civil society, academia and communities.

At an initial stage of the implementation of the 2030 Agenda for Sustainable Development, the Voluntary National Review is an important step for Thailand to take stock of sustainable development efforts. It allows the country to strengthen SDG implementation efforts and build public awareness and encourage broad contributions from diverse sections of Thai society toward the achievement of SDGs.

The Voluntary National Review (VNR) task force comprises the lead agencies working towards the 17 SDGs, as well as the National Statistical Office. The National Statistical Office is working to expedite the implementation by using the country's official statistics as a centralized database, collecting, compiling and developing additional statistical data and indicators. It is also enhancing the statistical capacity of relevant agencies and personnel to make the database and indicators for SDGs as comprehensive as possible. The VNR is seen as a practical tool and part of an engagement process that should be encouraged.

The VNR process has now been completed. According to the final VNR report These forums and committees have provided spaces for private businesses, academics and CSOs to engage with the government on issues related to sustainable development and have allowed for coordination to occur between these groups (Thailand VNR, 1-2). The government has also conducted several rounds of stakeholder engagement, consulting with groups such as youth and parliamentarians.Views on the success of these forums in consulting adequately with relevant stakeholders are mixed. The

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[118] Thailand Greenhouse Gas Management Organization (Public Organization),Greenhouse Gas emission, at http://www.tgo.or.th/2015/thai/content.php?s1=7&s2=16&sub3=sub3, (last visited 2 April 2019).

Thai government reports that stakeholders have been able to make "contributions in accordance with their respective roles and expertise," while civil society reports have noted that these efforts have been inadequate and ineffective. Some civil society groups have complained that the government's SDG consultations and implementation plans are elitist or overly insular, resulting in "many minority groups and ordinary people" being overlooked.

A shadow report to Thailand's VNR reported both that civil society had not been invited to participate in the VNR process and that "partnerships with CSOs as an equal partner" have yet to occur. Despite this, the report also notes the government is engaging with the private sector, and that the government is engaging with civil society in its efforts to reach some specific SDGs.

In 2017, Thailand ranked 55th out of 157 countries in an index set up "to enable countries to take stock of where they stood with regards to fulfilling the SDGs". The country has invested a lot of efforts on reducing poverty (Goal 1) and ensuring access to clean water and sanitation (Goal 6). More meaningful and collaborative actions, however, are still required for the country to achieve significant progress across all the SDGs[119].

2.3 Model Simulation and Spurious Correlation

The following regression equation illustrates the correlation between an assortment of variables and 1 independent variable[120]:

$$Y_t = \beta_1 + \beta_2 X_t + u_t, t=1,2, \ldots, T \quad (2.1)$$

Where Y_t is a dependent variable, X_t isan independent variable, and β_1 and β_2 areparameters,while u_t is thestochastic disturbance term, or random error term, in which time series Y_t and X_t are used for regression analysis under the assumptions of the classical linear regression model (CLRM) with the related conditions of u_t as follows:

$$E(u_t) = 0$$
$$\text{Var}(u_t) = \sigma^2$$
$$\text{Cov}(u_t, u_s) = 0, t \neq S$$

[119] Office of the National Economic and Social Development Board (NESDB),National Income of Thailand,at http://www.nesdb.go.th/nesdb_en/more_news.php?cid=154&filename=index. (last visited 1April 2019).

[120] Walter Enders, Applied econometrics time series (New York: John Willey & Sons., 2003), pp. 319-372.

These conditions show that the stochastic disturbance term (u_t) should be stationary with a time series, of which the symbol can be written as u_t ~I(0),while time series Y_t and X_t can be either stationary or non-stationary whereby the equation of (2.1) when X_t or u_t must be one will beI(1) Y_t must certainly beI(1)too. If X_t and u_t are bothI(0), this means Y_t must also beI(0),too. Therefore, the attributes of estimator by the least squares method can be illustrated whenusing time series in analyzing regression equations by dividing according to the nature of X_t and u_t ,which are eitherI(0) orI(1), as shown in Table 2.1

Table 2.1 Attribute of estimator by the Least Squared Method using time series in analyzing regression equation

	u_t ~I(0)	u_t ~I(1)
X_t ~I(0)	b_2 With attributes of Consistency andAsymptotically Normal Distribution	b_2 Without attributesof Consistency andAsymptotically Normal Distribution
X_t ~I(1)	b_2 With attributeof Consistency But without attributeof Asymptotically Normal Distribution	b_2 Without attributesof Consistency andAsymptotically Normal Distribution

Where: b_2 with attribute of consistency is whenthe sample size is largeand the probability of b_2 is equal to the parameter value of β_2

b_2 without attribute of consistency is when the sample size is largeand the probability of b_2 is not equal to the parametervalue of β_2

b_2 with attribute ofasymptotically normal distribution is whenthe sample size is largeand the probability distribution of b_2 is close to normal distribution.

b_2 without attributeof asymptotically normal distribution is whenthe sample size is largeand the probability distribution of b_2 is not close to normal distribution.

In practice, it is found that dependent variable data and independent variable data will beI(1) and u_t ~ I(1) ; this estimated regression is what we callspurious regression.

2.3.1 Spurious Regression

When analyzing regression equations with time series,dependent variable (Y_t)

independent variable (X_t) and stochastic disturbance Term or random error term (u_t) can be time series with or without stochasticity. However, if it is a variable that has stochasticicity, it will affect theattributes of the estimator with the least squares method. Even if the sample size is large, the probability of b_2 will not be equal to the parametervalue of β_2 or of the estimator, which is not a normal distributor. Hence, the testing of the hypothesis will not be reliable. We can illustrate this case as follows[121]:

If the dependent variable (Y_t) and independent variable (X_t) are time series in the form of random walk as follows:

$$Y_t = Y_{t-1} + v_t \qquad (\text{Where } Y_t = 0) \qquad (2.2a)$$

$$X_t = X_{t-1} + w_t \qquad (\text{Where } X_t = 0) \qquad (2.2b)$$

Given v_t and w_t are white noise with the average of 0 and the variance is 1. The equation can be re-written in the following sequence.

$$Y_t = +\sum_{i=0}^{t} v_i \qquad (2.3a)$$

$$X_t = +\sum_{i=0}^{t} w_i \qquad (2.3b)$$

Where v_t and w_t have no correlation to Y_t~I(1) and X_t~I(1). Therefore, time series Y_t and X_t will have no correlation with each other, too. The assumption of regression equations to illustrate the correlation between Y_t and X_t can be shown as follows:

$$Y_t = \alpha_1 + \alpha_2 X_t + \varepsilon_t \qquad (2.4a)$$

When the parametervalue of $\alpha_1 = 0$, the correct regression equation is

$$Y_t = \alpha_1 + \varepsilon_t \qquad (2.4b)$$

Which illustrates that ε_t has stochasticity,or ε_t ~I(1) due to

$$\varepsilon_t = Y_1 - \alpha_1$$

$$= \sum_{i=0}^{t} v_i + \alpha_1 \qquad (2.5)$$

Granger and Newbold (1974) simulated Y_t and X_t in such a format more than 100 times,and got the results, with attributes, by estimating a regression equation (2.4a) which tests

[121] Andrea C. Harvey, Forecasting, structural time series models and the Kalman Filter (Cambridge: Cambridge University Press,1989), p. 145.

whether hypothesis of $H_0 : \alpha_2 = 0$ will be of statistical significance. The multiple coefficients of determination R^2 are at high values, as well as adjusted R^2, but the Durbin-Watson statistic had a low value. Such results of regression equations are called "spurious regression".

Therefore, caution is necessary in the analysis of regression equations with time series data where dependent variables and independent variables with stochasticity exist due to the possibility of finding spurious regression. Such problems can be examined by calculating the error in the first step with regression equation (2.4a) as follows:

$$e_t = Y_t - \hat{\alpha}_1 - \hat{\alpha}_2 X_t$$

When $\hat{\alpha}_1$ and $\hat{\alpha}_2$ are estimators α_1 and α_2 by using the least squares method. The value of e_t should then be tested with the Augment Dicky Fuller method to see whether it is I(1) or not. If the conclusion from the test is e_t ~I(1), this estimated regression equation shows spurious regression.

2.3.2 The correction of Spurious Regression

Sutthichaimethee (2017)[122] proposed to correct the spurious regression problem by finding the first difference of dependent variable and independent variable so that the stochastic trend could be eliminated. The First Difference of Y_t and X_t from the equations of2.2aand2.2bare as follows:

$$\Delta Y_t = v_t \quad (2.6a)$$

$$\Delta X_t = w_t \quad (2.6b)$$

Time series ΔY_t and ΔX_t from the equation of 2.6a and2.6b have had the stochastic trend eliminated, so the attribute is white noise, which is the concept to be applied to regression equation(2.4a) to derive regression equation(2.4a) back by 1 period of time interval as follows[123]:

$$Y_{t-1} = \alpha_1 + \alpha_2 X_{t-1} + \varepsilon_{t-1} \quad (2.7)$$

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[122] Pruethsan Sutthichaimethee, "Varimax Model to Forecast the Emission of Carbon Dioxide from Energy Consumptionin Rubber and Petroleum Industries Sectors in Thailand," Journal of Ecological Engineering 18 No.3 (2 May 2017): 112–117.

[123] Pruethsan Sutthichaimethee and DanuponAriyasajjakorn, "Forecast of Carbon Dioxide Emissions from Energy Consumption in Industry Sectors in Thailand,"Environmental and Climate Technologies 22 No.1 (5 December 2018): 107–117.

The subtraction of equation(2.7) from equation (2.4a) can be shown as follows:

$$Y_t - Y_{t-1} = (\alpha_1 + \alpha_2 X_t + \varepsilon_t) - (\alpha_1 + \alpha_2 X_{t-1} + \varepsilon_{t-1})$$

$$\Delta Y_t = \alpha_2 \Delta X_{t-1} + \varepsilon_t - \varepsilon_{t-1}$$

$$\Delta Y_t = \alpha_2 \Delta X_{t-1} + v_t \quad (2.8)$$

From equation 2.8, thestochastic disturbance term or random error term v_t ~I(0) and both dependent variable (ΔY_t) and independent variable (ΔX_t) are I(0) as well. Therefore, when this equation is estimated, it is not a spurious regression. The result from the estimation with the least squares method will have attributesof consistency andasymptotically normal distribution, and forwhich we can use the statistical value of t in testing hypothesis $H_0 : \alpha_2 = 0$ and $H_1 : \alpha_2 \neq 0$. If time series Y_t~I(0), X_t~I(0) and ε_t~I(0), then it is necessary to return to the concept of equation (2.8) in estimating parameter values, which creates the autocorrelation problem of stochastic disturbance term or random error termdue to $v_t = \varepsilon_t - \varepsilon_{t-1}$, which causes $v_{t-1} = \varepsilon_{t-1} - \varepsilon_{t-2}$, then$\mathrm{Cov}(v_t - v_{t-1}) \neq 0$

2.4 Problems arising from Model Simulation

The estimation of models is often a problem when it is wrongly utilized, which can cause mistakes and damages. Some such problems includeheteroskedasticity,autocorrelation and multicollinearity[124].

2.4.1 Heteroskedasticity Problem

The heteroscadasticity problem is disturbance term: u_i of inconstant disturbance variable. The value of inconstant disturbance variables will vary according to the value of independent variables(X_i).When there are more independent variables, $(i = 1,2,3,...n)$ it will result in an increase in variance of u_i as follows:

$$\sigma^2 \text{ or} \mathrm{Var}(u_i) = \sigma_i^2 \quad (2.9)$$

[124] Pruethsan Sutthichaimethee and Danupon Ariyasajjakorn, "Forecasting Model of GHG Emission in Manufacturing Sectors of Thailand,"Journal of Ecological Engineering 18 No.1 (1 January 2017): 18–24.

1. The causes of heteroskedasticity

Heteroskedasticityarises from the following causes:

1) The incorrectness of the model selection on some independent variable which is significant to the model and for which such independent variable has correlation to the variation of such disturbance variables.

2) Taking cross-sectional data into the model will cause higher heteroskedasticity than using time series data due to the fact that cross-sectional data has more variance from disturbance variables in each observation value, which may have a high probability of unstability and which are varied by size or sequence.

2. The impact of heteroskedasticity

When the estimated model leads to heteroskedasticity, it causes errors in estimation, which can be explained as follows:

1) From the assumption in which Whered Variance should have the lowest value so that the result could be analyzed for confidence as per the equation that follows:

$$\text{var}(\hat{\beta}) = \frac{\sigma^2}{\sum x_i^2} \tag{2.10}$$

From the above equation, the variance of $\hat{\beta}$ can be analyzed for confidence, but if heteroskedasticity arises, it will not be able to be analyzed for confidence, as follows:

$$\text{var}(\hat{\beta}) = \frac{\sum x_i^2 \sigma_i^2}{(\sum x_i^2)^2} \tag{2.11}$$

2) The estimatied result lacks the attribute of efficiency, even though it has the attributes of unbiasedness andconsistency.

3) The estimated result lacks reliability when testing a hypothesis by using t-test orF-test, which may have a lower value than normal.

4) The forecasting has high error.

3. The examination ofheteroskedasticity

Heteroskedasticity can be examined in 2 formats as follows:

1) Graphical Technique – This method is performed by drawing a graph to represent the correlation between variation according to the changing value of observation: u_i. If the

analyzed results show that there is a systematic change, there will be no issues with heteroskedasticity, but if there is a non-systematic change or the variation of variance is larger, then there is a problem with heteroskedasticity.

2) Formal Methods. There are four popular methods, as follows:

The Spearman Rank-Correlation Test – This method is used together with observation from small to large scales with the following steps:

To define testing hypothesis by:

$$H_o : \rho = 0$$
$$H_a : \rho \neq 0$$

Regression equation is calculated fromActual Value $e = Y - \hat{Y}$

To calculate correlation co-efficient rank from sequential data using formula as follows:

$$r = 1 - 6\frac{\sum D_i^2}{n(n^2-1)} \tag{2.12}$$

Given D, which is the difference between the rank of X_i and e_i

n is Observation

To summarize the analysis of the results or the conclusion of the hypothesis, if the result is to reject the main hypothesis, Reject H_o orAccept H_a, it means the calculated equation has statistical significance. Therefore, it can be concluded that it has a correlation between X_i and e_i or that the variance is an inconstant value, or that there is a problem with heteroskedasticity. On the other hand, if the result isAccept H_o orReject H_a, the calculated equation has no statistical significance, which shows that there is no correlation between X_i and e_i, or that the variance has a constant value which is a homoscedasticity problem.

However, statistical t value can be used in testing with the following formula:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \tag{2.13}$$

or

$$Z = \frac{r^s}{\sigma_{r^s}} = r * \sqrt{n-1} \tag{2.14}$$

Given a degree of freedomequalto n – k

where k is the number of parameters to be calculated

The Goldfeld and Quandt test method is suitable for observation data with a large

scale, or at least the size of observation should not be less than 2 times that ofthe parameter value as per the following steps:

(1) Define the testing of the hypothesis as follows:

$H_o : \varepsilon_i = 0$ showshomoscedasticity

$H_a : \varepsilon_i \neq 0$ shows heteroskedasticity

(2) Arrange the significance of independent variable: X_i

(3) Group number of observations by high group and low group

(4) Calculate regression equation fromthe actual value $e = Y - \hat{Y}$ of each sample group

(5) Calculate the proportion between the variance of disturbance variables by definingthe degree of freedom, which is divided by 2 from the following formula:

$$F = \frac{\sum \varepsilon_2^2}{\sum \varepsilon_1^2} \qquad (2.15)$$

The Glejser test tests the correlation between independent variables and variances by the following steps:

To calculate regression equation from Actual Value $e = Y - \hat{Y}$

Summary of analysis result or Hypothesis conclusion – The test value is R^2 F-test andt-statistics if the analysis result reject main hypothesis, Reject H_o or Accept H_a it means that the calculated equation has statistical significance and correlation between X_i and e_i, or the variance of disturbance variable has an inconstant value or is heteroskedastic. On the other hand, if Accept H_o orReject H_a, the calculated equation has no statistical significance and no correlation between X_i and e_i, or the variance of disturbance variables has a constant value, which is homoscedasticity.

White's Heteroskedasticity test, developed by H. White, is different from other methods above, especially the Goldfeld-Quandt test, and proceeds with the following steps:

(1) Define the equation format as auxiliary regression

(2) Calculate regression equation fromActual Value $e = Y - \hat{Y}$ byordinary least squares: OLS

The format of White's test statistic is aChi-Square distribution, which can be shown as follows:

$$n.R^2 \sim \chi^2_{df} \qquad (2.16)$$

In this test, if the calculated Chi-Square isnR^2. If the analysis result is that the value of the Chi-Square test is greater than Chi-Square at a critical level from the defined level of significance during testing, then Reject H_o orAccept H_a, forwhich the calculated equation has statistical significance and correlation between X_i and e_i, or the variance of disturbance variables has an inconstant value and is heteroskedastic. If the result is Accept H_o orReject H_a, the calculated equation has no statistical significance and no correlation between X_i and e_i, or the variance of disturbance variable is constant, or homoscedastic.

(3) Solving heteroskedasticity: Use of the weighted least squares method, which can derive a non-heteroskedastic model, is one method for adjusting heteroskedastic models.

2.4.2 Autocorrelation Problem[125]

Autocorrelation is incurred from the violation of hypothesis of $E(u_i u_j) = 0$, which is when the disturbance variables have correlation with each other. This correlation has 2 categories: positive autocorrelation and negative autocorrelation. Mostly it will be incurred with time series data rather than cross-sectional data. There are 4 ranks of correlation between the disturbance variables from 1-k (first-k-order autocorrelation).

1. Cause of Autocorrelation Problem

There are 3 main causes of Autocorrelation problems which are:

1) The incorrectness of model selection on necessary independent variables, which impacts the correlation of disturbance variables, passing to the ignored independent variable.

2) Incorrect functional form

3) Self autocorrelation, also known asa pure autocorrelation problem

2. The impact of autocorrelation

When the estimated model is autocorrelated, it will have an impact on the following:

1) Lack of efficiency attribute, whichis when the value of variance is not the lowest value.

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[125] Pruethsan Sutthichaimethee and DanuponAriyasajjakorn, “The revised input-output table to determine total energy content and total greenhouse gas emission factors in Thailand,” Journal of Ecological Engineering 18 No.6 (1 November 2017): 166–170.

2) There is some attribute which isunbiased andconsistent.

3) The forecast value will have high deviation.

3. Testing of autocorrelation

There are many methods to test for autocorrelation. The most popular method is theDurbin – Watson Test, which is suitable to the internal correlation in the level offirst-order regression, and for models which are composed ofC (Constant or Intercept), and when the data should not correlate with lagged dependent variables with the following testing steps[126]:

1) Define testing of hypothesis

$H_o : \rho = 0$ NoAutocorrelation

$H_a : \rho \neq 0$ Autocorrelation

2) Testing statistics usingDurbin Watson: d from the following formula:

$$\hat{d} = \frac{\sum_{t=2}^{n}(e_t - e_{t-1})^2}{\sum_{t=1}^{n} e_t^2}$$

$$\hat{d} \approx -\frac{2\sum e_{t-1}^2}{\sum e_{t-1}^2} - \frac{2\sum e_t e_{t-1}}{\sum e_{t-1}^2}$$

$$\hat{d} \approx 2(1 - \frac{\sum e_t e_{t-1}}{\sum e_{t-1}^2})$$

Where $\hat{\rho} = \frac{\sum_{t=2}^{n} e_t e_{t-1}}{\sum_{t=1}^{n} e_t^2}$ $\hat{d} \approx 2(1-\hat{\rho})$ is suitable to the large volume of data. If the data is rather sparse, the popularity will be onTheil andNagar from the formula $\hat{p} = \frac{n^2(1-d/2)+k^2}{n^2+k^2}$

If the analysis result is foud that

$\rho = -1$ $\hat{d} = 4$: Perfect Negative Correlation problem

$\rho = 0$ $\hat{d} = 2$: autocorrelation

$\rho = +1$ $\hat{d} = 0$: Perfect Positive Correlation problem

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[126] Pruethsan Sutthichaimethee,"Modeling Environmental Impact of Machinery Sectors to Promote SustainableDevelopmentofThailand,"Journal of Ecological Engineering 17 No.1 (1 January 2016):18–25.

3) To compareDurbin test and Durbin Criticalby using the Durbin-Watson Table which shows the statistical distribution $\hat{d}$ to be in between d_L and d_U as shown in Figure 3.1

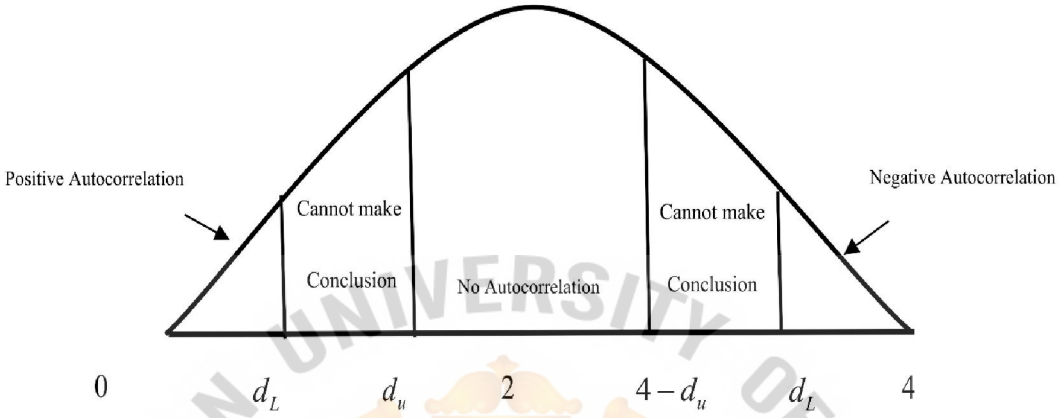

Figure 2.1 Statistical Distribution of $\hat{d}$

From Figure 2.1, it can be seen that if $\hat{d}$ falls in the range between d_u and $4-d_U$,there is no autocorrelation, but if $\hat{d}$ falls in the range between d_L and d_U and in the range between $4-d_U$ and d_L, the detection of autocorrelation will be inconclusive. Mostly, this would imply that the model is acceptable. However, if $\hat{d}$ falls in the range between 0 and d_L, there is a Positive Autocorrelation Problem, and if $\hat{d}$ falls in the range between d_L and 4, there is a Negative Autocorrelation Problem.

4. SolvingAutocorrelation

To solvethe most critical autocorrelation problem, pure autocorrelation, one can calculate the autoregressive coefficient (ρ) and transfer the previous data of all variables to the model as follows:

$$U_t = \rho u_{t-1} + \varepsilon_t \quad (2.17)$$

$$Y_{t-1} = \alpha + \beta X_{t-1} + \varepsilon_{t-1} \quad (2.18)$$

Whereas to bring the value of ρ to multiple by equation (2.18)

$$\rho Y_{t-1} = \rho\alpha + \rho\beta X_{t-1} + \rho\varepsilon_{t-1} \quad (2.19)$$

Bringing the equation of (2.19) – (2.18)

$$Y_t - \rho Y_{t-1} = (\alpha - \rho\alpha) + (\beta X_t - \rho\beta X_{t-1}) + (\varepsilon_t - \rho\varepsilon_{t-1}) \quad (2.20)$$

$$Y_t^* = \alpha^* + \beta X_t^* + \varepsilon_t \quad (2.21)$$

There are many alternative ways to solve autocorrelation. The most popular one is the Cochrane-Orcutt Iterative Method, which is suitable for data with largeobservations; if the observation is rather small, it will cause an impact ofbias through the following steps:

To bring along the results from the estimation of the model to calculate the variation of variance at each level by starting from the first–round residuals as follows:

$$e' = Y_t - \hat{Y}$$
$$e' = Y_t - \hat{\alpha} - \hat{\beta}X_i \qquad (2.22)$$

Where $\hat{\rho} = \frac{\sum_{t=2}^{n} e_t e_{t-1}}{\sum_{t=1}^{n} e_t^2}$ by calculating to find $\hat{\rho}$ in the first rank from the formula

$$\hat{\rho}' = \frac{\sum_{t=2}^{n} e_t' e_{t-1}'}{\sum_{t=1}^{n} e_t'^2} \qquad (2.23)$$

Then put (2.23) to substitute into the equation of (2.20) as follows:

$$Y_t - \hat{\rho}' Y_{t-1} = (\alpha - \hat{\rho}'\alpha) + (\beta X_t - \hat{\rho}'\beta X_{t-1}) + \varepsilon_t^* \qquad (2.24)$$

From the equation(2.24) to put variation to perform Durbin –Watson Test, if the result of hypothesis is Accept H_0, there is noautocorrelation, and one can therefore stop the calculation. But if the result of hypothesis is Reject H_0, there is a problem with autocorrelation, and it will be necessary to calculate ε, ρ at a higher level.

2.4.3 Multicollinearity Problem[127]

1. Category of Multicollinearity Proble

The estimated model is composed of dependent variables and independent variables. These variables should be correlated. While normally we look to the strength of correlation to make comparisons with the degree of change in dependent variables, in reality, some independent variables should have correlation, as well. If independent variables show correlation, it will impact the correctness of estimation, or there will be a multicollinearity problem, which will violate the

[127] Pruethsan Sutthichaimethee, "Modelof Environmental Problems Priority Arising from the Useof Environmental and Natural Resources in Machinery Sectors of Thailand," Environmental and Climate Technologies 17 No.1 (1 May 2016): 18–29.

hypothesis of the classical assumption of linear regression. Thus, the correlation between each independent variable is different, and can be divided into 2 categories as follows:

1) Perfect multicollinearity refers to the problem from the correlation of more than 2 independent variables in the equation as follows:

$$Y_i = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \varepsilon_i \qquad (2.25)$$

Sample of Multicollinearity problem is shown in equation (2.26)

$$X_{1i} = \alpha + \beta_3 X_{3i} + \varepsilon_i \qquad (2.26)$$

From (2.26) it is found that if variable X_{1i} has full correlation to variable X_{3i}, it will not be able to estimate the value of $\hat{\beta}_1$ and $\hat{\beta}_3$. $S.E.E(\hat{\beta}_1)$ and $S.E.E(\hat{\beta}_2)$ equalInfinity because the value of $(X'X)^{-1}$ is a singular matrix and cannot be calculated for inverse.

2) Imperfect multicollinearityis the problem of high multiple correlation, but not as high as in perfect multicollinearity problem due to the existence of a random variable δ_i, as shown in equation (2.27):

$$X_{1i} = \alpha + \beta_3 X_{3i} + \delta_i \qquad (2.27)$$

2. The impact of multicollinearity

Perfect multicollinearity can be substituted to variables which have correlation with other variable. Sometimes, it benefits some rare data. Althoughimperfect multicollinearity will have no issues with bias, it may impact the following:

1) Correlation: r will be high for the correlation of both independent variables

2) The higher result of estimated value of $S.E.E(\hat{\beta}_i)$ will impact the decreasing t-test value, which leads to higher Reject H_0, which means thatthe parameter value of the variables is not deviated from 0, which can cause mistaken results.

3) The estimated model of multicollinearity is the high sensitive model when there are any minimal chages and has a large impact on the structure of the model, such as changingfrom positive to negative, or from no statistical significance to statistical significance.

3. Examination of the problem

Multicollinearity can be incurred in almost every dataset due to the fact that in real situations, variables should have correlation. If the data is found to haveperfect multicollinearity, it will impact the value of R^2 = 1, which causes changes in independent variables. But in the case of

imperfect multicollinearity, which is not too severe and is in fact necessary, then compromises must be made to be able to still use the data, or, ideally, a better solution can be found by selecting a higher level model, such as the ARIMAX Model or thevector autoregressive model. The imperfect multicollinearity problem can be examined in many ways, with the most popular being the consideration of Correlation: r, and to use Variance Inflation Factors (VIF) from the formula $VIF = \frac{1}{1-R^2}$; each method has its own pros and cons from the selection of Correlation: r, as shown in the following formula.

$$r = \frac{n\sum XY - \sum X \sum Y}{\sqrt{\left[n\sum X^2 - \left(\sum X\right)^2\right]\left[n\sum Y^2 - \left(\sum Y\right)^2\right]}} \qquad (2.28)$$

By $$SS_{(x)} = \sum X^2 - \frac{\left(\sum X\right)^2}{n}$$

$$SS_{(y)} = \sum Y^2 - \frac{\left(\sum Y\right)^2}{n}$$

$$SS_{(xy)} = \sum XY - \frac{\left(\sum X\right)\left(\sum Y\right)}{n}$$

From Equation (2.28) it is found that if $r_{y,x}$ has a value close to 1, it means dependent variable Y has high correlation with independent variable X, which means that the independent variable can explain the changes of dependent variable. The independent variables have high correlation ($X_i,...,X_n$) and will highly impact mistakes in the model, as well. If r_{x_i,x_n} is closer to 1, multicollinearity will also be high and it will impact the correctness of the model.

4. Solving multicollinearity

Solving multicollinearity is up to the model attributes of which sometimes it is not necessary to make any changes at all, in the case of a model with the attribute of being unbiased. However, it is necessary for some models to change some independent variables or to add more independent variables to the model as appropriate.

2.5 Stationary

2.5.1 Attribute of Stationary

If Y_t is a stochasticvariable time series and has the stationary attribube, it should be

composed of 3 attributes as follows[128]:

Mean: $E(Y_t) = E(Y_{t-k}) = \mu$

Variance: $\mathrm{Var}(Y_t) = E(Y_t - \mu)^2 = (Y_{t-k} - \mu)^2 = \sigma^2$

Covariance: $\mathrm{E}[(Y_t - \mu)^2 (Y_{t-k} - \mu)^2] = \gamma_k$

The height or the distance of covariance has equal attributes. The distance between two Y_t does not depend on time. The 3 attributes will be called Stationary.

Stationarystochasticprocessesare when the data of a time series which has the average or meanorexpectedvalue and variance and covariance is constantover time, andwhich does not depend on time but instead depends on distance or lag, shown as follows:

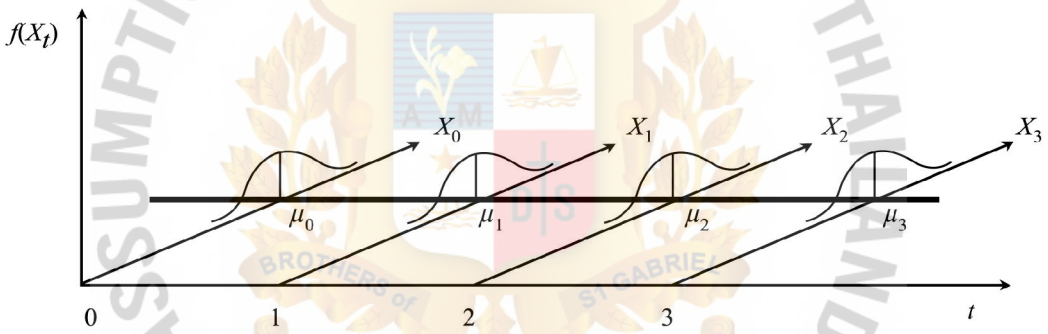

Figure 2.2 Stationary Attribute

If time series data lack any of these attributes, it will be called non–stationary,which has the following attributes:

Mean : $E(Y_t) = E(Y_{t-k} - \mu)^2 = t\mu$

Variance : $\mathrm{Var}(Y_t) = E(Y_t - \mu)^2 = E(Y_{t-k} - \mu)^2 = t\sigma^2$

Covariance : $\mathrm{E}[(Y_t - \mu)^2 (Y_{t-k} - \mu)^2] = t\gamma_k$

Non–stationarystochasticprocesseswill have expectation, variation and inconstant covariation which depends on time; this type of data set is also called RandomWalk, and is shown as follows:

[128] Pruethsan Sutthichaimethee, “Varimax Model to Forecas the Emission of Carbon Dioxide

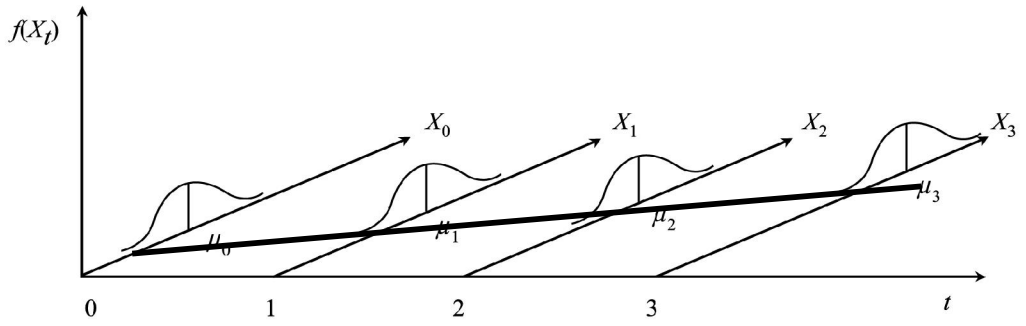

Figure 2.3Non–stationary Attribute

2.5.2 The impact of Non–stationary attribute data

Most time series data is non–stationary and is composed ofUnitRoot. Estimation usingnon–stationaryattribute or UnitRoot to runa regressionmodel by ordinary least squares (OLS), the derived parameter value will have significance and will lack reliability, which is a spurious regression problem.

For the adjustment of the non–stationaryattribute into stationaryattribute or a weakstationary, only the data ofthe firstandsecondmoment will be adapted. In the case that the data is strictlystationary, the consideration will not by only the first or the secondMomentbut also the moment at the higher level, as well.

The consideration of moments is composed of 2 main concepts, which is that variables with the stationary attribute will slightly vary in the mean, while data with the non–stationaryattribute will vary more when compared to higher observation,andif there are external factors, from economics to shock, the stationary attribute will vary from mean only temporarily and come back to momentum quickly. If the analyzed data is non–stationary, the result will be an opposite impact on the model or other variables in the model, which meansthat non–stationarydata will have no longrunmean level.

2.5.3 Examination of Stationary data[129]

There are many methods for examining Stationary data, such as the Dickey Fuller (DF) and Augmented Dickey Fuller (ADF) methods.

To examine dependent variable attribute of DickeyFullerTestandAugmentedDickey FullerTestby usingUnitRootTest

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[129] Pruethsan Sutthichaimethee and DanuponAriyasajjakorn, “Forecast of Carbon Dioxide

The Dickey–Fuller Test can solve problems with non–stationary data by using a regression equation in the form of a differenceregression. This equation is calleda first order autoregressive process in either one of the 3 equations as follows:

1. $\Delta Y_t = \delta Y_{t-1} + \varepsilon_t$ (random walk process orpurerandomwalk)
2. $\Delta Y_t = \alpha_1 + \delta Y_{t-1} + \varepsilon_t$ (random walk withdriftor the increasing value of intercept)
3. $\Delta Y_t = \alpha_1 + \alpha_2 T + \delta Y_{t-1} + \varepsilon_t$ (randomwalkwithdriftand lineartimetrendto add todrift term andTvalue in which T is the trend variable

Where

ΔY_t = variable to be studied

δ = coefficient of lagged dependent variable

ε_t = error term where ε_t has normal distribution, mean = 0,variance = σ^2

Hypothesis of Unit Root Test

H_0 : $\delta = 0$, Non–stationary

H_a : $\delta < 1$,Stationary

ΔY_t is non–stationaryattribute Accept H_0 it means δ=0and the exponential or explosive increase in variation will be greater for a longer period of time with the details of each format shown as follows:

$$\Delta Y_t = \delta Y_{t-1} + \varepsilon_t \qquad (2.29)$$

Equation(2.29) is a simple model withmean equal to 0, which is suitable for data with an overall average equal to 0 only. Therefore, the drift term will be added to the adjusted model in the equation as follows:

$$\Delta Y_t = \alpha_1 + \delta Y_{t-1} + \varepsilon_t \qquad (2.30)$$

Whereas α_1=Drift Term

Equation(2.30)can be adjusted for the examination ofunitroottest when there are components in the process oftrend stationary (TS)and difference stationary (DS),as shown in the equation as follows[130]:

$$\Delta Y_t = \alpha_1 + \alpha_2 T + \varepsilon_t \qquad (2.31)$$

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[130] Rajdeep Grewal Joseph A. Cote and Hans Baumgartner, "Multicollinearity and Measurement Error in Structural Equation Models: Implications for Theory Testing," Marketing Science 23 No.4 (Fall 2004): 519–529.

When

T = Time Trend

α_2 = Coefficient of Trend

ε_t Stationary which mean is 0, Variance is equal to σ^2 or $\varepsilon_t \sim IID$, $(0,\sigma^2)$

However, taking timeseries to findthe firstdifferenceor higher difference is shown by the difference stationarymethod as follows:

$$Y_t = Y_t - Y_{t-1}$$

Which will become the following equation:

$$\Delta Y_t = \alpha_1 + \alpha_2 T - \delta Y_{t-1} + \varepsilon_t \qquad (2.32)$$

From equation(2.32) it is found that at an increase of period at Level.IfReject H_a or Accept H_0, such data isnon–stationary, and the coefficient is $\delta = 0$ at significant level. It shows that the Tau statistics of the coefficient being calculated in the form of absolutetermhas a lower value than the DFCriticalin the form of absoluteterm. In such cases, it shows that ε_t lacks the whitenoiseattribute or that the analyzed data which is autocorrelated will require theAugmented Dickey Fuller (ADF)test with the hypothesis andgoodnessoffit to be used in the testing, just as in DickeyFuller(DF),of which the equation has been adjusted by increasing the lagged variables of thedependentvariable at a higher level to eliminate autocorrelation as follows:

Hypothesis ofUnitRootTest

H_0: $\delta = 0$, Non–stationary

H_a: $\delta < 1$,Stationary

At Level, ifReject H_0 orAccept H_a, the data isstationary, meaning the coefficient $\delta \neq 0$at significance. It shows thatthe Tau statisticsof the coefficient being calculated in the form of absolutetermhas a greater value than the DFCriticalin the form of absoluteterm. In such cases, it is found that ε_t hasthe whitenoiseattribute, or that the time series data of the variable has the stationary attribute where ΔY_t is integrated with rank d, noted as $\Delta Y_t \sim I(d)$

$$\Delta Y_t = \delta Y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta Y_{t-i+1} + \varepsilon_t \qquad (2.33)$$

$$\Delta Y_t = \alpha_1 + \delta Y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta Y_{t-i+1} + \varepsilon_t \qquad (2.34)$$

$$\Delta Y_t = \alpha_1 + \alpha_2 T + \delta Y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta Y_{t-i+1} + \varepsilon_t \qquad (2.35)$$

Where

P =LaggedValuesofFirst Differenceof theVariable

From equation(2.33),(2.34)and (2.35)it is found that the most appropriate equation which is used with real data is Augmented Dickey Fuller, in equation (2.35)

$$\Delta Y_t = \alpha_1 + \alpha_2 T + \delta Y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta Y_{t-i+1} + \varepsilon_t$$

However, the equations of DFandADFhave no difference. The ADF method is used to solveerrortermsproblem that havethe white noise attribute or to haveMean equal to 0 on the errorterm.

2.6 Co-integration

Concept to analyze correlation in long-run[131]

2.6.1 Concept of correlation in long term equilibrium

Engle and Granger (1987) developed concepts and statistical methods about long-run relationships, orcointegration. In economic and financial analysis, using time series data has been applied popularly with the following methods.

If time series Y_t and X_t has random trend, the variance of each variable will increase over time. But if both variables have gaps between each other in either form,such as if one substitutes symbol with $Y_t - \beta_2 X_t$ and the gap isstationary, or if writen as $Y_t - \beta_2 X_t \sim I(0)$, it will be called time series Y_t and X_t as equilibrium correlation in long-run.

To define $Y_t - \beta_2 X_t = u_t$ Time series Y_t and X_t has a stationary gap, it has been shown that both variables will move to the same direction together due to the fact that both time series havecommon stochastic trends, and we call it $\begin{bmatrix} 1 \\ -\beta_2 \end{bmatrix}$ (also written as $\begin{bmatrix} 1 & -\beta \end{bmatrix}'$) a Cointegrating Vector, and refer to the equation $Y_t - \beta_2 X_t = u_t$ as cointegratingregression.

u_t is used in considering variables Y and X whether t is in long-run equilibrium or not. If time series Y_t and X_t are in long-run equilibrium $Y_t - \beta_2 X_t = 0$ or $u_t = 0$, but if time series Y_t and X_t are not in long-run equilibrium, $Y_t - \beta_2 X_t \neq 0$ or $u_t \neq 0$. In this case X_t and Y_t has long-run deviationand short-term adjustment to become long-run equilibrium correction orerror correction.

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[131] Pruethsan Sutthichaimethee, "Model of Environmental Problems Priority Arising from the Useof Environmental and Natural Resources in Machinery Sectors of Thailand," Environmental and Climate Technologies 17 No.1 (1 May 2016): 18–29.

The relationship of common stochastic trends and cointegrating vectors in the equation is as follows:

To define time series Y_t and X_t in the following equations,

$$Y_t = \mu_t + \varepsilon_{Yt} \quad (2.36a)$$

$$X_t = \mu_t + \varepsilon_{Xt} \quad (2.36b)$$

Where μ_t is Random walk, and ε_{Yt} and ε_{Xt} are white noise.

From Equation (2.36a) and (2.36b) it can be shown that Y_t and X_t are random walk due to the fact that such time series depend on μ_t which is random walk. Moreover, Y_t and X_t have the common stochastic trendof μ_t

Using Equation (2.36a) and (2.36b) to find Y_t and X_t as follows:

$$\begin{aligned} Y_t - X_t &= (\mu_t - \mu_t) + \varepsilon_{Yt} - \varepsilon_{Xt} \\ &= \varepsilon_{Yt} - \varepsilon_{Xt} \end{aligned} \quad (2.37)$$

From Equation (2.37), when ε_{Yt} and ε_{Xt} are white noise,thereby $\varepsilon_{Yt} - \varepsilon_{Xt}$ is white noise. Time series $Y_t - X_t$ is static, in which the vector shows long-run equilibrium as $\begin{bmatrix} 1 \\ -1 \end{bmatrix}$ or $[1 -1]'$

If Y_t and X_t have long-run cointegration, coefficient β_t is not equal to 0, and the result will be as follows:

1. Result of line Y_t and X_t $(\beta_1 Y_t + \beta_2 X_t)$ is stationary and is referred to $[\beta_1 - \beta_2]'$ as cointegrating vector.

2. Common stochastic trend in variable X_t and Y_t is ceased.

It is shown in the model to reach Error Correction Model: ECM as follows:

$$Y_t - Y_{t-1} = \varepsilon_t + \phi_1 (Y_{t-1} - X_{t-1}) \quad (2.38a)$$

$$X_t - X_{t-1} = w_t + \phi_2 (Y_{t-1} - X_{t-1}) \quad (2.38b)$$

$\phi_1 (Y_{t-1} - X_{t-1})$ and $\phi_2 (Y_{t-1} - X_{t-1})$ are called equilibrium correction mechanisms, or error correction mechanisms, and equations (2.38a) and (2.38b) as error correction model (ECM) with the least squares method.ECM will not create spurious regression problems, as the dependent variables,independent variablesand stochastic disturbance terms or random error terms are all still.

2.6.2 Estimation of Cointegration Based on a Single Equation[132]

A method of estimating cointegration by using a single equation, as proposed by Engle and Granger (1987), can be explained as follows.

1. Analysis of the cointegration of two time series

1) Examine whether any two time series have cointegration.

Given Y_t and X_t is I(1) and has the cointegration on one another. Their cointegrating regression can be written as below.

$$Y_t = \beta X_t + \varepsilon_t \qquad (2.39)$$

Where ε_t is White Noisewith a mean of zero. The constant variance (σ^2) or ε_t ~I(0) and variable Y_t have a coeffiecient value of 1. Hence, variable Y_t is called a Normalized Variable). Equation (2.39) can rewritten as the following:

$$Y_t - \beta X_t = \varepsilon_t \qquad (2.40)$$

Here, a nomalized cointegrating vector is $\begin{bmatrix} 1 \\ -\beta \end{bmatrix}$ or $[1 - \beta]'$

Engle and Granger (1987) introduced a test of identifying the cointegration for time series Y_t and X_t by testing whether ε_t has aunit root. The testing steps go as follows:

(1) Estimate a parameter in Equation (2.39) with an OLStechnique.

(2) Calculate an error value obtained from the estimation of the regression equation (Residual: e_t) and check the value to find the presence of Unit Root. The testing result concludes that e_t has a Unit Root (e_t inconstant) indicating that variable X_t and Y_t are not cointegrated. In contrast, if e_t is found to have a unit root (e_t constant), it shows that variable X_t and Y_t have such a relationship (cointegration).

A unit root test of e_t can apply the ADFmethod, as below:

$$\Delta e_t = \psi^* e_{t-1} + \sum_{i=1}^{p-1} \psi_i \Delta e_t + \delta_0 + \delta_1 t + \omega^* < 0 \qquad (2.41)$$

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[132] Pruethsan Sutthichaimethee and Danupon Ariyasajjakorn, "Forecasting Model of GHG Emission in Manufacturing Sectors of Thailand," Journal of Ecological Engineering 18 No.1 (1 January 2017): 18–24.

Where ω_t is White Noise, a constant (δ_0) and the deterministic trend independent variable (t) construct a primary and secondary hypothesis to test wherther X_t and Y_t are cointegrated, as shown below.

$$H_0: \omega^* = 0 \text{ and} H_1 = \psi^* < 0$$

Any statistic used to testify the above hypotheses is a statistical value of *t** and has a critical value calculated based on the concepts of MacKinnon (1991, 1996)

2) Vector estimation for the cointegration

A nomalized cointegrating vector is $[1-\beta]^t$. Engle and Granger (1981) proposed to estimate a parameter β with the technique of ordinary least squares, in which the estimated value is indentified as super consistency. However, the estimated value is not normally distributed even though the sample is large. Therefore, a parameter reference cannot use critical values from table t, F, Z.

3) A short-term adaptation model to the cointegration (Error Correction Model: ECM)

Given dependent variable Y_t is affected by both past-and-present independent variables (X_t, X_{t-1} ,..., X_{t-q}) as shown below.

$$Y_t = \gamma_0 X_t + \gamma_1 X_{t-1} + \gamma_2 X_{t-2} + ... + \gamma_q X_{t-q} + u_t \qquad (2.42)$$

The equation (2.42) is called the distributed-lag model), and we can find the result of the effect in all terms; short, interim and long term, of the independent variable *X* on the dependent variable *Y*as demonstrated below.

A short-run effect of *X* on *Y* means an immediate effect occurs at the same, and it can be denoted as γ_0.

An interim effect of *X* on *Y*means an effect occurs over time, such as over 2 previous periods (*t*-2), over past 1 preiod (t-1), and a present period (*t*) interim effect can be written as $\gamma_0 + \gamma_1 + \gamma_2$.

A long-run effect of *X* on *Y*is defined as an effect of *X* over all periods on *Y*. Such an effect can be written as $\gamma_0 + \gamma_1 + \gamma_2 + ... + \gamma_q$.

Generally, as time passes, the effect of *X*will slowly influence the dependent variable, written as $\gamma_0 > \gamma_1 > ... > \gamma_q$, as in Equation (2.42). If *X* and *Y*are at the equilibrium point at 1 time period, that shows the value of *X* will not change over time. This is written as

$X_t = X_{t-1} = X_{t-2} = \ldots X_{t-q}$, and there will be no discrepancies, written as $u_t = 0$. Therefore, the cointegration of *Y* and *X*is drawn as follows.[133]

$$Y_t = \gamma_0 X_t + \gamma_0 X_t + \gamma_2 X_1 + \ldots + \gamma_q X_t$$
$$Y_t = (\gamma_0 + \gamma_1 + \gamma_2 + \ldots + \gamma_q) X_t$$

If Y_t is given to be affected by the independent variable in both past and present periods ($X_t, X_{t-1}, \ldots, X_{t-q}$) and a past value of the dependent variable ($Y_{t-1}, \ldots, Y_{t-p}$) , an equation of adjustment Y_t can be written as follows.

$$Y_t = \gamma_0 X_t + \gamma_1 X_{t-1} + \ldots + \gamma_q X_{t-q} + a_1 Y_{t-1} + \ldots + a_p Y_{t-p} + u_t \quad (2.43)$$

Equation (2.43) is a Dynamic Model or Autoregressive Model. If *Y* and *X* are at the equilibrium point of *t*, that means the value of *X* and *Y* remains unchanged over time, and it will not be any error or $X_t = X_{t-1} = \ldots = X_{t-q}$, $Y_t = Y_{t-1} = \ldots = Y_{t-p}$, and $u_t = 0$. Therefore, the cointegration of *Y* and *X* is written as below.

$$Y_t = \gamma_0 X_t + \gamma_1 X_{t-1} + \ldots + \gamma_q X_{t-q} + a_1 Y_{t-1} + \ldots + a_p Y_t$$
$$(1 - \alpha_1 - \ldots - a_p) Y_t = (\gamma_0 + \gamma_1 + \ldots + \gamma_q) X_1$$
$$Y_t = \frac{\gamma_0 + \gamma_1 \ldots + \gamma_q}{1 - \alpha_1 - \ldots - \alpha_p} X_t$$

Considering Equation (2.43), if $X_t, X_{t-1}, X_{t-2}, \ldots, X_{t-q}$ has no relationship with u_t, it shows that the variable*X*is a strongly exogenous variable, meaning that variable X_t affects Y_t. Also, $X_{t-1}, X_{t-2}, \ldots, X_{t-q}$ affect Y_t. In the meantime, time series Y_t does not affect any time series X_t. Simply put, the variable X_t will not adjust either the short or long term towards cointegration. Hence, we will not consider the ECM of time series X_t. Additionally, the autogressive model can reflect that when time series *X* and *Y* are not at long-term equilibrium, time series *Y* will adjust towards cointegration.

Thus, Equation (2.43) can be written as below when p = *1* and q = *1*.

$$Y_t = \gamma_0 X_t + \gamma_1 X_{t-1} + \alpha_1 Y_{t-1} + u_t \quad (2.44)$$

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[133] Pruethsan Sutthichaimethee and Danupon Ariyasajjakorn, "Forecast of Carbon Dioxide Emissions from Energy Consumption in Industry Sectors in Thailand," Environmental and Climate Technologies 22 No.1 (5 December 2018): 107–117.

When time series Y_t and X_t are in long-term equilibrium, this means the values of both time series remain constant. $X_t = X_{t-1}$ and $Y_t = Y_{t-1}$ have no discrepency, or $u_t = 0$. Therefore, if such a condition is integrated into Equation (2.44), we will retrieve the cointegration as expressed below.

$$Y_t = \gamma_0 X_t + \gamma_1 X_1 + a_1 Y_t$$
$$(1-\alpha_1) Y_t = (\gamma_0 + \gamma_1) X_t$$
$$Y_t = \frac{\lambda_0 + \gamma_1}{1-\alpha_1} X_t$$

Therefore, $$Y_t = \beta X_t \qquad (2.45)$$

$\beta = \frac{\gamma_0 + \gamma_1}{1-\alpha_1}$ from Equation (2.45) indicates the cointegration between time series Y_t and X_t and the normalized cointegrating vector is $[1 - \beta]$.

Considering the condition of α_1 affecting both the short and long term, Equation (2.44) can be re-expressed as follows.

$$Y_t = \gamma_0 X_t + \gamma_1 X_t + \alpha_1 L Y_t + u_t$$
$$(1-\alpha_1 L) = (\gamma_0 + \gamma_1 L) X_t + u_t$$
$$Y_t = \frac{\gamma_0 + \gamma_1 L}{1-\alpha_1 L} \varepsilon_t$$

or written as $$Y_t = \beta X_t \qquad (2.46)$$

where $\varepsilon_t = \frac{u_t}{1-\alpha_1 L}$, and L is a lag operator, expressed in the following equation.

$$Y_t = \frac{\gamma_0}{1-\alpha_1 L} X_t + \frac{\gamma_1}{1-\alpha_1 L} X_{t-1} + \varepsilon_t$$

The above equation can be written as an infinite series:

$$Y_t = \gamma_0 (1 + \alpha_1 L + \alpha_1^2 L^2 + \ldots) X_t + \gamma_1 (1 + \alpha_1 L + \alpha_1^2 L^2 + \ldots) X_{t-1} + \varepsilon_t$$
$$= \gamma_0 (X_t + \alpha_1 X_{t-1} + \alpha_1^2 X_{t-2} + \ldots) + \gamma_1 (X_{t-1} + \alpha_1^2 X_{t-3} + \ldots) + \varepsilon$$

If $0 < \alpha_t < 1$, it facilitates the determination of both the short and long term effects.

Equation (2.44) is used to construct an Error Correction Model of *Y*, and it can be seen below.

Deducting Y_{t-1} in Equation (2.44) from both sides of the equation, a new equation is written as follows.

$$Y_t - Y_{t-1} = \gamma_0 X_t + \gamma_1 X_{t-1} - Y_{t-1} + \alpha_1 Y_{t-1} + u_t$$

Adding - $-\gamma_o X_{t-1} + \gamma_0 X_{t-1}$ on the right side of the equation.

$$\Delta Y_t = \gamma_0 (X_t - X_{t-1}) + (\gamma_0 + \gamma_1) X_{t-1} - (1-\alpha_1) Y_{t-1} + u_t$$

$$\Delta Y_t = \gamma_0 \Delta X_t - (1-\alpha_1)(Y_{t-1} - \frac{\gamma_0 + \gamma_1}{1-\alpha_1} X_{t-1}) + u_t$$

$$\Delta Y_t = \gamma_0 \Delta X_t - (1-\alpha_1)(Y_{t-1} - \beta X_{t-1}) + u_t \qquad (2.47)$$

Where $\beta = \frac{\gamma_0 + \gamma_1}{1-\alpha_1}$, explaining Equation (2.47) in such a way that when Y_{t-1} is higher than ($Y_{t-1} - \beta X_{t-1} > 0$), ΔY_t is foundto be negative, reflecting that Y_t is negatively adjusted, while γ_0 is the short-term effect of *X* on *Y*.

Equation (2.43) may include a constant, as expressed below.

$$Y_t = \delta_0 + \gamma_0 X_t + \gamma_1 X_{t-1} + \alpha_1 Y_{t-1} + u_t \; Y_t = \beta X_t \qquad (2.48)$$

In this case, a cointegrating equation can be structured based on the common concept, which is $Y_t = Y_{t-1}, X_t = X_{t-1}$, and $u_t = 0$ as shown below:

$$Y_t = \delta_0 + \gamma_0 X_t + \gamma_1 X_t + \alpha_1 Y_t$$

$$(1-\alpha_1) Y_t = \delta_0 + (\lambda_0 + \gamma_1) X_t$$

$$Y_t = \frac{\delta_0}{1-\alpha_1} + \frac{\gamma_0 + \gamma_1}{1-\alpha_1} X_t$$

or rewritten as $$Y_t = u + \beta X_t \qquad (2.49)$$

Where $u = \frac{\delta_0}{1-\alpha_1}$ and $\beta = \frac{\gamma_0 + \gamma_1}{1-\alpha_1}$ we can use the same method to produce the error correction model of time series $Y_t$as below:

$$Y_t = \delta_0 + \gamma_0 X_t + \gamma_1 X_{t-1} + \alpha_1 Y_{t-1} + u_1$$

Bring Y_{t-1} to deduct from both sides of the equation;

$$Y_t - Y_{t-1} = \delta_0 + \gamma_0 X_t + \gamma_1 X_{t-1} - Y_{t-1} + \alpha_1 Y_{t-1} + u_t$$

Bring $-\gamma_0 X_{t-1} + \gamma_0 X_{t-1}$ to add to the right side of the equation;

$$\Delta Y_t = \delta_0 + \gamma_0(X_t - X_{t-1}) + (\gamma_0 + \gamma_1)X_{t-1} - (1-\alpha_1)Y_{t-1} + u_t$$

$$\Delta Y_t = \delta_0 + \gamma_0 \Delta X_t - (1-\alpha_1)(Y_{t-1} - \frac{\gamma_0 + \gamma_1}{1-\alpha_1} X_{t-1}) + u_t$$

$$\Delta Y_t = \delta_0 + \gamma_0 \Delta X_t - (1-\alpha_1)(Y_{t-1} - \beta X_{t-1}) + u_t \qquad (2.50)$$

If it is found that $u = \frac{\delta_0}{1-\alpha_1}$, hence $\delta_0 = (1-\alpha_1)u$, and if we later substitute δ_0 in Equation (2.50), we will have;

$$\Delta Y_t = \gamma_0 \Delta X_t - (1-\alpha_1)(Y_{t-1} - u - \beta X_{t-1}) + u_t \qquad (2.51)$$

Therefore, we can present a constant in the form of the normalized cointegrating vector as below:

$\begin{bmatrix} 1 \\ -u \\ -\beta \end{bmatrix}$ or $\begin{bmatrix} 1 & -u & -\beta \end{bmatrix}'$ and the constant in ECM is removed.

If it is found that $u \neq \frac{\delta_0}{1-\alpha_1}$, where $\delta_0 = u(1-\alpha_1) + \lambda$, hence substitute δ_0 into Equation (2.50), and we will obtain:

$$\Delta Y_t = \lambda + \gamma_0 \Delta X_t - (1-\alpha_1)(Y_{t-1} - u - \beta X_{t-1)} + u_t \qquad (2.52)$$

In which the constant exists in the model, the normalized cointegrating vector, $\begin{bmatrix} 1 \\ -u \\ -\beta \end{bmatrix}$ or $\begin{bmatrix} 1 & -u & -\beta \end{bmatrix}'$, and Equation (2.44) along with a deterministic trend variable. We can express the above scenario as follows:

$$\begin{bmatrix} 1 & -u & -\beta \end{bmatrix}' \qquad (2.53)$$

In the case of this cointegrating equation, it can be found with the same method, $Y_t = Y_{t-1}, X_{t-1}$ and $u_t = 0$, and that can be expressed as below:

$$Y_t = \delta_0 + \delta_1 t + \gamma_0 X_t + \alpha_1 Y_t$$

$$Y_t = \frac{'\delta_0}{1-\alpha_1} + \frac{\delta_1 t}{1-\alpha_1} + \frac{\gamma_0 + \gamma_1}{1-\alpha_1} Y_t$$

or rewritten as $$Y_t = u_0 + u_1 t + \beta X_t' \qquad (2.54)$$

where $u_0 = \frac{\delta_0}{1-\alpha_1}, u_1 = \frac{\delta_1}{1-\alpha_1}$ and $\beta = \frac{\gamma_0 + \gamma_1}{1-\alpha_1}$

Hence, we can use the same method to identify the error correction model of time series Y_1 as shown below.[134]

$$Y_t = \delta_0 + \delta_1 t + \gamma_0 X_t + \gamma_1 X_{t-1} + \alpha_1 Y_{t-10} + u_t'$$

$$Y_t - Y_{t-1} = \delta_0 + \delta_1 t + \gamma_0 X_{t-1} + \gamma_1 X_{t-1} - Y_{t-1} + \alpha_1 Y_{t-1} + u_t$$

$$\Delta Y_t = \delta_0 + \delta_1 t + \gamma_0 (X_t - X_{t-1}) + (\gamma_0 + \gamma_1) X_{t-1} - (1-\alpha_1) Y_{t-1} + u_t$$

$$\Delta Y_t = \delta_0 + \delta_1 t + \gamma_0 \Delta X_t - (1-\alpha_1)(Y_{t-1} - \frac{\gamma_0 + \gamma_1}{1-\alpha_1} X_{t-1}) + u_t'$$

$$\Delta Y_t = \delta_0 + \delta_1 t + \gamma_0 \Delta X_t - (1-\alpha_1)(Y_{t-1} - \beta X_{t-1}) + u_t \quad (2.55)$$

If it is found that $u_0 = \frac{\delta_0}{1-\alpha_1}'$ and $u_1 = \frac{\delta_1}{1-\alpha_1}'$, we will get $\delta_0 = (1-\alpha_1)u_0'$ and $\delta_1 = (1-\alpha_1)u_1'$. Therefore, when δ_0' and δ_1 are substituted into Equation (2.55), we will have:

$$\Delta Y_t = \gamma_0 \Delta X_1 - (1-\alpha_1)(Y_{t-1} - u_0 - u_1 t - \beta X_{t-1}) + u_t \quad (2.56)$$

Thus, we can write a value of constant and coefficient of the deterministic trend variable in the form of the normalized cointegrating vector as follows:

$$\begin{bmatrix} 1 \\ -u_0 \\ -u_1 \\ -\beta \end{bmatrix} \text{ or } \left[' 1 - u_0 - u_1 - \beta \right] \text{ and it does not exist in ECM}$$

But, if it is found that $u_0 \neq \frac{\delta_0}{1-\alpha_1}$ and $u_1 \neq \frac{\delta_1}{1-\alpha_1}$, which $\delta_0 = u_0(1-\alpha_1) + \lambda_0$ and $\delta_1 = u_1(1-\alpha_1) + \lambda_1$ When substituting δ_0 and δ_1 into Equation (2.55), we will have an ECMof time series $Y_t$as follows:

$$\Delta Y_t = \lambda_0 + \lambda_1 t + \gamma_0 \Delta X_t - (1-\alpha_1)(Y_{t-1} - u_0 - u_1 t - \beta X_{t-1}) + u_t \quad (2.57)$$

The value of constant and coefficient of the deterministic trend variable in the form of the normalized cointegrating vector is written as follows:

[134] Pruethsan Sutthichaimethee and DanuponAriyasajjakorn, "The revised input-output table to determine total energy content and total greenhouse gas emission factors in Thailand," Journal of Ecological Engineering 18 No.6 (1 November 2017): 166–170.

$$\begin{bmatrix} 1 \\ -u_0 \\ -u_1 \\ -\beta \end{bmatrix} \text{ or } \left[1 - u_0 - u_1 - \beta\right], \text{and it does exist in ECM}$$

In the same case of Equation (2.43) where $p = 2$ and $q = 2$, it is written as follows:

$$\Delta Y_t = \gamma_0 \Delta X_t - \gamma_2 \Delta X_{t-1} - \alpha_2 \Delta Y_{t-1} + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + u_t \qquad (2.58)$$

Equation (2.58) can be used to identify the Error Correction Model as shown below:

$$\Delta Y_t = \gamma_0 \Delta X_t - \gamma_2 \Delta X_{t-1} - \alpha_2 \Delta Y_{t-1} - (1 - \alpha_1 - \alpha_2)(Y_{t-1} - \beta X_{t-1}) + u_t \qquad (2.59)$$

Where $\beta = \dfrac{\gamma_0 + \gamma_1 + \gamma_2}{1 - \alpha_1 - \alpha_2}$

In the same flow of Equation (2.43) whose $p = 3$ and $q = 3$, it is written as follows:

$$\Delta Y_t = \gamma_0 X_t + \gamma_1 X_{t-1} + \gamma_3 X_{t-3} + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \alpha_3 Y_{t-3} + u_t' \qquad (2.60)$$

Equation (2.60) can also be used to identify ECM as follows:

$$\Delta Y_t = \gamma_0 \Delta X_t - (\gamma_2 + \gamma_3)\Delta X_{t-1} - \gamma_3 \Delta X_{t-2} - (\alpha_2 + \alpha_3)\Delta Y_{t-1} - \alpha_{3\Delta} Y_{t-2} - (1 - \alpha_1 - \alpha_2)(Y_{t-1} - \beta X_{t-1}) + u_t' \qquad (2.61)$$

Where $\beta = \dfrac{\gamma_0 + \gamma_1 + \gamma_2 + \gamma_3}{1 - \alpha_1 - \alpha_2 - \alpha_3}$

And we use Equation (2.43) to write ECMin the normal form as:

$$\Delta Y_t = \gamma_0 \Delta X_t - (\gamma_2 + \ldots + \gamma_q)\Delta X_{t-1} - (\gamma_3 + \ldots + \gamma_q)\Delta X_{t-2} - \ldots - \gamma_q \Delta X_{t-(q-1)}' - (\alpha_2 + \ldots + \alpha_p)\Delta Y_{t-1} - (\alpha_3 + \ldots + \alpha_p)\Delta Y_{t-2} - \ldots - \alpha_p \Delta Y_{t-(p-1)}' - (1 - \alpha_1 - \ldots - \alpha_p)(Y_{t-1}\beta X_{t-1}) + u_t' \qquad (2.62)$$

Where $\beta = \dfrac{\gamma_0 + \gamma_1 + \ldots + \gamma_q}{1 - \alpha_1 - \ldots - \alpha_p}'$

Thus, Equation (2.62) is constructed as follows:

$$\Delta Y_t = \gamma_0 \Delta X_t + \gamma_1^* \Delta X_{t-1} + \gamma_2^* \Delta X_{t-2} + \ldots + \gamma_{q-1}^* \Delta X_{t-(q-1)} + \alpha_1^* \Delta Y_{t-1} + \alpha_2^* \Delta Y_{t-2} + \ldots + \alpha_{p-1}^* \Delta Y_{t-(p-1)} - \alpha(Y_{t-1} - \beta X_{t-1}) + u_t \qquad (2.63)$$

Where $\gamma_1^* = -(\gamma_2 + \gamma_3 + ... + \gamma_q)$,

$\gamma_2^* = -(\gamma_3 + ... + \gamma_q)$,

.

.

$\gamma_q^* = -\gamma_q$

$\alpha_1^* = -(\alpha_2 + \alpha_3 + ... + \alpha_p)$,

$\alpha_2^* = -(\alpha_3 + ... + \alpha_p)$,

.

.

$\alpha_p^* = -\alpha_p$

and $\alpha = (1 - \alpha_1 - ... - \alpha_p)$

2. The relationship between common stochastic trend and cointegration in the case of the 3 aforementioned sets of time series.

Consider that there are two sets of time series, Y_t and X_t, whereby both series areI(1). The regression analysis can be observed below.

$$Y_t = \beta X_t + u_t \qquad (2.64)$$

Where u_t is at I(0).

Therefore, Y_t and X_t are conintegrated, and the integrating vector is

$$\begin{bmatrix} 1 \\ -\beta \end{bmatrix} \text{ or } \begin{bmatrix} 1 & -\beta \end{bmatrix}$$

If given that k is a constant, it still reflects $kY_t - k\beta X_t$ at I(0), which is $\begin{bmatrix} k \\ -k\beta \end{bmatrix}$. This is the vector indicating a number of infinitive cointegration. Yet, we need to find a normalized integrating vector $\begin{bmatrix} 1 & -\beta \end{bmatrix}$ to explain the cointegration of *Y* and*X*. In addition, such an integrating vector has to be only in one single form, $\begin{bmatrix} 1 & -\beta \end{bmatrix}$, not in the form of $\begin{bmatrix} 1 & -\gamma \end{bmatrix}$. This can be investigated as follows.

If $\begin{bmatrix} 1 & -\gamma \end{bmatrix}$ is a cointegrating vector of *Y* and*X*, an equation can be demonstrated as below.

$$Y_t = \gamma X_t + v_t \qquad (2.65)$$

Where v_t is at I(0)

When we bring deduct Equation (2.65) out of Equation (2.64), the next equation will be:

$$0 = (\beta - \gamma) X_t + (u_t - v_t)$$

Or we can rewrite it as

$$(\gamma - \beta)X_t = (u_t - v_t) \qquad (2.66)$$

Since both u_t and v_t are at I(0), $(u_t - v_t)$ has to be at I(0). When we look at X_t as I(1), the Equation (2.66) becomes true if $\beta = \gamma$.

Therefore, we can conclude that if $[1 - \beta]$ is the normalized cointegrating vector of *Y* and *X*, there will be no other forms of cointegrating vector (Uniqueness). However, if the variables are more than 3 units, it tells us that there can be a cointegrating vector of more than one form as explained below.

3. Parameter Reference for Cointegration based on Dynamic Generalized Least Squares (DGLS)

According to Engle and Granger (1987), a cointegrating vector estimation of *Y*and *X*, such as $Y_1, = \beta_0 + \beta_1 X_t + u_t$, can be completed through a method of least squares. Altough the obtained estimator has super consistency, it still does not qualify for being asymptotically normal distribution, even though the sample size is big. However, the probability distribution of the least squares estimator is not close to the normal distribution, so we cannot use *t* or *F* statistics to refer the coefficients of the cointegration.

Stock and Watson (1993) proposed an approach called "dynamic generalized least squares: DGLS). This approach allows us to increase in variables in the past, present and future of ΔX_t. Thus, the equation will be:

$$Y_t = \beta_0 + \beta_1 X_t + \sum_{j=-k}^{k} d_j \Delta X_{t-1} + v_t \qquad (2.67)$$

Where v_t is white noise, and^is a lead and lag value.

A vector estimation of Equation (2.67) with the least squares method is generally called dynamic ordinary least squares (DOLS).Such a method allows the estimator to use t or F statistics to measure the coefficients of the cointegration. If v_t is found to be autocorrelated in Equation (2.67), we need to tackle the problem by using this estimation method.

There are two ways to select the correct lead and lag values (*k**) of variable ΔX_t. The options are as follows:

1) Use the method of general to specific by determining *k* at certain higher levels and testing it for the statistical significance of the lead and lag coefficient at the final level. We

will gradually reduce the value of*k* untill we obtain the final statistically significant coefficient of lead and lag.

2) Start determining *k* at a certain level, and then estimate lead and lag, which sets Akaike (orSchwarz, orHannan-Quinn) Information Criterion to the lowest value.

2.7 Forecasting Models and Their Application

2.7.1 Autoregressive Conditional Heteroscedasticity (ARCH) Model[135]

1. Features of ARCHModel

The model of ARCHhas two main features:

1) An unexpected event (ε_t) does not depend on past unexpected events or has no serial correlation. It is equivalent to:

$$\varepsilon_t = \sigma_t v_t \qquad (2.68a)$$

v_t is white noise, with a value of zero, and variance is equal to 1, while σ_t is a parameter indicating a standard deviation of short-term unexpected events.

2) A variance of a conditional unexpected event in the quadratic form of the past unepected event is written as:

$$Var(\varepsilon_t | I_{t-1}) = \sigma_t^2 = \gamma_0 + \gamma_t \varepsilon_{t-1}^2 + \gamma_2 \varepsilon_{t-2}^2 + \ldots + \gamma_m \varepsilon_{t-m}^2 \qquad (2.68b)$$

Where I_{t-1} is the total information at *t* -1 time period, and γ_0, γ_1, ..., γ_m are the papameters $\gamma_0 > 0, \gamma_i \geq 0$ when*i*>0. This is the condition to ensure that the variance is not a positive value. However, another observation from the above equation is that at *t* -1 time period, the value of $\varepsilon_{t-1}^2, \ldots, \varepsilon_{t-m}^2$ is not a random variable anymore, but rather a constant. Hence, σ_t^2 is a certain parameter. If the squared value of a past unexpected event at *m*time period or $\{\varepsilon_{t-i}^2\}_{t=1}^m$ is getting higher, the value of $\text{var}(\varepsilon_t | I_{t-1})$ will climb up, too. In such cases, we can refer to a model aligning with Equation (2.68a) and (2.68b) as an "autoregressive conditional heteroscedastic" model at the *m*level, or ARCH(*m*). The equation of ARCH(1) can be written as follows:

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[135] Pruethsan Sutthichaimethee," Varimax Model to Forecast the Emission of Carbon Dioxide from Energy Consumptionin Rubberand Petroleum Industries Sectors in Thailand," Journal of Ecological Engineering 18 No.3 (2 May 2017): 112–117.

$$\varepsilon_t = \sigma_t v_t \tag{2.69a}$$

$$Var(\varepsilon_t | I_{t-1}) = \sigma_t^2 = \gamma_0 + \gamma_1 \varepsilon_{t-1}^2 \tag{2.69b}$$

Where $\gamma_0 > 0$ and $\gamma_t \geq 0$

Equation (2.69b) presents the short-term variance of ε_t, and that can be represented in another formula as below:

$$E(\varepsilon_t^2 | I_{t-1}) = \gamma_0 + \gamma_1 \varepsilon_{t-1}^2 \tag{2.70}$$

An unconditional mean and unconditional variance of ε_t can be estimated via the value of the double expected value.

$$E(\varepsilon_t) = E[E(\varepsilon_t | I_{t-1})] = E[\sigma_t E(v_t)] = \sigma_t E(v_t) = 0 \tag{2.71}$$

At the same time, we can look for the long-term or unconditional variance of ε_t through the following equation:

$$\begin{aligned} E(\varepsilon_t^2) &= E[E(\varepsilon_t^2 | I_{t-1})] \\ &= E[\gamma_0 + \gamma_1 \varepsilon_{t-1}^2] \\ &= \gamma_0 + \gamma_1 E(\varepsilon_{t-1}^2) \end{aligned}$$

Therefore, $Var(\varepsilon_t) = \gamma_0 + \gamma_1 Var(\varepsilon_{t-1})$

ε_t is a white noise with a constant variance, $Var(\varepsilon_t) = Var(\varepsilon_{t-1}) = \sigma^2$. This can be observed in the equation below.

$$\sigma^2 = \gamma_0 + \gamma_1 \sigma^2$$

$$\sigma^2 = \frac{\gamma_0}{1 - \gamma_1} \tag{2.72a}$$

or

$$Var(\varepsilon_t) = \frac{\gamma_0}{1 - \gamma_1} \tag{2.72b}$$

when we consider Equation (2.72a) and (2.72b), we can see that the mean and variance of long-term unexpected events are constant without any relation to previous events. Thus, it requires another condition of which $\gamma_0 > 0$ and $0 \leq \gamma_t < 1$ as to ensure that $Var(\varepsilon_t)$ is a positive value and computable.

As for the conditional mean and conditional variance, they can be found through the equation below.

$$E(\varepsilon_t | I_{t-1}) = 0$$
$$Var(\varepsilon_t | I_{t-1}) = \gamma_0 + \gamma_1 \varepsilon_{t-1}^2$$

The above equation shows that the average of short-term unexpected events is constant, but the variance depends on a previous unexpected event.

The ARCH model has an interesting point worth highlighting. If the random variable is assumed, the variance, ε_t, is ARCH (1), and that causes the time series *Y* to have the same ARCH(1) pattern. If an unexpected event grows bigger, it has a stronger effect on the variance. Hence, the positive or negative impact of shocks that affect the short-term variance in variable *Y* due to the shock, ε_t, is squared. In the real world, it affects the variance of variable *Y* differently. In addition, the time series used in ARCH has to be stationary, even though the short-term variance of Y_t is inconstant, while the long-term variance of Y_t constant.

2. An Application of ARCHwith Time Series

The application of ARCHcan be done in 4 different steps.

1) Formulate a mean equation of time series Y_t based on Box-Jenkins or regression analysis mode to obtain a no serial correlation variable. An example of mean equation in the form of a regression equation is presented below.

$$Y_t = \beta_1 + \beta_2 X_{2t} + ... + \beta_K X_{Kt} + \varepsilon_t \qquad (2.73)$$

Where $X_{1t} + X_{2t},...,X_{Kt}$ is an independent variable at *t*time period, and $\beta_1, \beta_2, ..., \beta_K$ is a parameter.

We can utilize the method of ordinary least squares to estimate the parameters in Equation (2.73), and that facilitates the calculation of Residual, e_t.

2) Use e_t of Y_t to test the ARCH model in terms of appropriateness in the application of Y_t, and that can be observed from two methods:

Method 1:Use a statistic of Ljung-Box Q or*Q(m)*ofe_t^2 , if the hypothesis is found:

If $H_0 : p_1 = p_2 = ... = p_m = 0$ is rejected, the ARCH model can be used with time series Y_t. If the hypothesis $H_0 : p_1 = p_2 = ... = p_m = 0$ is accepted, the ARCH modelshould not be integrated with time series Y_t.

Method 2: Use the following equation:

$$e_t^2 = \gamma_0 + \gamma_1 e_{t-1}^2 + \gamma_2 e_{t-2}^2 + ... + \gamma_m e_{t-m}^2 - u_t \quad (2.74)$$

Later, we do a test on the hypothesis, $H_0 : \gamma_1 = \gamma_2 = \ldots = \gamma_m = 0$, where the statistic used is $LM = NxR^2 \sim X_m^2$. This is where ^ is the number of data points used in Equation (2.74). While R^2 is the coefficient derived from Equation (2.74), or we can use F statistic to test that hypothesis. However, if the main hypothesis is rejected, the ARCH model can be applied to time series Y_t. If the main hypothesis is accepted, the ARCH model should not be used for the time series Y_t.

3) Estimate a Variance Equation of an unexpected event. If the main hypothesis in step 2 is rejected, then we will estimate the whole parameter of the average equation and variance equation simultaneously with the maximum likelihood method.

4) Check whether the ARCH model is properly built by using the following rule, which is that $\tilde{e}_t$ (standard value of e_t)must not have a relationship within, and $\tilde{e}_t^{\,2}$ (squared standard value of e_t) must not have a relationship within.

The above test can be done via the use of the statistic of Ljung-Box Q of $\tilde{e}_t$ and $\tilde{e}_t^{\,2}$, respectively. The calculation formula for a standard value of $\tilde{e}_t$ is $\tilde{e}_t = \frac{e_t}{\sigma_t}$, while σ_t can be estimated from a squared value of the forecasting value obtained from the Equation (2.74)

3. A Short-term Variance Forecast based on ARCH(1)

In the case of the ARCH(1) model, the forecasting of such variance can be done through the application of the following equation.

$$Var(\varepsilon_t | I_{t-1}) = \sigma_t^2 = \gamma_0 + \gamma_1 \varepsilon_{t-1}^2$$

Upon a condition attached, the available information at *t-1*time period or denoted as I_{t-1} has to be known in all variables since time period 1, 2, ..., until *t*-1, such as the calculation of forecasting value of the short-term variance at *t,* *t*+1, *t*+2and *t*+3 time period is shown below.

$$\hat{\sigma}_t^2 = \hat{\gamma}_0 + \hat{\gamma}_t \varepsilon_{t-1}^2$$
$$\hat{\sigma}_{t+1}^2 = \hat{\gamma}_0 + \hat{\gamma}_t \hat{\sigma}_t^2$$
$$\hat{\sigma}_{t+2}^2 = \hat{\gamma}_0 + \hat{\gamma}_t \hat{\sigma}_{t+1}^2$$
$$\hat{\sigma}_{t+3}^2 = \hat{\gamma}_0 + \hat{\gamma}_t \hat{\sigma}_{t+2}^2$$

Here, ε_{t-1}^2 has to be the value used in the parameter estimation by maximum likelihood. Therefore, the forecasting value of the short-term variance in the general form can be expressed as below.

$$\hat{\sigma}^2_{t+j} = \hat{\gamma}_0 + \hat{\gamma}_t \hat{\sigma}^2_{t+j-1} \qquad (2.75)$$

Where $\hat{\sigma}^2_{t+j-1} = \varepsilon^2_{t+j-1}$, when$j-1 < 0$ *and*$j \longrightarrow \infty$

We can calculate such forecasting value by using the following equation.

$$\hat{\sigma}^2_{t+j} = \frac{\hat{\gamma}_0}{1-\hat{\gamma}_1} \qquad (2.76)$$

2.7.2 AGeneralized Autoregressive Conditional Heteroscedasticity (GARCH) Model[136]

Based on the ARCH model, if the order mhas a higher value, it will make the parameter higher as well. Here, Bollerslev (1986) proposed a model of GARCH to reduce the parameters. The GARCH model will consider past short-term variance, and it can be symbolized as GARCH (p, m), as expressed below:

$$\varepsilon_t = \sigma_t v_t \qquad (2.77a)$$

$$Var(\varepsilon_t \left| I_{t-1}\right.) = \sigma^2_t = \gamma_0 + \sum_{t=1}^{m} \gamma_1 \varepsilon^2_t + \sum_{i=1}^{p} \theta_i \sigma^2_{t-1} \qquad (2.77b)$$

Where v_t is white noise with a mean of zero, while the variance is equal to I_t, whereas $\gamma_1, \gamma_2, \ldots, \gamma_m$ indicates the parameters of ARCH, and $\theta_1, \theta_2, \ldots, \theta_p$ shows the parameters of GARCH. If p = 0, GARCH(p,m) = GARCH(0, m) or ARCH(m).

Since σ_t^2 and σ^2_{t-t} are the parameters that do not keep information, Equation (2.77b) is written with a certain condition, as shown below.

$$E(\varepsilon^2_t) = \sigma^2_t$$

Therefore, $\varepsilon^2_t = \sigma^2_t + \eta_t$

Or rewritten as $\sigma^2_t = \varepsilon^2_t + \eta_t$

and $\sigma^2_{t-1} = \varepsilon^2_{t-i} - \eta_{t-i}$

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[136] Pruethsan Sutthichaimethee and DanuponAriyasajjakorn, "Forecasting Model of GHG Emission in Manufacturing Sectors of Thailand," Journal of Ecological Engineering 18 No.1 (1 January 2017): 18–24.

where η_t is a random variable with a mean of zero $(E(\eta_t) = 0, \quad i = 1, 2, ..., T)$

When taking σ_t^2 and σ_{t-1}^2 from the above equation to substitute into Equation (2.77b), a new equation can observed as follows.

$$\varepsilon_t^2 - \eta_t = \gamma_0 + \sum_{i=1}^{m} \gamma_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \theta_i (\varepsilon_{t-1}^2 - \eta_{t-i})$$

$$\varepsilon_t^2 = \gamma_0 + \sum_{i=1}^{m} \gamma_i \varepsilon_{t-i}^2 + \sum_{i-1}^{p} \theta_i \varepsilon_{t-i}^2 - \sum_{i=1}^{p} \theta_i \eta_{t-i} + \eta_t$$

$$\varepsilon_t^2 = \gamma_0 + \sum_{i=1}^{\max(m,p)} (\gamma_i + \theta_i) \varepsilon_{t-i}^2 - \sum_{i=1}^{p} \theta_i \eta_{t-i} + \eta_t \qquad (2.77c)$$

From Equation (2.77c), it can be noticed that the ARMA(max(*m,p*), *p)* is the GARCH, and that is a similar application of ARMAfor time series ε_t^2 . The following equation is formed to find out the long-term variance.

$$E(\varepsilon_t^2) = \gamma_0 + \sum_{i=1}^{\max(m,p)} (\gamma_i + \theta_i) E(\varepsilon_{t-i}^2)$$

Since ε_i is white noise, where the variance is constant, $E(\varepsilon_t^2) - E(\varepsilon_{t-1}^2)$, we will have:

$$Var(\varepsilon_t) - E(\varepsilon_t^2) = \frac{\gamma_0}{1 - \sum_{i=1}^{\max(m,p)} (\gamma_t + \theta_i)} \qquad (2.78)$$

When considering Equation (2.77b) and (2.78), we can conclude the following:

1. So as to ensure both short- and long-term variance to be positive, we must set a condition of $\gamma_0 > 0, \gamma_i \geq 0, \quad \theta_i \geq 0$ and $\sum_{i=1}^{\max(m,p)} (\gamma_i + \theta_i) < 1$

2. Equation (2.78) shows that the long-term variance of unexpected events (ε_t) is constant, and it does not relate to any previous unexpected events.

3. From Equation (2.77b), the short-term variance of unexpected events (ε_t) is not constant, and it is involved with previous unexpected events. The short- andlong-term variance can be calculated in the same way as in the case of ARCH, which is found to be zero in both cases. GARCH modeling is similar to ARCH modeling, but the GARCH model is used when the appropriate order of the ARCH model is found to be larger. Generally, GARCH is used only when there are orders, in which GARCH(1,1) GARCH(1,2) orGARCH (2,1). In cases of short-term variance forecasting based on the GARCH, the calculation can be derived from an estimation of Equation (2.77b). However, when the variance forecasting goes ahead, it is found that the short-term variance tends to approach the long-term variance, as evidenced by Equation (2.78).

2.7.3 Other Models used with non-stationary time series in the volatility of random variables.[137]

Other models are inclusive of models developed based on GARCHso as to ensure its appropriateness with time series, particularly in the time series of financial information.

1. A Model of GARCH in Mean (GARCH-M)

It is to bring a short-term variance of present unexpected event as a variable to explain a mean equation, and this is called GARCH in Mean (GARCH-M) Model, as shown below.

$$X_t = u + \delta \sigma_t^2 + \varepsilon_t \quad (2.79a)$$

$$e_t = \sigma_t v_t \quad (2.79b)$$

$$Var(\varepsilon_t \mid I_{t-1}) = \sigma_t^2 - \gamma_0 + \sum_{i=1}^{m} \gamma_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \theta_i \sigma_{t=i} \quad (2.79c)$$

If we use a short-term standard deviation of such an event as a measurement tool to investigate on the model's risk, the GARCH-Mcan be written as below.

$$X_t = \mu + \delta \sigma_i + \varepsilon_t \quad (2.80a)$$

$$\varepsilon_t = \sigma_t v_t \quad (2.80b)$$

$$Var(\varepsilon_t \mid I_{t-1}) = \sigma_t^2 - \gamma_0 + \sum_{i=1}^{m} \gamma_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \theta_i \sigma_{t-i}^2 \quad (2.80c)$$

If we use a natural logarithm of short-term variance of such events as a measurement tool, GARCH-M can be expressed as follows:

$$X_t = \mu + \delta \mid n(\sigma_t^2) + \varepsilon_t \quad (2.81a)$$

$$\varepsilon_t = \sigma_t v_t \quad (2.81b)$$

$$Var(\varepsilon_t \mid I_{t-1}) = \sigma_t^2 - \gamma_0 + \sum_{t=1}^{m} \gamma_i \varepsilon_{t-i}^2 + \sum_{t=1}^{p} \theta_i \sigma_{t-i}^2 \quad (2.81c)$$

2. A model with non-symmetrical event occurance by considering a volatility equation in GARCH(*p,m*)

$$Var(\varepsilon_t \mid I_{t-1}) = \sigma_t^2 - \gamma_0 + \sum_{t=1}^{m} \gamma_i \varepsilon_{t-i}^2 + \sum_{t=1}^{p} \theta_i \sigma_{t-i}^2$$

[137] Walter Enders, op.cit., pp.319-372.

The unexpected event at earlier times (ε_{t-i}), be it negative $(\varepsilon_{t-i} < 0)$ or positive $(\varepsilon_{t-i} > 0)$, will produce a symmetric effect.In reality, especially with financial time series such as the prices of financial assets, when a negative unexpected event occurs, it will reduce the financial asset price. While the unexpected event is positive, it will increase the price.Simply put, the occurrence of negative unexpected events will affect the short-term volatility of the price greater than positive unexpected events. The above scenario is then called the "leverage effect", which can be explained through the following models.

1) A Model of Threshold GARCH (TGARCH)

The TGARCH model is a model used to reflect the leverage effect, and it is written as follows.

$$Var(\varepsilon_t | I_{t-j}) = \sigma_t^2 - \gamma_0 + \sum_{t=1}^{m} \gamma_i \varepsilon_{t-i}^2 + \sum_{i=1}^{r} \delta_i d_{t-i} \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \theta_i \sigma_{t-i}^2 \qquad (2.82)$$

Where $d_{t-i} = \begin{cases} 1, \text{ when } \varepsilon_{t-i} < 0,\ i = 1,2,...,r \text{ (negative unexpected event at } t\text{-}I \text{ } timeperiod) \\ 0, \text{ when } \varepsilon_{t-i} \geq 0 \end{cases}$

2) A Model of Exponential GARCH (EGARCH)

Assume that $Z_t = \frac{\varepsilon_t}{\sigma_t}$ in which $E(z_t) = 0$ and $E\{|Z_t| - E|Z_t|\} = 0$. The EGARCH model is a model allowing one to determine function $g(z_t)$ for the leverage effect, as explained below.

$$g(z_t) = \lambda z_t + \varpi\{|z_t| - E(|z_t|)\} \qquad (2.83)$$

Where z_t is the effect of either positive or negative unexpected events affecting function $g(z_t)$ unequally.

$|z_t| - E(|z_t|)$ is the effect of either positive or negative unexpected events affecting function $g(z)$ asymmetrically, symmetrically, or it can be called the "magnitude effect."

λ *and* ω are the parameters.

The EGARCH(*p,m*) model uses function $g(z)$ to illustrate the leverage effect, and it is written as follows:

$$X_t = \mu + \varepsilon_t \qquad (2.84a)$$

$$\varepsilon_t = \sigma_t v_t \qquad (2.84b)$$

$$In(\sigma_t^2) = \gamma_0 + \sum_{i=1}^{p} \theta_i \ \ln(\sigma_{t-i}^2) + \sum_{i=1}^{m} \gamma_t g(z_{t-i}),\ \gamma_i = 1 \qquad (2.84c)$$

If Z_t is normally distributed, Equation (2.84c) can be expressed as follows:

$$In(\sigma_t^2) = \mu + \sum_{i=1}^{p} \theta_i \ \ln(\sigma_{t-i}^2) + \sum_{i=1}^{m} \gamma_t \varpi \left| \frac{\varepsilon_{t-i}}{\sigma_{t-i}} \right| + \sum_{k=1}^{r} \gamma_k \lambda \frac{\varepsilon_{t-k}}{\sigma_{t-k}} \qquad (2.84d)$$

Where $\mu = (\gamma_0 - m\omega\sqrt{2/\pi})$

3) A Model of Integrated GARCH (IGARCH)

From the model of GARCH(*p,m*), it can be observed as follows:

$$\varepsilon_t = \sigma_t v_t \qquad (2.77a)$$

$$Var(\varepsilon_t | I_{t-i}) = \sigma_t^2 = \gamma_0 + \sum_{t=1}^{m} \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \theta_i \sigma_{t-i}^2 \qquad (2.77b)$$

The short-term variance equation (2.77b) can be seen in anther equation as follows:

$$\varepsilon_t^2 = \gamma_0 + \sum_{t=1}^{\max(m.p)} (\gamma_i + \theta_i)\varepsilon_{t-i}^2 - \sum_{i=1}^{p} \theta_t(\eta_{t=i}) + \eta_t \qquad (2.77c)$$

While the long-term variance can be written as shown below:

$$Var(\varepsilon_t) = E(\varepsilon_t^2) = \frac{\gamma_0}{1 - \sum_{i=1}^{\max(m.p)} (\gamma_i + \theta_i)} \qquad (2.78)$$

When $\sum_{i=1}^{\max(m,p)} (\gamma_i + \theta_i) < 1$, the long-term variance, Var(ε_t), is a constant valued at more than zero, and that is when the unexpected event becomes($\varepsilon_t \neq 0$). The short-term variance, (σ_t^2), will gradually drop and turn into long-term variance when time passes by.

If $\sum_{i=1}^{\max(m,p)} (\gamma_t + \theta_i) = 1$ or $\sum_{i=1}^{m} \gamma_i + \sum_{i=1}^{p} \theta_i = 1$. The long-term variance, var(ε_t), is infinitive, which is when the unexpected event becomes$(\varepsilon_t \neq 0)$. The short-term variance, σ_t^2 , will not reduce, but instead increase to infinity. We then call such a modeling scenario an "Integrated GARCH (IGARCH) Model."

2.7.4 LT-ARIMAXS Model

The LT-ARIMAX Model is a model developed from the ARIMA Model consisting of exogeneous variables along with an error correction mechanism. The model is structured as shown below.[138][139]

Given a set data of time series, $\{X_T, X_{T-1}, X_{T-2}, ..., X_1\}$, which is called "information available at period $T(I_T)$", the forecast of such a time series h-ahead is calculated from an expected value of X_{T-h} under condition (I_T), which is written as follows.

$$\hat{X}_T(h) = E(X_{T+h}|I_T) = E(X_{T+h}X_1, X_1, X_2, ..., X_T)| \quad (2.85)$$

Appying the forecasting value based on Equation (2.85) will generate the mean of minimum means square Error (MSE) Forecasting, which is later to be incorporated with the model of Box-Jenkins. The error from the use of Equation (2.85) for forecasting can be calculated like below.

$$e_T(h) = X_{T+h} - \hat{X}_{T+h} \quad (2.86)$$

The variance of the error in using Equation (2.86) for forecasting is observed from the following equation:

$$Var(e_T(h)) = Var(X_{T+h} - \hat{X}_{T+h}) \quad (2.87)$$

1. A Time Series Forecast with ARMA

1) A Forecast based on AR(1)

The forecast with the use of AR(1)is written as below:

$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \varepsilon_t$$

Where $t = 1,2,\ldots T$

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[138] Pruethsan Sutthichaimethee and Boonton 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 7 No. 4 (18 December 2018): 87.

[139] Pruethsan Sutthichaimethee and KuskanaKubaha, "The Efficiencyof Long-Term Forecasting Modelon Final Energy Consumption in Thailand's PetroleumIndustries Sector: Enriching the LT-ARIMAXS Modelundera Sustainability Policy," Energies 11 No.8 (8 August 2018): 2063.

When considering at T time period, the AR(1) model can be in the following equation.

$$X_T = \alpha_0 + \alpha_1 X_{T-1} + \varepsilon_T \qquad (2.88)$$

When $X_1, X_2, ..., X_T$ is known (or denoted as I_T).

A 1- step Ahead Forecast

Based on Equation (2.88), the time seires X at $T+1$ time period can be expressed as below.

$$X_{T+1} = \alpha_0 + \alpha_1 X_T + \varepsilon_{T+1} \qquad (2.89)$$

Whereas, a 1- step ahead forecast can be retrieved from the following equation.

$$\hat{X}_T(1) = E(X_{T+1}|I_T)$$
$$= \alpha_0 + \alpha_1 E(X_T|I_T) + E(\varepsilon_{T+1}|I_T) \qquad (2.90)$$

Since $I_T = \{X_1, X_2, ..., X_T\}$ as the available information. Therefore, X_T is a constant (not a random variable). Due to the inavailability of information at T+1 time period, ε_{T+1} is still considered as a random variable identical to white noise. Hence, Equation (2.90) is written as:

$$\hat{X}_T(1) = \alpha_0 + \alpha_1 X_T \qquad (2.91)$$

While the 1-step ahead forecast error can be calculated based on the following equation.

$$e_T(1) = X_{T+1} - \hat{X}_T(1)$$
$$= \varepsilon_{T+1} \qquad (2.92)$$

Whereas the variance of such error is computed through the following equation.

$$Var(e_T(1)) = Var[\varepsilon_{T+1}] = \sigma^2 \qquad (2.93)$$

A 2-step Ahead Forecast

From Equation (2.88), the value of time series X at T+2 time period is calculated below.

$$X_{T+2} = \alpha_0 + \alpha_1 X_{T+1} + \varepsilon_{T+2} \qquad (2.94)$$

Thus, the2-step ahead forecast can be seen in the following.

$$\hat{X}_T(2) = E(X_{T+1}|I_T)$$
$$= \alpha_0 + \alpha_1 E(X_{T+1}|I_T) + E(\varepsilon_{T+2}|I_T)$$
$$= a_0 + a_1 \hat{X}_T(1) \quad (2.95)$$

The 2-step ahead forecast error can be derived from the following.

$$e_T(2) = X_{T+2} - \hat{X}_T(2)$$
$$= a_1(X_T - \hat{X}_T(1) + \varepsilon_{T+2} = \alpha_1 e_T(1) + \varepsilon_{T+2}$$
$$= \alpha_1 \varepsilon_{T+1} + \varepsilon_{T+2} \quad (2.96)$$

While the variance of the above error can be computed via the following equation.

$$Var(e_T(2)) = Var(\alpha_1 \varepsilon_{T+1} + \varepsilon_{T+2})$$
$$= \alpha_1^2 Var(\varepsilon_{T+1}) + Var(\varepsilon_{T+2}) + 2\alpha_1 Cov(\varepsilon_{T+1}, \varepsilon_{T+2})$$

As of the criterion of ε_T as a white noise, a new equation can be written as follows:

$$Var(e_T(2)) = (\alpha_1^2 + 1)\sigma^2 \quad (2.97)$$

A j-step Ahead Forecast

Based on Equation (2.88), the value of time series X at $T + j$ time period is derived from the following:

$$X_{T+j} = \alpha_0 + \alpha_1 X_{T+(j-1)} + \varepsilon_{T+j} \quad (2.98)$$

The $j-step$ ahead forecast can be derived from the flowing equation.

$$\hat{X}_T(j) = E(X_{T+j}|I_T)$$
$$= \alpha_0 + \alpha_1 E(X_{T+(j-1)}|I_T) + E(\varepsilon_{T+j}|I_T)$$
$$= \alpha_0 + \alpha_1 \hat{X}_T(j-1) \quad (2.99)$$

When $j \to \infty$, the forecasting value can be calculated as shown below.

$$X_T(j) = \frac{\alpha_0}{1-\alpha_1} \quad (2.100)$$

Equation (2.100) indicates that when the forecast goes further, the forecasting value approaches $\frac{\alpha_0}{1-\alpha_1} = E(X_t)$, that is the mean of time series X_t in the form of AR(1). While the j-step ahead forecast error and its variance can be explained as below.

$$e_T(j) = \alpha_1^{j-1}\varepsilon_{T+1} + \alpha_1^{j-2}\varepsilon_{T+2} + \ldots + \alpha_1\varepsilon_{T+j-1} + \varepsilon_{T+j} \quad (2.101)$$

$$Var(e_T(j)) = \left(\alpha_1^{2(j-1)} + \alpha_1^{2(j-2)} + \ldots + \alpha_1^2 + 1\right)\sigma^2 \quad (2.102)$$

When $j \to \infty$, the variance is written as follows:

$$Var(e_T(j)) = \frac{\sigma^2}{1-\alpha_1^2}$$

The above scenario illustrates that if we forecast further, the variance based on AR(1)is found to increase. However, if the time series X_t is stationary, $|\alpha_1| < 1$, the variance tends to get closer to a constant, $\frac{\sigma^2}{1-\alpha_1^2}$, which is the variance of time series X_t based on AR(1).

2) A Forecasting with MA(1)

The MA(1) can be expressed as below.

$$X_t = \beta_0 + \varepsilon_t + \beta_1\varepsilon_{t-1}$$

Where $t = 1,2,\ldots T$

When considering at T time period, MA(1)becomes:

$$X_T = \beta_0 + \varepsilon_T + \beta_1\varepsilon_{T-1} \quad (2.103)$$

And that provides the value of $X_1, X_2, \ldots, X_T$ and $\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_T$ (also denoted as I_T)

Therefore, $I_T = \{X_1, \ldots, X_T, \varepsilon_1, \ldots \varepsilon_T\}$

A 1-step Ahead Forecast

From Equation (2.103), the value of time series X at $T+1$ time period can be computed from the following equation.

$$X_{T+1} = \beta_0 + \varepsilon_{T+1} + \beta_1\varepsilon_T \quad (2.104)$$

Whereas the 1-step ahead forecast is computed through the following.

$$\hat{X}_T(1) = E(X_{T+1}|I_T)$$

$$= \beta_0 + E(\varepsilon_{T+1}|I_T) + \beta_1 E(\varepsilon_T|I_T) \quad (2.105)$$

Since $I_T = \{X_1,...,X_T,\varepsilon_1,..\varepsilon_T\}$, and becomes available information, $\varepsilon_T$is then not considered as a random variable, but ε_{T+1} is the random variable yet also is white noise. Therefore, Equation (2.105) can be written as:

$$\hat{X}_T(1) = \beta_0 + \beta_1\varepsilon_T \qquad (2.106)$$

The error of 1-step ahead forecast is calculated through the following.

$$e_T(1) = X_{T+1} - \hat{X}_T(1)$$
$$= \varepsilon_{T+1} \qquad (2.104)$$

And the variance of such error is computed through the equation below.

$$Var(e_T(1)) = Var[\varepsilon_{T+1}] = \sigma^2 \qquad (2.105)$$

A 2-step Ahead Forecast

Based on Equation (2.103), the value of ime series X at $T+2$ time period is derived from what is shown below.

$$X_{T+2} = \beta_0 + \varepsilon_{T+2} + \beta_1\varepsilon_{T+1} \qquad (2.106)$$

The 2-step ahead forecast is calculated through the below equation.

$$\hat{X}_T(2) = E(X_{T+2}|I_T)$$
$$= \beta_0 + E(\varepsilon_{T+2}|I_T) + \beta_1 E(\varepsilon_{T+1}|I_T) \qquad (2.107)$$

Since $I_T = \{X_1,...,X_T,\varepsilon_1,..\varepsilon_T\}$, and becomes the available information, ε_{T+1} and ε_{T+2} are the sandom variable yet white noise. Therefore, Equation (2.107) can be written as:

$$\hat{X}_T(2) = \beta_0 \qquad (2.108)$$

The error of 2-step ahead forecast can be calculated through the following.

$$e_T(2) = X_{T+2} - \hat{X}_T(2)$$
$$= \varepsilon_{T+2} + \beta_1\varepsilon_{T+1} \qquad (2.109)$$

While the variance of such error can be observed from the following.

$$Var(e_T(2)) = (1+\beta_1^2)\sigma^2 \qquad (2.110)$$

Equation (2.110) is the variance of time series X_t based on MA(1).

A j-step Ahead Forecast

According to Equation (2.103), the value of time series X at $T+j$ time period can be written as follows.

$$X_{T+j} = \beta_0 + \varepsilon_{T+1}\beta_1\varepsilon_{T+(j-1)} \qquad (2.111)$$

The j-step ahead forecast can be derived from the following equation.

$$\hat{X}_T(j) = E(X_{T+j}|I_T)$$
$$= \beta_0 + E(\varepsilon_{T+j}|I_T) + \beta_1 E(\varepsilon_{T+(j-1)}|I_T) \quad (2.112)$$

Since $I_T = \{X_1,...,X_T,\varepsilon_1,..\varepsilon_T\}$ and it is the available information, ε_{T+j} and $\varepsilon_{T+(j-1)}$ are the white noise. Hence, Equation (2.112) is written as the following.

$$\hat{X}_T(j) = \beta_0 \qquad (2.113)$$

While the j-step ahead forecasterror can be seen from the equation below.

$$e_T(j) = X_{T+j} - \hat{X}_T(j)$$
$$= \varepsilon_{T+j} + \beta_1\varepsilon_{T+(j-1)} \qquad (2.114)$$

And, the variance of such error can be retrieved from the equation below.

$$Var(e_T(j)) = (1+\beta_1^2)\sigma^2 \qquad (2.115)$$

From Equation (2.108) and (2.113), they show that the time series in the form of MA(1) will have a forecasting value 2-step ahead. j $\geq$ 2 is constant and equivalent to β_0, and that is the mean of time series according to MA(1), while Equation (2.110) and (2.115) use the time series in the form of MA(1), and their variance of errors is constant and equivalent to $(1+\beta_1^2)\sigma^2$. Hence, it is the variance of MA(1).

When using the same method to forecast time series based on MA(q), the conclusion is similarily drawn. That is when the forecast goes further since $q+1$ time period, it is found that the forecasting value is the mean of time series based on MA(q), and that is β_0 while the variance of the error is equivalent to the variance of MA(q), which is $(1+\beta_1^2+\beta_2^2++...+\beta_q^2)\sigma^2)$.

3) Forecast Based on ARMA(1,1)

Considering the model of ARMA(1,1), the following is its equation form.

$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \varepsilon_t - \beta_1 \varepsilon_{t-1}$$

Where $t = 1,2,\ldots T$

When taking at T time period into account, the ARMA(1,1) can be written like the following.

$$X_T = \alpha_0 + a_1 X_{T-1} + \varepsilon_T - \beta_1 \varepsilon_{T-1} \qquad (2.116)$$

When we know the value of $X_1, X_2, \ldots, X_T$ and $\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_T$ (or denoted as I_T)

A 1-step Ahead Forecast

In Equation (2.116), the value of time series X at $T+1$ time peiod can be expressesed like below.

$$X_{T+1} = \alpha_0 + a_1 X_T + \varepsilon_{T+1} - \beta_1 \varepsilon_T \qquad (2.117)$$

The 1-step ahead forecast can be computed with the following equation.

$$\hat{X}_T(1) = E(X_{T+1} | I_T \qquad (2.118)$$

Since $I_T = \{X_1, \ldots, X_T, \varepsilon_1, \ldots, \varepsilon_T\}$, which is the known information. Hence, X_T and ε_T are the certain constant (it is not random variable anymore), while ε_{T+1} is still the random variable in the form of white noise. Thus, Equation (2.118) can also be written as follows:

$$\hat{X}_T(1) = \alpha_0 + a_1 X_{T-1} - \beta_1 \varepsilon_T \qquad (2.119)$$

The errors of 1-step ahead forecast can be calculated by using the following equation.

$$\begin{aligned} e_T(1) &= X_{T+0} - \hat{X}_T(1) \\ &= \varepsilon_{T+1} \end{aligned} \qquad (2.120)$$

Whereas the variance of 1-step ahead forecast can be computed from the following.

$$Var(e_T(1)) = Var[\varepsilon_{T+1}] = \sigma^2 \qquad (2.121)$$

A 2-step Ahead Forecast

From Equation (2.116), the value of time series X at $T+2$ time peiod can be written as follows:

$$X_{T+2} = \alpha_0 + a_1 X_{T+1} + \varepsilon_{T+2} - \beta_1 \varepsilon_{T+1} \qquad (2.122)$$

Whereas the 2-step ahead forecast can be computed with the following equation.

$$\begin{aligned} \hat{X}_T(2) &= E(X_{T-2} | I_T) \\ &= \alpha_0 + a_1 E(X_{T+1} | I_T) + E(\varepsilon_{T+2} | I_T) - \beta_1 E(\varepsilon_{T+1} | I_T) \\ &= \alpha_0 + a_1 \hat{X}_T(1) \end{aligned} \qquad (2.123)$$

The errors of 2-step ahead forecast can be calculated by using the following equation.

$$\begin{aligned} e_r(2) &= X_{T+2} - \hat{X}_T(2) \\ &= \alpha_1 \left(X_{T+1} - \hat{X}_T(1) \right) + \varepsilon_{T+2} + \beta_1 \varepsilon_{T+1} \\ &= \alpha_1 e_T(1) + \varepsilon_{T+2} - \beta_1 \varepsilon_{T+1} \end{aligned}$$

In the meantime, the variance of 2-step ahead forecast can be computed as follows:

$$\begin{aligned} Var(e_T(2)) &= a_1^2 Var(e_T(1)) + Var(\varepsilon_{T+2}) + \beta_1^2 Var(\varepsilon_{T+1}) \\ &= \alpha_1^2 \sigma^2 + \sigma^2 + \beta_1^2 \sigma^2 \\ &= (1 + \alpha_1^2 + \beta_1^2) \sigma^2 \end{aligned} \qquad (2.124)$$

A j-step Ahead Forecast

From Equation (2.116), the value of time series X at $T+j$ time peiod can be seen as illustrated below.

$$X_{T+j} = \alpha_0 + \alpha_1 X_{T+(j-1)} + \varepsilon_{T+j} - \beta_1 \varepsilon_{T+(j-1)} \qquad (2.125)$$

The j-step ahead forecast can be observed with the following equation.

$$\begin{aligned} \hat{X}_T(j) &= E(X_{T+j} | I_T) \\ &= \alpha_0 + \alpha_1 E(X_{T+j} | I_T) + E(\varepsilon_{T+j} | I_T) - \beta_1 E(\varepsilon_{T+(j-j)} | I_T) \\ &= \alpha_0 + \alpha_1 \hat{X}_T(j-1) \end{aligned} \qquad (2.126)$$

And when $j \to \infty$, then the forecast is calculated from the following equation.

$$\hat{X}_T(j) = \frac{\alpha_0}{1-\alpha_1} \qquad (2.127)$$

Equation (2.127) illustrates that when we forecast futher, the forecasting value keeps close to $\frac{\alpha_0}{1-\alpha_1} = E(X_t)$, and the mean of the time series X_t in the form of ARMA (1,1), while the j-step ahead forecasterror and its variance can be demonstrated in the following equation.

$$e_T(j) = \alpha_1^{j-1}\varepsilon_{T+1} + \alpha_1^{j-2}\varepsilon_{T+2} + ... + \alpha_1\varepsilon_{T+j-1} + \alpha_{T+j}$$
$$- \beta_1\{\alpha_1^{j-1}\varepsilon_T + \alpha_1^{j-2}\varepsilon_{T+j} + ... + \alpha_1\varepsilon_{T+j-2} + \varepsilon_{T+j-1}\} \quad (2.128)$$

$$Var(e_T(j)) = (1+\beta_1^2)\left(\alpha_1^{2(j-1)}\alpha_1^{2(j-2)} + ... + \alpha_1^2 + 1\right)\sigma^2 \qquad (2.129)$$

That means the further we forecast, the higher a variance of forecasting error for ARMA(1,1) will get.

From Equation (2.129), when $j \to \infty$, that produces $Var(e_T(j)) = \frac{(1+\beta_1^2)\sigma^2}{\left(1-\alpha_1^2\right)}$

And that means the further we forecast, the higher a variance of forecasting error for ARMA(1,1) to reach this constant value of $\frac{(1+\beta_1^2)\sigma^2}{\left(1-\alpha_1^2\right)}$ whenever the time series X_t becomes stationary due to $|\alpha_1| < 1$. Moreover, this constant is a combination of the error variance of the AR(1) model and the MA (1) model.

4) A Forecasting with ARMA(p, q)

Considering ARMA(p, q) is written like below.

$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + ... + \alpha_p X_{t-p} + \varepsilon_t - \beta_2\varepsilon_{t-2} - ... - \beta_q\varepsilon_{t-q}$$

Where $t = 1,2,...T$, if we consider at T time period, the model of ARMA(p, q)is written as:

$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \alpha_2 X_{T-2} + ... + \alpha_p X_{T-p} + \varepsilon_T - \beta_1\varepsilon_{t-1} - \beta_2\varepsilon_{t-2} - ... - \beta_q\varepsilon_{T-q} \quad (2.130)$$

or can be expressed in another equation as:

$$a(L)X_T = a_0 + \beta(L)\varepsilon_T \qquad (2.131)$$

Where $\alpha(L) = 1 - \alpha_1 L - \alpha_2 L - ... + \alpha_p L^p$ and $\beta(L) = 1 - \beta_1 L - \beta_2 L - ... + \beta_q L^q$. The available data at T time period can be displayed as $I_T = \{X_1,...,X_T, \varepsilon_1,...,\varepsilon_T\}$, and Equation (2.130) will give the value of X_{T+1} and X_{T+2} as follows.

$$X_{T+1} = a_a + a_1 X_T + a_2 X_{T-1} + ... + a_p X_{T+(1-p)} + \varepsilon_{T+1} - \beta_1 \varepsilon_T - \beta_2 \varepsilon_{T-1} = ... - \beta_q \varepsilon_{T+(1-q)}$$

$$X_{T+2} = a_a + a_1 X_{T+1} + a_2 X_T + ... + a_p X_{T+(2-p)} + \varepsilon_{T+2} - \beta_1 \varepsilon_{T+1} - \beta_2 \varepsilon_T - ... - \beta_q \varepsilon_{T+(2-q)}$$

A forecasting of time series ahead 1 and 2 time period based on ARMA(p, q) is written as follows:

$$\hat{X}_T(1) = E(X_{T+1} | I_T)$$

$$= a_0 + a_1 X_T + a_2 X_{T-1} + ... + a_p X_{T+(1-p)} - \beta_1 \varepsilon_T - ... - \beta_q E_{T+(1-q)}$$

$$\hat{X}_T(2) = E(X_{T+2} | I_T)$$

$$= a_0 + a_1 \hat{X}_T(1) + a_2 X_T + ... + a_p X_{T-(p-2)} - \beta_2 \varepsilon_T - ... - \beta_q E_{T+(2-q)}$$

And it can be displayed in the general form is X_{T+j} , as shown below.

$$X_{T+j} = a_a + a_1 X_{T+(j-j)} + ... + a_p X_{T+(j-P)}) + \varepsilon_{T+j} - \beta_1 \varepsilon_{T+(j-1)} - ... - \beta_q \varepsilon_{T+(j-q)} \quad (2.132)$$

And the prediction of prior to j time period is generally formed as follows:

$$\hat{X}_T(j) = E(X_{T+j} | I_T)$$

$$= \alpha_0 + \sum_{i=1}^{p} \alpha_i \hat{X}_T(j-i) - \sum_{i=1}^{q} \beta_i \varepsilon_T(j-i) \quad (2.133)$$

Where $\hat{X}_T(j-i) = X_{T+(j-i)}$ when $j = i \le 0$

$$\varepsilon_T(j-i) = \begin{cases} \varepsilon_{T+(j-i)}, \text{if } j-i \le 0 \\ 0, \text{if } j-i > 0 \end{cases}$$

Additionally, we can do an examination similar to the case of ARMA(1,1), when $j \to \infty$, and the forecasted value is computed through the following equation.

$$\hat{X}_T(j) = \frac{\alpha_0}{1 - \alpha_1 - ... - \alpha_p} \quad (2.134)$$

Equation (2.134) means that when forecasting keeps a distance, the forecasted value will approach closely to $\frac{\alpha_0}{1 - \alpha_1 - ... - \alpha_p} = E(X_t)$, which is the same as time series X_t in the form ofARMA(p, q), whereas an error of the forecasting j at ahead time period can be easily done when revising ARMA(p, q)into MA(∞), as explained below.

Since time series X_t is stationary, Equation (2.131) can be revised as:

$$X_T = \frac{\alpha_0}{\alpha(L)} + \frac{\beta(L)}{\alpha(L)}\varepsilon_T \qquad (2.135)$$

When considering $\frac{\alpha_0}{\alpha(L)} + \frac{\alpha_0}{1-\alpha_1-\ldots-\alpha_p} = E(X_t)$, which is the average, while considering $\frac{\beta(L)}{\alpha(L)}\varepsilon_T$, we can see the relationship of variable ε_T. Therefore, $\frac{\beta(L)}{\alpha(L)}\varepsilon_T = \frac{1-\beta_1 L-\ldots-\beta_q L}{1-\alpha_1 L-\ldots-\alpha_p L}\varepsilon_T$, and it is not constant.

If giving $\frac{\alpha_0}{\alpha(L)} = \mu$

and $\frac{\beta(L)}{\alpha(L)} = \varphi(L) = 1 + \varphi_1 L + \varphi_1^2 L^2 + \ldots$ (2.136)

Hence, Equation (2.135) showing of ARMA (p,q) can be restructured to MA(∞) as follows.

$$X_T = u + \varepsilon_T + \varphi_1\varepsilon_{T-1} + \varphi_2\varepsilon_{T-2} + \ldots \quad (2.137)$$

Or written as

$$X_T = u + \varphi(L)\varepsilon_T \qquad (2.138)$$

We call $\varphi_i (i = 1,2,\ldots)$ as an impulse response function of ARMA. The time series X_t becomes stationary and obtains $\varphi_1, \varphi_2, \varphi_3, \ldots$exponentially decreasing when, as time passes, an unexpected situation occurs at present, where it will reduce the effect on time series X_t. We can use Equation (2.137) to estimate j-step ahead forecast error and its variances as follows:

From Equation (2.137), time series X_{T+1}, X_{T+2}, and X_{T+3} can be explained as follows.

$$X_{T+1} = u + \varepsilon_{T+1} + \varphi_1\varepsilon_T + \varphi_2\varepsilon_{T-1} + \ldots$$
$$X_{T+2} = u + \varepsilon_{T+2} + \varphi_1\varepsilon_{T+1} + \varphi_2\varepsilon_T + \varphi_3\varepsilon_{T-1} + \ldots$$
$$X_{T+3} = u + \varepsilon_{T+3} + \varphi_1\varepsilon_{T+2} + \varphi_2\varepsilon_{T+1} + \varphi_3\varepsilon_T + \varphi_4\varepsilon_{T-1} + \ldots$$

And the forecasted value ahead 1, 2 and 3 time period is

$$\hat{X}_T(1) = E(X_{T+1}|I_T) = u + \varphi_1\varepsilon_T + \varphi_2\varepsilon_{T-1} + \ldots$$
$$\hat{X}_T(2) = E(X_{T+2}|I_T) = u + \varphi_2\varepsilon_T + \varphi_3\varepsilon_{T-1} + \ldots$$

$$\hat{X}_T(3) = E(X_{T+3}|I_T) = u + \varphi_3\varepsilon_T + \varphi_4\varepsilon_{T-1} + ...$$

And the error of such a forecasting (ahead 1, 2 and 3 time period) is

$$e_T(1) = X_{T+1} - \hat{X}_T(1) = \varepsilon_{T+1}$$
$$e_T(2) = X_{T+2} - \hat{X}_T(2) = \varepsilon_{T+2} + \varphi_1\varepsilon_{T+1}$$
$$e_T(3) = X_{T+3} - \hat{X}_T(3) = \varepsilon_{T+3} + \varphi_1\varepsilon_{T+2} + \varphi_2\varepsilon_{T+1}$$

And the variance of such a forecasting is

$$Var(e_T(1)) = \sigma^2$$
$$Var(e_T(2)) = (1+\varphi_1^2)\sigma^2$$
$$Var(e_T(3)) = (1+\varphi_1^2+\varphi_2^2)\sigma^2$$

Therefore, the error and variance of forecasting ahead at j time period are written as

$$e_T(j) = \varepsilon_{T+j} + \varphi_1\varepsilon_{T+(j-1)} + \varphi_2\varepsilon_{T+(j-2)} + ... + \varphi_{j-1}\varepsilon_{T+1} \quad (2.139a)$$
$$Var(e_T(j) = (1+\varphi_1^2+\varphi_2^2+...\varphi_{j-1}^2)\sigma^2 \quad (2.139b)$$

2. Time Series Forecasting with ARIMA Model

Differentiating at d level with non-stationary time series makes the time series stationary.Applying such a differential series at d into the model of Box-Jenkins is known as ARIMA Model (*p, d, q*)

Given that X_t is a non-stationary time series, where $Z_t = \Delta X_t = X_t - X_{t-1}$, and that it is a stationary time series, while the right model for time series X_t is the ARIMA Model (1,1,0). This can be written in the following form.

$$\Delta X_t = \alpha_0 + \alpha_1\Delta X_{t-1} + \varepsilon_t \qquad \text{where } t = 1,2,...T \qquad (2.140a)$$

Or rewritten as:

$$Z_t = \alpha_0 + \alpha_1 Z_{t-1} + \varepsilon_t \quad \text{where } t = 1,2,...T \qquad (2.140b)$$

If we consider at *T* time period, the ARIMAModel (1,1,0)becomes

$$Z_T = \alpha_0 + \alpha_1 Z_{T-1} + \varepsilon_T \qquad (2.141)$$

And we get to know the value of $X_1, X_2, ..., X_T$ (also denoted as I_T)

When using Equation (2.141), we can estimate a forecasted value of $\hat{Z}_{T+1}, \hat{Z}_{T+2}, \hat{Z}_{T+3}$ from the following equation.

$$\left.\begin{aligned} \hat{Z}_{T+1} &= \alpha_0 + \alpha_1 \Delta X_T \\ \hat{Z}_{T+2} &= \alpha_a + \alpha_1 \Delta \hat{X}_{T-1} \\ \hat{Z}_{T+3} &= \alpha_0 + \alpha_1 \Delta \hat{X}_{T+2} \\ &\vdots \\ \hat{Z}_{T+j} &= \alpha_0 + \alpha_1 \Delta \hat{X}_{T+(j-1)} \end{aligned}\right\} \qquad (2.142)$$

The forecasted value retrieved from ARIMA (*1,1,0*)as Equation *(*2.141*)* will be in the differential form at level *1 (*I=1*)*, $\hat{Z}_{T+j} = \Delta \hat{X}_{T+j}$, but if we want to forecast a value of time series $\hat{X}_{T+j}$, it can be done through the following consideration.

Since
$$\hat{Z}_{T+1} = \hat{X}_{T+1} - \hat{X}_T \qquad (2.143a)$$
$$\hat{Z}_{T+2} = \hat{X}_{T+2} - \hat{X}_{T+1} \qquad (2.143b)$$
$$\hat{Z}_{T+3} = \hat{X}_{T+3} - \hat{X}_{T+2} \qquad (2.143c)$$
$$\vdots$$
$$\hat{Z}_{T+j} = \hat{X}_{T+j} - \hat{X}_{T+j} \qquad (2.143d)$$

Based on Equation(2.143a), it can be observed that $\hat{X}_T$ does not require forecasting, because we know its real data, which is X_T. Thefore, the forecasted value of $\hat{X}_{T+1}$ can be calculated from the equation below.

$$\hat{X}_{T+1} = X_T + \hat{Z}_{T+1} \qquad (2.144a)$$

While the forecasted value of $\hat{X}_{T+2}$, $\hat{X}_{T+3}$, ... $\hat{X}_{T+j}$ is calculated through the following equation.

$$\hat{X}_{T+2} = X_T + \hat{Z}_{T+1} + \hat{Z}_{T+2} \qquad (2.144b)$$
$$\hat{X}_{T+3} = X_T + \hat{Z}_{T+1} + \hat{Z}_{T+2} + \hat{Z}_{T+3} \qquad (2.144c)$$
$$\vdots$$
$$\hat{X}_{T+j} = X_T + \sum_{k=1}^{j} \hat{Z}_{T+k} \qquad (2.144d)$$

Another method of forecasting values of $\hat{X}_{T+1}, \hat{X}_{T+2}$,...is from the ARIMA Model (1,1,0), and that can be done via a new stipulation of Equation (2.140a)as shown below.

$$X_t - X_{i-1} = \alpha_0 + \alpha_1(X_{t-1} - X_{t-2}) + \varepsilon_t$$
$$X_t = \alpha_a + (\alpha_1 + 1)X_{t-1} - \alpha_1 X_{t-2} + \varepsilon_t \text{ where } t = 1,2,\ldots T \quad (2.145)$$

Or can be rewritten as:

$$X_t = \varphi_0 + \varphi_1 X_{t-1} + \varphi_2 X_{t-2} + \varepsilon_t \text{ where } t = 1,2,\ldots T \quad (2.146)$$

In which $\varphi_0 = \alpha_0, \varphi_1 = \alpha_1, \varphi_2 = -\alpha_1$, and that can calculate the forecasted value of $\hat{X}_{T+j}$ by using Equation (2.146)in producing the same result. In terms of estimating a forecasting error and its variances, it is shown that the variances tend to increase, deviating from any constant due to the non-stationary nature of time series X_t.

As with the forecasting based on the ARIMA Model (p,1,q), we can apply the concept of Equation (2.144)or (2.146), but the stipulation of the equations become more complex, as seen below.

Assuming that ARIMA(p,1,q)is as follows:

$$\Delta X_t = \alpha_0 + \alpha_1 \Delta X_{t-1} + \alpha_2 \Delta X_{t-2} + \ldots + \alpha_p \Delta X_{t-p} + \varepsilon_t - \beta_1 \varepsilon_{t-1} - \beta_2 \varepsilon_{t-2} - \ldots - \beta_1 \varepsilon_{t-q}$$
$$X_t - X_{t-1} = a_a + a_1(X_{t-1} - X_{t-2}) + a_2(X_{t-2} - X_{t-3}) + \ldots + a_p(X_{t-p} - X_{t-p-1}) + \varepsilon_t - \beta_t \varepsilon_{t-1} - \beta_2 \varepsilon_{t-2} - \ldots - \beta_1 \varepsilon_{t-q}$$
$$X_t = \alpha_0 + (\alpha_1 + 1)X_{t-1} + (\alpha_2 - \alpha_1)X_{t-2} + (\alpha_3 - \alpha_2)X_{t-3} + \ldots + (\alpha_p - \alpha_{p-1})X_{t-p} - \alpha_p X_{t-p-1} + \varepsilon_t - \beta_1 \varepsilon_{t-1} - \beta_2 \varepsilon_{t-2} - \ldots - \beta_{1\varepsilon_{t-q}}$$

Hence, the LT-ARIMAXS model can be written below.

$$X_t = \varphi_0 + \varphi_1 X_{t-1} + \varphi_2 X_{t-2} + \varphi_3 X_{t-3} + \ldots + \varphi_p X_{t-p} + \varphi_{p+1} X_{t-p-1} + \varepsilon_t - \beta_1 \varepsilon_{t-1} - \beta_2 \varepsilon_{t-2} - \ldots - \beta_1 \varepsilon_{t-q} + \sum_{i=1}^{p} Y_{t-i} + \sum_{i=1}^{p} ECT_{t-i} \quad (2.147)$$

Let $\varphi_0 = \alpha_0, \varphi_1 = \alpha_1 + 1, \varphi_j = \alpha_{j-1}, \varphi_{p+1} = -\alpha_p$, $\sum_{i=1}^{p} Y_{t-i}$ = exogeneous variables, which are stationary at the level and $\sum_{i=1}^{p} ECT_{t-i}$ = the error correction mechanism test.

Equation (2.147) indicates the components of the LT-ARIMAXS model comprised of: (1) Autoregressive variables (AR); (2) Moving Average (MA); (3) exogenous variables ($\sum_{i=1}^{p} Y_{t-i}$); and (4) error correction mechanism $\sum_{i=1}^{p} ECT_{t-i}$. The LT-ARIMAXS model is built and developed with the assurance of being Heteroskedasticity, Multicollinearity, and Autocorrelation free. There is

also an analysis of period identification with the Q-statistics test as to ensure that the model is not spurious while it becomes efficient in the forecasting with fewer errors. The model is then able to be applied in a different context and management policy.

2.7.5 VARIMAX-ECM Model[140]

The VARIMAX-ECM model isa new model adapted from the vector autoregressive model, incorporating influential variables in both short-term and long-term relationships so as to produce the best prediction model with the maximum performance and least error.

In this section, we consider the segment of the deterministic component in a time series of the VAR model.In order to simplify the concept for a better understanding, we consider the VAR model as follows:

$$X_t = A_1 X_{t-1} + \mu_0 + \mu_1 t + u_t \qquad (2.148)$$

where μ_0 is the vector of the parameter representing a constant value in theVAR(p) model, μ_1 is the vector of the parameter indicating a defined trend in the VAR(p) model, and vectors μ_0 and μ_1 are shown below:

$$\mu_0 = \begin{bmatrix} \mu_{01} \\ \mu_{02} \\ \vdots \\ \mu_{0n} \end{bmatrix}_{nx1} \quad \text{and} \quad \mu_1 = \begin{bmatrix} \mu_{11} \\ \mu_{12} \\ \vdots \\ \mu_{1n} \end{bmatrix}_{nx1}$$

When vectors μ_0 and μ_1 are not zero, Equation (2.148) reflects that at least one time series in the VAR (1)model must be a deterministic component, in which it can either be a constant or a defined trend, or both forms. The above VAR(p) model can be converted into the VARIMAX-ECM model as shown below:

$$\Delta X_t = \alpha\beta' X_{t-1} + \mu_0 + \mu_1 t + u_t \qquad (2.149)$$

From the above equation, it can be observed that vectors μ_0 and μ_1 exist in both the VAR and VARIMAX–ECM models, and that both ΔX_t and $\beta' X_{t-1}$ have to be stationary in the deterministic area.

However, to observe a deviation out of the long-term co-integration of *j* (*j=1, 2, ..., r*) denoted as vector $\beta' X_{t-1}$, the mean of the above deviation must be zero. In order to obtain such a

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[140] Pruethsan Sutthichaimethee and Kuskana Kubaha, "A Relational Analysis Modelof the Causal Factors Influencing CO_2 in Thailand's Industrial Sectorundera Sustainability Policy Adapting the VARIMAX-ECMModel,"Energies 11 No.7 (1 July 2018): 1704.

result, the deterministic component must be eliminated from the deviation out of long-term balance $(\beta' X_{t-1})$ by separating vectors μ_0 and μ_1 in the VARIMAX-ECM model, as illustrated in Equation (2.150), and by combining them into $\beta' X_{t-1}$ as explained below.

Vector μ_0 and vector μ_1 can be separated into the sum of the two vectors by using the following equation:

$$\alpha(\beta'\alpha)^{-1}\beta' + \beta_\perp(\alpha'_\perp\beta_\perp)^{-1}\alpha'_\perp = I \qquad (2.150)$$

Where $\beta_\perp$ and $\alpha_\perp$ are the orthogonal matrices with β and α , respectively. Here, it is seen that $\beta'\beta_\perp = 0$ and $\alpha'\alpha_\perp = 0$.

When we multiply vector μ_0 with Equation (2.150), the result is obtained from:

$$\alpha(\beta'\alpha)^{-1}\beta'\mu_0 + \beta_\perp(\alpha'_\perp\beta_\perp)^{-1}\alpha'_\perp\mu_0 = \mu_0 \qquad (2.151)$$

If given:

$$\beta_0 = (\beta'\alpha)^{-1}\beta'\mu_0 \qquad (2.152)$$

$$\gamma_0 = \beta_\perp(\alpha'_\perp\beta_\perp)^{-1}\alpha'_\perp\mu_0 \qquad (2.153)$$

We substitute Equations (2.152) and (2.153) into Equation (2.151), we obtain:

$$\mu_0 = \alpha\beta_0 + \gamma_0 \qquad (2.154)$$

At the same time, if we use vector μ_1 to multiply with Equation (2.150), obtaining:

$$\mu_1 = \alpha\beta_1 + \gamma_1 \qquad (2.155)$$

where $\beta_1 = (\beta'\alpha)^{-1}\beta'\mu_1$ and $\gamma_1 = \beta_\perp(\alpha'_\perp\beta_\perp)^{-1}\alpha_1\mu_1$.

If we substitute Equations (2.154) and (2.155) into Equation (2.149), we obtain:

$$\Delta X_t = \alpha\beta' X_{t-1} + \alpha\beta_0 + \alpha\beta_1 t + \gamma_0 + \gamma_1 t + \mu_t \qquad (2.156)$$

Equation (2.156)can be restructured as follows:

$$\Delta X_t = \alpha(\beta' X_{t-1} + \beta_0 + \beta_1 t) + \gamma_0 + \gamma_1 t + \mu_t \qquad (2.157)$$

where ΔX_t is the $n \times 1$ vector, X_t is the $n \times 1$ vector, α is the $n \times r$ matrix, and $\beta$is the $n \times r$ matrix. β_0 is the $r \times 1$ matrix, β_1 is the $r \times 1$matrix, γ_0 is the $n \times 1$ matrix, γ_1 is the $n \times 1$ matrix, and μ_t is the $n \times 1$ matrix. n is the number of time series in vector X_t .

Equation (2.157) shows that if vector X_t determines $(\mu_0 + \mu_1 t)$, there is a possibility that the ARIMAX-ECM model determines $(\gamma_0 + \gamma_1 t)$ and the long-term co-integration detemines $(\beta_0 + \beta_1 t)$. In addition, Equation (2.157) can be rewritten as:

$$\Delta X_t = \alpha \begin{bmatrix} \beta' & \beta_0 & \beta_1 \end{bmatrix}_{r\times(n+2)} \begin{bmatrix} X_{t-1} \\ 1 \\ t \end{bmatrix}_{(n+2)\times 1} + \gamma_0 + \gamma_1 t + \mu_t \qquad (2.158)$$

Let $\widetilde{\beta}' = \begin{bmatrix} \beta' & \beta_0 & \beta_1 \end{bmatrix}$, $\widetilde{X}_{t-1} = \begin{bmatrix} X_{t-1} & 1 & t \end{bmatrix}'$, and we can then structure another equation as:

$$\Delta X_t = \alpha \widetilde{\beta}' \widetilde{X}_{t-1} + \gamma_0 + \gamma_1 t + u_t \qquad (2.159)$$

The above equation contains the following characteristics:

$$E(\Delta X_t) = \gamma_0 + \gamma_1 t \,,\; E(\widetilde{\beta}' \widetilde{X}_{t-1}) = 0 \qquad (2.160)$$

Moreover, Equation (2.159) explains the connection between the deterministic area of the VARIMAX-ECM model and the long-term co-integrating vector, which can be classified into five situations.

Situation 1:If $\gamma_0 = \gamma_1 = \beta_0$ (or $\mu_0 = \mu_1 = 0$) for both the VARIMAX-ECM model and the long-term co-integrating vector (deviation out of long-term balance), they not deterministic or can be expressed as $E(\Delta X_t) = 0$ and $E(\beta' \widetilde{X}_{t-1}) = 0$.Therefore, the VARIMAX-ECM model in this position is:

$$\Delta X_t = \alpha \beta' X_{t-1} + u_t \qquad (2.161)$$

The case of $\mu_0 = \mu_1 = 0$ indicates a time series in vector X_t and is not deterministic (it is not constant nor a defined trend) in the equation.

Situation 2: If $\gamma_0 = 0$, $\gamma_1 = \beta_1 = 0$ (or $\mu_1 = 0$) but $\beta_0 \neq 0$, then the vector of the long-term co-integration reflects a constant value ($\beta_0 \neq 0$)or can be written as $E(\beta' X_{t-1}) = \beta_0$. Meanwhile, the VARIMAX-ECM model is not deterministic at all or can be written as $E(\Delta X_t) = 0$. In order to remove the constant value out of the long-term co-integration, the VARIMAX-ECM model must be in the form of:

$$(\Delta X_t) = \alpha \widetilde{\beta}' \widetilde{X}_{t-1} + u_t \qquad (2.162)$$

where $\widetilde{\beta}' = \begin{bmatrix} \beta' & \beta_0 \end{bmatrix}$ and $\widetilde{X}_{t-1} = \begin{bmatrix} X_{t-1} & 1 \end{bmatrix}$. Thus, we can retrieve $E(\widetilde{\beta}' \widetilde{X}_{t-1}) = 0$.

The case of $\mu_1 = 0$ and $\gamma_0 = 0$, but $\beta_0 \neq 0$, indicates at least one time series in vector X_t and is constant (but it is not a defined trend) in the equation.

Situation 3: If $\gamma_1 = \beta_1 = 0$ (or $\mu_1 = 0$) but $\gamma_0 \neq 0$ and $\beta_0 \neq 0$, the vector of the long-term co-integration is not a defined trend but is constant ($\beta_0 \neq 0$) or can be written as $E(\beta' X_{t-1}) = \beta_0$. If the VARIMAX-ECM model is found to be constant, $\gamma_0 \neq 0$ or can be written as $E(\Delta X_t) = \gamma_0$, and the above fixed value in the long-term co-integrating vector can be removed by using the long-term co-integration $\widetilde{\beta}' \widetilde{X}_{t-1}$ in the VARIMAX-ECM model, as illustrated below:

$$\Delta X_t = \alpha \widetilde{\beta}' \widetilde{X}_{t-1} + \gamma_0 + u_t \qquad (2.163)$$

where $\widetilde{\beta}' = \begin{bmatrix} \beta' & \beta_0 \end{bmatrix}$ and $\widetilde{X}_{t-1} = \begin{bmatrix} X_{t-1} & 1 \end{bmatrix}$.

The case of $\mu_1 = 0$ but $\gamma_0 \neq 0$ and $\beta_0 \neq 0$ indicates that at least one time series is a defined trend.

Situation 4: If $\gamma_1 = 0$ but $\gamma_0 \neq 0$, $\beta_0 \neq 0$ (or $\mu_0 \neq 0$), and $\beta_1 \neq 0$, the long-term co-integration $\beta' X_{t-1}$ cannot eliminate the constant value and defined trend, and it can be rewritten as $E(\beta' X_{t-1}) = \beta_0 + \beta_1 t$. This can be described in such a way that the long-term co-integration is a stationary trend, while the VARIMAX-ECM model is found to have a fixed value of $\gamma_0 \neq 0$ or can be written as $E(\Delta X_t) = \gamma_0$. The fixed value and defined trend that exist in the long-term co-integrating vector could be removed out by using a $\widetilde{\beta}' \widetilde{X}_{t-1}$ long-term co-integration in the VARIMAX-ECM model as follows:

$$\Delta X_t = \alpha \widetilde{\beta}' \widetilde{X}_{t-1} + \gamma_0 + u_t \qquad (2.164)$$

where $\widetilde{\beta}' = \begin{bmatrix} \beta' & \beta_0 & \beta_1 \end{bmatrix}$ and $\widetilde{X}_{t-1} = \begin{bmatrix} X_{t-1} \\ 1 \\ t \end{bmatrix}$, which can also be written as $\begin{bmatrix} X_{t-1} & 1 & t \end{bmatrix}$

The case of $\mu_1 \neq 0$ and $\gamma_1 = 0$ but $\beta_1 \neq 0$ demonstrates that at least one time series in vector X_t has to be constant and a defined linear trend, but it is not a quadratic trend.

Situation 5: If $\gamma_1 \neq 0$, $\gamma_0 \neq 0$, $\beta_0 \neq 0$, and $\beta_1 \neq 0$, this shows that the long-term co-integration has to be a stationary trend $(\beta_0 + \beta_1 t)$, while the VARIMAX-ECM model has to be constant and defined trend $(\gamma_0 + \gamma_1 t)$, which can be written as below:

$$\Delta X_t = \alpha \widetilde{\beta}' \widetilde{X}_{t-1} + \gamma_0 + \gamma_1 t + u_t \qquad (2.165)$$

Where $\tilde{\beta}' = [\beta' \quad \beta_0 \quad \beta_1]$ and $\tilde{X}_{t-1} = [X_{t-1} \quad 1 \quad t]$. The case of $\mu_0 \neq 0$ and $\mu_1 \neq 0$ occurs when at least one time series in vector X_t has to be defined by a quadratic trend $(\mu_0 + \mu_1 t + \mu_2 t^2)$.

An Estimation of the Co-Integrating Vector with the Use of Various Equations

Consider the VARIMAX-ECM model as follows [61]:

$$\Delta X_t = \alpha\tilde{\beta}'\tilde{X}_{t-1} + \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + ... + \Gamma_{p-1}\Delta X_{t-(p-1)} + \phi D_t + u_t \qquad (2.166)$$

where $\tilde{\beta}' = [\beta' \quad \beta_0 \quad \beta_1]$ is the $r \times (n+2)$ matrix, β is the $n \times r$ matrix, β_0 and β_1 are the $r \times 1$ vector, $\tilde{X}_{t-1} = [X_{t-1} \quad 1 \quad t]$ is the $(n+2) \times 1$ vector, α is the $n \times r$ matrix, and rank (α) = rank $(\tilde{\beta}) = r$. Also, D_t is the matrix indicating a deterministic component.

The estimation of the parameter of the long-term co-integrating vector $\tilde{\beta}$ can be achieved with the application of maximum likelihood by assuming vector $u_t \approx$ Normal (0, $\sum$) 0 is zero, and $\sum$ is the variant matrix of u_t. Johansen (1995) proved that the estimation of vector $\tilde{\beta}_{n\times r}$ with this method would result in an eigenvector in accordance with the eigenvalue from the minimum to maximum value. This is achieved using the equation below:

$$\left|\lambda S_{11} - \quad S_{10} S_{00}^{-1} S_{01}\right| = 0 \qquad (2.167)$$

$S_{ij} = \frac{1}{T} R_{it} R_{jt}'$, $i = 0,1$ and $j = 0,1$; where T is the number of data used in the VARIMAX-ECM model. R_{0t} is the $n \times T$ matrix of the residual retrieved from a regression equation with a variable of ΔX_t, and the independent variable is ΔX_{t-1}, ΔX_{t-2},..., ΔX_{t-p+1}, D_t. R_{1t} is the $(n+2) \times T$ matrix of the residual retrieved from a regression equation with a variable of $\tilde{X}_{t-1}$, and the independent variable is ΔX_{t-1}, ΔX_{t-2},..., ΔX_{t-p+1}, D_t.

If $\hat{\lambda}_i (i = 1,2,..., n)$[11] is the eigenvalue computed from Equation (2.166) where $_1 > \hat{\lambda}_1 > \hat{\lambda}_2 > ... > \hat{\lambda}_n \geq 0$, let the eigenvector consistant with the eigenvalue $\hat{\lambda}_1$, $\hat{\lambda}_2$, ..., $\hat{\lambda}_n$ be written as $\hat{V} = [\hat{v}_1 \quad \hat{v}_2 \quad \ldots \quad \hat{v}_n]_{(n+2)\times(n+2)}$. Therefore, we can obtain the estimator of the co-integrating vector as follows:

$$\hat{V} = [\hat{v}_1 \quad \hat{v}_2 \quad \ldots \quad \hat{v}_r]_{(n+2)\times r} \qquad (2.168)$$

Commonly, there are two popular patterns of forming primary and secondary assumptions pertaining to the number of the long-term co-integration.

Pattern 1: H_0 isthe maximal number of vectors indicating the long-term co-integration equivalent to r. H_1 is the number of vectors indicating the long-term co-integration greater than r.

In the above, $r = 0,\ \ 1,\ \ 2,\ \ \ldots, n-1$, and the statistical value to testify the above assumption is trace statistic (λ_{trace}), which can be computed using the equation below:

$$\lambda_{trace}(r) = -T\sum_{i=r+1}^{n}(1-\hat{\lambda}_i) \qquad (2.169)$$

Pattern 2: H_0 is the maximal number of vectors indicating the long-term co-integration equivalent to r. $H_1$is the number of vectors indicating the long-term co-integration equivalent to $r+1$.

In the above, $r = 0,\ \ 1,\ \ 2,\ \ \ldots, n-1$, and the statistical value to testify the above assumption is maximumeigenvalue $\lambda_{\max}$, which can be computed using the equation below:

$$\lambda_{\max}(r, r+1) = -T(1-\hat{\lambda}_{r+1}) \qquad (2.170)$$

$$\hat{A}_i = \begin{cases} I + \widehat{\Pi} + \widehat{\Gamma} & , i = 1 \\ \widehat{\Gamma}_i - \widehat{\Gamma}_{i-1} & , 2 \le i \le -1 \\ -\widehat{\Gamma}_{p-1} & i = p \end{cases} \qquad (2.171)$$

After that, we use the VARIMAX-ECM forecasting model of the time series in vector X_t by using the same concept, which is the forecasting of the minimum mean square error.Hence, the forecast of $1,2,\ldots,h$ pre-timing of the time series in the vector X_t can be illustrated as:

$$\hat{X}_{T+1} = \hat{A}_1 X_T + \hat{A}_2 X_{T-1} + \hat{A}_p X_{T-p+1} \qquad (2.172)$$

$$\hat{X}_{T+2} = \hat{A}_1 X_{T+1} + \hat{A}_2 X_{T-1} + \hat{A}_p X_{T-p+2} \qquad (2.173)$$

$$\hat{X}_{T+h} = \hat{A}_1 X_{T+h-1} + \hat{A}_2 X_{T+h-2} + \ldots + \hat{A}_p X_{T-p+h} \qquad (2.174)$$

where $\hat{X}_{T+j} = \hat{A}_1 X_{T+j}$ if $j < 0$

2.7.6 SEM- VARIMAX

The SEM-VARIMAX was developed through the application of advanced statistics, consisting of the causal factor relationship called structural equation modeling (SEM), and the estimation of such a relationship with the vector autoregressive model. The model was structured to be the best model, hereafter referred to as the SEM-VARIMAX model. Furthermore, the model is characterized with the best linear unbiased estimate, and is not spurious. The details are provided below.

SEM-VARIMAX model

Structural equation modeling (SEM) is a second generation model, which can analyze the relationships between multiple levels of SEM. This is inclusive of completely analyzing

relationships in the inner model (structure model) and outer model (measurement model). This feature differs from first generation modeling, such as regression analysis, ANOVA, and MANOVA, which are used to analyze a single subject at a time and so may take longer for the path model. Even though the outcome is no different, of which the study findings is parallel with this result, it is not a numerical value of regression coefficients, statistical values t (t-test) and other indicators. This is because these values are commonly different as their method is different; however, they still have similar values [141].

SEM has 2 approaches.

1. Covariance-based SEM (CBSEM), such as LISREL, AMOS, EQS, analyzes the data using the method of maximizing the similarity between the theory-based covariance structure and empirical-based covariance structure. Analysis based on this approach requires an adjustment in the modelling longer than both of those structures will be closely joined, which can be measured by certain criteria, such as RMSE chi-square and various fit indices. The adjustment is often about creating a relationship between the error term of the manifest variable [142].

2. Variance-based SEM (VBSEM and also known as component-based SEM as it uses a principal component regression (PCR) in the algorithm to estimate VBSEM by using OLS in the analysis. This is simply about minimize $\sum e_t^2$ based on analyzing the regression by dividing block by block (1 block is constructed with a construct and its indicator).

Hence, the SEM model is the model indicating the relationship of variables, as explained below.

Given that $X = \{X_1, X_2, \ldots, X_H\}$ represent the observed value of the exogenous latent variable.

Given $\xi = \{\xi_1, \xi_2, \ldots, \xi_H\}$ is the exogenous latent variable (we may call the latent variable the score or component).

Given that $Y = \{Y_1, Y_2, \ldots, y_K\}$ represent the observed value of the endogenous latent variable.

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[141] Pruethsan Sutthichaimethee and Boonton 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 7 No. 4 (18 December 2018): 87.

[142] Sanghee Lim and Nigel P. Melville, Robustness of Structural Equation Modelingto Distributional Misspecification: Empirical Evidence & Research Guidelines, at http://ssrn.com/abstract=1375251, (last visited 31August 2019).

Given $\eta = \{\eta_1, \quad \eta_2, \quad \ldots, \quad \eta_K\}$ is the endogenous latent variable.

The relationship between the latent variable (LV) and manifest variable (MV or indicator or proxy) can either be reflective or formative depending on the following contexts.

1. A reflective indicator is a factor analysis-based relationship. In each particular block, LV will influence MVs, of which these MVs will change altogether. This kind of relationship is then called the outer-directed measurement model. With this type of relationship, we will study a covariance of relative equation MV between LV and MVs in any block, as shown below.[143]

$$X_{jh} = \lambda_{xj}\xi_j + \varepsilon_{xj} = \Lambda_x\xi + \varepsilon_x; j = 1, 2, \ldots, H; h = 1, 2, \ldots, m_j \qquad (2.175)$$

Where H is the number of all exogenous latent variables, and m_j is the number of MV in block j.

$$Y_{jh} = \lambda_{xj}\eta_j + \varepsilon_{yj} = \Lambda_y\eta + \varepsilon_y; j = 1, 2, \ldots, K; h = 1, 2, \ldots, n_j \qquad (2.176)$$

Where K is the number of all endogenous latent variables, and n_j is the number of MV in block j, as illustrated in the figure below. However, $\mathrm{E}(\xi_j) = a_j$, $V(\xi_j) = 1$, $\mathrm{E}(\eta_j) = b_j$, $V(\eta_j) = 1$, $\mathrm{E}(\varepsilon_j) = 0$, $V(\varepsilon_j) = 1$, and the coefficient λ_j is the factor loading.

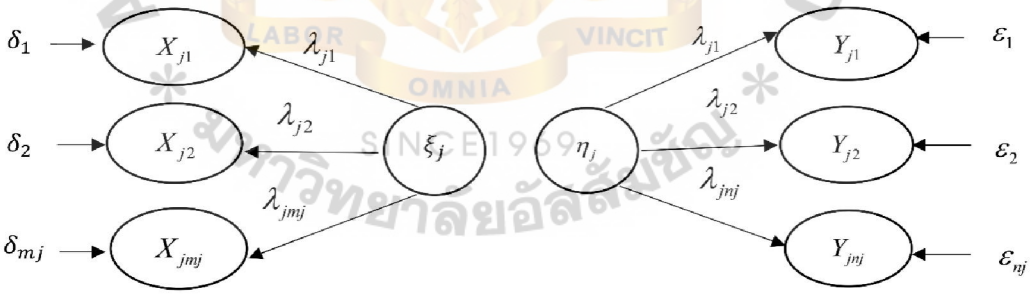

Figure 2.4 Reflective Indicator

2. The formative indicator is the case in which MV joins in making LV, and it is called the inner-directed measurement model. The objective of SEM in this case is to minimize the residual of the structural relationship.

[143] Pruethsan Sutthichaimethee and KuskanaKubaha, "The Efficiencyof Long-Term Forecasting Modelon Final Energy Consumptionin Thailand's PetroleumIndustries Sector: EnrichingtheLT-ARIMAXSModelunderaSustainabilityPolicy," Energies 11 No.8 (8 August 2018), 2063.

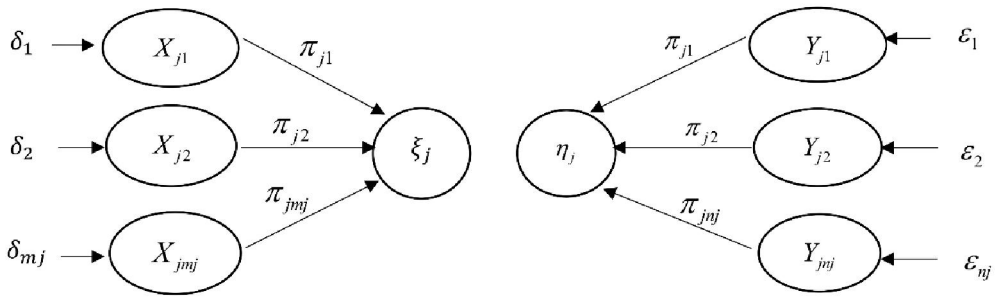

Figure 2.5 Formative Indicator

The relationship between LV and each MV in any block can be explained as below.

$$\xi_j = \pi_{xj} X_{jh} + \delta_{\xi j}; j = 1,2,...,H; h = 1,2,...,m_j \quad (2.177)$$

$$\xi = \prod_x X + \delta_\xi \quad (2.178)$$

$$\eta_j = \pi_{xj} Y_{jh} + \delta_{\eta j}; j = 1,2,...,K; h = 1,2,...,n_j \quad (2.179)$$

$$\eta = \prod_y Y + \delta_y \quad (2.180)$$

The analysis of the relationship in block j may apply a multiple regression analysis.

$$\xi_j = \pi_{j0} + \pi_{j1} X_{j1} + \pi_{j2} X_{j2} + \ldots + \pi_{jm} X_{jm} + \delta_j \quad (2.181)$$

Or $$\eta_j = \pi_{j0} + \pi_{j1} Y_{j1} + \pi_{j2} Y_{j2} + \ldots + \pi_{jn} Y_{jn} + \delta_j \quad (2.182)$$

The coefficient π_j is the multiple regression coefficient.

The reflective relationship has been developed to positively connect MV and LV, and it is a loading, and/or the regression coefficient must be a positive value. Yet, it is allowable to have a negative value, but such value tells us some issues with data. For instance, it indicates an incompatibility in the scale of measurement, and that the mean or variance does not reflect the real meaning of the data.

Therefore, the solution is to change the estimation method by using the Vector Autoregressive model at p: VAR(p) as follows. [144]

There are 2 series of time series, which are Y_t and Z_t. They can be written in the VAR(p) model as shown below.

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[144] Pruethsan Sutthichaimethee and KuskanaKubaha, "A Relational Analysis Modelof the Causal Factors Influencing CO_2 in Thailand's Industrial Sectorundera Sustainability Policy Adapting the VARIMAX-ECMModel," Energies 11 No.7 (1 July 2018): 1704.

$$Y_t = a_{10} + a_{11,1}Y_{t-1} + a_{12,1}Z_{t-1} + a_{11,2}Y_{t-2} + a_{12,2}Z_{t-2} + \ldots + a_{11,p}Y_{t-p} + a_{12,p}Z_{t-p} + u_{1t} \quad (2.183)$$

$$Z_t = a_{20} + a_{21,1}Y_{t-1} + a_{22,}Z_{t-2} + a_{21,2}Y_{t-2} + a_{22,2}Z_{t-2} + \ldots + a_{21,p}Y_{t-p} + a_{22,p}Z_{t-p} + u_{2t} \quad (2.184)$$

If we have n series of time series, including $X_{1t,}$ $X_{2t,}$ …, X_{nt}, we will write that time series in the VAR(p) model as illustrated below.

$$X_t = A_0 + A_1X_{t-1} + A_2X_{t-2} + \ldots + A_pX_{t-p} + u_t \quad (2.185)$$

where $X_t = \begin{bmatrix} X_{1t} \\ X_{2t} \\ \vdots \\ X_{nt} \end{bmatrix}_{n\times 1}$, $A_0 = \begin{bmatrix} a_{01} \\ a_{02} \\ \vdots \\ a_{0n} \end{bmatrix}_{n\times 1}$, $A_i = \begin{bmatrix} a_{11,i} & \cdots & a_{1n,i} \\ a_{21,i} & \cdots & a_{2n,i} \\ \vdots & \vdots & \vdots \\ a_{n1,i} & \cdots & a_{nn,i} \end{bmatrix}_{n\times n}$, $i = 1, \ldots, P$, and $u_t = \begin{bmatrix} u_{1t} \\ \vdots \\ u_{nt} \end{bmatrix}_{n\times 1}$

As for measuring the mean and variance of the VAR(p) model, the same method can be used as that of the VAR(1) model. When observing the VAR(p) model, the value of the parameter is many, that is constant in the number of n. In addition, the parameters as the coefficient value of X_{t-1}, X_{t-2}, ..., X_{t-p} are $n^2 + n^2 + \ldots + n^2 = pn^2$. Hence, all parameters of the VAR model are $n + pn^2$. Here, it indicates that the greater the number of time series is by 1 unit or sequence of VAR is bigger by 1 unit, the parameters will also be greater at the same time. Thus, any time series used in the VAR model should be an impactful time series, that can explain each other's effect.

However, constructing a model as the best model requires a BLUE feature. In the actual context, there should be exogenous variables in the modelling. This simplifies that the model should have white noise and be free from a spurious in which heteroskedasticity, multicollinearity and autocorrelation are eliminated. The authors, therefore, developed a new model called the SEM-VARIMAX model, which effectively incorporates various exogenous variables in different contexts or various sectors. The details of the SEM-VARIMAX model are explained as follows.

$$Y_t = \beta_{10} - \beta_{12}Z_t + \gamma_{11}Y_{t-1} + \gamma_{12}Z_{t-1} + \varepsilon_{yt} \quad (2.186)$$

$$Z_t = \beta_{20} - \beta_{21}Y_t + \gamma_{21}Y_{t-1} + \gamma_{22}Z_{t-1} + \varepsilon_{yt} \quad (2.187)$$

$$BX_t = \Gamma_0 + \Gamma_1X_{t-1} + \varepsilon_{yt} \quad (2.188)$$

Where $B = \begin{bmatrix} 1 & \beta_{12} \\ \beta_{21} & 1 \end{bmatrix}$, $X_t = \begin{bmatrix} Y_t \\ Z_t \end{bmatrix}$, $\Gamma_0 = \begin{bmatrix} \beta_{10} \\ \beta_{20} \end{bmatrix}$, $\Gamma_1 = \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix}$, $\varepsilon_t = \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix}$

When considering Equation (2.186), it indicates that ε_{yt} will affect Y_t, while Y_t will affect Z_t when considering Equation (2.187) (or briefly written as $\varepsilon_{yt} \rightarrow Y_t \rightarrow Z_t$). Hence, we can say that $Cov\left(Z_t, \ \varepsilon_{yt}\right) \neq 0$ or time series of Z_t and ε_{yt} are related, indicating the assumption of

CLRM is incorrect. Therefore, the parameter estimation in Equation (2.186) will be a biased estimator. Even if the sample is large, it still finds that the probability of the estimator with the least squares method with not be as the actual value (inconsistent estimator). Equation (2.187) will also give the same result as above. However, when the SEM-VARIMAX model is transformed into a deformed model, or VAR(1) model by multiplying B^{-1} throughout Equation (2.188), Equation (2.189) will be as follows.

$$X_t = A_0 + A_1 X_{t-1} + u_t \qquad (2.189)$$

where $A_0 = B^{-1}\Gamma_0 = \begin{bmatrix} a_{01} \\ a_{02} \end{bmatrix}$, $A_1 = B^{-1}\Gamma_1 = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$ and $u_t = B^{-1}\varepsilon_t = \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix}$, or rewritten as Equation (2.190) and (2.191) like below.

$$Y_t = a_{10} + a_{11} y_{t-1} + a_{12} Z_{t-1} + u_{1t} \qquad (2.190)$$

$$Z_t = a_{20} + a_{21} y_{t-1} + a_{22} Z_{t-1} + u_{2t} \qquad (2.191)$$

We can see that the VAR (1) model will not cause any problems like what occurred in the SEM-VARIMAX(1) model. Besides, we can estimate the parameters in the VAR(1) model with the least squares method. By observing the SEM-VARIMAX(1) model and the VAR(1) model, it was found that

1. The parameters in the VAR(1) model are actually caused by the parameters in the SEM-VARIMAX(1) model, or the parameters of both models are related.

2. The number of parameters in the VAR(1) model was 9, namely the $a_{10}, a_{11}, a_{12}, a_{20}, a_{21}, a_{22}$, parameters of $Var(u_{1t})$, the parameters of $Var(u_{2t})$ and the parameter of $Cov(u_{1t}, u_{2t})$.

3. The number of parameters in the SEM-VARIMAX(1) model was 10, namely the $\beta_{10}, \beta_{11}, \beta_{20}, \beta_{21}, \gamma_{11}, \gamma_{12}, \gamma_{21}, \gamma_{22}$, parameters of $Var(\varepsilon_{1t})$ and the parameters of $Var(\varepsilon_{2t})$.

It can be observed that the number of parameters in the VAR(1) model is less than the SEM-VARIMAX(1) model's. Even though all the parameters can be estimated in the VAR(1) model, we still cannot use the relationship between the parameters of both models to find the parameter estimator in the SEM-VARIMAX(1) model.

However, if we can place some limitations in the SEM-VARIMAX(1) model, then it would cause a reduction in the number of parameters to 9, allowing us to use the parameter estimator in the VAR model(1) in discovering the parameter estimator of the SEM-VARIMAX(1).

As for the SEM-VARIMAX (p) model, it can run up to sequence (p) as determined in the study, aiming at benefiting future applications.

2.7.7 Measurement of the Forecasting Performance

To evaluate the forecasting effect of each model, we employed the mean absolute percentage error (MAPE) and the root mean square error (RMSE) to compare the forecasting accuracy of each model. The calculated equations are shown below [145].

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{\hat{y}_i - y_i}{y_i}\right| \tag{2.192}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)^2} \tag{2.193}$$

[145] Walter Enders, op.cit., pp.319-372.

Chapter 3

The Law Enforcement for Environmental Management

The main essence of enforcing a law in managing the environment evolves around the issue of inefficient environmental management from a country's development and the raising global concern on the environment. Flashing back to the time when Thailand started establishing the national economic and social development plan as a model for basic public policy, the industrial development has been the main focus, leading Thailand's economy a quick transformation from social agriculture into social industry. Such a transformation aims at growing the economy, increasing investments, distributing basic consumption and circulating national income. During the first three decades of the plan, including the 1st plan (1961-1966) to the 4th plan (1977 to 1981), the national development did not emphasize and concern in having a policy and plan to protect and preserve the environment along together with the national development, resulting in the overconsumption of energy and the devastation of the environment. This result has created a lot of environmental issues. Hence, the government needs a tool to tackle the issues, leading to the creation of rules and regulations. In the early stage of solving the issues, it went about solving a case by case basis. Thus, the enforcement of the rules was for specific issues, for instance, the Factory Act 1969.

In 1972, the global concern was realized and presented the United Nations Conference on the Human Environment in Sweden, as to call upon national actions to play a role in managing the environment. Interestingly, Thailand also participated in the conference, and implemented the practices and concepts under Stockholm Agreement 1972 for the national environmental management. This can be seen from the Constitution of the Kingdom of Thailand 1974, where the environmental policy is identified along with the development of regulatory framework for the action. The first environmental law is the Enhancement and Conservation of National Environmental Quality Act, B.E. 2518 (1975), allowing the establishment of the National Environmental Board and office to oversee the environmental affairs and coordinate with all involving parties. Due to the weak authority of the dedicated board in controlling and conserving the quality, another "The Enhancement and Conservation of National Environmental Quality Act, B.E. 2535 (1992), was enacted to replace the first Act. The newly enacted Act was there to enhance the board authority and establish the Office of the Environmental Policy and Planning or the Office of the Natural Resource and Environmental Policy and Planning, as it is present till today. However, the Department of Pollution Control and Environmental Quality Enhancement are there to support the board and work closely with other

concerned offices in order to improve the effectiveness of the affair management. Besides, there are some law amendments as to improve in solving the environmental issues for specific cases. For instance, the replacement of the Factory Act 1969 with the Factory Act 1992 was made. In the same year, the 2nd United Nations Conference on the environment and development was held in Brazil. This second conference was carried out to call upon the member states to participate in preserving the environment while implementing the mutual principles and concepts in managing the environment under the international agreement or the Rio Convention 1992. The Convention was expected to be deployed by member states in their policy making and law enactment for the purpose of the environmental management.[146]

This can be said that the enforcement of law for the environmental management in Thailand is based on many versions of Acts. However, to this study, two main Acts are used to explore; the Enhancement and Conservation of National Environmental Quality Act 1992 and the Factory Act 1992, which are further elaborated in this chapter.[147]

3.1 The Enforcement of Law for the Environmental Management

A law is a tool designed to govern a society, and it is a mechanism for the social regulation formation. It also establishes roles to different stakeholders in the society, including a public sector, a government, that plays a role as a law implementor in ensuring for a social security and safety at all levels, and a private sector, the people and private entities, that plays both as a law implementor and follower. Therefore, an enforced law must determine the regulatory framework as a standard that allows people in the society to follow. If there is any circumstance of disobeying the law, then there should be a form of processes or steps for the control and protection. This may include a form of imprisonment, charges, arresting and compensation to a victim. This can be seen from the following Acts.

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[146] Thailand Greenhouse Gas Management Organization (Public Organization), Greenhouse Gas emission, at http://www.tgo.or.th/2015/thai/content.php?s1=7&s2=16&sub3=sub3, (last visited 2 April 2019).

[147] Pollution Control Department Ministry of Natural Resources and Environment, Enhancement and Conservation of National Environmental Quality Act, B.E. 2535, at http://www.pcd.go.th/info_serv/reg_envi.html, (last visited 1 July 2019).

(1) The Enhancement and Conservation of National Environmental Quality Act 1992 is dedicated to ensure that Thailand's development is run smoothly without affecting the environment while improving its quality. The essence and significance of this Act is that the use of policy measures, planning and administration, pollution control, and the establishment of governing and civil responsibilities. The above law consists of many sections; Section 1: the National Environmental Board, Section 2: the environmental funds; Section 3: the environmental protection; Section 4: the pollution control; Section 5: the promotional measures; Section 6: the civil responsibilities; and the penalties.

(2) The Factory Act 1992 is another significant tool for the government in controlling the factories affairs, and it further explains measures aiming at ensuring the operation of the factories is in line with the present economy and society. The main sections of this Act are Section 1: the factory operation, Section 2: the factory supervision and control and Section 3: the penalties.

The implementation of law under the government command can be divided into two main categories. The first category is the implementation of law under the Command and Control (CAC). This CAC is the command made by the government. For instance, the announcement of the quality measures on the environment stipulates that all pollutants, if they are out of control and released into the environment beyond the specific limit in which the environment can absorb and eliminate by itself, or danger to the public health, requires the government to establish an environmental quality standard so that the amount of pollutants emitted into the environment is under the control. The CAC also covers the prosecution of which the responsibility and punishment for violators is determined. This violation may account the action to force the members of society or those under the law to obey the law. Thesecond category is the implementation of law under the negative measures or known as Stick and Carrot, the monitoring and inspection measures and incentive measures. This implementation aims at enhancing the capacity of those pollutants generators to act in line with the environmental law. However, these two categories are built on the purpose of regulatory adherence in managing the environment.

3.2 The Legal Measures for Environmental Management

In order to make the law enforcement more efficient and enforceable in accordance with legal objectives for the environmental management, the government shall account different measures in the practices. The first measure, the government as the executor of the national power and duty to protect the public health and environment, is the Command and Control measure, which consists of administrative and criminal measures. Besides, the government established the civil measures to

determine the responsibility for polluters held responsible for treating and contributing the damage to humans and the environment, which can be further explained below[148].

3.2.1 Administrative Measure

Administrative measures are considered an important measure of the nation in the environmental management. It is the power assigned by the legislative department to the management board, which is the authorized officer or the administrative department that is responsible for enforcing the law and has the power to specify rules and details related to the environmental management. In addition, it grants the authority to perform duties according to the law. The administrative measures consist of the followings.

1. The Duties of the Administrative Department

1.1 Rule issuance or common administrative order or secondary law is of that ministerial regulations, ministerial notice, local regulations, rules and regulations. This law is set up to support the enforcement of the large measures as stipulated in the Act, such as the exercise of power to control individuals' freedom for the benefit of the public and to maintain the standards of the activities resulted from the freedom, which neither harms the society nor destroys the environmental quality. The environmental protection measures are to determine the quality standard of water, air, and noise and pollution control as a general guideline for auditing, monitoring and controlling the legal operation of a law user. For instance, Article 32 of the Enhancement and Conservation of National Environmental Quality Act 1992 stipulates that he National Environment Board can exercise the power to issue announcements in the Government Gazette or legal notices to determine standards for environmental quality in each category, such as water in water sources, air in the atmosphere, noise and vibration level, in order to promote environmental quality. Whereas Article 55 of the Enhancement and Conservation of National Environmental Quality Act 1992 allows the Ministers, with the advice of the Pollution Control Board and the approval of the National Environment Board, to issue a legal notice in the Government Gazette determining standards for pollution control from sources in overseeing water and waste management, air emission or any other pollutants from different pollution sources.

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[148] Legal affairs Division Ministry of Natural resources and Environmental, Enhancement and Conservation of National Environmental Quality Act, B.E. 2535, at http://legalgroup.mnre.go.th/en/index, (last visited1 December 2019).

1.2 Paving specific administrative measures or orders is an administrative activity according to the rules. General regulations or various statutory provisions giving an authority to officials or administrative officials include the issuance of orders and the revocation of license, among any other activities. It can be seen that the use of authorization is an important governing measure in controlling business behavior within the rules and regulations, which does not affect the public and the environment. Besides, such usage can be used to control the operations or projects the government needs the control and special care in order to prevent damage to the economy, society and environment. The Article 12 Clause No. 5of the Industry Act 1993 grants the officials an authority for the permission of operating a 3rd category industry considering an issuance of the approval as prescribed in the Ministerial regulations under Section 8 and the Minister's announcement issued by the Ministry and Section 32, including the safety of persons and property under the principle and policy of the law, namely economy, environmental conservation and national security.

1.3 The use of the power of the authority or the administrative department in carrying out duties within the law while violating the administrative measures can be examined by the law, which the officials are given an authority to investigate, correct, or protect from any damage for the environment and the public, and this authority can be reinforced by Article 42 of the Industry Act 1993.

2. Administrative punishments include administrative charges as to urge for a compliance with orders and laws. The officials or the administrative department can issue a fine within a given time and in line with the conditions of the law without filing to the court. This type of charge has an economic objective requiring violators of administrative measures held responsible economically via paying off the fines. Therefore, the fines must be higher than the cost of legal adherence.[149]

3.2.2 Criminal Measures

The nature of a criminal offense under the environmental law is the violation of the safety measures for the life and well-being of the public, or an offense that violates the prohibitions or stipulated requirements or even the conditions in the license. Therefore, the establishment of the criminal measures presents and applies in every country for the purpose of law enforcement,

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[149] 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, at http://infofile.pcd.go.th/law/Environmental%20law55_1.pdf?CFID=1741861&CFTOKEN=32274043, (last visited1 November 2019).

including huge penalties, limited time imprisonment, forfeiture of property for wrongdoing, in order to achieve the objective of preventing pollutants.

The enforcement of criminal measures consists of the followings.

1. Officials prosecuting offenders are those people under the responsibility of investigating and prosecuting the offenders in managing the environment. It is a duty of the officials in managing the environment under the observation of each and every single law. Those officials are the control officers under the Enhancement and Conservation of National Environmental Quality Act 1992 and the Industry Act 1992. The above responsibility of the officers can be divided into two cases:

1.1 The action of officials under the law is specified as administrative or police officers based on the Criminal Procedure Code. Therefore, when there is a violation of the environmental law, the officers can impose criminal penalties, including arrestment, inspection and prosecution, on the offenders for the environmental management. The officials are the factory officials.

1.2 The pollution control officials carry the action of the officials under the law with the power to inspect but not arrest and suppress. If a legal offense is found, the officials must notify the case to the inspectors for the legal suit.

2. Inspection officials are there for the prosecution of offenders under the law for the environmental management, which is later enforced in accordance with the Criminal Procedure Code. In short, the prosecution of criminal cases and the investigation of offenders under the Criminal Procedure Code has to be carried out by the second lieutenant level police officers or sheriffs or even governors. Currently, the officers of the Special Investigation Department can carry an inspection of offenses related to the environment.

3. Due to the nature of the use of criminal measures for violators of the law on environmental management, it is not considered a serious crime, so the punishment used is not meant for the prosecution, the pay fine officer will exercise the power according to the law for the affairs of the environmental management, as so a quick and efficient enforcement can be achieved.

In addition, some environmental management laws grant the people, even if they are not directly affected, the right to file a complaint or to prosecute criminal offenses against those who destroy the environment, and Article 64 of the Industry Act 1992 can be one of those laws. The criminal penalties like fines, imprisonment, forfeiture of property, are the process of determining punishments for offenders or the person causing the crime in order to suppress the offense and stop it.

It can be seen that in order to comply with the law for environmental management, the enforcement of the national laws requires the criminal measures to activate such an enforcement, as so the conditions and punishments for violators can be executed.

3.2.3 Civil Measures

The nature of civil liability is the damage to the environment, which causes pollution and natural damages but not destroys the rights of individuals. It is a type of action over the properties or public interest and normally comes with a wide impact, which may include a future generation. Also, it may come a form of affecting negatively on the people and properties caused by leakage or spread of pollution from its sources.

Enforcing the civil measures for the environmental management aims at allowing polluters to be responsible and compensate for the damage they caused on the environment. Therefore, the enforcement of the said measures prescribes special considerations for civil compensation, and that may form a civil liability as a strict liability in order to effectively enforce the civil liability according to the environmental law with fairness to the affected party.The enforcement of the civil measures consists of the explanation below.

1. State

The state comes as a responsible entity responsible for protecting and preserving the environment. When there is damage to natural resources and the public's environment. The environmental law requires the state to be responsible for the infringement compensation, the damages that must be paid by the pollutant.

2. People (Public)

The people are as the victims according to the law, who have suffered damage caused by the sources of pollution. They can sue for a compensation upon the damages from the polluters. This right is granted by the Enhancement and Conservation of National Environmental Quality Act 1992 and Article 420 of Civil and Commercial Code on Liability for Wrongful Acts, for instance.

3. Pollutant

The pollutant or responsible person for damages is of those own a source of pollution, and they are normally the owners of a factory(es), business(es) or development project(s), or the right holder of the toxic sources, referring to the person possesses the right to source of pollution or associates in the care after the sources of pollution on behalf of the owners.

4. Indemnity or Compensation

The compensation is what is paid to the victims or affected parties generally estimated higher cost than the damages, such as medical expenses or compensation for loss of organs.

The law enforcement for the environmental management is, therefore, necessary to impose civil measures so pollutants held responsible and compensate for what they have caused. The Article 96 of the Enhancement and Conservation of National Environmental Quality Act 1992 stipulates that the owner or possessor of the pollution sources and they leak or spread of pollution causing someone else a harm to life, body, health or properties or the state's properties, must be liable to pay a compensation to the affected parties in all cases, except the following three cases.

1) Forced majeure or wars
2) Acts taken based on the government order or government officials
3) Acts of the persons who have suffered damage, yet they are directly or indirectly responsible for causes.

It can be seen that the use of civil measures under this law establishes strict principles of responsibility to alleviate the burden of those injured or victimized by pollution in the court process of the plaintiff. The Article 97 of the Enhancement and Conservation of National Environmental Quality Act 1992 stipulates the liability in case of damaging the natural resources due to an act or omission of an individual, including the destruction or loss or damage to government-owned resources. This further can be seen that the main purpose of this Article is when environmental damage is caused by unlawful acts, the state, as a responsible entity for insurance of the natural resources and public domain, has the right to demand the offenders a liability or compensation and pay for the damages. While Article 42 of the Industry Act 1992 states that the damages caused by the failure of legal compliance under Article 37 leading to the government action in solving the pollution or tackling the environmental issue caused by the factory, the owner must be responsible for all expenses, including 3% fine per annum of that entire expenses.

In summary, the use of legal measures for the environmental management consists of the use of Command and Control measures. The civil measures must be truly connected significantly together with other measures in order to make the law enforcement more efficient in the environmental management. Having said that, when determining administrative measures to set environmental quality standards or to protect the environment, it is necessary to include criminal measures in order to ensure that a compliance of the administrative measures is strictly followed. If the compliance is not fulfilled by them, the criminal punishment will be imposed, including the determination of civil measures for pollutants responsible for a compensate for the damage.

3.3 Problems in the Law Enforcement for Environmental Management

Although the nature of the enforcement of Command and Control measures and civil measures is a clear legal framework by the state, it is, however, weak when it comes to enforcing them for the environmental management on the polluters, in addition to the law ineffectiveness. This limitation causes the occurrence of various problems in enforcing those measures, which later leads to a failure on the strict legal practice of entrepreneurs or businesses. From the study of relevant literatures, the following summary is the result.

3.3.1 Legal issues

1. Issues of enforcing administrative measures

1) The problems and limitations of the government's Command and Control measures in determining environmental quality standards, giving the amount allowance of pollutants emitting to the environment too high, leading to harms. That is to say the administrative measures in the law must be clear in order to formulate rules for the further actions by the followers. For instance, the Minister of Science, Technology and Environment exercised the power under Article 69 of the Enhancement and Conservation of National Environmental Quality Act 1992 to announce the types of pollution sources that must be controlled in terms of wastewater release or waste release into public water sources or to the environment outside the place of pollution sources. However, it can be observed that such control in compliance with environmental quality standards does not impose any legal punishment on those owners or associates of pollution sources that do not meet environmental quality standards under the same Act, therefore, resulting in zero fear of legal measures and control.

2) The administrative measures are measures that give authorities and administrative officials the ability to enact secondary laws in order to specify details for effective law enforcement, but the problem is found due to the failure in enacting ordinances. In fact, such power falls under administrative measures for protection, which change accordingly when the environment and pollution problems do change.

3) The issue of lacking knowledge in enforcing administrative measures for effective environmental management and environmental protection of government officials is found, because many laws are used to enforce administrative measures and regulate their details.

4) The problem of using the power of officials is noticed during the implementation of the administrative duties. When there is a violation of administrative commands or

administrative measures, the officials are unable to exercise real power. For instance, they may be in a difficult state to exercise the administrative power to revoke the order of the closure or suspension of an enterprise. In fact, it requires a careful consideration on such affair as its impact may affect the environment, as well as the economic system.

5) The restrictions on the environmental management itself grant the officials an authority to perform the tasks. Some restrictions may be on the use of legal power to monitor and inspect the operations of those under their controls, partially requiring impact assessment reports in making any consideration. However, some requirements like this report might be beyond the officials' legal authority. Therefore, they require a coordination with the responsible agencies, mirroring that they need additional approval to carry out administrative measures, which results in the ineffectiveness of some types of businesses behaviors.

2. The enforcement issues of criminal measures

The use of criminal measures is aimed at enforcing the compliance with the laws of the followers. The issues are noticed when the restrictions on criminal measures result in less effective law enforcement.

1) The problem of enforcing criminal measures for imprisonment cannot be imposed on the pollution sources or pollutants, whom an entity is juristic by law. For example, in the case of a project or development activities responsible by the government, such a government or the head of government agencies have no responsibility with the actions of the development project, because it is the state affair.

2) The problem of determining the use of criminal measures is noticed. The criminal measures cannot be enforced immediately by the officials of the responsible agency, but it can be done through the judicial process or court process. This process may take a longer time and reduce efficiency.

3) The problem of determining criminal punishment measures is realized. Since the criminal penalties intend to be amended and restrained from. Therefore, it may be difficult to prohibit other people in committing the same offence., especially in cases where the offender is a juristic person, such as Juristic committee and corporate manager.

4) The problem comes with the criminal charges. In order to make the charges effective and complaint with the law, the imposition of a fine must be appropriate enough to affect the property to cause deterrence and fear of committing an offense, but the charges enforced under the

law for the environmental management cannot cause deterrence. In fact, the fines cost less than the benefits of a violator.

5) The problem of enforcing criminal measures results from litigation with polluters. In investigating a crime, the criminal internal proof is still required in practices. Here, the responsibility must be done intentionally or negligently. Therefore, the proof to punish the offender must be proven of the internal elements as well. In order to prove this element, it must be based on the evidence obtained from scientific tests for the case analysis, and that is a difficult talk.

3. The issues of enforcing civil measures

When damage occurs to the environment, the public is obliged to have a person responsible for indemnification or compensation for the damage and the remedy of such damage. The affected parties cannot proceed to enforce civil liability by themselves. They must use the right of the court so that the polluter can be responsible for civil action. Upon exploring all the possibilities, the issues can be listed as below.

1) The problem of exercising rights in the court is found due to the judicial process may take longer to reach a final verdict, which may prevent delay for immediate treatments; either the damage becomes severer or it is difficult to repair the damage.

2) The issue of limitation in examining the damage is present. That is to say that even though the state has enforced special civil measures in the environmental law, the victims or affected parties do not have to prove either the damage is caused intentionally or unintentionally. However, they have a duty by law to explain the relationship in terms of actions and result between them and polluters to the court.

3) The issue of determining the cost of the damage is also realized. At present, the determination of damages arising from violations is done by the court. The court has principles in which it is considered the offender must compensate as much as the victims or affected entity actually suffered and the estimated cost of the damage in the future. This consideration does not account the cost that might occur from pollution in the future.

Chapter 4

Result

In this research, the results of mixed methods research are presented, and organized based on twon mian analysis components: 1) the empirical analysisis to assess the relationship impact in modelling theSEM-VARIMAX modeland future forecasting, and 2) the future environmental management analysis on the basis of quantitative and qualitative method under the environemtal law. This analysis is defined hrough the government regulation when new policies scenario occurs. While the qualitative analysis uses economic measures to enforce the environmental law. This can be further explained in details as below.

4.1 Empirical Analysis

4.1.1 Screening of Influencing Factors for Model Input

Inthispaper, the structure equation modeling framework was determined. Four factors were modelled as latent variables as follows: Sustainable development policy under environmental law $(S.D.EL)$, economic $(ECON)$, social $(SOCI)$, and environmental $(ENVI)$, while the observed variables comprised of 13 indicators inclusive of energy consumption (EC).The economic indicators were percapitaGDP(GDP), urbanizationrate (UR),industrialstructure (IS), net exports $(E-M)$, indirect foreign investment (IF), and foreign tourists (FT). The social indicators are employment (EM), health and illness (HI), social security (SS), consumer protection (CP).The environmental indicators comprised Carbon dioxide emissions (CO_2) and energy intensity (EI). This research analyzed the influence of the relationship of the causal factors with the SEM-VARIMAX model. All the causal factors used in the model must be stationary at the same level only. Here, the natural logarithm of every variable is taken, so that linear data can be obtained and tested for stationary. The value obtained from this process is then compared to MacKinnon critical value at level I (0) based on the Dickey-Fuller theory. In this paper, all variables were found to be non-stationary at level I (0). Therefore, those variables were carried forward to perform stationary tests at the first difference I (1), as illustrated in Table 4.1

Table 4.1 Stationary at first difference I (1).

Stationary		MacKinnon Critical Value		
Variables	Tau Test	1%	5%	10%
Δln(EC)	−5.69 ***	−4.15	−3.20	−2.50
Δln(GDP)	−5.21 ***	−4.15	−3.20	−2.50
Δln(UR)	−5.16 ***	−4.15	−3.20	−2.50
Δln(IS)	−4.65 ***	−4.15	−3.20	−2.50
Δln(E-M)	−5.05 ***	−4.15	−3.20	−2.50
Δln(IF)	−4.50 ***	−4.15	−3.20	−2.50
Δln(FT)	−4.32 ***	−4.15	−3.20	−2.50
Δln(EM)	−4.29 ***	−4.15	−3.20	−2.50
Δln(HI)	−4.68 ***	−4.15	−3.20	−2.50
Δln(SS)	−4.91 ***	−4.15	−3.20	−2.50
Δln(CP)	−5.01 ***	−4.15	−3.20	−2.50
$\Delta \ln(CO_2)$	−5.85 ***	−4.15	−3.20	−2.50
Δln(EI)	−5.34 ***	−4.15	−3.20	−2.50

Notes: EC is energy consumption, GDP is per capita GDP, UR is urbanizationrate, IS is industrialstructure, $E-M$ is the net exports, IF is indirect foreign investment, FT is foreign tourists, EM is employment, HI is health and illness, SS is social security, CP is consumer protection, CO_2 is carbon dioxide emissions, EI is energy intensity. *** 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 4.1 shows that all factors were stationary at the first difference or stationery at Level I (1). When calculating the Tau test of every causal factor, the values were found to be greater than the MacKinnon critical value, which indicates all causal variables were stationary at a significance level of 1%, 5%, and 10%. When all causal factors were stationary at the same level, we used them for the co-integration test proposed by Johansen and Juselius, as shown in Table 4.2

Table 4.2 Co-integration test by Johansen and Juselius.

Variables	Co-Integration Test		Mackinnon Critical Value	
$\Delta\ln(EC)$, $\Delta\ln(GDP)$, $\Delta\ln(UR)$, $\Delta\ln(IS)$, $\Delta\ln(E\text{-}M)$, $\Delta\ln(IF)$, $\Delta\ln(FT)$, $\Delta\ln(EM)$, $\Delta\ln(HI)$, $\Delta\ln(SS)$, $\Delta\ln(CP)$, $\Delta\ln(CO_2)$, $\Delta\ln(EI)$	Trace statistic test	Max-Eigen statistic test	1%	5%
	215.75 ***	121.01 ***	15.25	11.75

Notes: *** denotes significance $\alpha = 0.01$

4.1.2 Analysis of Co-Integration

According to Table 2, the co-integration test result based on Johansen and Juselius shows that all causal factors, which were stationary at first difference in the SEM-VARIMAX model, were co-integrated at the significance level of 1% and 5% because the Trace statistic test value (215.75) and the Maximum Eigen statistic test value (121.01) were greater than the MacKinnon critical values at significance levels of 1% and 5%, respectively. Therefore, all variables could be used in analyzing the impact of causal factors using the SEM-VARIMAX model, as shown in Figure 4.1 and Table 4.3.

4.1.3 Formation of Analysis Modeling with the SEM-VARIMAX Model

The SEM-VARIMAX model is a model that consists of short-term and long-term causal relationships, which show the impact of the latent variables, with the analysis explained as follows.

Figure 4.2 shows the impact of the causal factor relationship in the SEM-VARIMAX modeldetermined by Sustainable development policy under environmental law $(S.D.EL)$, where thelatent variables are: economic $(ECON)$, social $(SOCI)$, and environmental $(ENVI)$; the observed variables consist of energy consumption (EC), percapitaGDP (GDP), urbanizationrate (UR),industrialstructure (IS), net exports $(E-M)$, indirect foreign investment (IF), foreign tourists (FT), employment (EM), health and illness (HI), social security (SS), consumer protection (CP), Carbon dioxide emissions (CO_2), energy intensity (EI), and error correction mechanism (ECM_{t-1}). The study findings reveal which factors had direct and indirect effects, as can be seen in Table 4.3

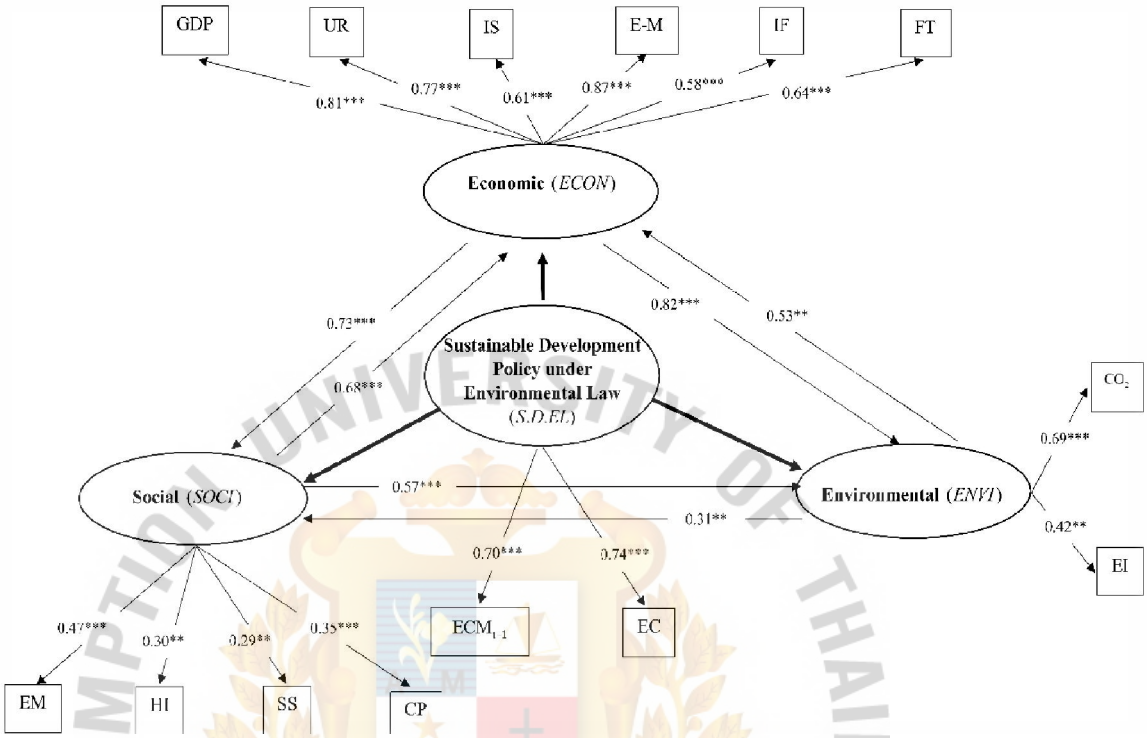

Figure 4.1 The casual relationship in the SEM-VARIMAX model.

Table 4.3 Results of the relationship of size analysis of the structural equation modeling/vector autoregressive model with exogenous variables (SEM-VARIMAX) model.

Dependent Variables	Type of Effect	Independent Variables			
		Economic ($ECON$)	Social ($SOCI$)	Environmental ($ENVI$)	Error Correction Mechanism (ECM_{t-1})
Economic ($ECON$)	DE	-	0.68 ***	0.53 **	-0.39 ***
	IE	-	0.05 ***	0.02 **	-
Social ($SOCI$)	DE	0.73 ***	-	0.31 **	-0.26 ***
	IE	-	-	0.09 **	-
Environmental ($ENVI$)	DE	0.82 ***	0.57 ***	-	-0.05 ***
	IE	0.12 ***	0.09 ***	-	-

Note:In the above, *** denotes significance α = 0.01, ** denotessignificance α = 0.05, χ^2 / df is 1.19, RMSEA is 0.05, RMR is 0.003, GFI is 0.95, AGFI is 0.90, R-squared is 0.94, the F-statistic is 225.05 (probability is 0.00), the ARCHtest is 22.85 (probability is 0.1), the LM test is 1.35 (probability is 0.10), DE is the direct effect, and IE is the indirect effect.

Table 4.3 illustrates the parameters of the SEM-VARIMAX model at the statistically significant level of 1% and 5%. With the analyzed findings, the SEM-VARIMAX model features with the goodness of fit standards, where the value of RMSEA and RMR is not far from 0 (zero), while the GFI and AGFI values approach 1. Furthermore, the BLUE testing indicates that the SEM-VARIMAX model has a BLUE feature, indicating that the model is not spurious yet it is reliable. This is due to the absence of heteroskedasticity, multicollinearity, and autocorrelation. In contrast, the F-test matters at the significance level of 1%. Besides, the SEM-VARIMAX modelexplains a lot about the model featured under Sustainable Development Policy with Environmental Law(*S.D.EL*). In detail, the economic factor ($ECON$) has a direct impact on the environmental factor ($ENVI$) amounting to 82% at a significance level of 1%, the economic factor ($ECON$) has a direct impact on thesocial factor ($SOCI$) of 73% at a significance level of 1%, the social factor ($SOCI$) has a direct impact on the environmental factor ($ENVI$) totaling 57% at a significance level of 1%, the environmental factor ($ENVI$) has a direct impact on the social factor ($SOCI$) at 31% at a significance level of 5%, and the environmental factor ($ENVI$) has a direct effect on the economic factor ($ECON$) of 53% at a significance level of 5%.

In the case of ECM_{t-1}, this has a direct effect on the economic factor ($ECON$), where theparameter value is –0.39 at a significance level of 1%, suggesting that the economic factor

$(ECON)$ has the ability to adjust toward the equilibrium at 39%. For the same case of ECM_{t-1}, this has a direct effect on social factor $(SOCI)$, where theparameter value is –0.26 at a significance level of 1%, telling us that the social factor $(SOCI)$ has the same stated ability of 26%, as is the same for ECM_{t-1}, which has a direct effect on the environmental factor $(ENVI)$, where theparameter value is –0.05 at a significance level of 1%, showing that the environmental factor $(ENVI)$ has the same ability at 5%.

As for this SEM-VARIMAX mode, it has been measured for performance monitoring of the forecasting model in comparison with other models, including the MLR, BP, Grey, ANN, ANFIS, and ARIMA models by using the MAPE and RMSE, as illustrated below.

Table 4.4 Performance monitoring of the forecasting models.

Forecasting Model	MAPE (%)	RMSE (%)
MLR model	20.06	22.91
BP model	13.50	16.87
Grey model	12.11	14.48
ANN model	8.65	10.15
ANFIS model	6.42	6.89
ARIMA model	6.29	3.41
SEM-VARIMAX model	1.06	1.19

Table 4.4 explains the SEM-VARIMAX model in terms of MAPE and RMSE, and they are found to be lower than any other existing model at 1.06% and 1.19%, respectively. If considering the performance monitoring result of the forecasting model for other models, the following was found. For the ARIMA model, its MAPE and RMSE were 6.29% and 3.41%, respectively; the ANFIS model generated MAPE and RMSE with a value of 6.42% and 6.89%, respectively; the ANN model generated MAPE and RMSE with a value of 8.65% and 10.15%, respectively; the Grey model generated MAPE and RMSE with a value of 12.11% and 14.48%, respectively; the BP model generated MAPE and RMSE with a value of 13.50% and 16.87%, respectively; and the MLR model generated MAPE and RMSE with a value of 20.06% and 22.91%, respectively.

Therefore, the above calculations show that the SEM-VARIMAX model is particularly suitable for future forecasting, especially long-term forecasting to support in strategy and effective planning.

4.1.4 TheForecasting Model and the Efficiency of the Sustainable Development Policy for Energy Consumption under Environmental Law in Thailandbasedon theSEM-VARIMAXmodel

For forecasting purposes, the SEM-VARIMAX model was applied to predict energy consumption for the next 17 years (2020–2036) so as to gauge the efficiency of the Sustainable Development Policy in Energy Consumption under Environmental Law in Thailand based on the national strategy set to support policy formulation of Thailand in the future (from the present to 2036), as illustrated in Figure 4.2

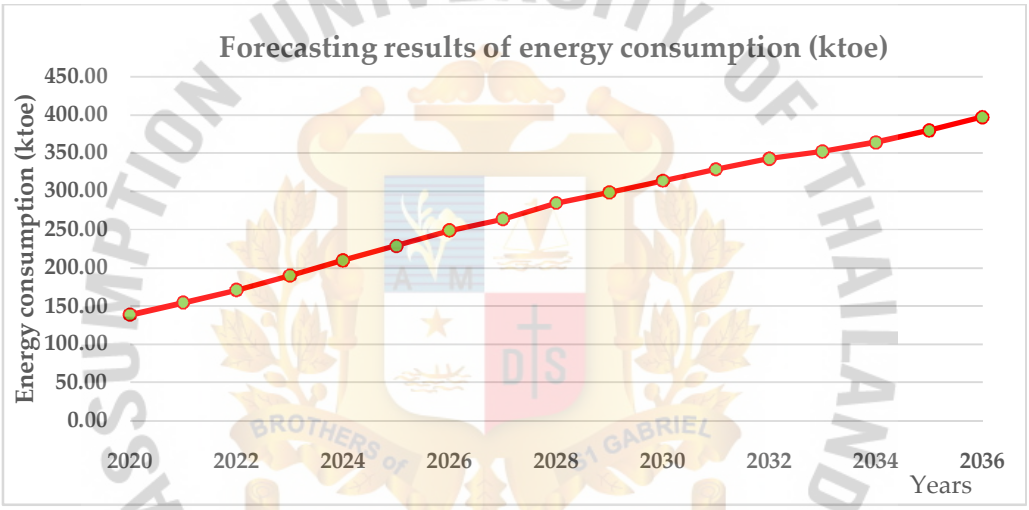

Figure 4.2 The forecasting results of energy consumption from 2020 to 2036 in Thailand.

Figure 4.2 shows that energy consumption from 2020 to 2036 under the Sustainable Development Policy for Energy Consumption under Environmental Law in Thailand will continuously increase from 2020 to 2036 with an increased growth rate from 185.66 (2036/2020) to 397.08 ktoe by 2536.

4.2 The analysis results of future environmental management based on quantitative and qualitative method according to the environmental law

4.2.1 The analysis result of having new policies scenario defined when the government enforces the law

Under the government's new policies scenario enforcement in term of environment $(ENVI)$, it has found that the analysis generates the value of error correction mechanism as low as -0.05, indicating the slowest adjustment ability to equilibrium. Therefore, the government has to

enforce a regulation in term of Environmental $(ENVI)$ aspect by creating strict measures on individual energy consumption (EC). The research applies the SEM-VARIMAX model to estimate the energy consumption for the next 17 years (2020–2036). Later, it reveals that the total final energy consumption is increasing gradually with a growth rate of 86.33% (2036/2020), as shown in Figure 4.3

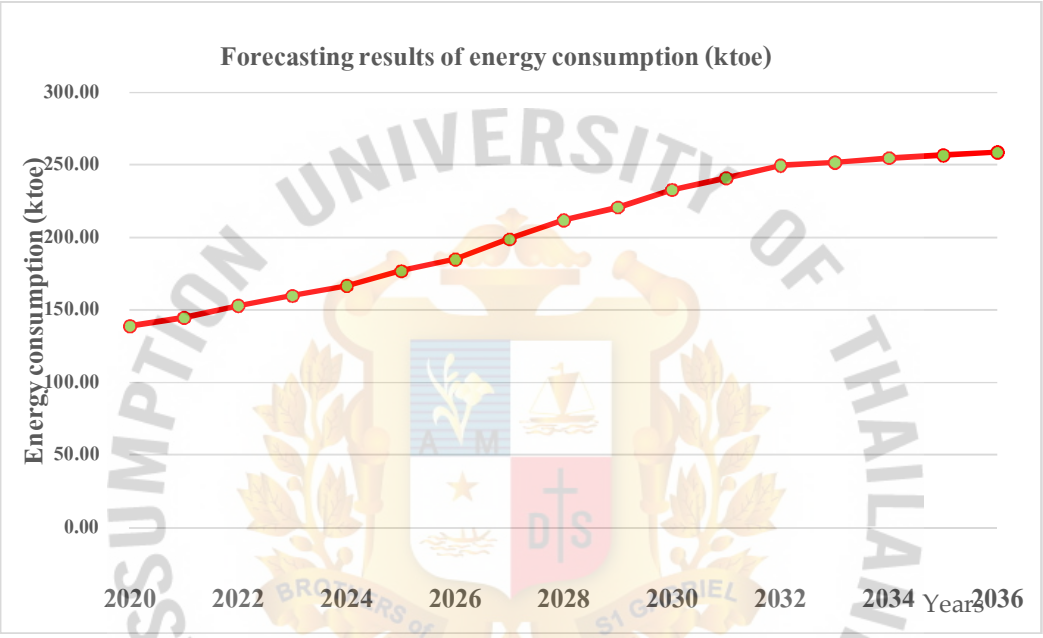

Figure 4.3 The forecasting results of the energy consumption in Thailand from 2020 to 2036 when new policies scenario is defined using theSEM-VARIMAX model

Figure 4.3 shows that thefinal energy consumption of Thailand from 2019 to 2028 in Thailand will increase along with a growth rate of 88.19% (2036/2020) within the context of new policies scenario, where it has been defined in the environmental law to limit the energy consumption of the private sector, in addition to the government effort to promote reducing the energy consumption and generating more renewable energy. Such promotion engages in the encouragement of using more electric vehicals and reducing the use of fuel. This has led to the reduction in the final energy consumption, which is not the case before defining the new policies scenario.

However, based on this quantitative research, it explains that either the implementation of the government measures is not sufficient for the national sustainable development, or the enforceable measures are not complete. This ineffincey may be due to the short-term solution intackling the environmental issue. Therefore, this research comes to integrate this result with the qualitative research by deplying economic measures, as so the enforcement of the environmental law can be strengthened. This integration can be seen in details as follows.

4.2.2 The Use of Economic Measures in the Legal Framework for Environmental Management

1. The Application of Economic Measures in the Legal Framework for Thailand's Environmental Management

In addition to the use of Command and Control measures and civil measures, the economic measures embedded in the legal system are also required to enforce laws for environmental management as so the environmental management can become more effective. The economic measures prescribed in the law for environmental management can be observed below.

1) Financial Subsidies

Financial subsidies are economic measures, which the state provides financial assistance in the form of grants or loans at low interest rates to people who meet the conditions set by the state. This is to act as a measure in promoting the prevention and reduction of environmental problems. Such measures have been adopted in the law for Thailand's environmental management. For instance, the National Environment Board can use the funds from the Environmental Fund established under Article 22 of the Enhancement and Conservation of National Environmental Quality Act B.E. 2535 (1992) for the purpose of establishing an environmental fund under Article 23 of the same Act, and this Act is explained below.

(1) The grants are eligible for those like government agencies; be it central or local, for the preparation of wastewater management or waste disposal systems, including investing and carrying out pollution control. Furthermore, it touches upon a procurement of land, materials, equipment, tools and appliances needed for operation and maintenance of the system.

(2) The state enterprise or local government can borrow from the fund for the control of air pollution, wastewater, disposal system or any other equipment for the business.

(3) A private sector can obtain a loan if an enterprise is bound with the legal duty to provide a wastewater or air control system, waste disposal systems or any other equipment for the control. This sector also covers those licensed service providers for wastewater management or waste disposal system.

(4) The grants and subsidies are given to any activity, that promotes and conserves the environmental quality upon the agreement of the Fund Committee with the approval of the National Environment Board.

Upon the observation of the above measures, the significant value is that the government can have a clear guideline based on the measures to define the environmental policies.

While the disadvantage of granting subsidies is that it will cause the state additional financial expenses, and this phenomenon will violate the principle of Polluters Pays. This is because the principle imposes a responsibility of action on the pollutant for preventing and solving the environmental problems. However, it can be observed that the conditions and criteria of the measures focus on the support of wastewater management and waste disposal systems in exclusive of the air control system.

2) Tax Measure

The type of tax measure, which is currently used for the environmental management, includes as follows.

(1) Tax incentives as a factor to change human behavior to be environmentally-committed reducing and eliminating pollution. The beneficiaries of this measure are explained below.

(1.1) The owner of the pollution source under Article 94 of the Enhancement and Conservation of National Environmental Quality Act B.E. 1992 (1992) or other relevant laws, whose responsibility is to provide air control system, wastewater management system or any other waste disposal systems. Also, any service provider of wastewater management and waste disposal system is eligible for the support and assistance from the government as follows.

- A reduction of duty collection or exemption of import duty on machineries, equipment, appliances and necessary materials related to pollution control system, which are to be imported from overseas.

- A right to bring foreign experts and specialists for installation, controlling or operation of the air control system or waste disposal system can be exercised. Additionally, these experts can request a tax exemption on income from the National Environment Board.

The implementation of such measure, therefore, aims to provide support and assistance to individuals with the legal duty but wish to carry out a pollution control. This measure further includes special services, allowing the attainment of the machineries, equipment and materials at a cheaper cost.

(1.2) Any operator wishing to import machineries, materials and equipment that are energy-saving and environmentally friendly for their businesses or any distributor or importer whose users have purchased or arranged those materials through them, which go in line with the 5th Economic and Social Development Plan 1982-1986 on energy saving, can apply for a duty reduction according to rules and regulations for energy saving and environmental protection 1987.

It can be seen that tax measure by means of tax deductions or tax

exemptions is used to create incentives for project operators or development activities, such as industrial factory that deems as an important business unit in creating the country's economic prosperity, enabling the state to implement the environmental policy to achieve its objectives.

(2) Product tax as a factor to create incentives for choosing environmentally friendly products, any less polluted product or any product that has a minimal environmental effect. With a taxation at different rates, the products are sold at different prices, resulting in the prices of environmentally friendly products lower than those polluted products.

(3) Recycle tax as a factor to create incentives for reuse and waste reduction. For instance, batteries are taxed at a different rate due to environmental issue associated with them, as they are toxic and difficult for disposal.

However, Thailand does not have a system to collect back batteries, yet most people lack of understanding to the extent how danger mercury, cadmium and lead of expired batteries are. In fact, they are disposed of as general waste, therefore the above measure does not incentivize the individuals as much as it is supposed.

3) Environmental Liability

The economic measures in this case lead to the market creation of the market, where the law requires polluters environmentally responsible. This is inclusive of liability for damage to people or the environment, liability for purifying and restoring natural resources and the environment. This environmental responsibility urges the owners or sources of pollution to manage the risk of their potential damage. If the liability has fallen upon them, the risk is transferred to an insurance company or a bank.

The environmental liability evolving around environmental insurance used in Thailand' law includes the responsibility for self-damage or any disturbance on other people, property or the environment as stipulated in Article 131/1 of the Mineral Act (Version 5) 2002, for instance.The advantage of using this environmental liability measure is that it can be used to ensure that there will be a responsible party to pay for damage if the environment is harmed. In principle, this measure is designed to create a market of buying insurance, incentivizing owners of pollution sources to prevent the environmental damage. However, this piece of environmental liability used in Thailand is limited to environmental liability of the mining businesses only.

4) Fees

The collection of fees is imposed on the wastewater management service and waste disposal service. However, if the owners of pollution sources with the legal duty to manage wastewater do not have their own pollution control system, they are obliged to pay service fees based

on the National Environment Board. In the implementation of such measure in collecting service fees for the environmental pollution reduction, the state must be prepared with a pollution control management mechanism. If the principle of Polluters Pays applies, the state must charge based on the amount of service used in order to motivate in the reduction of toxic. However, the implementation of this measure is currently unsuccessful. Therefore, the development of existing measures should be encouraged by using the principle of Polluters Pays in a better manner in order to prevent environmental problems from potential pollution sources.

2. The Application of Economic Measures in the European Union Environmental Law

1) Facts

The European Union (EU) has an international organization established by the Maastricht Treaty with the aim of creating cooperation in various fields, especially in the economy, trade, finance, society, foreign policy, security, protection and justice. This cooperation further includes the environmental affairs. Underpinning all objectives, EU wishes is to share economic success, trade and create a better quality of life for citizens. Currently, EU has 28 Member States in Europe. The initiation of the European Union began with the founding of the European Community. The European Community originated from the merger of the three communities in 1967, namely the European Coal and Steel Community under the Treaty of Paris 1951, the Economic Community and the European Atomic Energy Community under the Treaty of Rome 1957. This merger was made to create a common European market and reduce economic and trade barriers between the Member States. Furthermore, it aimed to create a working organization, containing Council, Commissioners, European Parliament and Courts of Justice, while the transfer of some sovereignty from Member States to various organizations of the community can be extended to neighboring countries. In 1986, the Single European Act was adopted to amend the treaties of the European Community and establish measures to eliminate physical, technical and tax barriers. This elimination means to achieving a single European market, where all four types of production factors; goods, capital, labor and services, are able to move freely between the Member States of the European Community and develop industrial cooperation at the same time.

2) The Origin of the European Union Environmental Law

The Treaty of Rome 1957 established the European Economic Community with the main objective of creating a common European market, as so the freedom in trade, labor, capital and services could be attained. Implemented policies aiming at the elimination and reduction

of environmental obstacles were not clearly identified. However, as of the environmental management for the Community, Article 2 of the Treaty of the European Economic Community is referred. In 1971, there was a discussion aimed at solving the environmental problems in the Community level. Later, the governments and international policy cooperation were in the same agreement to work on the above objective, leading to the next meeting of the Member States or so called the Paris Summit in 1972. The Singe European Act 1986 includes the environmental packaging, making it as a reference for issuing environmental standards and law. Moreover, it becomes as a guideline for the Community in dealing with the environmental measures and criteria. In addition, it is the foundation of European environmental law and used in the development of environmental action plans, especially Article 130R that specifies the objectives of the Community in carrying out activities related to the environment, including early protection, preventive action and protection and improvement of the environmental quality in order to support the protection of human health and the optimization of natural resources. The Maastricht Treaty has been amended by adding Article 130R-130T specifying the environment as a policy of the European Union while maintaining the objectives of the environmental measures of Article 130R of the single European Treaty. Moreover, it stresses an additional concern of the environmental measures to address the environmental problems at both regional and global scale.

The regulations of the European Union are the codes established by various institutions of the European Union and have a secondary status with the virtue of the EU Treaty. Therefore, the EU regulations on the environment will depend on the environmental policy and the legal basis of the EU treaty. Rules and regulations are divided into various categories, which are explained below.

(1) Regulations are the laws of the community in which every element of the regulations is effective and enforceable to all Member States.

(2) Provisions are a guideline for the Member States, where the Council often uses the provisions to set objectives. The Member States must use such provisions alongside with their legislation or amendment of existing internal laws.

(3) Command is a regulation to the government of the Member States, companies or private organizations, and it is binding only those specified in the command.

3) The Application of Economic Measures in the European Union Environmental Law

The initial concern on the environment of the European Union was for the first time in the 1970s, and most laws and regulations related to the environment would be in terms of

Command and Control measures, such as the setting of environmental quality standards and the formation of liability of environmental damage. The use of economic measures in the European Union environmental law can be summarized as follows.

(1) 1st Environmental Action Plan specifies the feasibility study of implementing appropriate economic measures for the environmental management.

(2) 4th Environmental Action Plan (1st issue) seriously puts an emphasis on economic measures by adopting the polluter principle by means of negative incentive and preventive measures.

(3) 5th Environmental Action Plan develops the use of economic measures in the law for the environmental management as well as the prevention of environmental pollution problems in conjunction with the Command and Control measures.

(4) 6th Environmental Action Plan continuously gives the importance of the determination of economic measures and market measures without abandoning old measures or Command and Control measures.

In addition, the Environmental Action Plan has established preventive measures, which identify actions to prevent the environmental damage before they occur. The economic meaning describes the cost of prevention is higher and difficult than the cost of solving and fixing.

(1) Product-life cycle system

The Product-life cycle system used in the European Union has a form of deposit system, which refund is also included. As can be seen from establishment of the European Union Product-life cycle system, it aims to support the recycling of old products or reusing them. It is a method of helping reduce waste based on the principle of solid and hazardous waste management policy. The main example of such system falls under the provision of 2002/96 / EC on Waste Electrical and Electronic Equipment. The important elements of the above provision are as follows:

(1.1) Manufacturers must bear all the costs of managing waste from electrical products and electronic devices they produce with a responsibility for both the cost incurred and the physical management.

(1.2) Manufacturers must carry out waste management by keeping the product waste. They are expected to provide a central collection point, where the households can access to discard the waste in order to ensure that they can actually recycle or refuse waste products.

(1.3) Manufacturers must establish a waste management system originated from electrical and electronic products.

(1.4) Informative measure should be put in place to enable the consumers aware of necessary information, such as waste category and type of product, as so the waste can be separated out of general waste.

(2) Environmental Taxation

Environmental taxation means tax measure or fees collection, which incentivizes people aware of the value of the price and the cost of the environment. The goal is to change the behavior of manufacturers and consumers by encouraging the use of environmentally friendly products and discouraging the otherwise products. The environmental tax consists of pollution tax, product tax, usage tax and management fees and many more. The idea of establishing the environmental tax measure of the European Union began in 1992. The Commission presented a report on the implementation of carbon tax measures, which later was revised the form of tax measure into product tax measure in 1997, as to facilitate the tax collection. In 2003, the tax provision of 2003/96 / EC on Restructuring the Community Framework for the Taxation of Energy Product and Electricity was made by specifying the minimum tax rate for energy product tax, including fossil fuels, animal carcass, petroleum and electricity. The main principles of the tax deduction measures in accordance with the above regulations are as shown below.

(2.1) An exemption or reduction of tax on the generation of clean energy or energy that does not affect the environment.

(2.2) The implementation of this measure is done through two methods; voluntary basis and licensing with the aim of environmental protection or work efficiency improvements.

(2.3) This provision also stipulates that the government subsidies are to encourage behaviors that are beneficial to the environment, including the subsidies for renewable energy projects.

(3) Emission Permits

In order to align with the EU climate change policy in reducing emissions, the European Union requires the use of a pollution discharge permit system under Article of 2003/87 / EC in Establishing a Scheme for Greenhouse Gas Emission Allowance Trading with the Community as part of the Tokyo Protocol compliance. This provision has the objective of reducing greenhouse gas emissions, and its main principles are composed of as follows.

(3.1) Licensing system specifies the quantity of the allowed pollutants to be discharged, and the use of carbon dioxide license began early than any others license. However, the license can be revised and added other gases into the coverage.

(3.2) Limiting greenhouse gas emissions is about determining the amount of allowable emission to be emitted.

In addition, the amount of emissions can be traded if a licensee is able to reduce the emission lower than the allocated amount. This trade can be done between parties in the European Union or between individuals in the European Union and the countries listed in Annex B of the Tokyo Protocol.

(4) Environmental Liability

The environmental liability is the duty of paying for actions that cause a damage on the environment. This measure is included in the agenda of the Board of Directors. The White Paper has been prepared to study the environmental liability, which the polluters are a payer for the damage. Under this measure, Article of 2004/35 / EC on Environmental Liability with Regard to the Prevention and Remedying of Environmental Damage is presented. This provision intends to determine the area of environmental liability on the basis of Polluters Pays. Also, the preventive actions are as a tool for law enforcement to help manage the environment. The key principles of this provision are explained below.

(4.1) Define the definition of damage to the environment as:

- damage to protected plant and animal species, as well as natural habitats, including a change or deterioration, which has a profound effect on a conservation area, habitat or species.
- damage to water sources, including a change or deterioration, signaling an effect on the ecosystem.
- damage to the land, including a sign of risk to human health effects.

(4.2) Require the Member States establish a liability agency to implement the provision.

(4.3) Require the operators with preventive and restorative measures although no damage has occurred.

(4.4) Require the operators with financial security in the form of insurance or any other possible forms. This requirement is an important part of the underlying successful concept of liability, and the Member States should support the development of measures for the use of financial collateral.

3. The Analysis of the Economic Measures Usage in the European Union Environmental Law As a Guideline for Thailand's Environmental Management

The gathering under the international law of various European countries in the establishment of the European Community to the European Union carried the main objective of creating a joint European market and reducing the obstacles and barriers, which may affect the common European market. The Member States are, therefore, subject to the laws issued by the European Union. When the trend of the global environment and environmental problems affect the Member States and become an obstacle to the common European market, the environmental issues are, therefore, triggered a serious attention by EU, allowing them integrated as part of policies and principles of the EU laws. The key principles and policies of the European Union environmental law can be summarized as follows.

1) Principles of Environmental Protection Measures Planning

2) Principles of Environment Damage Management

3) Principle of Polluters Pays

Law is, therefore, an important tool of the European Union to comply with the principles, policies and the enforcement process of the environmental law of the European Union by using Command and Control measures as to affirm the compliance of the rules and laws. For instance, the use of licensing systems is applied to control the business activities. However, due to the aforementioned measures, there are some limitations, creating a slow attainment of effective environmental prevention and repair.

Therefore, the development of the enforcement of environmental law in the European Union has shifted to the use of economic measures in conjunction with Command and Control measures, resulting in the improved protection, and this can be summarized as follows.

1) Provision of 2002/96/EC on the Management and Disposal of Waste from Electrical Products and Electronic Devices of the European Union aims to reduce the amount of harmful waste. The economic measures in this directive will be able to increase the efficiency in solving the problem of hazardous waste. This statement expects the followings.

(1) Requiring the manufacturers responsible to retrieve back the carcass of electric products and electronic equipment for proper disposal, implying that the manufacturers will be well-informed about the responsibility for the environmental impact caused by them.

(2) Requiring the manufacturers responsible to retrieve back the carcass of electric products and electronic equipment for proper disposal, implying the increase in disposal cost to the manufacturers, and that urges them to improve the manufacturing process.

2) Provision of 2003/96/EC on Restructuring the Community Framework for the Taxation of Energy Products and Electricity aims to promote and support clean energy, enabling to reduce greenhouse gas emissions in accordance with the Tokyo Protocol. This limitation can be further used to solve the global warming as follows.

(1) Specifying the use of tax deduction or exemption methods for business units that use clean energy. This can inspire these business units to develop energy use so that they do not affect the environment.

(2) Providing financial subsidies for the operators, motivating them to use clean energy in the production process. This will help incentivize them to join the government in improving energy consumption in the production process.

From the early discussion, it can be observed that the tax measure is being adopted in the European Union environmental management. For example, England has adopted the climate change Levy in the Finance Act 2000, Northern Ireland exempts taxes for those factories using natural gas-based energy, and France uses the Finance Act 2000 to introduce taxation for the energy use in the factories. All these tax measures are there to promote the use of renewable energy and help with the taxation adjustment for those energy-intensive factories based on the governmental conditions.

(3) Provision of 2003/87/EC on Establishing a Scheme for Greenhouse Gas Emission Allowance Trading with the Community of the European Union aims to reduce the greenhouse gas emission. This provision explains the followings.

(3.1) The use of a licensing system (Permit) for pollution disposal can be used to solve the problem of emission by setting the environmental quality standards through Command and Control measures, imposing the liability when the disposal or release exceeds the allocated limit.

(3.2) The permissibility to trade the permit will help promote the use of an emission permit system effectively reducing the pollution into the environment.

(3.3) The permissibility to trade the permit will provide incentives for license holders to improve pollution control systems so that they do not need to acquire another permit if they can lower pollution emission amount than what has been stipulated in the license.

(3.4) Provision of 2004/35/EC on Environmental Liability with regard to the prevention and remedying of Environmental damage of the European Union aims to support the Polluters Pays by transferring risk via financial security or guarantees. The use of this economic

measure in this particular provision can build a confidence for the European Union that those operators have ways to prevent and remedy the environmental damage. This is to explain that:

- The operators with potential risk in damaging the environment must have financial security for liability in damaging the environment. Therefore, those operators will have a proper prevention plan and remediation strategy for the damage in order to protect their financial security.

- The application of financial security can ensure the state that any damage on the environment will be resolved urgently by a responsible party as suggested by the principle of Pollutions Pays.

In addition, the advantages of each economic measure in these provisions are of which the economic measures are utilized to determine targets for the prevention and solving of the environmental issues better than Command and control measures by law, implying a prescription for general use without discrimination.

Chapter 5

Conclusion, Discussion and Recomentdations

5.1 Conclusion

This research was developed from relevant theories and advanced statistics to develop the SEM-VARIMAX model. This model differs from previous ones because it attempts to close several gaps and generate a functional model for the present, leading to research outcomes that are inclusive of special features relevant to different sectors and contexts. The software used in this research was LISREL incorporating EVIEWS, which are widely regarded to be the best choices for application. This research was conducted thoroughly and carefully while considering factors that influence policy implementation. This effort differentiates this research from other studies. In addition, this forecasting model determines real relationships between relevant causal and influential factors and the efficiency of Sustainable Development Policy for Energy Consumption under Environmental Law in Thailand $(S.D.EL)$. The model comprises three latent variables: economic $(ECON)$, social $(SOCI)$, and environmental $(ENVI)$ factors,while the observed variables are energy consumption (EC), percapitaGDP (GDP), urbanizationrate (UR),industrialstructure (IS), net exports $(E-M)$, indirect foreign investment (IF), foreign tourists (FT), employment (EM), health and illness (HI), social security (SS), consumer protection (CP), Carbon dioxide emissions (CO_2) and energy intensity (EI). Each factor has undergone various processes to ensure its significance. To the greatest extent possible, this research also eliminated potential issues that may lead to spurious results, a problem that is faced in the development of any model. This elimination ensures the absence of heteroskedasticity, multicollinearity, and autocorrelation [103,110]. In this research, we identified the relevant factors and their impact direction. Most importantly, the approach used was able to adjust each latent variabletoward equilibrium, which renders it significant for studying the change and balance resulting from the Sustainable Development Policy for Energy Consumption under Environmental Law in Thailand. The key measurement indicator is the error correction mechanism.In addition, the SEM-VARIMAX model passed the qualification for the BLUE feature and thus met the goodness-of-fit requirements. This research also examined the performance of the model in terms of MAPE and RMSE values and compared them with those of existing models, including the MLR, BP, Gray, ANN, ANFIS, and ARIMA models. It was found that the SEM-VARIMAX model had the

lowest MAPE and RMSE, followed by the ARIMA, ANFIS, ANN Grey, BP, and MLR models, ordered in descending performance.

The SEM-VARIMAX model was used to predict energy consumption for the period of 2020–2036, and energy consumption was found to have an increased growth rate from 185.66 (2036/2020) to 397.08 ktoe by 2036. This rate is obviously higher than the government's set target, which is 251.05 ktoe by 2036. This further reflects the inefficiency of the Sustainable Development Policy for Energy Consumption under Environmental Law in Thailand; the findings predict the disruption of the government's plan for carrying capacity under the environmental law currently enforced in Thailand. In addition, this research found that the adjustment to the environmental equilibrium in Thailand can be measured by the parameter of the error correction mechanism. The value of the parameter reflected a low adjustment rate of only 5% in the environmental aspect, while the economic side had an adjustment rate of 39%. For the social aspect, the adjustment rate was 26% of total capacity. This finding presents clear evidence of the inefficiency of the environmental law in Thailand. In fact, this law has not been fully updated and modernized for the current context.

Recommendations for the future application of this research include the selection of appropriate statistics and research procedures that fit efficient long-term forecasting. This forecasting requires the best model and a white-noise-type model. The findings of this research explicitly reveal that the country will be at disadvantage if the policy is implemented according to the past or present practice or according to ordinary least squares or only the ARIMA model is used in the research. Quality research must focus on the forecasting task, with an emphasis on forecasting quality and validity. This is to avoid any possible damage that may arise.

The limitation of this research is that Thailand's policy planning does not consider causal factors or their impact. This is evident from Thailand's attempt to improve the economy and society through the implementation of various measures. However, the environmental law in Thailand does not fit the current situation or context, which constantly change, leading to a failure to support a green environment. In addition, some factors were found to be inconsistent with the model because of the intervening factor of fuel price control and government interference in certain sectors, resulting in the imbalance between demand and supply. This further causes instability in these factors at certain times. However, long-term forecasting is always a challenging task that requires detail and consistency. The SEM-VARIMAX model can be applied to different contexts and sectors, but it has to be carefully utilized because of its in-depth analysis, complexity, and advanced statistics used in the modeling process. If this model is properly applied, it will have great potential to provide extensive knowledge in the future.

5.2 Discussion

Law enforcement for environmental management is an essential tool of state to protect and solve environmental problems. For law enforcement to manage environment in Thailand, it composed of environmental law such as National Environmental Quality Promotion and Conservation Act 1992 and specific environmental problem solving law such as the Factory Act 1992. The majority of law enforcement would be directing and controlling measures including civil measures to take responsibility and compensation on damages and other supporting measures for law compliance.

Directing and controlling measures are composed of administrative measure as being the primary measures to grant authority to administrators for environmental management which is to issue general orders or secondary laws, to issue specific administrative order, to execute operation power for law enforcement and penalty.

Criminal measures which are the important measures for law enforcement to strictly comply with the law. Criminal measures are to define period on legal imprisonment and the high fine penalty to restrain of offense.

Civil measures are being used for the purpose of having the polluters to compensate those who are physically suffered or property damaged from the offender to environmental act to receive compensation easier by enforcing the civil liability as the severe liability.

However, law enforcement to manage environments by directing and controlling measures including civil measures still do not cause the strict compliance due to the restrictions to be summarized as follows:

- Problem on executing administrative measures: by attributes of environmental act which is related to various interdisciplinary of knowledge and expertise of administrators and the readiness of administrators to monitor closely the law compliance which is very costly to the state on such operation.
- Problem on enforcing criminal measures: normally state would consider to get fine at high rate rather than imprisonment same as administrative measures. Therefore, it would require closed monitoring and controlling on law compliance with limited resources of state staff which lead to the negligence for the protection but will observe only when the occurrence of damages happened which is not the good environmental management plan, and
- Problem on enforcing civil measures: although there is a strict measure but the problem is that the victim has the duty to prove such damage is caused from the polluter which is a hard burden to find out the information which the polluter knows well on all of them. Also it is necessary

to have experts to prove on such damages. Moreover, calculation of the damages based on the proof of current actual damage or the estimation of damage is not relevant to the environment act of interdisciplinary which composed of sciences and to have expert to prove the damages link to the visible or invisible damage possibility in the future. The author's opinion is that the court justice process cannot clearly secure the full compensation from the polluter.

- The direction of current problem solving is that the economical measures are the supportive measures to enhance the effectiveness of the environmental law enforcement.

- To execute the economical measures for environment management, from the study of relationship of environment and economic there is a relationship at significant level. The occurrence of environment problem cause from the economic system that is the environment system is a cost of production and also the supporter of waste incurred from the production process of the economic system. Therefore, the economical tool as the measures to manage environment by which such measures will control economic system to operate with the consideration that the environment system as a valuable cost and expenses so that the economic system would add on such cost as part of the production cost according to the principle that polluters have to pay for such cost. As such, the environment system will become more effective and be advantage to both utilization and prevention of environment from the beginning stage.

- Economical measures composed of a) Monetary and tax collection b) Support and concession tax c) Incentive by financial forcing d) Deposit and refund system e) Ownership and marketing system.

However, the current economical measures for environmental management act of Thailand such as tax measures to promote the compliance and to change the behavior of manufacturer to be environment friendly and for consumers to select goods which is environment friendly. The financial supportiveness is a partial of economical measures for developed countries which can be utilized for further improvement.

- The author's opinion is that Thai law enforcement for environmental management should apply economical measures to support the efficiency by studying the law enforcement of European Union which is improved by combining the incentive of the economical measures, directing and controlling measures and civil measures to enforce for effectiveness of environmental management such as:

- Products life cycle system or deposit and refund system for waste management of electric and electronic components. The objective is to reduce the quantity of dangerous waste by defining that the producers have duty to take back expired salvage for the further proper elimination

method. The advantage is that the producers have to improve the production system so that such waste components can be reused to reduce the cost of getting rid of.

- Tax measures for energy or electrical products with the objective to promote and support the utilization and development of clean energy. The advantage is to reduce the releasing of carbon dioxide to the environment which is the cause of global high climate.

- The licensing to release pollution system, the objective is to reduce the releasing of Greenhouse Gas into the environment by persuading the benefit received from the selling of license. The advantage is to grant incentive to producers who reduce less pollution so they can sell the remaining license.

The objective of environmental liability is to have the polluters to pay by defining that the producers who are at risk to create damages to the environment should have financial guarantee. This is to encourage the producer to have preventive and restore measures on the damages. The advantage to the state is that there is a guarantee that the polluter will pay for the cost of preventive and the restore measures and there is an incentive for them to carefully run the business.

As of aresult, this research shows a clear evidence of which the government must enforce the regulation together with the economic measures to enforce the environmental law, as so the sustainable development can be achieved, enabling Thailand 4.0 policy. This is where all dimensions of economic, social and environment development are realized.

5.3 Recommendations

The policy recommendations of Thailand derived from this research all concern the environmental law of Thailand. Although Thailand currently has the National Environmental Quality Promotion and Preservation Act (Version 2) B.E. 2561, it is still too weak to achieve the efficiency of sustainable development policy under environmental law. This is due to the failure to achieve the determined target along with some weaknesses, that require correction. In order to improve the environmental law, the following is suggested.

1. Increase community participation in the management and preservation of natural resources and the environment. For instance, there is the requirement of community representatives, state and public representatives who are elected or nominated to be part of the National Environment Board (Category 1).

2. Revisit the direction of the National Environmental Development Plan locally, provincially and nationally.

3. Adopt the concept and philosophy of Thai traditions about the environment, as well as universal environmental law concepts, such as environmental justice being integrated into the constitution, so that the law and ordinances become supportive.

4. There are currently many environmental laws under different wings of administrations. Therefore, this has to be organized and systemized.

5. At present, the environmental case is under the judicial process of both the civil court and administrative court. Hence, all environmental cases shall be dealt with only by the administrative court, as the cases are wholly a matter of environmental justice, relating to the benefits of individuals, society and public interest. This settlement requires special expertise, which differs from civil cases. This further requires a revision of the law to switch the jurisdiction.

6. Mobilize scientific experts about the environment in various fields to help making legal decisions, conducting research, and developing environmental knowledge, as well as keeping environmental laws up to date.

7. Revise the processes and penalties from the polluter pays principle (PPP) with serious implementation and clarity.

8. Establishing the standards and limit of chemical decomposition from a factory is a method of controlling a root cause, resulting the factory helds responsible for air pulltion. Most importantly, it is essential to an environmental impact assessment (EIA), forcing the factory to report what chemicals have been released into the air, and what volume exceeds the carrying capacity. In this part, the private sector must act truthfully and avoid any falsehood, as so the environment and the people are protected.

9. Using the state power to create environmental management measures is an essential strategy to preserve the environment. In regulating the environmental law requires the controlling measure of plant sources, which comes with a systematic and clear direction by the government while the law is strictly followed. In addition, the environmental law must specify the controlling quantity of waste releaseinto the environment. At the same time, the goal of green house gas reduction must be clearly and strictly identified.

10. To amend “National Environmental Quality Promotion and Preservation Act B.E. 2535” to have economical measures to support law enforcement. The economical measures which should be executed are:

1) To apply the licensing to release pollution system which is sellable to support the law enforcement for environmental management with directing and controlling measures in setting up the standard of pollution control. The objective of this licensing system is for the producers to reduce

releasing quantity of pollution to environment by giving incentive of sellable license and to be in line with the environmental quality standard. To define the appliance of licensing to release pollution system, composed of :

a) Defining categories of pollutions to be controlled

b) Defining the source of origin of pollutions to be controlled, the releasing and the right according to the license.

c) Defining the areas to be controlled

d) Defining the quantity of pollution in accordance with the definition of environmental quality standard

The author believes that the licensing to release pollution in European Union is a good example of initiation to apply such system in Thailand because the categories of gas to be controlled can be defined and the type of business to be appropriately controlled. Moreover, it can be linked to the tax of energy product measures to also encourage for clean energy.

2) The implementation on tax measures for energy components by reducing tax or tax exemption to the business using clean energy such as energy from steam power or solar cell. This is the persuasion for producer to use clear energy and to develop clean energy and to support Energy Conservation Promotion Act B.E. 2535 of which the principle and reason is to control utilization of energy by the directing and controlling measures to define category of factory and building to be under controlled.

Although the implementation on tax measures by reducing tax or tax exemption will decrease the amount of tax collected, state will get benefit in return on decreasing cost from directing and controlling of environmental management.

3) Environmental liability measures by defining that the producer or owner of such pollution origin should have financial guarantee so that the decree 96 and 97 of this act will be more effective.

The author believes that regulation of European Union defining the environmental liability of which the state is the responsible organization for the damage, same as decree 96 clause 2 and decree 97 of the National Environmental Quality Promotion and Preservation Act B.E. 2535 and the definition of financial guarantee composed of bank guarantee, bond and environmental insurance or other guarantees will secure the state that the polluters will be the payer of such damages to the environment. This is to protect and restore the damages to environment including the encouragement to producer to prevent the damage and not to incur costs from insurance premium or to lose the financial guarantee.

11. To bring products life cycle system or deposit and refund system to reduce dangerous waste. At present, due to none direct law enforcement to manage dangerous waste, it is necessary to issue new laws to enforce the deducing of waste from electric and electronic components by defining that the producers have duty to take back expired products for the proper elimination method or to be reused. This system will encourage the producers to develop the production system or production design to be complied with the elimination process of such salvage.

The author believes that the regulation of European Union, to define the salvage of electric and electronic components is good example for Thailand to initiate this system.

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ENHANCEMENT AND CONSERVATION OF NATIONAL ENVIRONMENTAL QUALITY ACT, B.E. 2535

BHUMIBOL ADULYADEJ, REX.
Given on the 29th Day of March B.E. 2535,
Being the 47th Year of the Present Reign

His Majesty King Bhumibol Adulyadej is graciously pleased to proclaim that :

Whereas it is deem expedient to reform and improve the law on enhancement and conservation of national environmental quality.

Be it, therefore, enacted by the King, by and with the advice and consent of the National Legislative Assembly, acting as the National Assembly, as follows :

Section 1 This Act shall be called "The Enhancement and Conservation of National Environmental Quality Act, B.E. 2535"

Section 2 This Act shall come into effect after the elapse of a period of sixty days from the date following its publication in the Government Gazette.

Section 3 The following Acts shall be repealed :

(1) The Enhancement and Conservation of National Environmental Quality Act, B.E. 2518.

(2) The Enhancement and Conservation of National Environmental Quality Act (No. 2), B.E. 2521.

(3) The Enhancement and Conservation of National Environmental Quality Act (No. 3), B.E. 2522.

Section 4 In this Act,

"Environment" means natural things which form the physical and biological conditions surrounding man and man-made things.

"Environmental Quality" means the balance of nature, being composed of animals, plants, natural resources and man-made objects which is for the benefit of subsistence of mankind and the sustenance of human-being and nature.

"Environmental Quality Standards" means the parameters of quality standards for water, air, noise and other conditions of the environment which are determined as the general criteria for enhancement and conservation of environmental quality.

"Fund" means the Environmental Fund.

"Pollutant" means wastes, hazardous substances and other polluting substances as well as residues, sediments or remainders of such matters, which are discharged from point sources of pollution or naturally occur in the environment, that have or are likely to have impacts on environmental quality or to cause conditions poisonous or harmful to the health and hygiene of the public, and shall mean to include radiation, heat, light, noise, odour, vibration or other nuisances eminated or

discharged from point sources of pollution.

"Pollution" means the state or environment that has been affected, changed or contaminated by pollutants, resulting in deterioration of environmental quality, such as water pollution, air pollution, soil pollution.

"Point Source of Pollution" means any community, factory, building, structure, vehicle, place of business or activity or any other thing from which pollution is generated.

"Waste" means refuse, garbage, filth, dirt, wastewater, polluted air, polluting substances or any other hazardous substances which are discharged or originated from point sources of pollution, including residues, sediments or remainders of such matters, either in the state of solid, liquid or gas.

"Wastewater" means waste in liquid state including polluting or contaminating substances contained in such liquid.

"Polluted Air" means waste in gaseous state in the form of vapour, steam, exhaust, fume, odour, smoke, gas, dust, soot, ash or other polluting substances in the form of particulate matters that can be suspended in the atmospheric air.

"Hazardous Substance" means explosive substances, inflammable substances, oxidizing and peroxiding substances, toxic substances, pathogenic substances, radioactive substances, genetic transforming substances, corrosive substances, irritating substances, or other substances whether chemical or not, which may cause danger to human-being, animal, plant, property or the environment.

"Nuisance" means nuisance according to the law on public health.

"Factory" means factories according to the law on industrial plants.

"Building" means buildings according to the law on building control.

"Vehicle" means automobiles or motorcycles according to the law on automobiles, vessels according to the law on Thai vessels and aircrafts according to the law on aviation.

"Monitoring Control Operator" means the person licensed to monitor, control, assess, operate and maintain wastewater treatment or waste disposal facility, or equipment, instrument, tools, appliances for control, treatment or disposal of any other pollution, which the owner or possessor of point source of pollution manages to construct and bring into operation by his own investment and expenses for the treatment of wastewaters or disposal of wastes or any other pollutants.

"Service Contractor" means the person licensed to render for hire the services of wastewater treatment or waste disposal or monitoring of environmental quality.

"Conservation Area" means the areas designated as national parks, wildlife reserves, tourism preserve and other protected areas pursuant to the governing laws related thereto.

"Local Official" means

(1) President of the Municipal Council within a municipality.

(2) President of the Sanitary District Board within a sanitary district.

(3) Changwat Governor within a local administration organization.

(4) Governor of the Bangkok Metropolitan Administration within Bangkok Metropolis.

(5) Permanent Secretary of Pattaya City Administration within the City of Pattaya.

(6) Head of local administrator in the administration of the local administration organization other than (1) to (5) above, established by specific law governing thereof, within such local administration organization.

"**Pollution Control Official**" means the person appointed by the Minister to perform the functions concerning pollution control under this Act.

"**Competent Official**" means the person appointed by the Minister to have power and duty to take action under this Act.

"**Minister**" means the Minister of Science, Technology and Environment.

Section 5 In case any provision under this Act refers to Changwat or mandates the power and duty of the Changwat Governor, such reference or mandate shall denote the inclusion of Bangkok Metropolitan Administration or the power and duty of the Governor of Bangkok Metropolitan Administration, as may be the case.

Section 6 For the purpose of public participation in the enhancement and conservation of national environmental quality, the following rights and duties may be accorded to individual person as provided by this Act or governing law related thereto :

(1) To be informed and obtain information and data from the government service in matters concerning the enhancement and conservation of environmental quality, except the information or data that are officially classified as secret intelligence pertaining to national security, or secrets pertaining to the right to privacy, property rights, or the rights in trade or business of any person which are duly protected by law.

(2) To be remedied or compensated by the State in case damage or injury is sustained as a consequence of dangers arisen from contamination by pollutants or spread of pollution, and such incident is caused by any activity or project initiated, supported or undertaken by government agency or state enterprise.

(3) To petition or lodge complaint against the offender in case of being a witness to any act committed in violation or infringement of the laws relating to pollution control or conservation of natural resources.

(4) To co-operate and assist government officials in the performance of duty relating to the enhancement and conservation of environmental quality.

(5) To strictly observe the provisions of this Act or other laws concerning the enhancement and conservation of environmental quality.

Section 7 In order to encourage public participation in the promotion and conservation of environmental quality, non-governmental organizations (NGOs) having the status of a juristic person under Thai law or foreign law which are directly engaged in activities concerning environmental protection or conservation of natural resources without any objective to be involved in politics or to make profits from the engagement in such activities, shall be entitled to register with the Ministry of Science, Technology and Environment as the NGOs for environmental protection and conservation of natural resources in accordance with the rules, procedures and conditions prescribed by ministerial regulation.

Section 8 The NGOs that have been registered pursuant to section 7 may request for government assistance or support in the following matters :

(1) The organization of volunteers to assist in the performance of duty of government officials under this Act or other laws concerning the enhancement and conservation of environmental quality.

(2) Public relations campaign and dissemination of information or data to promote public awareness and proper understanding and knowledge about environmental protection and conservation of nature and natural resources.

(3) Providing assistance to people in certain areas of the country to initiate projects or activities for environmental protection and conservation of natural resources in such areas.

(4) Conducting study and research in respect of environmental protection and conservation of natural resources and bringing to the attention of the Government or agencies concerned on what are the viewpoints and suggestions based upon the outcome of such study and research.

(5) Providing legal aid to people who are in jeopardy of or afflicted by pollution damage caused by leakage of pollutants or contamination as well as acting as representative of such pollution victims to bring lawsuit and litigate claim in court for compensation or damages to which they are entitled as legal remedies.

In case any registered NGOs, in the carrying out of activities indicated in the first paragraph, encounter problems or difficulties and request for help from the National Environment Board, the Prime Minister shall, with the recommendation of the National Environment board, have the power to direct for appropriate recourse or order the government agency or state enterprise concerned to render assistance or facilitation as seen fit under the circumstances.

The Fund Committee, with the approval of the National Environment Board, may consider to allocate grants or loans in support of any activity of the registered NGOs as deemed appropriate.

The registered NGOs may propose for nomination of candidates as representatives of the private sector to be appointed by the cabinet as qualified members of the National Environment Board.

In case any registered NGO's activities are undertaken by causing disturbances or contrary to public order or unsuitable, the Minister shall have the power to revoke the registration of the NGO involving in such activities.

Section 9 In case there is an emergency or public danger arising from natural disaster or pollution caused by contamination and spread of pollutants which will, if left without any remedial actions, seriously endanger the safety of life, body or health of the people, or aggravatedly cause damage to the properties of the people or the State, the Prime Minister shall have the power to order, as deemed appropriate, government agencies, state enterprises or any persons, including the persons who are or may be the victims of such danger or damage, to take prompt action, individually or jointly, in order to be able to control, extinguish or mitigate the adverse effects of such danger or damage. In case any polluters are known and can be identified, the Prime Minister shall be empowered to enjoin such persons from any acts which may aggravate the adverse effects of pollution during the occurrence of such endangering incident.

The Prime Minister may delegate the power to give orders pursuant to the first paragraph to the Changwat Governor to exercise such power and act on his behalf within the territorial jurisdiction of that Changwat. The said delegation of power shall be made by a written order and published in the Government Gazette.

When any order is given by the Prime Minister by virtue of the first paragraph, or by the Changwat Governor acting on behalf of the Prime Minister by virtue of the second paragraph, such order shall be published in the Government Gazette without delay.

Section 10 In order to prevent, remedy, extinguish or mitigate the emergency or danger of pollution envisaged by section 9, the Minister shall determine preventive measures and prepare a contingency plan to rectify the situation in advance.

Section 11 The Prime Minister and the Minister of Science, Technology and Environment shall have charge and control of the execution of this Act, insofar as it is concerned with their respective powers and duties conferred upon them under this Act.

The Minister of Science, Technology and Environment shall have the power to appoint pollution control officials and other competent officials, issue ministerial regulations prescribing fees not exceeding the rates attached hereto and prescribing other activities for the execution of this Act.

The Ministerial Regulations shall come into force upon their publication in the Government Gazette.

Chapter I
National Environment Board

Section 12 There shall be a National Environment Board consisting of the Prime Minister as the Chairman, a Deputy Prime Minister designated by the Prime Minister as the first Vice Chairman, the Minister of Science, Technology and Environment as the second Vice Chairman, the Minister of Defence, the Minister of Finance, the Minister of Agriculture and Cooperatives, the Minister of Transport and Communications, the Minister of Interior, the Minister of Education, the Minister of Public Health, the Minister of Industry, the Secretary-General of the National Economic and Social Development Board, the Secretary-General of the Board of Investment, the Director of the Bureau of the Budget as members *ex officio* and members qualified in environmental matters not more than eight persons of which no less than half shall be representatives from the private sector and the Permanent Secretary of the Ministry of Science, Technology and Environment as member and secretary.

The appointment of qualified members shall be made by drawing from persons who are knowledgeable and known for their expertises, contributions and experiences in the matters concerning the enhancement and conservation of environmental quality.

Section 13 The National Environment Board shall have the power and duty as follows :

(1) To submit policy and plan for enhancement and conservation of national environmental quality to the cabinet for approval.

(2) To prescribe environmental quality standards pursuant to section 32.

(3) To consider and give approval to the Environmental Quality Management Plan proposed by the Minister according to section 35.

(4) To consider and give approval to the Changwat Action Plan for environmental quality management according to section 37.

(5) To make recommendations to the cabinet in respect of financial, fiscal, taxation and investment promotion measures for the implementation of the policy and plan for enhancement and conservation of national environmental quality.

(6) To propose for amendment or improvement of laws relating to the enhancement and

conservation of environmental quality to the cabinet.

(7) To consider and give approval to the action plan for prevention and remedy of danger caused by contamination of pollutants or spread of pollution proposed by the Pollution Control Committee pursuant to section 53 (1).

(8) To consider and give approval to the setting of emission or effluent standards proposed by the Minister pursuant to section 55.

(9) To supervise, oversee and expedite the enactment of royal decrees and issuance of ministerial regulations, rules, local ordinances, notifications, bye-laws and orders which are necessary to ensure systematic operation of the laws relating to enhancement and conservation of environmental quality to the fullest extent possible.

(10) To submit opinion to the Prime Minister for his directions in case it appears that any government agency or state enterprise infringes or refrains from complying with the laws and regulations for environmental protection which may cause extensive damage to the environment.

(11) To specify measures for the strengthening and fostering of co-operation and co-ordination among government agencies, state enterprises and the private sector in matters concerning the promotion and conservation of environmental quality.

(12) To supervise the Fund management and administration.

(13) To submit reports on national environmental quality situation to the cabinet at least once a year.

(14) To perform other functions as may be provided by this Act or other laws to be within the authority of the National Environment Board.

Section 14 A qualified member appointed by the cabinet shall hold office for a term of three years and may be re-appointed for a period of not more than one consecutive term.

In case an additional appointment of qualified member is made during the term of those members who have already been appointed to hold office, the term of additional membership shall be equal to the remainder of the term of those members who have already been appointed before.

Section 15 In addition to the expiration of the term of office according to section 14, a qualified member appointed by the cabinet shall vacate office upon :

(1) death;

(2) resignation;

(3) being a bankrupt;

(4) being an incompetent or quasi-incompetent person;

(5) being punished by a final judgement to a term of imprisonment except for an offence committed through negligence or a petty offence.

(6) Being dismissed by the cabinet for incompetence or misconduct or having vested interests in any activity or business that may have a direct impact on or adversely affect the environmental quality.

When a qualified member vacates office before the expiration of his term of office, the cabinet may appoint another person to fill the vacancy and such person shall hold office only for the remaining

term of his predecessor.

Section 16 In convening the National Environment Board meeting, if the Chairman is absent or unable to perform the function, the first Vice Chairman shall act as the Chairman. If the Chairman and the first Vice Chairman are both absent or unable to perform the function, the second Vice Chairman shall act as the Chairman. If the Chairman and both the two Vice Chairmen are all absent or unable to perform the function, the members who attend the meeting shall elect one of the attending members to act as the chairman of the meeting.

Section 17 A meeting of the National Environment Board requires the presence of not less than one-half of the total member of its members to constitute a quorum.

The decision of a meeting shall be made by a majority of votes. In casting votes, each member shall have one vote. In case of an equality of votes, the Chairman of the meeting shall have an additional vote as a casting vote.

Section 18 The National Environment Board may appoint an expert committee or subcommittee to consider or carry out any matter as may be entrusted by the National Environment Board.

Section 16 and section 17 shall apply *mutatis mutandis* to the meeting of the expert committee or subcommitee.

Section 19 The National Environment Board shall have the power to require government agencies, state enterprises and other persons to deliver documents relating to the examination of impacts on environmental quality and documents or data concerning the projects or workplans of such government agencies, state enterprises and persons for its consideration. For this purpose, the Board may summon persons concerned to give explanation. If the Board is of the opinion that any project or workplan may seriously affect the environmental quality, it shall recommend remedial measures to the cabinet.

In case the documents or data required to be delivered to the National Environment Board pursuant to the first paragraph are relevant to trade secrets in the nature of a patent and protected by the law on patent rights, the National Environment Board shall specify suitable measures and methods for preventing such documents or data from being disclosed to anyone to ensure that they shall only be used strictly for the purpose of this section.

Section 20 In the performance of its function, the National Environment Board, the expert committee or the sub-committee may invite any person to present facts, explanation, opinion or technical advice as it deems fit and may request co-operation from any person with a view to ascertaining any fact or surveying any activity which may have an adverse effect on environmental quality.

Section 21 In the performance of its duties under this Act, the National Environment Board may entrust the Office of Environmental Policy and Planning, the Pollution Control Department or the Environmental Quality Promotion Department under the Ministry of Science, Technology and Environment with the operation or preparation of propositions to be made to the National Environment Board for further actions.

Chapter II
Environmental Fund

Section 22 There shall be established a fund called the "Environmental Fund" in the Ministry of Finance with the following moneys and properties :

(1) Money from the Fuel Oil Fund in the amount determined by the Prime Minister.

(2) Money transfered from the Revolving Fund for Environmental Development and Quality of Life established by the Annual Budget for the Fiscal Year of B.E. 2535 Act, B.E. 2535.

(3) Service fees and penalties collected by virtue of this Act.

(4) Grants from the Government from time to time.

(5) Moneys or properties donated by donors in the private sector both domestic and foreign, by foreign governments or by international organizations.

(6) Interest and benefits accrued from this Fund.

(7) Other moneys received for the operation of this Fund.

The Comptroller-General's Department, Ministry of Finance, shall keep the moneys and properties of the Environmental Fund and make disbursements from the fund in accordance with this Act.

Section 23 Fund disbursements shall be made for the following activities and purposes :

(1) As grants to government agency or local administration for investment in and operation of the central wastewater treatment plant or central waste disposal facility, including the acquisition and procurement of land, materials, equipment, instrument, tools and appliances necessary for the operation and maintenance of such facility.

(2) As loans to local administration or state enterprise for making available of air pollution control system, wastewater treatment or waste disposal facilities to be used specifically in the activities of such local administration or state enterprise.

(3) As loans to private person in case such person has the legal duty to make available and install an on-site facility of his own for the treatment of polluted air, wastewater or waste disposal or any other equipment for the control, treatment or eliminate pollutants that are generated by his activity or business undertaking, or such person is licensed to undertake business as a Service Contractor to render services of wastewater treatment or waste disposal under this Act.

(4) As aids or grants to support any activity concerning the promotion and conservation of environmental quality as the Fund Committee sees fit and with the approval of the National Environment Board.

(5) As expenditures for administering the Fund.

Section 24 There shall be a Fund Committee consisting of the Permanent Secretary of the Ministry of Science, Technology and Environment as the Chairman, the Permanent Secretary of the Ministry of Agriculture and Cooperatives, the Secretary-General of the National Economic and Social Development Board, the Director of the Bureau of the Budget, the Director-General of the Department of Local Administration, the Comptroller-General of the Comptroller-General's Department, the Director-General of the Department of Public Works, the Director-General of the Department of Industrial

Works, the Director-General of the Department of Mineral Resources, the Director-General of the Pollution Control Department, the Director-General of the Environmental Quality Promotion Department and not more than five qualified persons appointed by the National Environment Board as members and the Secretary-General of the Office of Environmental Policy and Planning as member and secretary.

Section 14 and section 15 shall apply *mutatis mutandis* to the holding office of the qualified members of the Fund Committee.

Section 25 The Fund Committee shall have the power and duty as follows :

(1) To consider on Fund allocation for use in the activities prescribed by section 23.

(2) To prescribe rules, conditions, procedures and methods concerning application for allocation or loan from the Fund.

(3) To lay down administrative rules and procedures concerning the power, duties and working methods of the Fund managers according to section 29 and section 30 as well as mechanisms for co-ordination among the Fund Committee, the Comptroller-General's Department and the Fund managers according to section 29 and section 30.

(4) To lay down rules and procedures for the receipt and disbursement of moneys from the Fund.

(5) To fix durations for repayment of loans from the Fund according to section 23 (2) or (3) as well as interest rates and securities as necessary and appropriate.

(6) To determine the ratio and criteria for deduction of service fees and penalties that are required by section 93 to be remitted to the Fund.

(7) To perform any other functions provided under this Act.

The prescription of rules according to sub-section (2), (3) or (4) and guidelines for action under sub-section (1) or (5) shall be approved by the National Environment Board.

The Fund Committee may appoint a subcommittee to consider or carry out any matter as may be entrusted by the Fund Committee.

Section 26 Section 16, section 17 and section 20 shall apply *mutatis mutandis* to the performance of functions of the Fund Committee and the subcommittee appointed by the Fund Committee.

Section 27 In consideration to allocate money from the Fund for the purpose of section 23 (1), the Fund Committee shall give first priority to the request for allocation under the Changwat Action Plan for environmental quality management according to section 39 to construct or operate the wastewater treatment plant or waste disposal facility, for which certain amount of government budget has been earmarked or revenues of the local administration have been allocated as additional contributions to the Fund allocation.

The proportion between the government budget or contributions from the local revenues and the Fund allocation to be determined by the Fund Committee according to the first paragraph shall be determined in accordance with the rules laid down by the National Environment Board.

Section 28 The Fund allocation as loans to the local administration, state enterprise or private person pursuant to section 23 (2) or (3) shall be determined by the Fund Committee in accordance with the rules and conditions stipulated by the National Environment Borad.

In order to encourage compliance with this Act, the Fund Committee may, with the approval of the National Environment Board, allocate from the Fund as an exceptional long-term loan to any local administration, state enterprise, or private person and may determine to reduce the interest rates or make exemption to the payment of such interest as deemed appropriate.

Section 29 The Comptroller-General of the Comptroller-General's Department, Ministry of Finance, shall be the Fund manager in relation to such portion of the Fund to be allocated as grants to the government agency or the local administration for investment in and operation of the central facility for wastewater treatment or waste disposal according to section 23 (1) and those portions of the Fund to be allocated for the purposes other than those provided by section 23 (2) and (3).

Section 30 The Fund Committee may authorize an appropriate financial institution owned by the State or the Industrial Financing Corporation of Thailand to be the Fund manager in relation to such portion of the Fund that will be allocated as loans to the local administration, state enterprise or private person pursuant to section 23 (2) or (3).

In carrying out the management of Fund according to the First paragraph, the Fund manager has the duty to study and analyse the investment and technical feasibility of the project and shall be empowered to enter the loan agreement on behalf of the Fund Committee in the capacity as the lender, to keep and disburse moneys to the borrowers from this portion of the Fund in accordance with the terms and conditions of the loan agreement, to pursue, demand and receive repayments and interest from the borrowers in order to pay back to the Fund, and shall be empowered to lay down rules and procedures, with the approval of the Fund Committee, for such matters.

Under the loan agreement to be entered into according to the second paragraph, there must be a condition stipulated as an essential element of the agreement that the borrower shall have the duty to make use of the loan specifically for the purpose of meeting the requirements with which the borrower has the legal duty to comply under this Act or other related laws.

Section 31 The moneys received into the Fund and kept by the Comptroller-General's Department, Ministry of Finance, shall be managed by deposit in saving or fixed accounts with State-owned financial institutions in order to earn accrued interest.

All moneys earned by the Fund according to section 22 shall be paid into its account for the purpose of uses in the activities indicated in section 23 and shall not be remitted to the Treasury as revenues of the Government.

Chapter III
Environmental Protection

Part 1
Environmental Quality Standards

Section 32 For the purpose of environmental quality enhancement and conservation, the National Environment Board shall have the power to prescribe by notifications published in the Government Gazette the following environmental quality standards :

(1) Water quality standards for river, canal, swamp, marsh, lake, reservoir and other public inland water sources according to their use classifications in each river basin or water catchment.

(2) Water quality standards for coastal and estuarine water areas.

(3) Groundwater quality standards.

(4) Atmospheric ambient air standards.

(5) Ambient standards for noise and vibration.

(6) Environmental quality standards for other matters.

The prescription of environmental quality standards pursuant to the foregoing paragraph shall be based upon scientific knowledge, principles, criteria and evidence related thereto and shall also take into account the practicability of such standards from the viewpoint of economic, social and technological considerations.

Section 33 The National Environment Board shall, if deemed reasonable, have the power to prescribe special standards, which are higher than the environmental quality standards prescribed pursuant to section 31, for the protection of areas designated as conservation or environmentally protected area according to section 42, or areas designated according to section 44, or pollution control areas designated pursuant to section 58.

Section 34 The National Environment Board shall have the power to make appropriate modifications and improvements to the prescribed environmental quality standards in the light of scientific and technological progresses and changes in economic and social conditions of the country.

Part 2
Environmental Quality Management Planning

Section 35 The Minister shall, with the approval of the National Environment Board, formulate an action plan called "Environmental Quality Management Plan" for implementation of the national policy and plan for enhancement and conservation of environmental quality determined by virtue of section 13 (1).

The Environmental Quality Management Plan pursuant to the first paragraph shall be published in the Government Gazette.

It shall be the duty of all government agencies concerned to take actions within their powers and functions that are necessary for effective implementation of the Environmental Quality Management Plan and in order to ensure that actions are taken to achieve the objectives and goals as prescribed, it shall be the duty of the Ministry of Science, Technology and Environment to give advice to government agencies and state enterprises which are concerned with the formulation of workplans or the taking of any actions with a view to implementing the Environmental Quality Management Plan.

Section 36 The Environmental Quality Management Plan pursuant to section 35 may be a short, intermediate or long-term plan, as appropriate, and should contain workplans and guidances for action in the following matters :

(1) Management of air, water and environmental quality in any other area of concerns.

(2) Pollution control from point sources.

(3) Conservation of natural environment, natural resources or caltural environment pertaining to aesthetic values.

(4) Estimation of financing to be appropriated from government budget and allocated from the Fund which is necessary for implementation of the Plan.

(5) Scheme for institutional arrangements and administrative orders by which co-operation and co-ordination among government agencies concerned and between the public service and private sector could be further promoted and strengthened, including the determination of a manpower allocation scheme which is required for implementation of the Plan.

(6) Enactment of laws and issuance of regulations, local ordinances, rules, orders and notifications necessary for implementation of the Plan.

(7) Scheme for inspection, monitoring and assessment of environmental quality by which the results of implementation of the Plan and enforcement of law related thereto can be evaluated objectively.

Section 37 After the Environmental Quality Management Plan has been published in the Government Gazette, it shall be the duty of the Governor of the Changwat, in which there is a locality designated as environmentally protected area according to section 43, or as pollution control area according to section 59, to formulate an action plan for environmental quality management at Changwat level and submit it to the National Environment Board for approval within one hundred and twenty days from the date on which the Governor of that Chanwat is directed by the National Environment Board to prepare the Changwat action plan for environmental quality management. If, however, there is a reasonable ground, the said duration may be extended as appropriate by the National Environment Board.

In preparing a Changwat Action Plan for the pollution control area according to section 59, the Governor shall incorporate into it the action plan for mitigation and elimination of pollution prepared by the local authority pursuant to section 60 and the local action plan shall form an integral part of the Changwat Action Plan.

In case there is any Changwat, in which no locality is designated as an environmentally protected area according to section 43, or as pollution control area according to section 59, that is nevertheless desirous to enhance and conserve the environmental quality within the limits of its territorial jurisdiction, the Governor of that Changwat may prepare a Changwat Action Plan, within the

framework of and in conformity with the requirements of the Environmental Quality Management Plan, and submit it to the National Environment Board for approval.

Section 38 The Changwat Action Plan to be submitted to the National Environment Board shall be an action plan which proposes a system of integrated management of environmental quality in conformity with the guidances specified in the Environmental Quality Management Plan, taking into account the severity of the problems and economic, social and environmental conditions of that Changwat, and should address and contain essential elements in the following matters :

(1) Plan for control of pollution from point sources.

(2) Plan for procurement and acquisition of land, materials, equipment, tools and appliances which are essential for the construction, installation, improvement, modification, repair, maintenance and operation of central wastewater treatment plants or central waste disposal facilities belonging to government agency or local administration concerned.

(3) Plan for collection of taxes, duties and service fees for operation and maintenance of central wastewater treatment plants or central waste disposal facilities referred to in sub-section (2) above.

(4) Plan for inspection, monitoring and control of wastewaters and other waste matters which are discharged from point sources of pollution.

(5) Law enforcement plan for the prevention and suppression of violation or infringement of laws and regulations pertaining to pollution control and conservation of nature, natural resources and cultural environment pertaining to aesthetic values.

Section 39 The Changwat Action Plan for environmental quality management to be given first priority for the consideration of the National Environment Board must propose an estimate of budgetary appropriation and allocation from the Fund for the construction or procurement for the acquisition of a central wastewater treatment plant or a central waste disposal facility pursuant to section 38 (2). In case any Changwat is not ready to take steps for the procurement and acquisition of the central wastewater treatment plant or the central waste disposal facility, it may instead propose a plan to promote private investment in the construction and operation of wastewater treatment or waste disposal facilities in order to make available of such services within its jurisdiction.

The Changwat Action Plan to be prepared according to the first paragraph with a request for budgetary appropriation and allocation from the Fund shall be accompanied by drawings, plans, specifications and an estimated price of the project for construction, installation, improvement, modification, repair, maintenance as well as the process and method for operation of the proposed central wastewater treatment plant or central waste disposal facility.

For the purpose of approving the Changwat Action Plan with a request for budgetary appropriation in accordance with the first paragraph, the Office of Environmental Policy and Planning shall be responsible for the gathering and analysis of the Changwat Action Plans for environmental quality management in order to make a proposal for annual budgets of the Office to be earmarked specifically for this purpose.

Section 40 In case the management of environmental quality in any matters will have to be carried out in an area adjoining the territorial jurisdictions of two or more provinces due to the geographical conditions or the characteristics of the natural ecosystems of that area, or for the

purpose of a sound, systematic and proper management in accordance with the principle of integrated management of environmental quality and natural resources, the Governors of the relevant provinces shall jointly prepare the action plan mandatorily required by section 37.

Section 41 In case any Changwat, which is mandatorily required to prepare the action plan according to section 37, fails or is incapable to evolve such a plan, or has prepared and submitted the plan as required but failed to get the approval of the National Environment Board for any reason, the National Environment Board shall consider the nature of the problems encountered by that Changwat and evaluate whether its environmental quality is adversely affected to such an extent that any action is warrant to rectify the situation. If action is deemed necessary, the National Environment Board shall propose to the Prime Minister to issue an order directing the Ministry of Science, Technology and Environment to prepare the Changwat Action Plan on behalf of the Changwat in question.

Part 3
Conservation and Environmentally Protected Areas

Section 42 Protection and management of areas within the limits of national parks and wildlife reserves shall be in accordance with the Environmental Quality Management Plan effective by virtue of section 35 and governed by the laws related thereto.

Section 43 In case it appears that any area is characterized as watershed area, or characterized by unique natural ecosystems which are different from other areas in general, or naturally composed of fragile ecosystems which are sensitive and vulnerable to destruction or impacts of human activities, or worthy of being conserved due to its natural or aesthetic values or amenities, and such area is yet to be designated as a conservation area, the Minister shall, with the advice of the National Environment Board, be empowered to issue ministerial regulation designating such area as an environmentally protected area.

Section 44 In issuing the ministerial regulation pursuant to section 43, any one or more of the following protective measures shall be prescribed thereunder :

(1) Land use prescriptions for preserving the natural conditions of such area or for preventing its natural ecosystems or its aesthetic values or amenities from being adversely impacted.

(2) Prohibition of any acts or activities that may be harmful or adversely affect or change the pristine state of the ecosystems of such area.

(3) Specifying types and sizes of projects or activities undertaken by government agencies, state enterprises or private entities, to be constructed or operated in such area, which shall have the legal duty to submit reports of environmental impact assessment.

(4) Determination of management approach and method specific to the management of such area including the scope of functions and responsibilities of relevant government agencies for the purpose of co-operation and co-ordination that are conducive to efficient performance of work towards the preservation of natural conditions or ecosystems or aesthetic values and amenities in such area.

(5) Prescriptions of any other protective measures which are deemed proper and suitable to the conditions of such area.

Section 45 In any area, despite having been designted as a conservation area, a master town and country plan area, a specific town and country plan area, a building control area, an industrial estate area pursuant to the governing laws related thereto, or designated as a pollution control area pursuant to this Act, but which nevertheless appears to have been adversely affected by environmental problems which assume a critical proportion to such an extent that an immediate action has become imperative and yet no action is taken by government agencies concerned to rectify the situation due to a lack of clear legal authorization or otherwise failure to do so, the Minister shall, with the approval of the National Environment Board, propose for a cabinet authorization to take any one or several protective measures provided by section 44, as necessary and appropriate, in order to control and solve the problems in such area.

When cabinet authorization is obtained as provided in the first paragraph, the Minister shall, by notification published in the Government Gazette, determine the limits of such area and prescribe in detail the protective measures and the duration for which such measures shall be effectively taken therein.

With the approval of the National Environment Board and the cabinet, the duration of effectiveness specified according to the second paragraph may be extended by notification published in the Government Gazette.

Part 4
Environmental Impact Assessment

Section 46 For the purpose of environmental quality promotion and conservation, the Minister shall, with the approval of the National Environment Board, have the power to specify, by notification published in the Government Gazette types and sizes of projects or activities, likely to have environmental impact, of any government agency, state enterprise or private person, which are required to prepare reports on environmental assessment for submission to seek approval in accordance with section 47, section 48 and section 49.

In the notification issued according to the first paragraph, procedures, rules, methods and guidelines shall be laid down for the preparation of environmental impact assessment report for each type and size of project or activity, including related documents that are required to be filed together with the report.

In case there has been an environmental impact assessment concerning project or activity of any particular type or size, or site selection for such project or activity in any particular area and such assessment can be used as a standard assessment applicable to the project or activity of the same type or size or to the site selection of such project or activity in the area of similar nature, the Minister may, with the approval of the National Environment Board, issue a notification in the Government Gazette exempting such project or activity of the same or similar nature from the requirement of environmental impact assessment, provided that the proponent of such project or activity shall express its consent to comply with various measures prescribed in the environmental impact assessment report which is applicable as the standard for assessment of such project or activity in accordance with the rules and methods specified by the Minister.

Section 47 In case the project or activity which is required to prepare the environmental impact assessment according to section 46 is the project or activity of a government agency or of a

state enterprise or to be jointly undertaken with private enterprise which is required the approval of the cabinet in accordance with official rules and regulations, the government agency or state enterprise responsible for such project or activity shall have the duty to prepare the environmental impact assessment report at the stage of conducting a feasibility study for such project, such report shall be filed with the National Environment Board for its review and comments and then submitted to the cabinet for consideration.

In considering to give approval to the environmental impact assessment report filed according to the first paragraph, the cabinet may as well request any person or institution, being an expert or specialized in environmental impact assessment, to study and submit report or opinion for its consideration thereof.

For project or activity of government agency or state enterprise which is not required to be approved by the cabinet according to the first paragraph, the government agency or state enterprise responsible for such project or activity shall prepare and file the environmental impact assessment report in order to obtain approval prior to the initiation of such project or activity in accordance with the rules and procedures as provided by section 48 and 49.

Section 48 In case the project or activity which is required by section 46 to prepare the environmental impact assessment report is the project or activity which is required by law to obtain permission prior to construction or operation, the person applying for the permission shall have the duty to file the environmental impact assessment report with the permitting authority under such law and with the Office of Environmental Policy and Planning simultaneously. The report to be filed as aforesaid may be made in the form of an initial environmental examination (I.E.E.) in accordance with the rules and procedures determined by the Minister pursuant to section 46, second paragraph.

The official who is legally authorized to grant permission shall withhold the granting of permission for the project or activity referred to in the first paragraph until having been notified by the Office of Environmental Policy and Planning of the result of consideration pertaining to the review of the environmental impact assessment report in accordance with section 49.

The Office of Environmental Policy and Planning shall examine the environmental impact assessment report and related documents filed therewith. If it is found that the report as filed is not correctly made in accordance with the rules and procedured specified by virtue of section 46, second paragraph, or the accompanied documents and data are incomplete, the Office of Environmental Policy and Planning shall notify the person applying for permission who files the report within fifteen days from the date of receiving such report.

In case the Office of Environmental Policy and Planning finds that the environmental impact assessment report together with related documents as filed is duly made and completed with the data as required, or has been duly amended or modified in accordance with the foregoing third paragraph, it shall review and make preliminary comments on the report within thirty days from the date of receiving such report in order that the report together with the preliminary comments shall be referred to the committee of experts for further consideration.

The appointment of the committee of experts according to the foregoing fourth paragraph shall be in accordance with the rules and procedures determined by the National Environment Board. The committee shall be composed of expert members who are qualified or specialized in various fields of related disciplines and the authority legally competent to grant permission for the given project or activity under review, or its representative, shall be included in its membership.

Section 49 The review and consideration by the committee of experts according to section 48 shall be carried out within forty-five days from the date of receiving the environmental impact assessment report from the Office of Environmental Policy and Planning. If the committee of experts fails to conclude its review and consideration within the said period, the report shall be deemed to have been approved by it.

In case the committee of experts approves or is deemed to have given approval to the report, the official legally empowered to grant permission shall accordingly order that the permission be granted to the person who applies for it.

In case approval of the report is denied by the committee of experts, the permitting authority shall withhold the granting of permission to the person applying for it until such person will resubmit the environmental impact assessment report that has been amended or entirely redone in conformity with the guidelines and detailed requirements determined by the order of the committee of experts.

When such person has resubmitted the environmental impact assessment report that has been amended or entirely redone, the committee of experts shall review and conclude its consideration within thirty days from the date of receiving the resubmitted report. If the committee of experts fails to conclude its review and consideration within the said period, it shall be deemed that the committee has approved the report and the permitting authority shall accordingly grant permission to the person who applies for it.

In case it is deemed reasonable the Minister may issue notification in the Government Gazette requiring that the project or activity of the type and size specified by the notification issued by virtue of section 46 also file the environmental impact assessment report when the application is made for renewal of permission for such project or activity in accordance with the same procedures as applicable to the application for the permission.

Section 50 For the purpose of review and consideration of the environmental impact assessment report pursuant to section 48 and section 49 and site inspection is deemed appropriate, the committee of experts or the competent official assigned by the committee shall be authorized to inspect the site of the project or activity identified in the report for which approval thereof is sought.

When the committee of experts has approved the environmental impact assessment report pursuant to section 49, the official who is legally competent to grant permission or the renewal of permission shall stipulate as the conditions of permission or renewal thereof all the mitigation measures proposed in the environment impact assessment report and all such conditions shall be deemed the conditions prescribed by virtue of the governing laws on the subject matter.

Section 51 For the purpose of compliance with section 47 and section 48, the Minister may, with the approval of the National Environment Board, require that the environmental impact assessment report as required by section 46 be prepared or certified by the person who is licensed to be a specialist in environmental impact assessment.

Application and issuance of licence, qualifications of specialists who will be eligible to prepare environmental impact assessment reports, control of the licensee's performance, renewal of licence, issuance of certificate in lieu of the licence, suspension or revocation of the licence and fee payments for the application and issuance of licence shall be in accordance with the rules, procedures and conditions stipulated by ministerial regulation.

Chapter IV

Pollution Control

Part 1

Pollution Control Committee

Section 52 For the purpose of pollution control under this Act, there shall be a committee called the "Pollution Control Committee" (PCC) which consists of the Permanent Secretary of the Ministry of Science, Technology and Environment as the Chairman, the Director-General of the Department of Local Administration, the Director-General of the Police Department, the Director-General of the Department of Land Transport, the Director-General of the Harbour Department, the Director-General of the Department of Public Works, the Director-General of the Department of Mineral Resources, the Director-General of the Department of Industrial Works, the Director-General of the Health Department, the Director-General of the Department of Agriculture, the Director-General of the Department of Environmental Quality Promotion, the Secretary-General of the Office of Environmental Policy and Planning, the Permanent Secretary for the Bangkok Metropolitan Administration and not more than five qualified persons appointed by the National Environmental Board as members and the Director-General of the Department of Pollution Control as member and secretary.

Section 14 and section 15 shall apply *mutatis mutandis* to the holding office of the qualified members in the Pollution Control Committee.

Section 53 The Polution Control Committee shall have the power and duty as follows :

(1) To submit an action plan for prevention or remedy of pollution harzards or contamination to the National Environment Board.

(2) To give opinion and recommend the National Environment Board on proposed amendments to or improvement of any laws cencerning the control, pevention, reduction or eradication of pollution.

(3) To propose incentive measures regarding taxation and private investment promotion in relation to pollution control and promotion and conservation of environmental quality to the National Environment Board.

(4) To recommend the National Environment Board on the determination of service fee rates for the central waste water treatment or central waste disposal services of the government.

(5) To give advice to the Minister on the setting of emission or effluent standards under section 55.

(6) To give advice to the Minister concerning the types of point sources of pollution that will be required to comply with section 68 and section 69.

(7) To make recommendation on the issuing of ministerial regulations specifying the types and categories of hazardous wastes under section 79.

(8) To coordinate government agencies, state enterprises and the private sector in their actions to control, prevent, mitigate or eradicate pollution.

(9) To prepare and submit the report on pollution situation to the National Environment Board once a year.

(10) To consider and resolve on the challenge to the order of the pollution control official under this Act.

(11) To perform other functions designated by this Act or other law to be the power and duty of the Pollution Control Committee.

(12) To carry out other matters assigned by the National Environment Board.

The Pollution Control Committe may appoint a subcommittee to consider or carry out any matter as may be assigned by the Pollution Control Committee.

Section 54 Section 16, section 17 and section 20 shall apply *mutatis mutandis* to the performance of functions of the Pollution Control Committee and subcommittee.

Part 2
Emission or Effluent Standards

Section 55 The Minister shall, with the advice of the Pollution Control Committee and the approval of the National Environment Board, have the power to publish notification in the Government Gazette prescribing emission or effluent standards for the control of wastewater discharge, pollutted air emissions, or discharge of other wastes or pollutants from point sources into the environment, in order to meet the environmental quality standards set by virtue of this Act for the conservation of national environmental quality.

Section 56 In case there have been standrads prescribed by virtue of the other laws concerning wastewater discharges, pollutted air emissions, or discharge of other wastes or pollutants from point sources of pollution into the environment and such standards are no less stringent than the emission or effluent standards set by the Minister by virtue of section 55, such standards shall continue to be effective by virtue of the laws related thereto. If however, such standards are less stringent than the emission or effluent standards set by the Minister pursuant to section 55, the government agencies empowered by such laws shall amend such standards in conformity with the emission or effluent standards under this Act. If there is any obstacle preventing from doing so, the National Environment Board shall resolve on such matter and the government agencies concerned shall act in accordance with such resolution.

Section 57 In case any government agency is empowered by the other law to prescribe emission or effluent standards in any matter, but that government agency fails to exercise its power, the Minister shall, with the recommendation of the Pollution Control Committee and with the approval of the National Environment Board, publish notification in the Government Gazette prescribing the emission or effluent standards in question and such standards shall be deemed to have been set by the governing law on such matter.

Section 58 If it is deemed reasonable, the Changwat Governor shall have the power to publish notification in the Government Gazette prescribing a special set of emission or effluent standards applicable to the pollution control area designated by section 59, higher than the standards set pursuant to section 55 or the standards set by virtue of other law which remain in force according to section 56.

Part 3
Pollution Control Area

Section 59 In case it appears that any locality is affected by pollution problems and there is a tendency that such problems may be aggravated to cause health hazards to the public or adverse impact on the environmental quality, the National Environment Board shall have power to publish notification in the Government Gazette designating such locality as a pollution control area in order to control, reduce and eliminate pollution.

Section 60 For the purpose of the Changwat Action Plan for environmental quality management to be prepared according to section 37, the local official in the locality designated as the pollution control area pursuant to section 59, shall prepare and submit an action plan for reduction and eradication of pollution in such area to the Changwat Governor in order to incorporate such plan into the Changwat Action Plan for environment quality management.

In preparing the action plan for reduction and eradication of pollution, steps shall be taken as follows :

(1) to survey and collect data concerning point sources of pollution located within the limits of that pollution control area.

(2) to make an inventory showing the number, type and size of point sources of pollution under survey and collection of data according to (1) above.

(3) to study, analyse and assess the state of pollution, as well as the scope, nature, severity of the problem and impacts on environmental quality in order to specify suitable and necessary measures for mitigation and eradication of pollution in that pollution control area.

The pollution control official shall give advice and assistance to the local official necessary for the preparation of the action plan to reduce and eradicate pollution according to the first and second paragraphs.

Section 61 The action plan for reduction and eradication of pollution in the pollution control area under section 60 shall propose the estimation and request for government budget and Fund allocations for construction or operation of the central wastewater treatment plant or the central waste disposal facility necessary to reduce and eradicate pollution in that pollution control area.

Section 62 In case it is necessary to acquire a piece of land to be used as the site of the central wastewater treatment or central waste disposal facility for any pollution control area but state-owned land is not available, steps shall be taken to select and acquire land for the siting purpose. If there are expenses, the estimate and request for government budget and Fund allocation shall be made in the Changwat Action Plan.

If it is unable to proceed under the first paragraph, suitable land shall be selected and proposed to the Minister in order to take steps to expropriate such land in accordance with the law on expropiation of immovable property.

Section 63 The Changwat Governor shall supervise and oversee the local official's actions under section 59. If no action is taken by the local official within a reasonable time, the Changwat Governor shall have the power to take action on behalf of the local authority upon notification to such

local authority and the National Environment Board.

Part 4
Air and Noise Pollution

Section 64 Usable vehicle shall conform to the emission standards prescribed for such vehicle pursuant to section 55.

Section 65 If it is found that the use of any vehicle is in violation of section 64, the competent official shall have the power to prohibit the use of such vehicle permanently or until it will have been modified or improved to meet the emission standard requirements prescribed pursuant to section 55.

Section 66 In issuing the order prohibiting to use of vehicle according to section 65, the competent official shall make the sign clearly shown by the words "Use Prohibited Permanently" or "Use Prohibited temporarily" or any other sign, known and understood by the general public to have the same meaning, on any part of such vehicle.

The making or removal of the sign under the first paragraph, or the use of vehicle while the said sign is on, shall be in accordance with the rules, methods and conditions specified in the ministerial regulation.

Section 67 In performing his duty under section 65, the competent official has the power to stop and inspect the vehicle, enter into the vehicle or to do any act necessary to check and test the engine and equipment of such vehicle.

Section 68 The Minister shall, with the advice of the Pollution Control Committee, have the power to publish notification in the Government Gazette specifying the types of point sources of pollution that shall be controlled in regard to the emission of polluted air, ray, or other pollutants, in the form of smoke, fume, gas, soot, dust, ash, particle or any other form of air pollutant, to the atmosphere, in conformity with the emission standards prescribed under section 55, or standards prescribed by any government agency by virtue of the other law which remain in force according to section 56, or standards set by the Changwat Governer in special case for the pollution control area according to section 58.

The owner or possessor of the point source of pollution under the first paragraph has the duty to install or bring into operation an on-site facility for air pollution control, equipment or other instrument as determined by the pollution control official in order to control, dispose, reduce or eliminate pollutants which may affect the air quality, unless such facility, equipment or instrument has already been in place and still in a working condition upon the inspection and test by the pollution control official. For the purpose of this section, the pollution control official may also require that the operation of such facility, equipment or instrument be controlled by the Monitoring Control Operator.

The provisions of the first and second paragraphs shall apply *mutatis mutandis* to the point source of pollution which emit or generate noise or vibration in excess of the emission standards set pursuant to section 55, or the standards set by any government agency by virtue the other law which remain in force according to section 56, or the standards set by the Changwat Governor in special case for the pollution control area according to section 58.

Part 5
Water Pollution

Section 69 The Minister shall, with the advice of the Pollution Control Committee, have the power to publish notification in the Government Gazette specifying the types of point sources of pollution that shall be controlled in regard to the discharge of wastewaters or wastes into public water sources or into the environment outside the limits of such point sources, in conformity with the effluent standards set pursuant to section 55, or the standards set by any government agency by virtue of the other law which remain in force according to section 56, or the standards set by the Changwat Governor in special case for the pollution control area according to section 58.

Section 70 The owner or possessor of the point source of pollution under section 69 has the duty to construct, install or bring into operation an on-site facility for wastewater treatment or waste disposal as determined by the pollution control official. For this purpose, the pollution control official may also require that such owner or possessor commission a Monitoring Control Operator to control the wastewater treatment or waste disposal facility that shall be constructed, installed or brought into operation accordingly.

If any point source of pollution has had an on-site facility for wastewater treatment or waste disposal before the date of notification of the Minister under section 69, the owner or possessor of such point source of pollution shall inform the pollution control official to check the functioning system of the facility. If its capability to treat wastewaters or dispose of wastes fails to meet the applicable standards, the owner or possessor has the duty to modify or improve it in conformity with the pollution control official's directions.

Section 71 In any pollution control area or locality where a central wastewater treatment plant or a central waste disposal facility has been brought into operation by the administration concerned, the owner or possessor of the point source of pollution according to section 70, first paragraph, who has not yet constructed, installed or brought into operation the on-site facility for wastewater treatment or waste disposal according to the prescription of the pollution control official, or may not want to construct or make arrangements for such a system, shall have the duty to send the wastewaters or wastes generated by his activities to the central wastewater treatment plant or central waste disposal facility in the pollution control area or in that locality for treatment or disposal and shall have the duty to pay the service fees at the rates fixed by virtue of this Act or the other related laws.

Section 72 In any pollution control area or locality where the central waste water treatment plant or central waste disposal facility has been brought into operation by the administration concerned, the owner or possessor of any point source of pollution, except those under section 69, shall have the duty to send wastewaters or wastes from his source of pollution to the central waste water treatment plant or the central waste disposal facility in that pollution control area or locality for treatment or disposal and shall have the duty to pay service fees at the rates fixed by virtue of this Act or the other related laws, except such point source of pollution has already had its own wastewater treatment or waste disposal facility which is capable to meet the standards prescribed under this Act.

Section 73 No person shall be employed as a Monitoring Control Operator or as a Service Contractor, who renders for hire the services of wastewater treatment or waste disposal, without obtaining the licence from the local official.

Application and issuance of licence, qualifications of the applicant, control of the licensee's performance, renewal of licence, issuance of certificate in lieu of the licence, suspension or revocation of the licence and fee payments for the application and issuance of licence shall be in accordance with the rules, procedures and conditions stipulated by ministerial regulation.

The person who has obtained a licence to be a Service Contractor shall also be deemed to have obtained a licence to be a Monitoring Control Operator.

In rendering the services of wastewater treatment or waste disposal by the Service Contractor according to the first paragraph, the service charges shall not exceed the rates fixed by the ministerial regulation.

Section 74 In any pollution control area or locality where the central wastewater treatment or central waste disposal facility of the public service is yet to be put into operation, but there is nonetheless a Service Contractor who is licensed to render such services within that area, the owner or possessor of the point source of pollution according to section 70 and section 71 shall be required to send the wastewaters or wastes from his point source for treatment or disposal by such Service Contractor in accordance with the rules, regulations, methods and conditions prescribed by the local official, with the advice of the pollution control official.

Section 75 In any pollution control area or locality where the central wastewater treatment or central waste disposal facility is yet to be put into service by the government and there is no licensed Service Contractor rendering services therein, the local official may, with the advice of the pollution control official, determine a temporary method necessary for the treatment of wastewaters or disposal of wastes from point sources of pollution under section 70 and section 71 until the central wastewater treatment or central waste disposal facility will have been constructed, installed and put into operation within such pollution control area or locality.

The temporary method for wastewater treatment or waste disposal according to the first paragraph shall mean to include the collection, transport or conveyance of wastewaters or wastes by whatever appropriate means to be treated or disposed by the central wastewater treatment plant or central waste disposal facility of the government in the other area; or to allow the licensed Service Contractor rendering services in the other area to render the same services in that pollution control area or locality temporarily; or to allow such licensed Service Contractor to collect and transport wastewaters or wastes to treat or dispose by his own wastewater treatment or waste disposal facility located outside that pollution control area or locality.

Section 76 Wastewaters treated by either the central wastewaters treatment plant of the government or by the wastewater treatment facility of the Service Contractor must also have the properties which meet the requirements of the effluent standards prescribed by virtue of section 55, or the standards prescribed by virtue of the other law which remain in force according to section 56, or the standards set by the Changwat Governor in special case for the pollution control area according to section 58.

Section 77 The government agency or the local authority which makes provision for the services of central wastewater treatment or central waste disposal facilities by using government budget, or revenues of the local authority, and Fund allocations under this Act shall be responsible for the management and control of such facilities. In this respect, the responsible agency or local

authority may employ a licensed Service Contractor under this Act to manage and control the operation of such facilities.

Regulations, rules and methods for conveyance, collection and transport of wastewaters or wastes from the point sources of pollution to the central wastewater treatment plant or central waste disposal facility as well as prescriptions, prohibitions, restrictions and other conditions for discharging and draining of wastewaters or wastes from factories and other point sources of pollution under section 72 into the systems of central wastewater treatment or central waste disposal facilities shall be prescribed by the ministerial regulation.

Part 6
Other Pollution and Hazardous Waste

Section 78 The collection, transport and other arrangements for the treatment and disposal of garbage and other solid wastes; the prevention and control of pollution from mining both on land and in the sea; the prevention and control of pollution from the exploration and drilling for oil, natural gas and all kinds of hydrocarbon both on land and in the sea; and the prevention and control of pollution resulting or originated from the discharge of oil and the dumping of wastes and other matters from sea-going vessels, tankers, and other types of vessel, shall be in accordance with the governing laws related thereto.

Section 79 In case there is no specific law applicable thereto, the Minister shall, with the advice of the Pollution Control Committee, have the power to issue ministerial regulation specifying the types and categories of hazardous wastes generated from the production and usage of chemicals or hazardous substances in the production process of industry, agriculture, sanitation and other activities which shall be brought under control. For this purpose, rules, regulations, measures and methods must also be prescribed for the control of collection, storage, safety measures, transportation, import into the Kingdom, export out of the Kingdom, and for proper and technically sound management, treatment and disposal of such hazardous wastes.

Part 7
Monitoring, Inspection and Control

Section 80 The owner or possessor of the point source of pollution, required by virtue of section 68 or section 70, to have his own facility for treatment of polluted air, equipment or instrument for control of the discharge of polluted air or other pollutants or the wastewater treatment or waste disposal facility, shall have the duty to collect statistics and data showing the daily functioning of the said facility or equipment and instrument, and make detailed notes thereof to be kept as recorded evidence at the site of that point source of pollution, and shall submit report summarizing the functioning results of the facility, equipment or instrument to the local official of the locality where such point source is situate at least once a month.

The collection of statistics and data, the making of notes and reports shall be in accordance with the rules, procedures, methods and format specified by ministerial regulation.

In case the facility for treatment of polluted air, wastewaters or waste disposal or equipment and instrument indicated in the first paragraph requires a Monitoring Control Operator as determined

by the pollution control official, the Monitoring Control Operator shall have the duty to act under the first paragraph on behalf of the owner or possessor.

The Service Contractor licensed to render wastewater treatment or waste disposal services shall have the duty to do the same as the owner or possessor of the point source of pollution is required under the first paragraph.

Section 81 The local official shall gather the reports received according to section 80 and send them to the pollution control official, who has jurisdiciton over that locality, on a regular basis at least once a month. In doing so, the local official may make comments for consideration of the pollution control official.

Section 82 In order to perform his functions under this Act, the pollution control official is empowered as follows :

(1) To enter into the building, place and site of the factory or point source of pollution or the site of wastewater treatment or waste disposal facility which belongs to any person, between the sun rise and sun set or during the working hours, to inspect the functioning process of wastewater treatment or waste disposal facility, air pollution control system or equipment and other instrument for the control of polluted air or other pollutants, as well as to examine the notes, statistics or data on the functioning of the said facility, equipment and instrument, or when there is a reasonable suspicion that there is a non-compliance with this Act.

(2) To issue an order in writing directing the owner or possessor, the Monitoring Control Operator, or the licensed Service Contractor rendering the services of wastewater treatment or waste disposal, to correct, change, improve or repair the air pollution control, wastewater treatment or waste disposal facility or other equipment and instrument for the control of polluted air or other pollutants. If however, the point source of pollution is a factory, the official under the law on industrial plants shall be notified to take action within his power and duty. If such official fails to do so, the pollution control official shall have the power to take action in accordance with this Act.

(3) To issue a written order directing the owner or possessor of the point source of pollution which is not a factory to pay penalties as provided under section 90, section 91 or section 92. If the point source of pollution is a factory the official under the law on industrial plants shall be notified to order the owner or possessor of such factory to pay the penalties and, in doing so, such official under the law on industrial plants shall be deemed to be the pollution control official under this Act. If, however, such official fails to issue the penalty order within a reasonable time, the pollution control official shall then have the power to issue the order directing the owner or possessor of such factory to pay the penalties.

(4) To issue a written order directing the Service Contractor licensed to render the services of wastewater treatment or waste disposal to stop or shut down his services, or revoking his license in case such Service Contractor violates or does not comply with this Act, or any ministerial regulation, local ordinance, rule, notification or condition issued or stipulated by virtue of this Act, or does not comply with the order of the pollution control official issued by virtue of this Act.

(5) To issue a written order suspending the Monitoring Control Operator under section 68 or section 70 in case such Monitoring Control Operator violates or does not comply with this Act, or any ministerial regulation, local ordinance, rule, notification, or condition issued or stipulated by virtue of this Act, or does not comply with the order of the pollution control official issued by virtue of this Act.

Section 83 In case it is deemed reasonable in the interest of co-ordination of action among agencies concerned, the pollution control official may :

(1) Recommend the official who has the legal power to control the point source of pollution, to close down its operation, to suspend or revoke the license of its owner or operator, or to bar its use or utilization in any way, especially in connection with the point source of pollution under section 68, section 69 or section 74 which has no intention to treat the polluted air, wastewaters or other wastes and illegally discharges the untreated wastes into the environment outside the limits of its site and premise.

(2) Recommend the local official to take legal action against the owner or possessor of the point source of pollution under section 71 or section 72 in order to coerce him to send wastewaters or wastes to be treated or disposed in accordance with this Act.

(3) Give advice and suggestions to the local official or the government agency concerned in connection with the operation and maintenance of the central wastewater treatment plant or the central waste disposal facility under the responsibility of such local official or government agency.

Section 84 In the performance of duty under this Act, the competent official or the pollution control official must produce his identity card at the request of the person concerned.

The identity card of the competent official and pollution control official shall be in such a form as prescribed in the ministerial regulation.

Section 85 The owner or occupier of premises, vehicles or any person concerned shall facilitate the performance of duty under this Act by the competent official or the pollution control official who shall be official under the Penal Code.

Section 86 The performance of duty by the competent official under section 50, first paragraph, or section 65 and the performance of duty by the pollution control official under section 82 (1) shall be done in the presence of the owner or occupier of the premise or vehicles; if such person cannot be found, it shall be done in the presence of at least two other persons requested by the competent official or the pollution control official to attend as withnesses.

Section 87 The owner or possessor of the point source of pollution, the Service Contractor licensed to render services of wastewater treatment or waste disposal, the Monitoring Control Operator or any other person who is not satisfied with the order of the pollution control official under section 82 (2), (3), (4) or (5), is entitled to challenge such order by petition to the Pollution Control Committee within thirty days form the date of receiving the order of the pollution control official.

If the petitioner does not agree with the decision of the Pollution Control Committee, he shall appeal to the Minister within thirty days from the date of receiving notification of the Pollution Control Committee's decision.

The decision of the Minister shall be final.

Part 8
Service Fee and Penalty

Section 88 In any pollution control area or locality where a central wastewater treatment plant of a central waste disposal facility has been constructed and brought into operation as a public utility service, funded by government budget or revenue of the local administration and money allocated from the Fund as provided in this Act, the National Environment Board shall, with the advice of the Pollution Control Committee, fix the rates of service fee to be applicable within the limits of each pollution control area or locality, being the site of and served by the operation of such facility.

The service fee rates fixed according to the foregoing first paragraph shall be notified and published in the Government Gazette.

Section 89 The rates of service fee fixed according to section 88 for treatment of wastewaters or for disposal of wastes eminated from point sources pursuant to section 71 and section 72 may be varied as appropriate.

The owner or possessor of the point source of pollution governed by the provision of section 72, in the category of domestic household, that can be classified as a small-scale user is entitled to be exempted from the payment of service fees in accordance with the rules and conditions stipulated by the National Environment Board, with the advice of the Pollution Control Committee.

Section 90 Any owner or possessor of point source of pollution who avoidedly refrains from sending wastewaters or wastes to the central wastewater treatment plant or the central waste disposal facility as required by section 71 or section 72 and illegally discharges such wastewaters or wastes into the environment outside the limits of the site of the point source owned or possessed by him, or does send the wastewaters or wastes to the central wastewater treatment plant or the central waste disposal facility of the public service for treatment but fails or refuses to make payment for the service fees without being entitled to the exemption as provided by section 89, second paragraph, shall be liable to pay as a penalty four time as much the amount of service fee that he is liable to pay at the rate fixed in accordance with section 88 until the provision of this Act is observed by him.

Section 91 Any owner or possessor of the point source of pollution, required by section 70 to have an on-site facility for wastewater treatment or waste disposal, who illegally discharges wastewaters or wastes into the central wastewater treatment plant or the central waste disposal facility of the public service, shall be liable to pay as a daily penalty four time as much the amount of daily expenses for the normal operation of his on-site facility for wastewater treatment or waste disposal throughout the duration of such illegal discharge and shall also be liable to pay damages if such illegal discharge has caused any damage or defection to the central wastewater treatment plant or the central waste disposal facility of the public service.

Section 92 Any owner or possessor of the point source of pollution subject to the requirements of section 68 or section 70, who refrains from using his on-site facilities or equipment for the control of air pollution, noise pollution and vibrations, or refrains from operating his on-site facilities for the treatment of wastewaters or disposal of wastes and illegally discharges such untreated wastewaters or wastes into the environment outside the limits of the site of the point source of pollution, shall be liable to pay as a daily penalty four time as much the amount of daily expenses for the normal

operation of his facilities, equipment or process for wastewater treatment or waste disposal throughout the duration of such illegal discharge.

Section 93 The local authority or the competent official of the government agency responsible for the operation of the public wastewater treatment plant or waste disposal facility shall have the power and duty to collect service fees, penalties and claim for damages as provided in this Part, particularly in connection with the operation of the central wastewater treatment plant or the central waste disposal facility of the public service which is made available by such local authority or government agency.

The service fees and penalties collectable in accordance with the foregoing first paragraph shall be exempted from being remitted to the Treasury as government revenues, but shall be deducted and remitted to the Fund at the ratio specified by the Fund Committee, whereas the balance therefrom shall be used as expenditures for operation and maintenance of the central wastewater treatment plant or the central waste disposal facility of the local authority or government agency which is responsible to collect such service fees and penalties.

Chapter V
Promotional Measures

Section 94 The owner or possessor of any point source of pollution, who has the duty according to this Act or other related laws to install an on-site facility for treatment of polluted air or wastewaters or for disposal of any other wastes, including the procurement of equipment, instrument, tools, appliances or materials necessary for control of pollution from such point source, or the Service Contractor licensed pursuant to this Act, is entitled to request for promotional supports and assistance from the government service in the following matters :

(1) Request for assistance regarding import duties for the import into the Kingdom of necessary machinery, equipment, instrument, tools, appliances or materials which are not available in the Kingdom.

(2) Application for permission to bring foreign experts or specialists into the country to carry out works concerning the installation, monitoring, control or operation of air pollution control systems wastewater treatment works or waste disposal facilities in case qualified persons within the Kingdom are not available for recruitment and commissioning to supervise and control machinery, equipment instrument or tools imported into the Kingdom pursuant to sub-section (1), including application for exemption of income tax that will incur from the performance of work as a supervisor of such person within the Kingdom.

The owner or possessor of the point source of pollution who has no legal duty as referred to in the foregoing first paragraph, but nonetheless wishes to install an on-site facility with his own equipment, instrument, tools or appliances for air pollution control, wastewater treatment or for disposal of other wastes eminated from his activities or business undertakings, is also entitled to request for promotional supports and assistance from the government service in accordance with the foregoing first paragraph.

Section 95 The request for promotional supports and assistance according to section 94 shall be made to the National Environment Board in accordance with the rules, procedures, methods

and formats prescribed by ministerial regulation.

The National Environment Board shall consider and proceed with the request for promotional supports and assistance according to the foregoing first paragraph as it sees fit, taking into account the economic, financial and investment necessities of each individual applicant. In case it is considered appropriate to give assistance to the applicant, the National Environment Board shall recommend the government agencies concerned to act within their powers and functions to render promotional supports and assistance to the applicant accordingly.

Chapter VI
Civil Liability

Section 96 If leakage or contamination caused by or originated from any point source of pollution is the cause of death, bodily harm or health injury of any person or has caused damage in any manner to the property of any private person or of the State, the owner or possessor of such point source shall be liable to pay compensation or damages therefor, regardless of whether such leakage or contamination is the result of a willful or negligent act of the owner or possessor thereof, except in case it can be proved that such pollution leakage or contamination is the result of :

(1) Force majure or war.

(2) An act done in compliance with the order of the Government or State authorities.

(3) An act or omission of the person who sustains injury or damage, or of any third party who is directly or indirectly responsible for the leakage or contamination.

The compensation or damages to which the owner or possessor of the point source of pollution shall be liable according to the foregoing first paragraph shall mean to include all the expenses actually incurred by the government service for the clean-up of pollution arisen from such incident of leakage or contamination.

Section 97 Any person who commits an unlawful act or omission by whatever means resulting in the destruction, loss or damage to natural resources owned by the State or belonging to the public domain shall be liable to make compensation to the State representing the total value of natural resources so destroyed, lost or damaged by such an unlawful act or omission.

Chapter VII
Penal Provisions

Section 98 Any person who violates or refuses to observe the order issued by virtue of section 8 or obstructs any act done in compliance with such order shall be punished by imprisonment not exceeding one year or fine not exceeding one hundred thousand baht, or both.

In case the person who violates or refuses to observe the order or obstructs any act done in compliance with such order is the person who has caused danger or damage arisen from pollution, such person shall be punished by imprisonment not exceeding five years or fine not exceeding five hundred thousand baht, or both.

Section 99 Any person who illegally encroaches upon, occupies, or enters into public land to act in any manner which results in the destruction, loss or damage to natural resources or treasures worthy of being conserved, or causes the occurrence of pollution having impact on the environment within the limits of environmentally protected area designated by virtue of section 43 shall be punished by imprisonment not exceeding five years or fine not exceeding five hundred thousand baht, or both.

Section 100 Any person who violates or refrains from observing the restrictions stipulated by ministerial regulation issued according to section 44 or by notification given by the Minister according to section 45 shall be punished by imprisonment not exceeding one year or fine not exceeding one hundred thousand baht, or both.

Section 101 Any person who spreads or disseminates false information about the danger from any point source of pollution with the intention to destroy its reputation or to undermine public trust on the lawful operation of its business or activity shall be punished by imprisonment not exceeding one year or fine not exceeding one hundred thousand baht, or both.

If the spread or dissemination of information according to the foregoing first paragraph is done by means of publication, announcement, advertisement or reports through newspaper, radio, television or other forms of mass media, the person who commits such act shall be punished by imprisonment not exceeding five years or fine not exceeding five hundred thousand baht, or both.

Section 102 Any person who violates the order of competent official forbidding the use of vehicle according to section 65 shall be punished by fine not exceeding five thousand baht.

Section 103 Any person who refuses to observe the order given by competent official according to section 67 shall be punished by imprisonment not exceeding one month or fine not exceeding ten thousand baht, or both.

Section 104 Any owner or possessor of the point source of pollution who refrains from observing the provision of section 71, or any person who refrains from observing the provision of section 72, or the rules laid down by the local authority by virtue of section 74 or section 75, first paragraph, or the ministerial regulation issued by virtue of section 80 shall be punished by imprisonment not exceeding one year or fine not exceeding one hundred thousand baht, or both.

Section 105 Any person who renders services as a Monitoring Control Operator or as a Service Contractor for wastewater treatment or waste disposal without the license granted according to section 73 shall be punished by imprisonment not exceeding one year or fine not exceeding one hundred thousand baht, or both.

Section 106 Any owner or possessor of the point source of pollution or any Monitoring Control Operator or any Service Contractor rendering the services of wastewater treatment or waste disposal, who refrains from collecting statistics or data or from making notes or reports as required by Section 80 shall be punished by imprisonment not exceeding one month or fine not exceeding ten thousand baht, or both.

Section 107 Any Monitoring Control Operator or Service Contractor having the duty to make notes or reports according to this Act, who intentionally makes such notes or reports showing false

information or statements shall be punished by imprisonment not exceeding one year or fine not exceeding one hundred thousand baht, or both.

Section 108 Any person who obstructs or refuses to comply with the order of the pollution control official given in the performance of his duty according to Section 82 (2) shall be punished by imprisonment not exceeding one month or fine not exceeding ten thousand baht, or both.

Section 109 Any Service Contractor rendering services for wastewater treatment or waste disposal ordered by the pollution control official to stop or close down his services pursuant to Section 82 (5), or any Monitoring Control Operator whose license has been revoked by the order of the pollution control official pursuant to Section 82 (6), who violates or refuses to comply with such order of the pollution control official or continues to carry on his service in violation of such order shall be punished by imprisonment not exceeding one year or fine not exceeding one hundred thousand baht, or both.

Section 110 Any owner or possessor of the point source of pollution who employs the person, whose license to be a Monitoring Control Operator has been revoked, to supervise and monitor the operation of air pollution control, wastewater treatment or waste disposal facility that he has the duty install and operate according to this Act, shall be punished by fine not exceeding fifty thousand baht.

Section 111 In case the offender who is liable to be punished according to this Act is a juristic person, the directors or managers of such juristic person or any person who is responsible for the business operation of such juristic person, shall also be punishable by the same penalties prescribed by law for such offence, unless it can be proved that they have no part to play in the commission of such offence.

Interim Provisions

Section 112 In the period during which the National Environment Board is yet to be appointed in accordance with section 12 of this Act, the National Environment Board appointed prior to the date of effectiveness of this Act shall continue to hold office in order to perform its function until the new Board shall be appointed and take over the office.

Section 113 All ministerial regulations, rules, procedures, notifications or orders, issued by virtue of the Enhancement and Conservation of National Environmental Quality Act, B.E. 2518 which remain in force on the date of effectiveness of this Act, shall continue to be effective, insofar as they are not in conflict with or contrary to this Act, unless and until ministerial regulations, rules, procedures, notifications or orders will have been issued in accordance with this Act.

Section 114 The person, who has ben holding a licence as an eligible person to prepare reports concerning the study and measures for the prevention of and remedy for the adverse effect on environmental quality by virtue of the Enhancement and Conservation of National Environmental Quality Act, B.E. 2518, shall continue to be eligible to prepare the environmental impact assessment report provided by this Act, until such person is required by the Minister to apply for licence in accordance with this Act.

Section 115 For all the reports concerning the study and measures for the prevention of and remedy for the adverse effect on environmental quality required for any project or activity pursuant to the Enhancement and Conservation of the National Environmental Quality Act, B.E. 2518, that have been filed prior to the date on which this Act shall come into effect and still pending review by the Office of National Environment Board, the review and approval of such reports shall be further proceeded with in accordance with the rules and procedures laid down by virtue of the Enhancement and Conservation of National Environmental Quality Act, B.E. 2518. For this purpose, the power and duty of the Office of National Environment Board in become the power and duty of the Office of Environmental Policy and Planning.

Countersigned by :
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Prime Minister

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