An Analysis of Future Energy Consumption with A Relational Model Based on Economic, Social and Environmental Sector under Thailand's Sustainable Development Policy by Adapting a GM-ARIMAX with HP Filter

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Abstract

Thailand has stepped further to reduce energy consumption by bringing out a five-year plan policy into actions. The limitations in economic development in Thailand become tighter than in years before. In order to acquire a future figure of energy consumption in the upcoming year of Thailand, this study seeks to propose a new GM-ARIMAX model by incorporating the HP filter to forecast the final consumption of energy. With the new approach proposed, it reflects the effectiveness of the model since it provides a more reliable result and an accurate outcome compared to those traditional methods. With the use of the above model, the study incorporates various economic circumstances to predict the energy consumption and possible changes in its structure in Thailand between 2018 to 2021 in order to further articulate any possibility of Thailand to have its minimization goal achieved. However, the study shows that the problem of energy conservation and emission minimization will remain unchanged for the next few years.

Keywords: forecasting model, energy consumption, GDP growth, ARIMAX Model, plan and Policy

การวิเคราะห์การบริโภคพลังงานในอนาคตด้วยแบบจำลองความสัมพันธ์จากภาคเศรษฐกิจ, สังคมและสิ่งแวดล้อม ภายใต้นโยบายการพัฒนาที่ยั่งยืนของประเทศไทย โดยประยุกต์ใช้ GM-ARIMAX with HP Filter

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บทคัดย่อ

ประเทศไทยได้ตั้งเป้าหมายในลดการบริโภคลง โดยกำหนดขึ้นเป็นนโยบายและแผนในช่วง 5 ปี เพื่อลดการบริโภคพลังงานลง จากการดำเนินการดังกล่าว พบว่า ยังมีข้อจำกัดในด้านเศรษฐกิจมีการพัฒนาที่เติบโตขึ้นในช่วงปีที่ผ่านมา ซึ่งเครื่องมือสำคัญในการบรรลุเป้าหมายในครั้งนี้ได้นำเสนอแบบจำลอง GM-ARIMAX with HP Filter เพื่อใช้สำหรับคาดการณ์การใช้พลังงานขั้นสุดท้าย โดยแบบจำลอง GM-ARIMAX with HP Filter นี้มีประสิทธิภาพและมีความน่าเชื่อถือมากกว่าแบบจำลองในอดีต ดังนั้น เมื่อนำแบบจำลอง GM-ARIMAX with HP Filter ไปใช้สำหรับการพยากรณ์การใช้พลังงานขั้นสุดท้ายในช่วง พ.ศ. 2561-2564 พบว่า ในช่วงระยะเวลา 2-3 ปีข้างหน้า นโยบายการลดการใช้พลังงานและนโยบายการลดการปล่อยแก๊สเรือนกระจกของประเทศไทยยังไม่มีประสิทธิภาพและไม่เป็นไปตามแผนที่กำหนดไว้

คำสำคัญ: แบบจำลองการพยากรณ์*;* การบริโภคพลังงาน*;* การเติบโตของ *GDP;* แบบจำลอง *ARIMAX Model;* นโยบายและแผน

Introduction

Thailand is a country situated right in the center of Southeast Asia with a population counted over 68 million people, and it has become a strategic area supportive to Thai economy. Due to recent instability in politics, Thailand has encountered a difficulty to increase in GDP. However, it is able to achieve to expand GDP up to 4 per cent slowly each year from 1995 to 2017. As of the consumption of energy, it keeps rising from 32.14 million tons of Standard Coal Equivalent (SCE) in 1995 to 425.21 million tons of SCE in 2017. Since then, the energy consumption has become one of the most influential factors in boosting economic growth in Thailand, and that comes with the adaptation of urbanization and opening of industrialization. At the same time, such consumption of energy creates a barrier to slow down the economic growth (Asian Development Bank, 2014; Office of the National Economic and Social Development Board, 2015; Sutthichaimethee, 2017). This, therefore, defines an issue of energy security at all levels; showing a shortage of energy supply while its demand increases. At the same, an issue of energy pollution and environmental negativity has shaken the economy to fluctuate. It has however gotten better after various conservative programs in energy are run by the government, and that pushes Thailand to reduce a usage of energy per unit of Gross Domestic Product by 21 per cent. Besides, those programs are structured based on the national goal in order to reduce such an emission (Office of the National Economic and Social Development Board, 2015; Sutthichaimethee & Sawangdee, 2016a, 2016b).

At the same, it has become a concern evolving around the possibilities of Thailand to attain such a goal, while its entire economy must be proven to its development (Dechackhamphu & Kulawong, 2018). Therefore, it is crucial to comprehend of future energy consumption in the future. As of a support for such realization, a new forecasting model in energy consumption is produced to use in energy consumption prediction under different economic condition, and that allows the government to come up with a proper government to promote the efficiency of energy and economic improvement.

Energy consumption and economic development have been in relation since many years ago, but, to some extent, it is still new for some circumstances on researches in forecasting the consumption in energy. Kalogirou and Bojic (2000) claimed that a time-consuming along annual results would commercialize a modelling framework and introduced ‘Artificial Neural Networks’ (ANNs) model to forecast the energy consumption. Nevertheless, ANNs model is found difficult to retrieve a clear equation of prediction. In recent years, some studies were conducted to simplify the model of ANNs, including a presentation of a new neural network algorithm based on ANNs model as to predict an energy consumption (Dong, Coa, & Lee, 2015; Ekonomou, 2010; Tso & Yau, 2007). In addition, other studies later explained an alternative application to form a clearer forecasting equation with different methods like Autoregressive model (ARMA), Autoregressive Integrated Moving Average model (ARIMA) and Seasonal Autoregressive Integrated Moving Average model (SARIMA), to forecast the primary energy needs in the future (Ediger & Akar, 2007). While Crompton and Wu (2005) use a different approach known as the Bayesian Vector Autoregressive methodology. They claim that such a method would help to predict Thailand's consumption in energy, while identifying some possibilities under its implication. However, this method gives a poor result if the time-series data is less and insufficient. In order to avoid any possible inefficient prediction outcome from few data sets, some researches have suggested the Gray Model (GM) to predict such energy consumption. To name a few, this issue was identified by the Gray Theory (Akay & Atak, 2007; Guo, Wu, & Wang, 2011; Kayacan, Ulutas & Kaynak, 2010). While Lee and Tong (2012) developed a new approach called a novel hybrid dynamic approach to tackle a non-linear data problem and provide a greater accuracy, and this method consists of The High Definition Geomagnetic Model (HDGM) and genetic programming used to predict and estimate the energy consumption. On the other hand, when the old result structure on energy consumption seems complicated and undivided, the HDGM is a good choice to use. Likewise, the new introduced model mentioned in this study is very supportive in both prediction of future energy consumption and enhancement of precision at the same time. Furthermore, such a method could be another help to support residual sequences obtained by the grey system theory. Upon some features of energy consumption in Thailand discussed, the study seeks to improve on a forecasting model in Thailand's energy consumption, and the new method on GM-ARIMAX with HP Filter concept is then proposed.

Short discussion on energy consumption in Thailand

As Thailand has an initiative to penetrate into the global market, Thailand has been associated with many challenging and opportunities, and those push Thailand into a better position in regional economy. Due to the rapid growth in economy, there is also an increment of 11 per cent annually in Thailand's total final consumption in energy. This rise is really affecting the future structure of energy consumption. Since the latest update of energy consumption is still in an early stage in Thailand, it is increasing linearly with economic growth (ADB, 2014; Sutthichaimethee, 2017, 2018).

In Thailand, a coal consumption shares a major portion in the final energy consumption for many years. Recently, the coal consumption in Thailand is dropping amounting 9.5 per cent by 2017. Whereas, the electricity contributes almost 65 per cent out of the entire energy consumption. It cannot be denied the fact that the technology of coal-based power generation produces over 82 per cent in Thailand, and this reflects worst circumstances, where a big amount of carbon dioxide is discharged to the air and other wastes are produced polluting the environment.

In worst case, the energy is not fully utilized. Continuously, the structure of industrial energy use mismatches to the national GDP, as the energy is consumed. In recent years, though Thailand is positioning into the economic development stage, the secondary sector like manufacturing, mining and construction, is still part of Thailand's economic structure. To simply this statement, Thailand uses the energy 425.21 tons of SCE in total as of 2017 with the growing energy consumption of the secondary sector almost 65 per cent, but only bringing the national GDP of 55 per cent. Contrarily, the data on energy efficiency indicates the secondary sector in Thailand is at low efficiency in term of energy consumption by comparing with other two sectors; primary and tertiary sector. Therefore, it has become the main task that Thailand must complete as to obtain the energy saving goal.

Particularly, this second sector as the manufacturing shares a larger volume in energy use amounting over 81 per cent, and another 19 per cent is from the construction industry. Plus, there are 66 different industries under the umbrella of the manufacturing industry. The following industries are listed as the high-energy consuming industry; namely nonmetal mineral products, production and supply of electric power and heat, petroleum refining, coking, smelting and pressing of ferrous metals, manufacture of raw chemical materials and chemical, manufacture of communication equipment, and computers. Within these industries, it can be observed that all of those industries engage in the energy production. Thus, it is no doubt that they are intensively using the energy and produce more pollutions. At the same time, they are still at the lower efficiency in terms of energy conversion efficiency. Hence, it becomes very interesting in the topic of reducing energy consumption and raising in the enerpgy efficiency.

Objective

This study aims to analyze a future trend of energy consumption from a relational model constructing based on Economic, Social and Environmental sector under Thailand's Sustainable Development policy by adapting a GM-ARIMAX with HP Filter.

Methodology

1) Hodrick–Prescott Filter model

In 1997, HP Filter model was introduced by Hodrick and Prescott (1997), and that model was put forth with the consideration of the economic issue. This is because they see that the sum of cyclical and growth components can be taken from some time series. Now, it is easy to identify the cyclical series or regular trend from some time-series model. In fact, HP Filter can facilitate in differentiating the cyclical and trend component from the original time-series (Enders, 2010).

Given that the original time series is equivalent to the sum of both growth and cyclical component as shown below.

$$Y_t = Y_t^T + Y_t^C \quad \text{(t= 1,2,3,...n)}$$
(1)

While HP Filter helps to separate the growth component out of the original time series through this equation.

$$\min\left\{\sum_{t=1}^{n}(Y_t - Y_t^T)^2 + \lambda\sum_{t=2}^{n-1}\left[(Y_{t+1}^T - Y_t^T - (Y_t^T - Y_{t-1}^T)\right]^2\right\}$$
(2)

Here, a variability in the growth component series is penalized by a positive number denoted as λ.

2) Grey Forecasting Model

In the industrial production and economy, the complete information may not be available to access. In order to reduce this risk of incomplete information, (Sutthichaimethee & Ariyasajjakorn, 2017a; (Sutthichaimethee, 2018; Deng, 1982) found a way to do so by introducing a theory of grey system. This new system is believed to incorporate well with the regular time series. With this idea of applying the grey system theory, Trivedi & Singh (2005) had come up another concept to demonstrate the rainfall-runoff process as to study the relationship between an input- output process, unclear mechanisms and inner relationship, and incomplete information. Based on this theory, Pai et al (2007) also optimized it in examination process of transportation effects concerning on air quality trends in Japan. As of the result, it was imputable to law enactment. Also, Huang and Jane (2009) used the theory to construct an automatic mechanism to predict a stock market and portfolio selection. The reason is that the theory allowed them to estimate a future value with a limited stored data. GM (1,1) is commonly used for computational efficiency, and it had been given an emphasis by many studies. Such a model is demonstrated as below.

Suppose a non-negative time series of energy consumption with n observations is denoted as $x^{(0)}$.

$$x^{(0)} = (x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n))$$

(3)

The below equation gives a new monotonically increasing series x $^{(1)}$ with the use of Accumulated Generating Operation (AGO).

$$x^{(1)} = (x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(n))$$

(4)

When $x^{(1)}(k) = \sum_{t=1}^{k} x^{(0)}(i), k = 1,2,3, \ldots n.$

This is an evidence of which the chaotic original series is transformed into a regular one, where the differential equations of GM help to approximate and is explained below (Deng, 1982).

$$\frac{dx^{(1)}}{dt} + \alpha x^{(1)} = \mu$$

(5)

Here, α denotes as developing coefficient and as the control variable.

Giving $\hat{\alpha} = (\alpha, \mu)^T$ as the vector, that is retrieved from the method of least squares:

$$\hat{\alpha} = (B^T B)^{-T} B^T Y$$

(6)

When B = $\begin{bmatrix} -\left[x^{(1)}(1) + x^{(1)}(2)\right]/2 & 1 \\ -\left[x^{(1)}(2) + x^{(1)}(2)\right]/2 & 1 \\ \vdots & \vdots \\ -\left[x^{(1)}(n-1) + x^{(1)}(n)\right]/2 & 1 \end{bmatrix}$, and Y = $\begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix}$

And we could predict the series x $^{(1)}$ in a way that

$$x^{(1)}(k) = \left[x^{(0)}(1) - \frac{\mu}{\alpha} \right]^{-\alpha k} + \frac{\mu}{\alpha}, k = 1,2,3, \ldots, n$$

(7)

Hence, $x^{(0)\hat{}}(k)$ is the original time series at time *k* predicted by:

$$x^{(0)\hat{}}(k) = x^{(1)\hat{}}(k) - x^{(1)\hat{}}(k-1), k = 2,3, \ldots, n$$

(8)

3) Auto-Regression Moving Average Model (ARMA)

In 1994, Box, Jenkins and Reinsel (1994) found out the way to simplify the vibrant structure of time series, and later introduced a model known as ARMA standing for Auto-regression moving average model. With its functional capability, the model is applied to do a forecasting with the stationary time series. The model of ARMA can be constructed as below.

$$r_t = \phi_0 + \phi_1 r_{t-1} + \phi_2 r_{t-2} + ... + \phi_p r_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - .... - \theta_q \varepsilon_{t-q}$$

(9)

at which an error term is ε_t .

Once the parameter *p* and *q* are examined, ARMA(p,q) (Enders, 2010) can then be taken to forecast the time series. Here, the forward estimation of r_{h+1} is shown like below when the time series at *h*.

$$\hat{r}_h(1) = E(r_{h+1} / r_h, r_{h-1} = \phi_0 + \sum_{i=1}^{p} \phi_i r_{h+1-i} - \sum_{i=1}^{q} \theta_i \varepsilon_{h+1-i}$$

(10)

with the corresponding error $e_h(1) = r_{h+1} - r_h(1) = \varepsilon_{h+1}$

4) GM-ARIMAX model according to HP Filter

A time series of final energy use considers as a non-stationary and chaotic, and is given in a form of x = $(x_1, x_2, ... , x_n)$. By using the HP Filter technology, two regular series would be decomposed from the original time series. Those regular series are the trend component and the cyclical component structured as $x_t = x_t^T + x_t^C \, (t = 1,2,3,..., n)$

In detail, the first component known as trend component x_t^T could be estimated by GM (1,1), while it could be incomplete time series but regular in the system of typical gray. Based on some studies, the sample size required at least is 4 when concerning the GM model. On the other hand, the error is getting bigger if the sample size is more than 35. A way to have a proper sample size and increase in its precision is to use and apply the golden section method of one-dimensional search into the studied model (Enders, 2010; Dicky and Fuller, 1981).

Whereas, the second component as the cyclical component x_t^C could do well with the time series model. As of compromising these two models in benefit, a hybrid GM-ARIMAX model is then introduced and presented to forecast the final energy use with more accuracy rate (Sutthichaimethee & Ariyasajjakorn, 2017b; Sutthichaimethee, 2015, 2016; Enders, 2010).

Here is showing the step of the model:

Step 1: Decomposing the original time series with HP Filter into the trend component x_t^T and cyclical component x_t^C , and do this in EVIEWS.

Step 2: Conducting GM (1,1) model with MATLAB toolbox to retrieve the gray predicted series x' with the grey residual error series of $\varepsilon = x - \hat{x}$ for the time series x_t^T .

Step 3: For the grey residual error series **ε** with the series is stationary, the Unit Root Test must be carried out, and ARMA model with parameters *p* and *q* is use to predict a new time series called ARMA forecasted series **ε**'.

Step 4: Reforming the original time series x and predict it with the grey forecasted series and ARMA forecasted series as $\hat{x} = \varepsilon' - x'$.

Step 5: Predicting and estimating the future time series via the improved GM-ARIMAX model with HP Filter technology.

Empirical Analysis

1) Data

As what have been mentioned earlier, the economic growth is clearly seen to relate to the final consumption of energy, and that is the reason why the growth is slow down as such a consumption keeps creating barriers. Hence, it is very important to predict the future amount of energy consumed as so the emission reduction could be in control and achieved. In this paragraph, the GM–ARMA model with HP Filter concept is emphasize to explain the above issue of the final energy consumption. Here, the study optimizes on time-series data of final energy consumption, because it is believed that it would give a clear picture the total energy used in the economy. Overall, the data used in the study is a non-stationary time series, mainly emphasizing the final energy use in Thailand for the period of 1995 until 2017, sizing with 23 samples in total. Within this set of data, a number of 18 samples is taken to build the GM-ARIMAX model, while the rest of the samples is used to examine the model. To originate the samples, they are taken from Thailand Statistical Yearbooks, while EVIEWS and STATA are utilized to calculate the data.

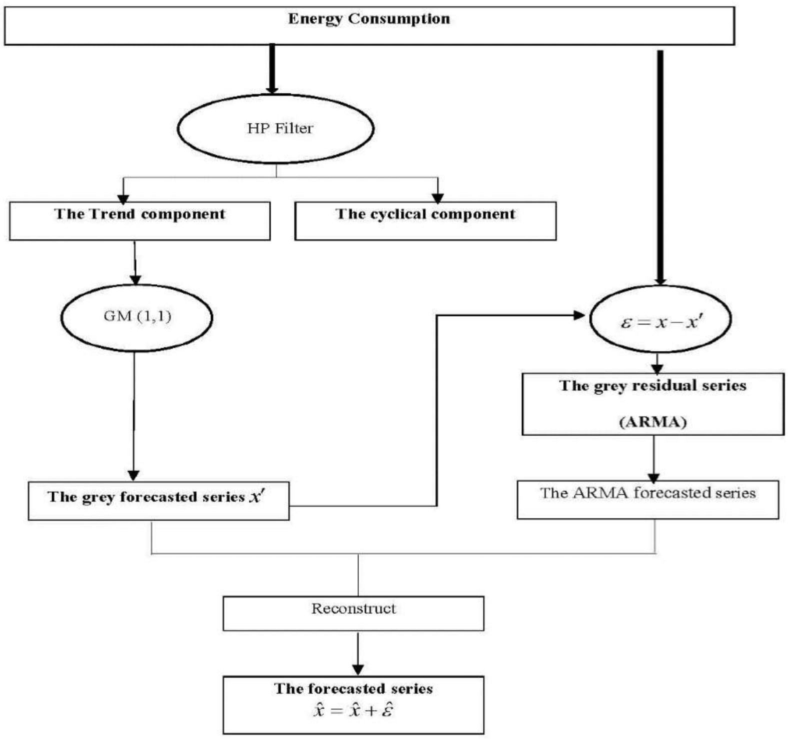

Fig. 1. The procedure of GM-ARIMAX with HP Filter

2) The Forecast Resulted from GM–ARMA Model with HP Filter Technology

Based on the steps of the forecast, the decomposition of the original time series of energy use comes for the first place, with 100 in value for the parameter λ. As of the above decomposition, the trend component and cyclical component are to be the result. In a given trend, it explains the time series of final energy use, and that further demonstrates a rising long-run pattern. Here, a repeated up and down movement can clearly be identified. Since the original time series provides both trend and cyclical component, it is possible to create trend-based and cyclical-based prediction accordingly with the use of GM and ARMA models (Sutthichaimethee & Sawangdee, 2016).

Accordingly, using the GM model (1, 1) to forecast the trend component time series is next. This step requires a specification of length in predicted series. Based on GM model, 8 is the proper length of forecasting series here as to acquire a better precision. As of the result, in addition, $x'_i, x'_2, ..., x'_n$ expresses the original time series with error ε in which $\varepsilon_i = x_i - x'_i$

Afterwards, the autocorrelation function (ACF) and the Partial Correlation function (PACF) plots shall be observed as to have the numbers of AR and MA terms, like the values of parameter p and q, identified. In observation, there is a possibility to come up with the AR (1) model or AR (2) model, while the MA (1) model can be taken into consideration. Furthermore, we find more evidence of the ARMA (2, 1) model through making trail calculations under different levels of parameter p and q and checking the minimum AIC value. Along the trail evaluation with various range of parameter p and q, plus with minimal AIC value test, the ARMA (2, 1) model appears with more evidences indicating its possibility. Fig. 2 is constructed to show the forecasting result of ARMA (2, 1). Whereas, brings about the residual error series of ARMA (2, 1) using Q test statistic approach as part of white noise process. Accordingly, ARMA (2,1) model is believed to be accurate and consistent. Also, the model could be useful to have the error series of Thailand's final energy use predicted.

To sum up, the new forecasting series by $\hat{x}$ both trend component $\hat{x}$ and the cyclical component ε can be restructured from the original time series, and that is $\hat{x} = \varepsilon' + x'$ Fig.2 is constructed to demonstrate both forecasting series and original series of final energy use (Sutthichaimethee and Ariyasajjakorn, 2017c).

3) Robustness Analysis

In the test of finding the right effect through the model of HP filter-based GM–ARMA, the paper takes the Absolute Relative Error (ARE) for evaluation at $ARE_i = \left|(\hat{x}_i - x_i)/x_i\right|.100\%$

Consequently, the paper establishes the GM–ARMA model with the application of the 1995-2012 samples, while using the other samples to evaluate the model. The equation (3)–(4) in Fig.2 is presenting the forecasting time series as well as the corresponding ARE of GM–ARMA model with HP.

Specifically, the comparison result of the original and forecasting time series of final energy use for the year 2013 until 2017 is presented in Fig.2. The above result is evaluated with 2.05 per cent of ARE of HP Filter-based GM-ARIMAX model. On the other hand, for a comparison purpose, the paper has sought to bring up some other models for the time series forecast as so there would be other forecasting results to support the studied model. Along the study, the paper provides Fig.2 in order to display the average ARE of different models. As mentioned in the Fig.2, the average ARE of GM model, ARMA model and GM-ARIMAX model are 5.74%, 6.12% and 4.01%, respectively. Based on the trail numerical calculation, it shows that, among other models in test, GM-ARIMAX model provides the best fitting effect of the samples.

Discussion

In this section, the GM-ARIMAX model is used in energy consumption estimation according to HP filter from the year 2013 up to 2017 to shows the results of future energy expected to the final consumption for the next 5 years as mentioned by GM-ARIMAX with HP filter. Also, Fig.2 shows that there would be an expected increment by 10.65% annually from 2013 to 2017, in which the future amount of energy consumption is predicted in 2013 would likely outreach 345 million tons of SCE. On top of everything, relying upon model GM-ARIMAX, it hits Thailand's 12^{th} Five year plan of Energy Development goal by reaching 371 million tons of SCE outreach energy used by the year of 2015 and the amount of energy consumed in in Thailand for the year 2015 is supposed to be within the range limit of 3.61 million tons SCE.

Based on the recent economic condition, Thailand faces a number of challenging uncertainty. As such, with cost reduction into a consideration, most manufacturing companies tend not to lower their inputs with energy efficient technology and equipment. However, they would rather go for the technology and equipment that are low at initial capital cost, polluting the environment, consuming a greater energy, but generating profits in a short period. With the same method used, it expands its function to predict the changes in pattern or structure of the future energy consumption in Thailand starting from the year 2018 until 2021. From the analysis done, it results that Thailand would grow in electricity and sustain as the major part of energy consumption. While the petroleum and coal are likely seen to drop, and other source of energy consumption like hydropower is coming to play a vital role in energy structure of Thailand. Due to these changes, a complexity of the consequences comes into play. Some provides positive environmental effects when there is an increase in other energy consumption. In fact, the coal consumption is becoming greater as the electricity accounts the biggest portion in the final energy consumption, as discussed in Section 2. Nonetheless, the probability of this change in the near future may be low, but it can happen anytime. In case of economic recession, things may get worst, and that pushes the power companies to choose a cheaper coal in energy generation. With these two circumstances, it creates a difficulty for Thailand to succeed in energy conservation.

From there, it is seen that the issue of emission reduction and energy conservation becomes gloomy in Thailand. Hence, some specific actions shall be given a full attention as quick as possible to slow down the consumption in energy during the economic downturn. The following actions are deemed to initiate.

Firstly, in case of the economic condition is not healthy, where the absolute value of secondary sector-based energy consumption drops and efficient energy use is not in place, the policy makers must be able to establish some innovative policies on energy, including imposing a tax-deductible policy or subsidize in energy conservation activities as so to urge the manufacturing companies to use energy-saving equipment’s and technology. In addition, the policy makers must keep their effort to further ameliorate an energy conservation management; strengthening a general accountability system to urge the companies to improve an energy efficiency as per unit of product and allocating special technology innovation funds to enhance the current technologies in bigger manufacturing companies.

Secondly, it is necessary to develop the structure of electricity consumption with an active involvement of safe and sound production improvement of hydropower and new energy. At the same time, the renewable energy shall increase in portion as to response with the future needs of energy.

$$\Delta\ln(CO_2)_t = -0.41 + 3.55\Delta\ln(CO_2)^{**}_{t-1} + 3.05\Delta\ln(CO_2)^{**}_{t-2} + 4.08\Delta\ln Population^{**}_{t-1} + 5.16\Delta\ln(GDP)^{**}_{t-1} + 2.25MA^{**}_{1} + 2.44ECM^{**}$$

$$\Delta\ln(Population)_t = -0.68 + 3.14\Delta\ln(Population)^{**}_{t-1} + 3.36\Delta\ln(Population)^{**}_{t-2} + 4.19\Delta\ln(CO_2)^{**}_{t-1} + 2.59\Delta\ln(GDP)^{**}_{t-1} + 2.07MA^{*}_{1} + 3.57ECM^{**}$$

$$\Delta\ln(GDP)_t = -0.73 + 4.96\Delta\ln(GDP)^{**}_{t-1} + 6.32\Delta\ln(GDP)^{**}_{t-2} + 3.47\Delta\ln Population^{**}_{t-1} + 6.11\Delta\ln(CO_2)^{**}_{t-1}\ 5.15MA^{**}_{1} + 2.13ECM^{*}$$

Fig. 2: ARMA Model (2,1)

Conclusion

A continuous increment in energy consumption of Thailand has affected Thailand's entire national management in term of implementing a sustainable development policy. This is due to the said increment becomes a causal factor towards a continuous national economic and social growth. Yet, it does not improve the environment, while this aspect has to be better at the same time. This indicates of which the increase in energy consumption has a negative relationship to the environment. Therefore, Thailand must have a forecasting model as an important tool to measure a future energy consumption needed as to support in a policy-making at a maximal efficiency and effectiveness. In this study, certain time-series models are presented to identify the appropriate models for the estimation. Here, the characteristics of data and modelling are scrutinized. Then, GM-ARIMAX is further developed and improved in accordance of HP Filter to estimate the energy consumption from 1995 to 2017. Upon a comparison of the result among various models; namely GM, ARMA and GM–ARMA, it indicates that GM-ARIMAX model with HP Filter provides the best fitting result in samples giving a minimum of 2.05 per cent of average absolute relative error. Hence, such a model is utilized to estimate the energy consumption in the year 2018 until 2021. As of the result, it predicts that Thailand's final energy consumption would go beyond 345 million tons of SCE in the future at an annual growth rate of 10.65 per cent, and that surpasses of what has been set by the State Council. This makes things harder to succeed in the energy conservation. At the same time, the study is able to explain that Thailand is encountering an instability at all level due to inefficient electricity and industrial structure. Therefore, Thailand needs to take immediate actions and efforts to promote the efficiency in energy consumption among manufacturing companies. For instance, Thailand may set up certain technology innovation funds or imposes tax-deductible policy, while offering conservation subsidies in energy. Alternatively, Thailand may engage seriously in other renewable energy generation and substitution.

Nonetheless, only final energy consumption is taken into consideration in the issue of energy. Although the energy consumption is a vital component constituting the economic development, lot of concerns and questions are still open for the discussion and future studies. As for further research, other new aspects can be brought into the discussion of new forecasting model to solve the energy issue; the structure of effective strategies, energy generation and its composition affecting the energy itself in Thailand could be great discussion topics in the future.

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