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Economic determinants of carbon dioxide emissions: A proof of the environmental kuznet curve hypothesis in Asia

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Abstract:
The study aims to analyze the economic determinants of carbon dioxide emissions in East and Southeast Asian countries and intend to prove whether the Environmental Kuznets Curve (EKC) applies both in East and Southeast Asia. The data used are secondary data from 1993-2015 which includes several countries in Southeast Asia that are included in the lower-middle-income category and several countries in East Asia that are classified as high income. The methods used include Generalized Least Squares (GLS) and Ordinary Least Squares (OLS). The results found that Foreign Direct Investment (FDI) and Economic Openness (OPEN) significantly influence carbon dioxide emissions in both East and Southeast Asia. The hypothesis of the Environmental Kuznets Curve (EKC) is proven to apply both East Asian and Southeast Asian countries, although it has not reached the turning point yet.

Keywords: *EKC, FDI, GLS, Economic Openness*

I INTRODUCTION

The increase of CO_2 gas over the past 70 years is almost 100 times that of the end of the ice age. The concentrations of CO_2now are 145 percent higher than pre-industrial levels (before 1750). The levels of $CO_2$and greenhouse which increase rapidly have the potential to initiate unprecedented climate system changes, which cause severe ecological and economic disruption (WMO, 2017). Increased CO_2 levels also indicate an increase in temperature. In the last century, there has been an increase in global temperatures due to increasing concentrations of greenhouse gases (GHG) in the atmosphere (Teaching Materials AMDAL, 2009). Deforestation, the use of fossil energy and human activities have increased CO_2 in the atmosphere which continues to increase temperatures. Increased temperatures have triggered drastic climate change. Melting of ice in the polar regions which has an impact on rising sea levels is also a result of the increase in temperature that continues to occur.

The increase of CO_2emissionsindicates that all human activities have an impact on the environment, especially economic activities. All the negative effects of economic activities are often ignored, even it is not included in the company's economic calculations. That impact is called a negative externality which is very detrimental if it is always ignored.

The hypothesis that connects economic growth with the environment is known as the Environmental *Kuznets Curve* (EKC) or the Kuznets environmental curve. During the initial stages of economic growth, degradation and pollution will increase, but after exceeding some level of income per capita (not the same on different indicators) the trend will reverse so that at higher income levels, economic growth leads to environmental improvement (Stern, 2004: 517).

This study took two regions in the Asian

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continent as the sample, namely East Asia and Southeast Asia. The two regions were chosen as a comparison between *high-income* countries and the countries which have *lower middle income*. East Asia is a region where the majority of countries are countries has *high income*. Whereas Southeast Asia is a region where the majority of countries have *lower middle income* (Classification on the *World Bank*, 2017).Countries selected as samples in each area because these countries have economic characteristics that are almost similar in terms of economic growth and per capita income which is expected to represent the characteristics of East and Southeast Asia. According to the EKC hypothesis, a country that is in development will show an increase in environmental damage and when a country has a high income, the environmental damage will decrease. The decline occurred because countries with high-income levels or developed countries, then they have realized the importance of the environment. The country also has sufficient capital and technology to repair and reduce environmental damage. The comparison between average CO_2 emissions and economic growth in sample countries in East and Southeast Asia is shown in Table 1

Table 1
Average GDP Growth Rate, GDP Value per Capita, and Emissions CO_2 (1994-2015)

Country	Growth (%)	GDP per Capita (Thousands US$)	CO_2 Emission per Capita (metric ton)
East Asia			
China	9,64	3.146,5867	4,68
Hong Kong	3,55	27.638,835	6,45
Japan	0,95	43.439,345	9,92
South Korea	4,84	18.160,237	10,67
Macao	6,41	38.624,722	3,47
Average	5,08	26.201,945	7,04
Southeast Asia			
Indonesia	4,58	2.691,045	1,55
Cambodia	7,67	614,079	0,22
Laos	7,10	909,217	0,35
Philippines	4,75	1.881,923	0,93
Vietnam	6,77	1.051,646	1,13
Average	6,17	1.429,582	0,83

Source: World Bank, EDGAR, 2017

Table 1 shows the differences between countries in East and Southeast Asia. The average rate of GDP growth in high-income countries in East Asia is smaller than in lower-middle-income countries in Southeast Asia. The average value of GDP per capita in East Asia is greater than Southeast Asia by a ratio of 18 times greater in East Asia. This shows that the average income of people in East Asia is greater than the income of people in Southeast Asia. CO_2 emissions which are an indicator of environmental damage also show a greater number in East Asia, which is 8.5 times that of CO_2 emissions in Southeast Asia. South Korea, which is a developed country, is the

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leader in producing the largest CO_2 emissions in both East Asia and Southeast Asia. This shows that not all developed countries are able to manage the environment to balance economic growth and not all developing countries are contributors to CO_2 emissions in carrying out economic activities.

II LITERATURE REVIEW

Grossman and Krueger (1995: 353) conduct research on the relationship between GDP per capita with various environmental indicators. The findings show that economic growth does not worsen environmental quality. For most indicators, economic growth did initially worsen environmental conditions, but then it was followed by environmental improvements after passing through a turning point.

In previous studies, environmental damage in EKC is often measured using greenhouse gas constituent indicators (carbon dioxide, methane, nitrogen dioxide, and other gases), water pollutants and feces. However, this study only uses carbon dioxide as an indicator of damage, because CO_2 is the most emitted gas by human activities, making it the largest constituent gas in GHGs. Economic factors used in this study are factors driving economic growth that are limited by economic indicators such as GDP per capita, foreign direct investment, and openness trade or economic openness indexes.

Grossman and Krueger (1995) and Selden and Song (1994) have proven that there is a positive relationship between economic growth as measured by GDP per capita on CO_2 emissions as well as other pollutants. Then for the variable FDI and trade openness, Ren et al (2014) examined the relationship between FDI, economic openness, and COemissions$_2$ in China, finding evidence that the growth of China's international trade surplus has an impact on the rapid increase in CO_2emissionsLikewise for FDI, where a large flow of FDI will exacerbate CO_2emissions.

Bosquet and Favard (2005) find that income inequality in Environmental Kuznet Curve's gives new insight for a positive relationship between pollution and economic growth. A simple model for proposing this hypothesis brings meta-analysis for the richest country and middle-income country to boost redistribution policy at present.

Auffhammer, Sun and Wu (2017) bring an understanding of city-level industrial CO_2 emissions in China. In this sense, larger cities enjoy less CO_2 emissions at the expense of the increasing emissions in medium- and small-sized cities. The policy recommendation for indicating towards less-energy-intensive industries, matter China in curbing carbon dioxide emissions during its ongoing urbanization and industrial progress.

Zheng, Siqi (2010) in his paper used microdata by giving a rating of 74 major Chinese cities to see household carbon footprints, then it was found that city temperatures in January have a negative correlation with household carbon footprints, so it shows that regional economic development with policies that support the growth of cities are likely to increase housing carbon emission

III METHODS

This study uses data *time series* which is annual data for 22 years which is from 1993 to 2015. While the cross-section data used covers a number of countries in East and Southeast Asia. The variables used in the study consisted of 4 variables, CO_2emissionsas the dependent variable and for the independent variables used GDP, FDI and economic openness. Sources of data obtained from data from the *World Bank*, the *United Nations Conference on Trade and Development* (UNCTAD), and the *Emission Database for Global Atmospheric Research* (EDGAR).

The study took a sample with the criteria of the majority of *high-income* countries or countries with strong economies and countries *lower-middle-income*. The sample chooses two regions in Asia, namely East Asia, the majority of which are *high-income* countries and those in Southeast

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Asia which have the majority of *lower middle income*. Selected countries in East Asia including Japan, China, South Korea, Hong Kong, and Macao and countries in Southeast Asia including Indonesia, Cambodia, Laos, the Philippines and Vietnam with the consideration that these countries represent the conditions contained in the two the area as explained in the background [1-14].

The specification model used to analyze the determinants of carbon dioxide in East Asia and Southeast Asia is as follows.

$$CO2_{it} = \beta_0 + \beta_1 \, FDI_{it} + \beta_2 \, OPEN_{it} + \varepsilon_{it} \quad (1)$$

where:

$CO2_{it}$ = Emissions of CO_2 for country i in year t

FDI_{it} = Foreign direct investment for country i in year t

$OPEN_{it}$= Openness of the economy for country i in year t

β_0 = Constant

$\beta_{1,2}$ = Coefficient

ε_{it} = Residual (error term)

The Kuznets hypothesis shows the relationship between economic growth and environmental damage. The form of the Kuznets or EKC curve is an inverted U-Shaped U curve which illustrates that a country will experience an increase in environmental damage during the initial stages of economic growth. Then after passing through a turning point, continued economic growth will reduce environmental damage.

The specification of the model used to test the Kuznets hypothesis in this study is the square in logarithm, but the coefficient sign α is changed to β with the assumption that it is still in the same meaning or α = β. The following quadratic models in the logarithm are used in this study

$$\text{Ln } CO2_{it} = \beta_0 + \beta_1 \ln (GDP)_{it} + \beta_2 [\ln (GDP)]_{it}^2 + \varepsilon_{it} \quad (2)$$

where:

ln = natural logarithm

CO2it = CO2 emissions per capita for country i in year t

GDP_{it} = Gross domestic income per capita for country i in year t

β_0 = Constant

$\beta_{1,2}$ = Coefficient

ε = Residual (error term)

The expected coefficient to form the ECC curve in accordance with the Kuznets hypothesis is positive on $\ln GDP_{it}$ and negative on $\ln (GDP_{it})^2$so that an inverted U curve will be formed. The formula for finding a turning point is to derive the logarithmic quadratic function from equation 2.

The formula for finding a turning point is to derive the quadratic logarithmic function from equation.2 above

$$\frac{d \ln CO2}{d \ln GDP} = \beta_1 + 2\beta_2 \ln GDP$$

$$0 = \beta_1 + 2\beta_2 \ln GDP \quad (4)$$

$$\ln GDP = -\frac{\beta_1}{2\beta_2} \quad (5)$$

So that turning points or turning points can be found using the formula, $-\frac{\beta_1}{2\beta_2}$. but the turning point is still in the form of natural logarithms, so it needs to be changed in the form of natural anti-logarithms.

IV RESULT AND DISCUSSION

The results of the selection test for the best estimation model to test the effect of FDI and OPEN in East Asia, found that the REM model was chosen as the most efficient model among other models with a 95 percent confidence level. This can be seen from the Hausman and LM test that received H_0 so that the REM model was chosen as the best estimation model.

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Table 2a
Estimation Results of the REM Model Effect of FDI and OPEN in East Asia

Variable	Coefficient	Std. Error	t-Statistics	Prob.
C	6.740594	1.906107	3.536314	0.0006 *
FDI	3.04E-06	5.43E-07	5.594224	0.0000 *
OPEN	-1.44E-05	7.02E-06	-2.049584	0.0427 **

Note:
* Significant at α 1%
** Significance at α 5%

Estimated results to choose the best estimation model through the Chow, Hausman and LM test, the FEM model was chosen as the best model for further testing. The following results are estimated by the REM model to test the effect of FDI and OPEN on COemissions$_2$ in Southeast Asia [15-24].

Table 2b
FEM Model Estimation Results Effects of FDI and OPEN in Southeast Asia

Variable	Coefficient	Std. Error	t-Statistics	Prob.
C	0.188418	0.033038	5.703076	0.8791 **
FDI	2.05E-06	3.26E-07	6.272830	0.0000 *
OPEN	0.000511	2.92E-05	17.48932	0.0000 *

Note:
* Significant at α 1%
** Not significant

Testing to choose the best estimation model in East Asia gets the result that the REM model is the most efficient model among other models with a 95 percent confidence level. The right method used to estimate random effects is Generalized Least Squares (GLS) (Widarjono, 2016: 361). The following are the results of the estimation of the REM model to test the EKC hypothesis in East Asia.

Table 3
ECC Estimation Results in East Asia with REM model

Variable	Coefficient	Std. Error	t-Statistics	Prob.
C	-8.595621	1.142256	-7.525129	0.0000 *
LN_PDB	1.641885	0.243772	6.735323	0.0000 **
LN_PDB2	-0.058202	0.013459	-4.324249	0.0000 *

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LN_PDB2	-0.058202	0.013459	-4.324249	0.0000 *
R-squared R-squared	0.7511590.751159	--	--	--
F-Statistics F-Statistics	169.04340.00000169.0434	-	-	0.00000 *

* * Significant * 1 Significant in * * Significant * 1

The resulting turning point is at the point of GDP 10.10505. This point is the GDP point in the natural logarithm. The real turning point for GDP is the natural anti-logarithmic form of the dot ln point of GDP, which is at the level of GDP per capita of 1,335,812,127 US $.

EKC test results or the relationship between income per capita and CO_2emissionsin countries in East Asia shows the coefficient of income per capita generated is positive, which is 1.64188 and the coefficient of income per capita squared shows a sign of a negative estimate of -0, 05820. The estimation results are in accordance with the EKC hypothesis, where CO_2 emissions will increase with increasing per capita income and then decrease with increasing per capita income after passing through a turning point. The interpretation of the estimation results is that when GDP per capita increases it will increase CO_2 emissions. Then when there is an increase in GDP per capita squared it will reduce CO emissions.

The turning point of the EKC estimation results in East Asia is at the point of GDP of 14.10505. Whereas the average value of ln GDP in East Asia in 2015 was 9.789177, meaning that the average GDP in East Asia was still below the turning point. The elasticity of the average value of ln East Asian GDP is as follows.

$$\varepsilon = \frac{d \ln CO2}{d \ln PDB} \times \frac{\ln PDB}{\ln CO2}$$
$$\varepsilon = 2{,}68296$$

Overall, the East Asian region has a positive elasticity when calculated using average GDP. The elasticity results also show that the relationship between GDP per capita and CO2 emissions is positive. The interpretation of elasticity in equation 4.16 is when ln GDP per capita increases by 1 percent, it will increase CO2 emissions by 2.68 percent. The following is an image of the EKC curve formed in East Asia.

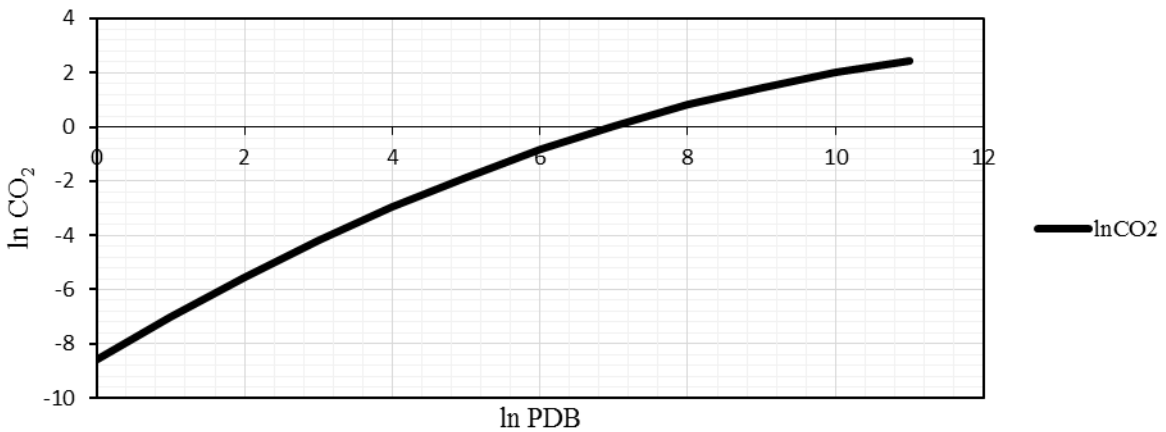

Fig.1. ECC Curves in East Asia

Figure 1 shows that countries in East Asia are still below the turning point number or at the point of GDP 14.10505. The EKC curve also shows that East Asia has a positive relationship between GDP per capita and its emissions, or it can be said that East Asia still producesCO_2emissionshighin its economic development stage. An increase in GDP per capita will also increase the rate of

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CO_2emissions. Although it has not yet reached a turning point, the estimation results in East Asia in theory show conformity with the EKC hypothesis that is positive at β_1 and negative at β_2.

GDP elasticity is also calculated for each country in East Asia. The elasticity of each country in East Asia also shows a positive relationship between GDP per capita and CO_2emissions. The elasticity results show that although the majority of East Asian countries are high-income countries, it turns out that the high income has not been able to reduce CO_2emissions. The increase in GDP per capita will also increase its CO_2emissions [25-27].

The results of the EKC test or the relationship between per capita income and CO_2emissions in countries in Southeast Asia also show the same coefficient sign as the EKC hypothesis. The sign of the coefficient of income per capita is positive as 2,244306 and the coefficient of income per capita squared shows a sign of a negative estimate that is equal to -0,090984. The estimation results in Southeast Asia are also in accordance with the EKC hypothesis.

The turning point of the EKC estimation results in Southeast Asia is lower than the turning point of East Asia which is at the point of ln GDP 12.33352, while the average value of the country's GDP in Southeast Asia is ln 7.063424 GDP, meaning that the average value of GDP in Asia Southeast is also still below the turning point. meaning that the average GDP in Southeast Asia is still below the turning point. Using equation 4.11, the elasticity of the average value of ln Southeast Asian GDP is 17.13. So, like East Asia, overall the Southeast Asian region also has a positive elasticity if calculated using average GDP. The elasticity results also show that the relationship between GDP per capita and $COemissions_2$ is positive. The interpretation of elasticity results is that when ln GDP per capita increases by 1 percent, it will increase $COemissions_2$ by 17.13 percent. The following is an image of the EKC curve formed in Southeast Asia.

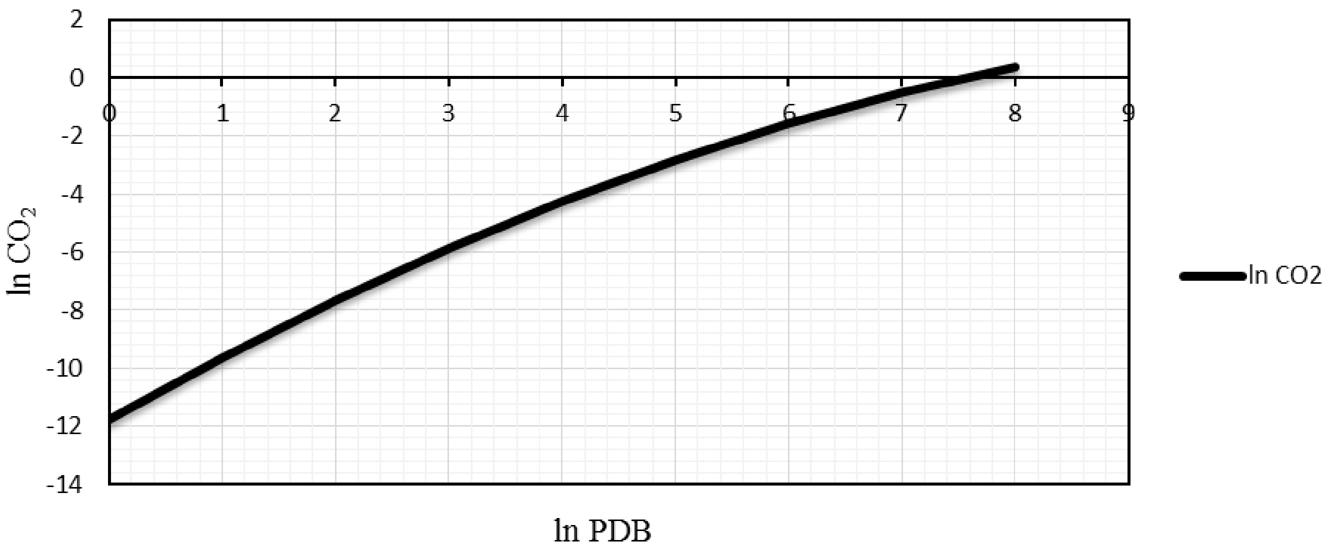

Fig 2. EKC Curves in Southeast Asia

Figure 2 shows countries in Southeast Asia still below the turning point number or at the point of GDP 12.33352. The EKC curve also shows that in Southeast Asia it has a positive relationship between GDP per capita and its emissions or can be said to be the same as in East Asia, Southeast Asia still produces CO2 emissions high in its economic development stage. The increase in

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GDP per capita will also increase the rate of CO_2emissions.

GDP elasticity is also calculated for each country in Southeast Asia. The GDP elasticity in each country has not yet reached a turning point. The elasticity results also show that countries in Southeast Asia, which have the majority of lower middle-income countries, have not been able to reduce COemissions$_2$. So that like East Asia, the increase in GDP per capita of each country in Southeast Asia will also increase its CO_2emissions.

The overall estimation results in two regions, East Asia and Southeast Asia have estimation marks that are consistent with the EKC hypothesis, which is positive at β_1 and negative at β_2. These results are in line with Hutabarat's research (2010) which examines COemissions$_2$ and GDP per capita in 5 ASEAN countries and gets the same coefficient mark as the EKC hypothesis. Testing of ECCs in East and Southeast Asia is also consistent with Grossman and Krueger's (1995) findings for 4 types of pollutant indicators with per capita income, where pollutants will increase with per capita income and then decrease after passing through a turning point or in accordance with the EKC hypothesis.

V CONCLUSION

FDI and OPEN estimation results show a significant effect on CO_2emissions, both in East and Southeast Asia. In countries with the majority of high income in East Asia, the FDI variable shows a positive and significant effect, but for the OPEN variable, the reverse results are negative and significant. While in lower-middle-income countries in Southeast Asia, both the FDI and OPEN variables show a positive and significant effect on CO_2emissions. The EKC hypothesis has been proven in theory to apply to both high-income countries in East Asia and lower-middle-income countries in Southeast Asia, although it has not yet reached a turning point. EKC results in East and Southeast Asia also showed no difference between high income and lower-middle-income countries.

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