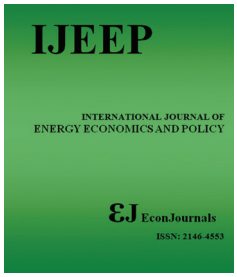

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Export Supply of Electricity from Laos to Thailand: An Econometric Analysis

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ABSTRACT

Thailand, as the largest electricity market for Laos, has imported significant amounts of electricity from Laos since the operation of first hydropower plant in Laos. However, currently there have been a number of new power particularly nuclear power plants in Thailand being studied implying the possibility of reduction in Thailand's electricity import from Laos. Since Thailand is the largest market of Laos' electricity, the change in demand for electricity from Thailand has substantial impact on the Lao economy. The first simulation conducted in this paper shows that Thailand reduces the import of electricity from Laos shows that it statistically has a large impact on Laos' electricity export sector, due to the reduction of income from electricity export. However, the feasibility of nuclear power projects in Thailand became unclear since the incident of damages of nuclear power plants in Japan on 11 March 2011. Therefore, there may be a possibility that Thailand may abolish the nuclear power projects. Consequently, Thailand may increase the import of electricity from Laos. The second case of simulation shows that the increase of Thailand's electricity import from Laos has positive effect on Lao economy through the significant increase in income from electricity export. The increase in Thailand's electricity import from Laos, not only has positive effect on Thai economy in terms of increasing consumption of electricity stimulating economic activities in Thailand, but it also has positive effect on Lao economy in terms of increasing income from electricity export.

Keywords: Electricity Export, Laos, Simultaneous Effects, Thailand
JEL Classifications: C5, Q43

1. INTRODUCTION

Laos is one of the poorest countries in Asia and the Pacific region with per capita gross domestic product (GDP) of only 1,204 USD in 2011 (IMF, 2011b). Half of its GDP is from subsistence agriculture which provides 80% of employment. The abundance of mineral resources has played an essential role in Lao economy. Metallurgy is an important industry which is expected to attract foreign investment to develop the substantial deposits of bauxite, coal, copper, gold, tin, and other valuable metals. In addition, Laos is rich in water resources and mountainous terrain which enable the country to generate and export large amounts of hydroelectricity to its neighbors. Around 8,000 MW of the potential capacity of approximately 18,000 MW have been committed for exporting to Thailand and Vietnam (ADB, 2007).

Since the growing demand for electricity exceeds its supply, Thailand has become a net electricity importing country. Up to now, Thailand has signed a number of memorandums of understandings (MOUs) to import significant amounts of electricity every year from its neighboring countries including Laos. The electricity trade between Laos and Thailand began since the commission of first dam built in Laos in 1972. Until now, there are several MOUs signed between the government of Laos and the Government of Thailand to increase the import of electricity from Laos. Consequently, Thailand has become the main market of electricity export from Laos, and Laos is also the main electricity exporter to Thailand.

However, there have been a number of new power plants particularly nuclear power plants in Thailand being studied and some have been

in commercial operation implying the possibility of Thailand's electricity import reduction. As the Intergovernmental Agreement on Regional Power Trade among the Greater Mekong Subregion (GMS) countries was signed by all six member countries at the first GMS Summit in 2002, this also may imply the possibility that Thailand would reduce the electricity import from Laos due to the increase of alternative markets for Thailand. Since Thailand is the largest market of Laos' electricity export, the change in Thai economy has also significant influence on Lao economy.

Thailand has considered nuclear power as an alternative energy source for electricity generation since 1966, and eventually approved the establishment of its first nuclear power plant in 2007. The nuclear power plants are projected to be in operation in 2020. On 23, 2010, Thai Cabinet had approved Thailand Power Development Plan 2010 (PDP 2010) for 2010-2030. The PDP 2010 states that there will be 5 units of a 1,000 MW nuclear power plant in operation from 2020 to 2028. However, the feasibility of building nuclear power plant in Thailand became unclear since the incident of Japanese nuclear power plants damages in Fukushima caused by earthquakes and tsunamis that struck the northeastern coastline of Japan on 11 March 2011. Since the accident in Japan's Fukushima nuclear power plant in March, the Thai government decided to postpone its nuclear power projects for three more years becoming 2023 (Sarnsamak, 2011). Moreover, there are severe conflicts to the case of building nuclear power plants in such a country unprepared in terms of potential and social responsibility as Thailand. According to The Nation (2011), the coordinator of the Thai People Don't Want Nuclear Power Plants Network told a news conference that the Japanese lesson indicated Thailand should not have nuclear plants. In related news, about 30 protesters in southern province of Thailand asked provincial governor to bring an immediate end to plans for construction of a power plant there due to the worries of future accident. Therefore, there is also a possibility that Thailand may abolish the nuclear power projects in the country, and import more electricity from its neighboring countries as well as from Laos.

The purpose of this paper is to describe the electricity export from Laos to Thailand. In addition, this paper is aimed to observe how the change of Thailand's electricity demand affects both Lao and Thai economies, simultaneously. In other words, if Thailand succeeds in construction of nuclear power plants in the country, there is a possibility that Thailand may decrease the import of electricity leading to the negative impact on Laos' electricity export. In contrast, if Thailand fails in construction of nuclear power plants in the country, there is a possibility that Thailand may increase the import of electricity leading to the positive impact on Laos' electricity export.

Some notable studies about electricity in Laos are found in Leechuefong (2006), Greacen and Pallettu (2007), and Phimmasone (2009). However, due to the lack of interest and limited data, the studies involving electricity trade between Laos and other countries are few and relatively limited. There are only a few studies about electricity trade between Laos and neighboring countries as can be found in the studies of Lahmeyer (2004) and Leechuefong (2006). Similarly, there are a few studies of power trade between Thailand and another country such as those found in Shrestha et al. (2007), and Watcharejyothin and Shrestha (2009). Despite the studies relating to power trade between two countries, their studies still focused on environmental considerations and impacts on Thai economy.

The next section describes the electricity industry in Laos, followed by the electricity industry in Thailand in section 3. The electricity export from Laos to Thailand is presented in section 4. How the data is applied or what kind of estimation method is applied in the study is described in section 5. The findings from simulation shown in section 6 present the model performance and simulation results. Key findings from the study are briefly discussed in the final section.

2. ELECTRICITY INDUSTRY IN LAOS

Laos is a natural rich country endowed with significantly indigenous energy potential. It has about 26,500 MW theoretical hydropower potential in the whole country. Approximately 18,000 MW is technically exploitable with about 12,500 MW discovered in the major Mekong sub-basins, and the rest in minor Mekong or non-Mekong basins. Referring to future hydropower development plans in the country, Laos has a new moniker employed by Thai Former Prime Minister Thaksin Shinawatra as "Battery of Asia." Regarding electricity exports, the annual growth rate during 1990 to 2004 reached the average of 11%, doubling the share of GDP from 1.4% in 1990 to 2.7% in 2004. Furthermore, solid growth of 8% in 2011 was mainly based on hydroelectricity and mining sectors (World Bank, 2012b).

The characteristic of power sector in developing countries is that there are such problems as high demand but limited supply, unstable power supply systems, delayed development of power distribution networks, and public enterprises in a financially fragile situation. These problems pave the way to promote Laos' electricity exports in the sense that it has significant potential hydroelectricity generation to meet the increasing demands.

According to Watcharejyothin (2007), the urbanization rate in Laos is estimated to gradually rise from 22% in 2005 to 36% by 2035 together with the planned increase of electrification rate in rural area from 33% in 2005 to 95% in 2035. These are in parallel with the governmental national target according to which 80% of households would have electricity usages by 2015, and 90% by 2020. Rural electrification is one of the major achievements in Laos with the connection rate increasing from approximately 16% of all households in 1995 to 38% of all households by the end of 2003 (World Bank, 2012a). There is an implication that the governmental poverty reduction plan can be implemented also through the electrification projects.

There are a number of power plants generating significant amount of electricity as illustrated in Figure 1. Large proportion of electricity produced in the country is for export, and some accounted for about 10% is for domestic consumption. In addition to the 10% of total capacity that was to be made available for domestic supply through independent power plants (IPP), several

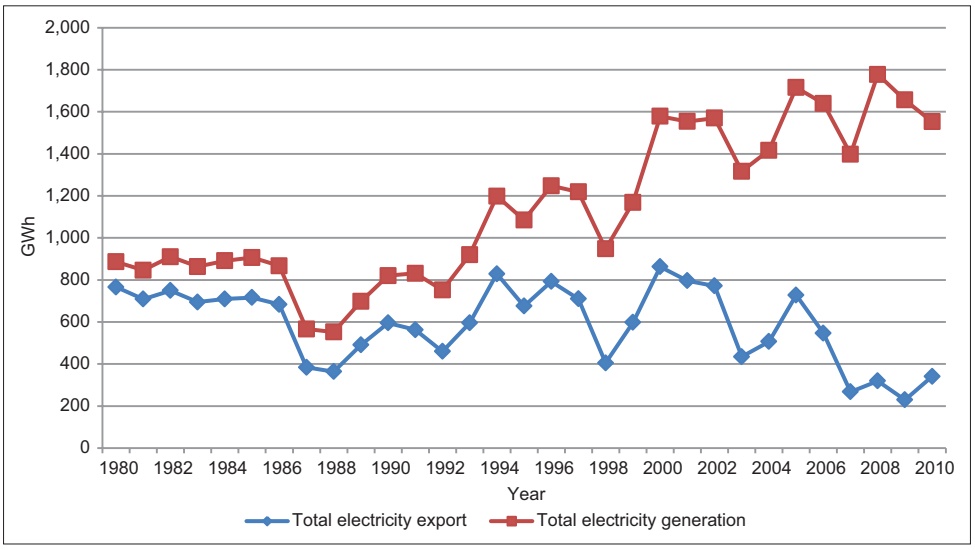

Figure 1: Total electricity generation and export (Unit: Gigawatt hour [GWh])

medium sized IPP projects have been nominated in order to meet the increasing demand in the country as well as demand from neighboring countries (EPD, 2009).

Although there is no confirmed oil or gas resource in the country, Laos has prodigious hydropower resource as the main source of energy generation. The country possesses abundant energy resources with less environmental impact, principally hydropower covering 97% of energy sources. Hydropower is the main indigenous energy resource in the country. Only a small proportion of hydro potentials have been developed, providing substantial exports and most of the generation needs of the country. The Nam Theun 2 hydropower project which is the largest plant in Laos is intended to enable Laos to export 995 MW to Thailand in addition to 75 MW for domestic use in the country. The export of electricity to Thailand is a foreign currency earner covering 10% of Laos' GDP (World Bank, 2012a).

Regarding electricity consumption in Laos, the Asian Development Bank has projected electricity demand to grow at an average of 7.7% until 2030, while electricity generation will grow faster at 12.1%. Table 1 shows the data on forecasted demand for electricity in Laos until 2020.

Under the country's Seventh National Socio-economic Development Plan for 2011-2015, the Lao government intends to build 10 more hydropower plants which have capacity to generate approximately 5,015 MW of electricity (Lao Voice, 2011). As illustrated in Table 1, Laos is not only exporting electricity to neighboring countries such as Thailand, but also imports some amount of electricity from its neighboring countries (Thailand, Vietnam and China) to accommodate the increasing consumption of electricity in the country especially the rural area. This is due to the fact that it is a significantly cheaper alternative than to extend the national grid to each corner of the country (The 22 KV transmission lines cost between 10,000 USD and 15,000 USD/km, depending on the accessibility of the road). However, from 2015, Laos will have adequate electricity to meet domestic demand, and even have surplus electricity prepared for export.

3. ELECTRICITY INDUSTRY IN THAILAND

According to ADB (2009), demand for energy in the GMS is rising rapidly. The rapid economic growth has fueled a significant expansion in energy demand, which has grown at over 8% per annum during 1993-2005. Most energy demand growth in each member country is foreseen to annually increase from 7% to 16%. The overall demand for energy in the GMS is forecasted to grow to over 238 GWh by 2025. Among other GMS countries, Thailand is the largest importer of energy, and has to import nearly 40% of its energy in the form of electricity, natural gas, and oil products.

In Thailand, initially the Electricity Generating Authority of Thailand was the sole electricity producer in the country. Due to the Thai government's policy in promoting the role of private sector in electricity generation, electricity sector was not monopolized by the government. Consequently, in 1994, there were a number of independent power producers and small power producers (SPP) taken part in the electricity supply, resulting in improvement in electricity generation and service quality in the country. Furthermore, Thailand is currently promoting the use of renewable energy in electricity generation resulting to the increase in a number of very SPP, using renewable energy as main fuel (EPPO, 2010).

Data obtained from EPPO (2012) shows that in 2011, total electricity generation in Thailand accounted for 162,343 GWh. In terms of the sources of energy generated in the country, natural gas covers the largest proportion of Thailand's power generation. In 2011, for example, the electricity generated from natural gas dominated about 72% of total national grid generation, followed by coal-lignite, and hydropower covering 18.2% and 3.3% of total national grid generation, respectively. However, power generation system in Thailand that relies mostly in natural gas is found to dramatically decrease within 29 years due to the limited domestic gas resource ability (Watcharejyothin and Shrestha, 2009).

According to EPPO (2010), prior to 1997 (i.e. before the economic crisis "Tom Yam Kung Crisis"), Thailand had experienced a high

Table 1: Forecast of domestic electricity demand for the whole country (2012-2020)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Demand	786	1,021	1,165	1,419	2,083	3,180	3,290	3,401	3,403	3,488
Supply	579	786	859	1,161	2,349	6,851	7,342	8,298	8,473	8,737
Balance	−207	−235	−306	−258	266	3,670	4,052	4,897	5,070	5,249
	Need to import					Excess electricity to be exported				

Source: EDL (2012).

growth rate of electricity consumption with an average growth rate of 11.9% since 1986 to 1996, and during the year of economic crisis, the demand decreased by 2.6%. After the crisis, there was a slowdown in the electricity demand with an average growth rate of 4.9% during 2000-2009. In 2011, the demand stood at 146,818.85 GWh (EPPO, 2012).

Linh et al. (2010) forecasted that energy requirement and peak demand of member economies as well as the whole GMS will increase by more than 3 times in the period from 2006 to 2020. Among the GMS countries, Thailand will remain the major energy-consumption center with 41% and 36% total shares in terms of energy consumption and peak demand respectively in 2020.

4. SUPPLY OF ELECTRICITY FROM LAOS TO THAILAND

Laos, historically one of the poorest countries in Asia and the Pacific region, has made impressive progress in developing its economy and reducing poverty spearheaded by the development of mining and hydroelectricity exports. The averaged 7% of annual GDP growth with 10% supported by hydroelectricity exports mainly to Thailand helped halve the share of the population below the national poverty line to less than 25% (IMF, 2011a). Concerning electricity trade between Laos and Thailand, in June 1993, the governments of Laos and Thailand signed the first Memorandum of Understanding (MOU) to promote the development of power projects in Laos through the supply of up to 1,500 MW of electricity to Thailand. Prior to 1993, there were only three power plants developed, and brought into operation. In order to accommodate the steady increase in electricity demand of Thailand, the governments of two countries extended the MOU several times up to December 2007. The Lao government agreed to supply electricity to Thailand with the amount of 5,000 MW by 2015 and 7,000 MW by the end of 2020 (EPD, 2009). Nevertheless, Thailand is likely to gradually raise the import of electricity from Laos, since the expansion of power plants in Laos mostly come from hydropower based plants which have less environmental issues. This is a significant benefit for Thailand in terms of reduction of CO_2 emission. Furthermore, import of electricity from Laos also provides political, and fuel diversity to balance Thailand's reliance on gas import from its neighboring country – Myanmar.

To increase the ability of electricity generation, the potential electricity of the Nam Theun River had been recognized for a long time. Eventually, in 1991, the Lao government began to study and identified a suitable project in the center of country to export electricity generated from this plant to Thailand, and provide local supply. The Nam Theun 2 hydroelectric project (NT2) which began the commercial operation in March 2010 is the largest of its kind in Laos. It has the capability to produce 1,070 MW, and generate 235 million USD in gross revenue from yearly sale to Thailand (Revenue from the export to Thailand is partially in USD and partially in Thai Baht). However, only this power plant cannot accommodate the significant demand, the Lao government has therefore attempted to increase more electricity generation by promoting more investment in electricity sector. As a result, there are more than 70 power projects mainly prepared to generate electricity for exporting to Thailand.

5. MODEL DEVELOPMENT FOR THE LAOS AND THAILAND ELECTRICITY TRADE

There are a number of macroeconometric models widely applied in several countries. The applications of macroeconometric model in Laos can be found in Kyophilavong (2003; 2009), Kyophilavong and Toyoda (2004; 2008), Toyoda and Kyophilavong (2005; 2007). The small macroeconometric model built in this paper is mainly based on their models.

In order to see the effect of changes in one economy (the decrease or increase of electricity demand from Thailand) on both economies, the following small macroeconometric models of Laos as a supply side and Thailand as a demand side are built. In order to differentiate each variable in the model and to easily understand, the symbols, superscripts, subscripts, are used in each equation. The plus sign (+) shows the positive relationship between the dependent variable and the independent variable and vice versa for the minus sign (−). The meanings of all variables in the model are shown in Appendix 2.

5.1. The Supply Side of Electricity Export (Laos)

GDP equation of Laos is based on expenditure approach including consumption, investment, government expenditure, and net export (export minus import) as shown in the following equation:

$$GDP_L = C_L + I_L + G_L + EX_L - IM_L \quad (1)$$

Consumption is divided into consumption of electricity and consumption of non-electricity products as illustrated in the below equation:

$$C_L = CE_L + CEN_L \quad (2)$$

Consumption of electricity is assumed to be a simple function of disposal income. Due to the difficulty of data collection of disposal

income, consumption of electricity in this study is specified as a function of GDP of Laos as follows:

$$CE_L = f(\overset{+}{GDP_L}) \quad (3)$$

Consumption of non-electricity products is also simply specified as a function of GDP as shown below:

$$CEN_L = f(\overset{+}{GDP_L}) \quad (4)$$

Due to the short of data on interest rate from 1985 to 1990, interest rate is not included in the function of the investment. Therefore, it is simply set as a function of GDP only. The investment function of Laos is illustrated as follows:

$$I_L = f(\overset{+}{GDP_L}) \quad (5)$$

Since the objective of the study is to analyze specifically the export of electricity of Laos, export of electricity is divided as a component of the whole export against export of other products that are not electricity (non-electricity products). Export equation hence consists of export of electricity, and non-electricity.

$$EX_L = EXE_L + EXEN_L \quad (6)$$

Since most of the export of electricity from Laos is destined to Thailand, export of electricity equation is set to consist of the export of electricity to Thailand and export of electricity to other countries (non-Thailand countries).

$$EXE_L = EXE_L^T + EXE_L^{TN} \quad (7)$$

It is assumed that export of electricity from Laos to Thailand (EXE_L^T) is influenced by the change in GDP of Thailand. Since electricity produced in Laos is not only for export, but also for domestic consumption, export of electricity from Laos to Thailand is also assumed to depend on the domestic consumption of electricity in Laos.

$$EXE_L^T = f(\overset{+}{GDP_T}, \overset{-}{CE_L}) \quad (8)$$

Since the import of electricity is included in aggregate import, import of goods and services is divided into import of electricity and import of non-electricity as shown in the following equation:

$$IM_L = IME_L + IMEN_L \quad (9)$$

Import of electricity is assumed to depend on GDP of Laos. In addition, since the main purpose to import electricity is to accommodate the increasing electricity consumption in the country particularly in rural areas, import of electricity is also assumed to depend on consumption of electricity. Nevertheless, when the production of electricity in Laos is not available to provide adequate electricity, Laos has to import from neighbors. The production of electricity is therefore assumed to have impact on the import of electricity. Thus, import of electricity function is structured as follows:

$$IME_L = f(\overset{+}{GDP_L}, \overset{+}{CE_L}, \overset{-}{EP_L}) \quad (10)$$

In the case of import of non-electricity products, it is assumed to simply depend on GDPs of Laos as shown in the equation below:

$$IMEN_L = f(\overset{+}{GDP_L}) \quad (11)$$

The electricity production is assumed to be a function of the installed capacity of electricity as well as total consumption[1]. Thus, the electricity production function is as follows:

$$EP_L = f(\overset{+}{CAPE_L}, \overset{+}{C_L}) \quad (12)$$

5.2. The Demand Side of Electricity Export (Thailand)

Gross domestic product of Thailand, based on expenditure approach, is defined as the sum of consumption, investment, government expenditure, and net export (export minus import).

$$GDP_T = C_T + I_T + EX_T - IM_T \quad (13)$$

Consumption is divided into consumption of electricity and consumption of other products (non-electricity products). Consumption of Thailand is illustrated in the following identity.

$$C_T = CE_T + CEN_T \quad (14)$$

Consumption of electricity is expected to be determined by GDP of Thailand as well as import of energy from other countries. Import of energy is used instead of import of electricity due to the lack of data on the import of electricity of Thailand in some years.

$$CE_T = f(\overset{+}{GDP_T}, \overset{+}{IMEN_T}) \quad (15)$$

Consumption of non-electricity products is specified similar to the Laos' consumption of non-electricity products function. It is simply defined as a function of GDP as shown in the following equation:

$$CEN_T = f(\overset{+}{GDP_T}) \quad (16)$$

1 In many capitalist countries, electricity is produced by private companies regardless of total consumption. In the case of Laos, electricity generating company is owned by the government. Therefore, electricity production is controlled by government based on consumption. When consumption of electricity increases, for example, government increases the electricity production in order to meet the demand, and vice versa. In addition, consumption of non-electricity products is also assumed to have impact on the electricity production. The increase or decrease in consumption of non-electricity products indicates the change in people's lifestyle. When lifestyle changes, government is assumed to adjusted electricity production in order to balance the trend of electricity demand. Therefore, change in lifestyle (indicated by change in consumption of non-electricity products) is also assumed to have impact on the government's decision whether to increase or decrease electricity production for balancing the demand. Thus total consumption consisting of consumption of electricity and consumption of non-electricity products is assumed to have effect on electricity production.

Import of electricity both from Laos and other countries are also consumed in investment sector. The behavior in investment sector is therefore related to the import of electricity from Laos. Investment is assumed to be a function of gross domestic product of Thailand as follows:

$$I_T = f(\overset{+}{GDP_T}) \quad (17)$$

Import of all goods and services is simply defined as the sum of import of energy and import of other products. The equation is shown as follows:

$$IM_T = IMEN_T + IMENN_T \quad (18)$$

Import of energy is the sum of the import of energy from Laos and import of energy from other countries (non-Laos countries). Although the import of energy includes import of oil, coal, natural gas, and etc., import of energy from Laos is in the form of electricity only. Therefore, import of energy from Laos exactly means import of electricity from Laos.

$$IMEN_T = IMEN_T^L + IMEN_T^{LN} \quad (19)$$

Since the amount of electricity imported from Laos means the amount of electricity exported from Laos to Thailand, it is assumed that import of electricity of Thailand from Laos equals to export of electricity from Laos to Thailand as shown in the following equation.

$$IMEN_T^L = EXE_L^T \quad (20)$$

In econometrics, there are two well-known analysis methods–ordinary least square (OLS) and two-stage least squares (2SLS). In this study, the latter approach is applied due to the fact that OLS method applied to an equation in a simultaneous system is generally biased, and inconsistent. This is due to the fact that an explanatory variable that is determined simultaneously with the dependent variable is generally correlated with the error terms, hence, the bias and inconsistency in OLS.

Regarding data collection, due to the limited data, the sample size is limited. In this study, there are 26 samples of time series data of both Laos and Thailand from 1985 to 2010. Although the exact data on electricity export from Laos to Thailand could not be obtained, according to Watcharejyothin (2007), Thailand is the biggest electricity importer from Laos accounted with about 90% of total electricity export. Therefore, the export of electricity from Laos to Thailand is assumed to be 90% of Laos' total electricity export. All of the data in USD terms are deflated by GDP deflator in order to obtain real values.

The estimated results obtained from 2SLS method show expected outcomes that independent variable(s) has expected relationship with dependent variable in each function. Regarding determinants of model fit, values of adjusted R^2, and F-statistic are relatively high. In addition, most of t-statistic values are statistically significant at 1% indicating that independent variable(s) explains dependent variable well.

Due to the limited space, only main function – export of electricity from Laos to Thailand (EXE_L^T) – is specifically explained. According to the result, gross domestic product of Thailand (GDP_T) shows positive effect whereas consumption of electricity in Laos (CE_L) shows negative effect on export of electricity from Laos to Thailand as assumed. Since electricity trade between Laos and Thailand is in the form of MOUs which is a long term agreement, gross domestic product of Thailand does not show high effect on electricity export from Laos to Thailand. Furthermore, the significantly increasing demand in Thailand indicated by the extension of MOU for increasing electricity from Laos also implies that Thailand can import more electricity from Laos as much as Laos can supply to Thailand. However, since Lao government recognizes the importance of poverty reduction goal through domestic consumption of electricity, export of electricity to Thailand rather much depends on consumption of electricity in Laos. In other words, the estimated result shows that when value of consumption of electricity in Laos increases by 10 million USD, electricity export to Thailand is reduced by 1.3 million USD. Different from other goods, value of electricity export to Thailand is assumed not to have impact from the price, since electricity export from Laos to Thailand is in the form of MOU which specifies the constant price for long term (or at least unchanged much price in the case that there is a renegotiation between two countries).

6. FINDINGS FROM SIMULATION

Since this study analyzes the effects on two economies simultaneously, the change in an exogenous variable not only affects one economy, but also affects another economy at the same time. After obtaining the results from 2SLS method, the study is finalized by the simulation. In order to see the effects of the change in an exogenous variable on both economies, two cases of simulations are built based on the possibility that will happen in both economies. The first case of simulation is decreasing the amount of electricity import from Thailand, and the second case is increasing the amount of electricity import from Thailand. In order to easily understand how one variable affects other variable, the flow chart of macroeconometric model is provided in Appendix 1. In addition, the results of the behavioral equations estimated using 2SLS method are shown in Appendix 3.

Prior to the simulation estimation, the root mean squared error (RMSE) is applied in order to check the fit of model performance. The RMSE is applied as a measure to quantify the difference between the predicted values predicted by the model and the values actually observed in the model[2]. The less RMSE value the higher performance of the model. Table 2 shows the RMSE values of variables in the models.

As shown in Table 2, the values of RMSE of the variables are very low ranging from 0.0008 to 1.1704. On Laos-side, the RMSE values of some key variables such as electricity consumption

2 RMSE ratio $= \sqrt{\frac{1}{n}\sum_{t=1}^{n}\left(\frac{Y_t - X_t}{X_t}\right)^2}$, X_t is actual value and Y_t is predicted value

Table 2: Final test result: RMSE

Variable (Laos)	RMSE ratio (%)	Variable (Thailand)	RMSE ratio (%)
C_L	0.0787	C_T	0.0929
CE_L	0.9446	CE_T	0.2402
CEN_L	0.0831	CEN_T	0.0700
EP_L	0.9551	GDP_T	0.1086
EX_L	0.0008	I_T	0.3139
EXE_L	0.3362	IM_T	1.1704
EXE_L^T	0.4150	$IMEN_T$	0.7108
GDP_L	0.0280	$IMEN_T^L$	0.4150
I_L	0.6219	$IMEN_T^{LN}$	0.7158
IM_L	0.3836		
IME_L	0.3945		
$IMEN_L$	0.5392		

Source: Authors. RMSE: Root mean squared error

(CE_L), export of electricity to Thailand (EXE_L^T), GDP (GDP_L), and investment (I_L) are only 0.94, 0.41, 0.02, and 0.62, respectively. On Thailand-side, the RMSE values of electricity consumption (CE_T), import of electricity from Laos ($IMEN_T^L$), GDP (GDP_T), and investment (I_T) are 0.24, 0.41, 0.10, and 0.31, respectively. These significantly low values of RMSE indicate the fairly good performance of the model.

In order to see the effect on different period of economy, the data is divided into three periods. Following Warr (2006), and Kyophilavong and Toyoda (2008), the first period: 1987-1996 is called "Post-Reform Adjustment Period" which is the period after the new economic mechanism introduced in 1986. During 1997-1999, the impact of Asian financial crisis hit many Asian countries particularly Thailand affecting directly Lao economy, the second period: 1997-1999 is therefore named: "Asian Crisis Period". The third period: 2000-2010 is called "Sustained Growth and Foreign Capital Inflows Period"[3] which is the period seen as having high growth with large foreign capital inflows.

Recently, all six member countries of the GMS (Cambodia, Laos, Myanmar, Thailand, Vietnam, and the Yunnan Province of China) signed the agreements for power exchange among them in order to reduce cost and environmental impact. This agreement implies that there is a possibility that Thailand will import more electricity from other countries and may reduce the import of electricity from Laos if the price of Laos' electricity is less competitive. Another possibility is that Thailand may reduce the import of electricity from Laos after the completion of nuclear power plants in Thailand. In 2007, the Thai Cabinet had approved the Nuclear Power Infrastructure Establishment Plan–a roadmap for nuclear power program development to meet a target commercial date in 2020. As specified in the Thailand PDP 2010-2030, there will be 5 units of a 1,000 MW nuclear power plant beginning to be in commercial operation in 2020. Nuclear power is expected to reduce Thailand's natural gas consumption in power generation from 70% to 40% (Thongrung, 2011). If it is the case, Thailand as the largest electricity market for Laos may reduce the import of electricity from Laos. If Thailand decreases its demand of electricity from Laos, it may have a large impact on Laos' electricity export sector. The result of this simulation is illustrated in Table 3. Due to the limited space, there are only important variables shown in the Table 3.

On Thailand-side, the decrease in import of electricity from Laos to Thailand negatively affects Thai economy indicated by the reduction of electricity consumption in the first (1987-1996), second (1997-1999), and third (2000-2010) period by 3.1540, 3.3306, and 3.3036 million USD, respectively. Since consumption of electricity is a component of total consumption, when it decreases the whole consumption also decreases. The decrease in consumption then leads to the large decrease in GDP of Thailand by 10.2730, 10.7666, and 10.7545 million USD in the first, second, and third period respectively. Since GDP is a function of investment, the decrease in GDP of Thailand leads to the decrease in investment as illustrated in Table 3.

The decrease in import of electricity from Laos has also large and negative impact on Lao economy indicated by the decrease in value of export of electricity to Thailand by 2.7613, 2.8930, and 2.8933 million USD in the first, second, and third period respectively. The decrease is due to the reduction in GDP of Thailand. Consequently, the decrease in export of electricity to Thailand leads to the decrease in aggregate export. As aggregate export decreases, GDP of Laos consequently decreases in the large value of 3.5830, 3.7540, and 3.7542 million USD in the first, second, and third period respectively. As shown in Table 3, the reduction of GDP has negative impact on the whole economy indicated by the decreases in the consumption of electricity as well as investment.

This simulation clearly shows that the decrease in import of electricity from Laos to Thailand not only has negative impact on Thai economy in terms of the decrease in GDP of Thailand, but the consequent decrease in GDP has also negative impact on electricity export in Laos. As a result of the decrease in electricity export to Thailand, GDP of Laos significantly decreases. The second main electricity market for Laos such as Vietnam and other neighboring countries may be the alternative for Laos if the import of electricity from Laos to Thailand is to be decreased. The extra simulation which is omitted due to the limited space shows that when the electricity export from Laos to non-Thailand countries[4] is assumed to increase by 10%, Lao economy benefits in terms of the increase in GDP. The other sectors such as consumption of electricity and investment are also positively affected by the increase in the GDP of Laos.

The idea about constructing nuclear power plants in Thailand dates actually back to the 1960s, but has been actively pursued only since 2007. However no final decision whether to construct the nuclear power plant in the country has been taken yet. Currently the projects are still in the first phase (2008-2010), which dealt

3 They used the data from 2000 - 2006 for the so called "Sustained Growth and Foreign Capital Inflows Period"

4 Since Vietnam is the second largest electricity market for Laos, most of the electricity exported to non-Thailand countries is to Vietnam.

Table 3: Estimation result of decreasing the import of electricity from Laos to Thailand (Unit: Million USD)

Country	10% Decrease in IME_T^L			
	Variable	1987-1996	1997-1999	2000-2010
Laos	CE_L	−0.0962	−0.1008	−0.1008
	EXE_L^T	−2.7613	−2.8930	−2.8933
	GDP_L	−3.5830	−3.7540	−3.7542
	I_L	−1.4709	−1.5411	−1.5412
Thailand	CE_T	−3.1540	−3.3066	−3.3036
	IME_T^L	−2.7613	−2.8930	−2.8933
	GDP_T	−10.2730	−10.7666	−10.7545
	IT	−2.8260	−2.9633	−2.9654

Source: Authors

mainly with feasibility studies and public relations (Pachaly, 2011). Regarding this idea, there have been doubts whether to build nuclear power plants in Thailand. Environmentalists and local villagers living in the provinces listed as potential sites for nuclear power plant construction have formed an alliance called the Network of People against Nuclear Power Plants to protest against the planned construction of nuclear power plants in the country (Wipatayotin and Praiwan, 2011)[5].

In addition, the earthquake and the subsequent nuclear disaster in Japan in March 2011 have opened up the discussion about the nuclear future of Thailand again. As the incident of leakage of radiation from Japanese nuclear power facilities damaged by earthquake and tsunami in March 2011, domestic opposition to the development of nuclear power plants has increased. On 15 March 2011, a forum was organized by Sustainable Energy Network Thailand, Nuclear Monitor, MeeNET, Greenpeace Southeast Asia, Thailand and Heinrich Böll Stiftung to discuss the consequences of the Japanese incident with representatives from the potentially affected communities. At the following press conference, the communities expressed their opposition that nuclear option has to be dropped from the PDP since the risk of nuclear energy is high. Instead of going nuclear the government should review the demand forecasts and invest in energy efficiency and promotion of renewable energies in the country. This call was repeated at a rally of 500 people on the following day, which was organized by the Ubon Anti-Nuclear Movement (Pachaly, 2011).

Should Thailand quit the construction of nuclear power plant in the country, there is a possibility that Thailand may increase the import of electricity from Laos and its neighboring countries to meet its increasing demand. Therefore, in the second simulation import of electricity from Laos to Thailand is assumed to be increased. As expected, the increase of the import demand for electricity from Thailand shows positive effect on both economies simultaneously. Since the proportion of the change is the same as in the case of the decrease in import of electricity from Laos to Thailand[6], table of estimated result from this simulation is omitted. When the import of electricity from Laos to Thailand is assumed to decrease, Thailand benefits in terms of the increase in consumption of electricity in the country. The increase in consumption of electricity stimulates Thai economy indicated by the increase in GDP of Thailand in the first, second, and third period by 10.2730, 10.7666, and 10.7545 million USD, respectively. Due to the increase in GDP, investment sector is also positively affected.

Not only having positive effect on Thailand-side, the increase in import of electricity from Laos to Thailand also has positive effect on Laos-side due to the increase in GDP of Thailand which is assumed to be a determinant of the import of electricity from Laos to Thailand function. Since import of electricity from Laos to Thailand is assumed to equal to export of electricity from Laos to Thailand, when there is an increase in import of electricity from Laos to Thailand (export of electricity from Laos to Thailand), GDP of Laos also increases. According to the simulation result, GDP of Laos increases by 3.5830, 3.7540, and 3.7542 million USD in the first, second, and third period respectively. The large increase in GDP also positively affects other sectors such as electricity consumption and investment. This simulation shows that rather than decreasing, increasing import of electricity from Laos to Thailand gives mutual benefits for both Thailand-side and Laos-side in terms of more electricity to consume, improvement in GDP, and other sectors in both countries. Moreover, increasing the electricity trade between Laos and Thailand will also strengthen political relationship between the two countries.

7. CONCLUSION

Thailand regarded as the biggest electricity market for Laos, has imported substantial amounts of electricity from Laos since the operation of first hydroelectricity plant in Laos. However, there have been a number of new power plants in Thailand being studied and some have been in commercial operation implying the possibility of reduction in Thailand's electricity import from Laos. The simulation in the case that Thailand decreases import of electricity from Laos shows that it would directly have a large impact on Laos' electricity export sector due to the reduction of revenues from electricity export leading to significant decrease in GDP of Laos. Other sectors such as consumption of electricity and investment in Laos would also be negatively affected due to the decrease in GDP.

However, the feasibility of building nuclear power plants in Thailand became unclear since the incident of damages of

5 On 15 March 2011, about 2,000 people from 18 districts of Kalasin Province in Thailand rallied outside the city hall to protest against the Electricity Generating Authority of Thailand's plan of building a nuclear plant in their province. On 26 March 2011, according to the Assumption Business Administration College (ABAC) poll at the Assumption University, over 80% of the respondents (83.4%) disagreed with the plan to construct nuclear power plants in the country. The poll involved 3,807 people aged 18 up in 17 provinces. It was conducted from March 1 to 25, 2011. Bangkok residents had the largest percentage of the objection of 95.2% followed by those in southern region (91.5%), the central (91.1%), the North (90.0%) and the Northeast (85.8%).

6 For example, in the case of the decrease in import of electricity from Laos to Thailand, the change of GDP of Laos are −3,5830, −3,7540, and −3,7542 million USD in the first, second, and third period respectively. In contrast, in the case of the increase in import of electricity from Laos to Thailand, the change of GDP of Laos are 3,5830, 3,7540, and 3,7542 million USD, respectively.

Japanese nuclear power plants in Japan on 11 March 2011. After this incident, the opposition of building nuclear power plants in Thailand became so severe that there may be a possibility that Thailand may abolish the nuclear power projects in the country. Consequently, Thailand may increase the import of electricity from Laos to meet its increasing demand. The second simulation shows that the increase of Thailand's electricity import from Laos has positive effect on Lao economy through the significant increasing in income from electricity export. As a result, GDP of Laos increases followed by the improvement in other sectors that are determined by the GDP such as investment as well as consumption of electricity.

The increase in Thailand's electricity import from Laos, not only has positive effect on Thai economy in terms of increasing consumption of electricity stimulating economic activities in Thailand, but it also has positive effect on Lao economy simultaneously in terms of increasing income from electricity export. Should Thailand reduce its electricity imports, Laos may consider other neighboring countries as markets for the electricity exports in particular Vietnam, because it is the second largest electricity market for Laos. Moreover, both Laos and Vietnam have deep relationship in terms of economic aspect as well as political aspect.

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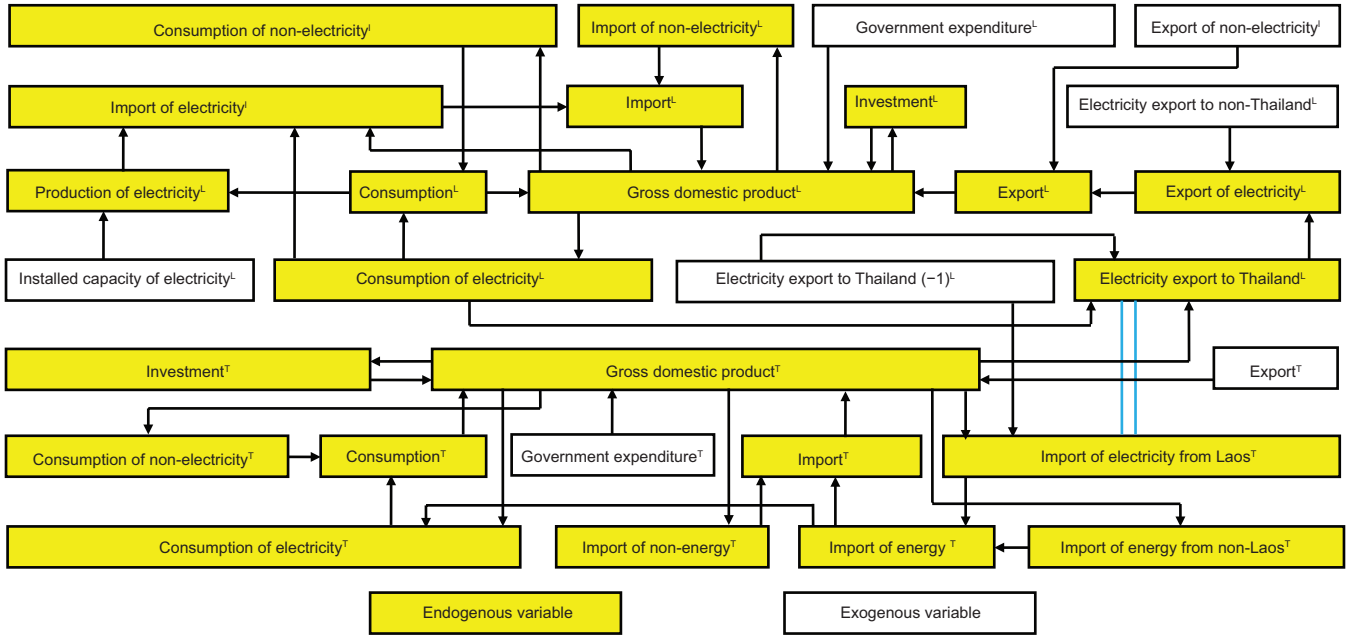
APPENDICES

Appendix 1: Flow Chart of The Model



Source: Authors.

Appendix 2: All variables in the model

Variable	Meaning	Unit
Laos		
$CAPE_L$	Installed capacity of electricity	Kw
C_L	Consumption	USD
CE_L	Consumption of electricity	USD
CEN_L	Consumption of non-electricity products	USD
EP_L	Electricity production	USD
EX_L	Export	USD
EXE_L	Export of electricity	USD
EXE_L^T	Export of electricity to Thailand	USD
$EXEN_L$	Export of non-electricity	USD
EXE_L^{TN}	Export of electricity to non-Thailand countries	USD
G_L	Government expenditure	USD
GDP_L	Gross domestic product	USD
I_L	Investment	USD
IM_L	Import	USD
IME_L	Import of electricity	USD
$IMEN_L$	Import of non-electricity products	USD
ThaiLand		
C_T	Consumption	USD
CE_T	Consumption of electricity	USD
CEN_T	Consumption of non-electricity products	USD
EX_T	Export	USD
G_T	Government expenditure	USD
GDP_T	Gross domestic product	USD
I_T	Investment	USD
IM_T	Import	USD
$IMEN_T$	Import of energy	USD
$IMEN_T^L$	Import of energy from Laos	USD
$IMEN_T^{LN}$	Import of energy from non-Laos countries	USD
$IMENN_T$	Import of non-energy products	USD

Source: Authors

Appendix 3: Estimation results from two-stage least squares estimation

Laos-side model

Thailand-side model

Consumption of electricity

Dependent variable: CE_T Included observations: 25 after adjustments				
Variable	**Coefficient**	**SE**	**t-statistic**	***P***
Constant	−4.10E+09	1.07E+09	−3.8190	0.0000
GDP_T	0.1154	0.0095	12.0770	0.0000
$IMEN_T$	0.7576	0.0628	12.0470	0.0000
Adjusted R^2	0.9887			
F-statistic	1,028.2320			
SE of regression	1.32E+09			
Durbin-Watson stat	1.7767			

SE: Standard error

Consumption of non-electricity products

Dependent variable: CEN_T Included observations: 25 after adjustments				
Variable	**Coefficient**	**SE**	**t-statistic**	***P***
Constant	1.75E+10	2.03E+09	8.6350	0.0000
GDP_T	0.3068	0.0118	25.9300	0.0000
Adjusted R^2	0.9664			
F-statistic	672.3820			
SE of regression	3.19E+09			
Durbin-Watson stat	0.5903			

SE: Standard error

Investment

Dependent variable: I_T Included observations: 25 after adjustments				
Variable	**Coefficient**	**SE**	**t-statistic**	***P***
Constant	4.42E+09	7.84E+09	0.5630	0.5780
CDP_T	0.2751	0.0457	6.0080	0.0000
Adjusted R^2	0.6106			
F-statistic	36.1000			
SE of regression	1.23E+10			
Durbin-Watson stat	0.2646			

SE: Standard error

Import of energy from Laos

Dependent variable: $IMEN^L_T$ Included observations: 25 after adjustments				
Variable	**Coefficient**	**SE**	**t-statistic**	***P***
Constant	4,990,104	6,459,466	0.7720	0.4480
GDP_T	5.64E-05	3.41E-05	1.656	0.1120
CE_L	−0.1371	0.0575	−2.384	0.0260
Adjusted R^2	0.5588			
F-statistic	10.9611			
SE of regression	5,274,956			
Durbin-Watson stat	2.0931			

SE: Standard error

Import of non-energy products

Dependent Variable: $IMENN_T$ Included observations: 25 after adjustments				
Variable	**Coefficient**	**SE**	**t-statistic**	***P***
Constant	−2.95E+10	7.65E+09	−3.8630	0.0000
GDP_T	0.6553	0.0446	14.6710	0.0000
Adjusted R^2	0.8998			
F-statistic	215.2399			
SE of regression	1.20E+10			
Durbin-Watson stat	0.5975			

SE: Standard error

Import of energy from non-Laos countries

Dependent variable: $IMEN^{LN}_T$ Included observations: 25 after adjustments				
Variable	**Coefficient**	**SE**	**t-statistic**	***P***
Constant	−1.07E+10	3.48E+09	−3.0710	0.0050
GDP_T	0.1305	0.0203	6.4200	0.0000
Adjusted R^2	0.6178			
F-statistic	41.2211			
SE of regression	5.48E+09			
Durbin-Watson stat	0.3693			

SE: Standard error