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The impact of urbanization and energy consumption on CO_2 emission in Thailand

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ABSTRACT

This paper investigates the impacts of urbanization and energy consumption on carbon dioxide (CO_2) emission in Thailand from 1971 to 2010 under the framework of STIRPAT model. All STIRPAT model's indicators add up with urbanization and energy consumption are modeled by long run and short run equation of Johansen co-integration and vector error correction model. The result indicates that only technology progression, proxy by added value of service sector, and energy consumption have positive impact to the amount of CO_2 emission in long run in Thailand. Urbanization is not the most concerning factor that Thailand needs to focus in term of environmental issue; yet, energy consumption does. Energy consumption has positive impact to CO_2 emission in both long run and short run. Therefore, Thailand needs to reduce the amount of energy consumption in order to reduce the CO_2 emission which is the biggest contributor of greenhouse gas (GHG) in environment.

Keywords: STIRPAT, Urbanization, Energy Consumption, Carbon Dioxide and Thailand.

1. INTRODUCTION

Urbanization refers to the transformation of the low income people experience with the new modernization and inter the rank of middle or high income (Spence, Annez, & Buckley, 2009). In general perspective, urbanization defines as the increasing of living in the city and the suburbs of the city. There are many causes that lead to an increasing of urbanization. People move from rural area to the city due to the lack of resource, education, electricity, jobs, poverty and to find a better living condition (M, 2006). However, there are many impacts that are the consequences of urbanization. Those impacts contributed to socio-cultural impact, socio-economic impact and environmental impact (M, 2006).

Thailand is one of the countries which experience urbanization and economy growth as a result of adopted the National Economic and Social Development Plan (Phuttharak & Dhiravisit, 2013). Urban area grows with an annual average of 1.4% since 2000 (World

Bank, The World Bank, 2015). This growth is accounted of 2,400 square kilometers with the population of 9.3 million in 2000 to 2,700 square kilometers with 11.8 million of population in 2010. The annual growth rate of population in urban area of Thailand is 3.4% since 1971 to 2010 (World Bank, The World Bank, 2015). The density population in the urban area was about 4,000 people per square kilometer in 2000 and increase to 4,300 people per square kilometer in 2010. This urbanization is dominated in Bangkok area with the proportion of 80% to the total urban area in Thailand. Bangkok is the capital city of Thailand with the total population in urban area of 9.6 million in 2010 which grew from 7.8 million people in 2000. However, the urbanization in Bangkok city distributes out of the Bangkok Metropolitan Administration with 60% of the total urban population in this city. Those areas are including Surat Thani and Hat Yai.

The rapid growth of urbanization in Thailand leads to both advantages and disadvantages. The advantage of urbanization is mostly focus on economic growth which is a sign of increasing in industries, manufacture and industrial manufacturing. However, urbanization also causes an increasing of population in urban area and pollution (Phuttharak & Dhiravisit, 2013). As mention above, the growth of population in the urban areas of Thailand was 3.4% which accounted as 11.8 million people. The increasing of this urbanization requires a huge amount of water supply, health care, food, education and energy consumption. All of these requirements affect directly and indirectly to the environment. Sadorsky (2014) indicated that there was an existent impact contributed from urbanization to Carbon Dioxide Emission (CO_2) in emerging economics countries in which accounted for Thailand as well. Moreover, since urbanization is one of the big sectors which lead to the increasing of energy consumption in this country (Chirarattananon, Chaiwiwatworakul, & Rakkwamsuk, 2014), we will use this as an indication for this paper research. In 2012, the energy consumption in Thailand increased with the ratio of 6.8% with the proportion of 1 981 thousand barrel per day (KBD) of crude oil equivalent (Ministry of Energy, 2013). Natural gas and oil is the main sources that contributed the largest share of energy consumption in this country with the ratio of 45% and 36% respectively (Ministry of Energy, 2013). Power generation, transportation and industry are the main sectors that consume a huge amount of energy. Therefore, we can conclude that urbanization cause an increasing of energy consumption. Zhang & Cheng (2009) and Soytas, Sari, & Ewing (2007) pointed out in their research papers that energy consumption is one of the main factors which determines the amount of CO_2 emission and pollution to environment. Moreover, Promjiraprawat & Limmeechokcha (2012) mentioned that energy consumption has become a greatest resource which produces the most CO_2 into the environment in Thailand. Therefore, these indications become the main problem for this paper reserch. This phenomenon does not depend on the region and condition of the countries. According to the report that was publish by Thailand Ministry of Energy in 2013, power generation produced 95,735 thousand tons of CO_2 which accounted for almost 40% of the total CO_2 emission in this country. This number follows by transportation and industry with the ration of 26% and 25% respectively while the rest of the emission approximately 9% comes from other sectors. CO_2 is the most contributed air pollution with more than 70% of its Greenhouse Gas (GHG) which concerns the most to global warming and climate change (Promjiraprawat & Limmeechokcha, 2012). Therefore, main purpose of this paper is to examine the impact of urbanization and energy consumption on CO_2 emission in Thailand.

As mention above, urbanization refer to the increasing number of population in urban area. This is one of the indicators which determine the amount of CO_2 emission contributes to environment. Many papers have been conducted to capture the impact of human being's activities to environment[1]. Every research papers designed the scope and methodologies differently depend on the data and variables. Some papers were designed to test the causality of human being's activities and environmental impact (Kasman & Duman, 2015). However, if we wish to investigate one directional impact of human being's activities to environmental impacts, Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) will be the best to capture those impacts and their causations (Dietz & Rosa, 1997). Many research papers used this model to apply with panel data in order to capture the impacts of human being's activities to environment such as urbanization and energy consumption. While apply STIRPAT model in the papers, researchers need to perform their equation under framework of Cobb-Douglas function of STIRPAT and extend to any form of function as their objectives. For example, Xu & Lin (2015) designed his model under the U-shape of non-linear relationship between industrial sector and CO_2 emission of three region in China and applied with STIRPAT model. Moreover, by using STIRPAT's applications, researcher also be able to to test long run and short runn relationship between human's activities and CO2 emission as well. This case happened in paper research conducted by Hossain (2011). The author constructed the panel co-integration and granger casulity hypothesis for newly industrial countries between CO_2 emission and urbanization to environment. Therefore, both linear and non-linear relationship of urbanization and CO_2 emission are being able to construct an equation formed under framework of STIRPAT model with its fundamental variables such as population, affluence and technology. This model will be the main part of this paper's methodology. Long run and short run relationship between variables will be conducted.

2. RESEARCH METHODOLOGY AND DATA

In 19971, Ehrlich & Holdren proposed a model so called IPAT, I = PAT, to examine the impact of population, affluence and technology to environment. In this model, I is denoted as an impact of environment and many authors used it as a proxy of CO_2 emission, P is denoted as number of populations, A is defined as affluence and T is denoted as the technology. However, this model still consists of some limitation. York, Rosa, & Dietz (2003) proposed the limitation of IPAT model such that it does not allow hypothesis testing since some terms determine the missing value of other term in the model. Moreover, the elasticity of the model with respect to population, affluence and technology were assumed to be one respectively (Zhang & Lin, 2012; Lantz & Feng, 2006). Furthermore, the model has no possibility to capture which one of variables is the main indicator which impact to the environment (Zhang & Lin, 2012). Therefore, Dietz & Rosa (1997) had proposed a Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model which treating IPAT model as a basis. The STIRPAT model was formed as below:

$$I = \alpha P^a A^b T^c e \tag{1}$$

where I is the impact of environment which is denoted as the amount of CO_2 emission in this paper research. P is the population of Thailand; A is the affluence which is defined as per capita GDP and T is a progression of technology and this variable is measured by the current value of service sector in Thailand as US dollar currency. We cannot model the Cobb-Douglas function of Eq (1) since it performs a multiplication form so that it is impossible to do regression. The natural logarithm form of Eq (1) is given as below:

$$\ln I = \ln \alpha + a \ln P + b \ln A + c \ln T + \ln e \tag{2}$$

[1] Zarzoso & Maruotti , 2011; Xu & Lin , 2015; Yuan, Ren, & Chen, 2015; Kasman & Duman, 2015; Al-mulali , Fereidouni, Lee , & Sab, 2013; Hossain, 2011; Sadorsky, 2014; Zhu, You , & Zeng, 2012.

This is the equation's form of the model under the framework of STIRPAT. We will rewrite all variables in the Eq (2) as below:

$$\ln CO_2 = \alpha_0 + a\ln Pop + b\ln GDP + c\ln Sv + \varepsilon \quad (2)$$

Since the purpose of this paper is to investigate the impact of urbanization and energy consumption to environment, so the form of the Eq (2) will be extend to the linear form of its fundamental variables and the stochastic variables that we want to measure such as urbanization and energy consumption. Eq (2) will be formed as below:

$$\ln CO_2 = \alpha_0 + a\ln Pop + b\ln GDP + c\ln Sv + d\ln EC + e\ln Urban + \varepsilon \quad (3)$$

All the abbreviation variables in Eq (2) and Eq (3) are summarized in table 1. The measurement of each variables, how we define their proxy and the units of them are shown in this table.

Table 1: summary of variables used in the research from 1971 to 2010.

Variables	Definition	Unit in used
Total CO_2 emission (CO_2)	Thailand total CO_2 Emissions	Kilogram
Total population (Pop)	Total population in Thailand	First differential population
GDP per capita (GDP)	Thailand current GDP per capita	US Dollar
Service sector (Sv)	Services sector value added	US dollar
Urbanization (Urban)	Total population in urban area	First differential population
Energy Consumption (EC)	Energy use	Kilo ton of oil equivalent

Source: World Bank

In this paper, short run long run relationship will be employed by using Johansen co-integration test. Unit root test will be conducted firstly to check the integrated level of each variable to insure that they are stationary at same level so there will be no violence to the condition of Johansen co-integration test. Johansen co-integration test is the development of general concept of vector autoregression model. It is formed in this paper as below:

$$\begin{aligned}\Delta\ln CO_{2_t} = {} & \sigma + \theta(\ln CO_{2_{(t-1)}} + \ln Pop_{t-1} + \ln GDP_{t-1} + \ln Suv_{t-1} \\ & + \ln Urban_{t-1} + \ln Ec_{t-1}) + \\ & \varphi_i\sum_{i=1}^{k} D(\ln CO_{2_{(t-i)}}) + \eta_i\sum_{i=1}^{k} D(\ln Pop_{t-i}) + \rho_i\sum_{i=1}^{k} D(\ln GDP_{t-i}) + \\ & \psi_i\sum_{i=1}^{k} D(\ln Suv_{t-i}) + \zeta_i\sum_{i=1}^{k} D(\ln Urban_{t-i}) + \vartheta_i\sum_{i=1}^{k} D(\ln Ec_{t-i}) + \varepsilon_t\end{aligned} \quad (4)$$

Eq (4) is the standard co-integration equation for both long run and short run term. This equation models by Vector Error Correction Model (ECM or VECM) and $\sigma, \theta, \varphi_i, \eta_i, \rho_i, \psi_i, \zeta_i$ and ϑ_i are the coefficients that need to be estimated. In Eq (4), $k = 2$ is denoted as a length of the lag in this model[2]. Speed of adjustment, θ, is required to be significant and negative so that it will insure the long run relationship in the model. Wald test will be conducted for short run coefficients, $\varphi_i, \eta_i, \rho_i, \psi_i, \zeta_i$ and ϑ_i, respectively to ensure that those coefficients are significant for the short run consistency of ECM model.

[2] The length of lag is based on the values of AIC and BIC of the regression of standard co-integration equation.

3. EMPIRICAL RESULT

As mention in the methodology part of this paper, the first result of this part is unit root test result. As shown in table 2, ADF test result is conducted with both of its tested equation in the case that variables obtain only intercept and intercept and trend. In the first case of obtaining only intercept, the absolute statistical values of ADF test are less than the absolute critical tested values at 10% at the zero level of integration. However, these values are greater than the absolute critical tested values at 10% at the first differential level. This confirms that all the variables that we use in the model are stationary at level 1 in intercept testing equation test. Now look at the result of obtaining both intercept and trend. The absolute statistical values of ADF test are less than those absolute critical values at 10% of significant except the population which stationary at zero level of integration. The absolute ADF statistics at first differential level are greater than the absolute critical value at 10% of significant. This confirms that all variables are stationary at first level if integration except for population which station at level zero. From both result of tested equation, intercept and intercept and trend, our variables are stationary at the first level of stationary.

Table 2: Unit root test

Variables	Level			First Level			Conclusion
	ADF-Statistic	Critical Value (10%)	P-value	ADF-Statistic	Critical Value (10%)	P-value	
Testing Equation: Intercept							
CO_2	0.890043	2.609066	0.7806	4.071936	2.609066	0.0030	I(1)
Pop	0.624313	2.610263	0.8530	5.871795	2.610263	0.0000	I(1)
GDP	1.469283	2.609066	0.5381	3.691456	2.609066	0.0082	I(1)
Sv	2.035846	2.609066	0.2709	3.730300	2.609066	0.0074	I(1)
Urban	1.449704	2.609066	0.5478	3.509153	2.609066	0.0131	I(1)
EC	0.465911	2.609066	0.8869	4.375874	2.609066	0.0013	I(1)
Testing Equation: Intercept and Trend							
CO_2	1.497990	3.198312	0.8128	4.083229	3.198312	0.0140	I(1)
Pop	4.716252	3.209642	0.0033	5.525481	3.200320	0.0003	I(0)
GDP	2.768953	3.198312	0.2169	3.717473	3.198312	0.0332	I(1)
Sv	2.469126	3.198312	0.3407	3.987515	3.198312	0.0177	I(1)
Urban	1.848621	3.198312	0.6610	3.550811	3.198312	0.0481	I(1)
EC	1.964385	3.198312	0.6014	4.317401	3.198312	0.0078	I(1)

Note: ADF-statistic and Tested Critical Value are shown in absolute value in this table

Table 3 is the estimated result of Eq (4) under the framework of STIRPAT model. The first part of the table is the long run estimation result conducted by Johansen test. The standard estimation of this model will generate the coefficients of long run elasticity of the model. However, since the equation in the model performs under the STIRPAT concept, the sigh of each variables indicate the direction of both dependent and independent variables. This means that the sign of each coefficients point out how the dependent variable moves with respond to the change of independent variable. For long run estimation, the speed of adjustment is -0.209974 with t-statistic of -4.293769 corresponding with probability of 0.0003. This result fulfills the requirement of Johansen co-integration test so that the model performs a significant long run relationship from independent to dependent variables. Vector Error Correction model, ECM, was estimated follow the concept of Eq (4). Short run coefficients were employed from this process. However, to fulfill requirement of the short run relationship, Wald test was utilized to test the coefficients of all variables in the short run model. Its result was shown in part two of the model. This means that the significant levels of all long run coefficients are confirmed by ECM estimation. The significant levels of all short run coefficients are confirmed by Wald test and ECM model.

The long run coefficient of population variable is equal to -1.868292 and short run coefficient is 0.309875. Both long run and short run coefficients are significant at 1% and 0% respectively to explain the dependent variable of CO_2 emission. The same to population, per capita GDP is significant for both long run and short run estimation with significant level of 1%. Long run coefficient of this variable is equal to -5.738026 and 1.117476 for short run. The measurement of technology which defined by service sector is equal to 3.391677 in long run estimation result with probability of 5% significantly. The short run coefficient of this variable is equal to -1.368877 with significant probability of 1%. Short run coefficient of urbanization is 0.175776 and -0.011552 in long run. Long run coefficient of this variable is significant while it is not in short run. The coefficient which determines the impact of energy consumption is equal to 0.217920 and 1.160348 for long run and short run respectively. Long run coefficient of energy consumption is significant with 1% of its p-value and the short run coefficient is significant at 0% level.

Table 3: Estimation Result

Long run estimation result			
Variables	$LnCO_2$ is treated as dependent variable		
	Coefficient	Standard Error	T-statistic
Pop	-1.868292**	0.23246	-8.03695
GDP	-5.738026**	1.01665	-5.64407
Sv	3.391677**	0.71375	4.75189
Urban	-0.011552**	0.08122	-0.14223
EC	0.217920**	0.22562	0.96589
Short run estimation result			
Variables	$D(lnCO_2)$ is treated as dependent variable		
	Coefficient	Standard Error	F-statistic
Pop	0.309875***	0.111460	10.44388

GDP	1.117476**	0.365933	4.786464
Sv	-1.368877**	0.399869	5.967267
Urban	0.175776	0.072608	3.023449
EC	1.160348***	0.254133	11.84848

*Note: *, ** and *** denote the level of significant at 5%, 1% and 0% level respectively.*

Table 4 is the result for serial correlation and normality test of this model. Breusch-Godfrey Serial Correlation LM test will be conducted to check for the serial correlation in this paper research. The probability of test is greater than 5% which lead to the acceptance of null hypothesis of no serial correlation in the model. Similarly, Jarqua-Bera test were utilized to ensure the normality of all variables in the model. P-value is greater than 5% and lead to the acceptance of the hypothesis of normality of variables in model. Therefore, the model performs under normal distribution.

Table 4: Result for Serial correlation and Normality test

Test	Serial Correlation	Normality
F-statistic	0.618754	0.999922
R-square	0.5481	
F-Probability	0.5481	0.606554

4. CONCLUSION

This paper research investigates the impacts of urbanization and energy consumption to environment in Thailand under the framework of STIRPAT model. The model was designed with the fundamental variables such as population, affluence and technology and the stochastic variables such as urbanization and energy consumption. The data are utilized from 1971 to 2010 with 40 observations. Johansen co-integration test was conducted to ensure the co-integration of all variables and to obtain the long run coefficients. Vector Error Correction model was conducted to check the consistency of long run coefficients and to gain short run coefficients. Wald test were tested to ensure the consistency of short run coefficients.

The empirical result shows that total population is significant in both long run and short run but it comes up with different signs. In long run, CO_2 emission and population move in different direction while in short run does not. This means that population positively determines the amount of CO_2 emission in short run. In the case of elasticity, these variables remain different because in long run CO_2 emission is perfectly elastic to the change of population while it is inelastic in short run. This means that even though population performs positively effect to CO_2 emission; yet, this affect is not too much.

The same to population, per capita GDP is significant for both long run and short run estimation. For this variable, both long run and short run coefficients are perfectly elastic. In short run, the change in per capita GDP is positively affected to the CO_2 emission in this country with highly sensitivity. There is impossible to conclude for this variable since it performs differently in both long run and short run estimation result.

It is opposite to the two above variables for service sector. This variable is also one of the elements in STIRPAT model. The measurement of technology is positively impact to the CO_2

emission in Thailand in long run while it does not in short run. In the concept of elasticity which conducted by Johansen co-integration, CO_2 emission is strongly sensitive because it elasticity value is perfectly elastic to the change in technology with value of 3.4. However, this variable negatively affect to the environment in Thailand in short run.

Urbanization is positively affect to the environment by contributes to the amount of CO_2 emission in short run. However, this variable performs as a negative impact to CO_2 emission in long run. This result indicates that urbanization in Thailand move in different direction with the level of CO_2 emission in long run. In the general perspective of elasticity, CO_2 emission is inelastic regarding to the level of urbanization in both long run and short run. Therefore, that the level of CO_2 emission is not too much sensitive to the movement of urbanization in this country.

It is the same to previous researchers; energy consumption is the most concern indicator which determines the amount of CO_2 emission in Thailand. Both long run and short run coefficients indicated positive impact regarding from energy consumption to CO_2 emission. In short run, CO_2 emission performs a perfectly elastic to the energy consumption which indicate a highly increase of CO_2 emission while there is an increasing amount of energy consumption. Even though CO_2 emission is inelastic corresponding to the change in energy consumption in long run but this number provides a conclusion of positively impact from energy consumption to CO_2 emission as well.

In the case of Thailand, there are many researchers investigated the impacts of urbanization and energy consumption to CO_2 emission such as Hossain, 2011; Zarzoso & Maruotti , 2011; Zhu, You , & Zeng, 2012. The result from this paper and the result from those authors' papers shown the same evidences that energy consumption is positively impact to CO_2 emission in both long run and short run. However, the long run result of urbanization in this paper is similar to the paper research that conducted by Zarzoso & Maruotti (2011) and by Zhu, You , & Zeng (2012) which sated that urbanization do not contribute to the higher CO_2 emission. Yet, urbanization contributes a higher level of CO_2 emission in short run and this result is the same as paper research conducted by Hossain in 2011. Therefore, there is not too much concern for the Thailand with the contribution from urbanization to the level of CO_2 emission in this country. However, Thailand needs more attentions to the level of CO_2 emission which is contributed from energy consumption. Therefore, the better way for Thailand to reduce the amount of CO_2 emission in environment is to reduce the energy consumption or to find a new way which can replace this consumption such as renewal energy. By the way, Thailand has its own policies and strategies to reduce the amount of energy consumption by proposing energy efficiency development plan, the energy conservation promotion act, the energy conservation promotion program and the energy efficiency resource standards (Institute for Industrial Productivity, 2013). However, Thailand needs to ensure that these policies work properly and do not affect to its own economy through the energy consumption.

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