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Does FDI Impact Carbon Dioxide Emissions?

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***Abstract*---*Foreign Direct Investment (FDI) is an important factor to bust economic development and stimulate economic growth. Rapid economic growth has an impact on environmental degradation. This study aims to determine the direct, indirect, and total effects of FDI on CO2 emissions based on GNI (Gross National Income), categorized as low-income countries, lower-middle income countries, upper-middle income countries, high income countries and global panel. This research uses General Method Moment (GMM) with three least square (3SLS) GMM approach. The data used in this research is retrieved from the World Development Indicator World Bank for period 1998-2014. The estimation results conclude there is a positive direct effect of FDI on CO2 emissions for lower-middle and upper-middle income countries, but not significant for low-income, high-income countries, and global panel. FDI has a significant positive indirect effect across all groups of countries and significant positive total effect across groups*.

***Keywords*---*CO_2 emissions, Foreign Direct Investment (FDI), GMM, economic growth*.

I. Introduction

Global warming has become the world's primary environmental problem. It causes extreme shifts in season and weather which impacts human's life in short and long term. The greenhouse gas works like greenhouse effect, it reflects radiation from earth back to earth again, naturally functions to warm the earth at an average temperature of 15℃. Aside from its natural occurance, the greenhouse gas can be originated from human activities (anthropogenic) [1]. The majority of anthropogenic greenhouse gas emissions are dominated by carbon dioxide (CO_2) emissions from combustion. CO_2 emission accounts for more than 60% in global warming. CO_2 emission level indicates environmental quality because CO_2 emission impacts the pollution level if it exceeds the ambient capacity [2]. The whole world is still very dependent on fossil fuels that are not environmentally friendly, so that high energy consumption causes high carbon emissions, which have a negative impact on the environment and ultimately lead to global warming [3].

CO2 emissions come from burning oil, coal and gas used for energy use, burning wood and waste materials, and from industrial processes such as cement production [4]. According to [5], recent growth of the world economy combined with an increase in its carbon intensity have led to rapid growth in fossil fuel CO_2 emissions since 2000. In addition, macroeconomic variables may drive CO_2 emissions through various transmissions, which, based on Kaya Identity, decomposed through four driving factors namely population, output per capita level, energy intensity, and carbon intensity of energy mix or primary energy sources groups [6,7,8]. Besides Kaya Identity, Kuznet Hypothesis also supports the relationship between per capita income and environmental quality. The hypothesis shows an increase in income will be followed by an increase in environmental degradation to a certain income point, then the opposite will occur. This condition indicates that a country's economic growth in achieving its output will eventually reduce environmental degradation or improve the environment [9].

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FDI flow is linked with CO_2 emissions through the increasing economic activity due to accumulated investment. FDI has a direct and indirect effect on CO_2 emissions. Studies related to FDI's effect on CO_2 emissions found that there is a direct effect based on Porter Hypothesis or Polution Haven Hypothesis (PHH) and indirectly based on Environmental Kuznet Curve (EKC) Hypothesis. The studies stating that there is a positive direct effect of FDI on CO_2 emissions are [7,10,11] while the indirect effect is examined by [6,12]. According to [13] there is a negative indirect effect of FDI on CO_2 emissions.

This research is conducted to analyze the effect of FDI on CO_2 emissions simultaneously using global data between countries based on its Gross National Income (GNI). Based on the Atlas Method, countries are categorized into low income (<1,005 US $), lower-middle income (1,006-3,955 US $), upper-middle income (3,956-12,235 US $), and high-income (> 12,235 US $).

II. Research Method

Model

Simultaneous model is used to see the effect of FDI on environment quality, proxied by CO2 emissions in countries with low income, lower-middle income, upper middle-income, and high income and estimated in natural logarithms (except for trade openness variable).

The simultaneous equations's stages are as follows:

Stage 1:

$$\text{In } GDP_{it} = a_0 + a_1 \text{In } FDI_{it} + \alpha_2 Tradeopp_{it} + \alpha_3 \text{In } Pop + \varepsilon_{it} \quad (1)$$

Stage 2:

$$\text{In } E_{it} = \beta_0 + \beta_1 \text{In } \widehat{GDP}_{it} + \beta_2 (\text{In } \widehat{GDP})^2{}_{it} + \beta_3 \text{In } FDI_{it} + \beta_4 \text{In } Energy_{it} + \varepsilon_{it} \quad (2)$$

Where: E is CO_2 emission per capita; GDP is per capita income; $(GDP)^2$ is per capita income squared; FDI is foreign direct investment; Tradeopp is trade openess; Pop is population; dan Energy is energy consumption.

The model is estimated using General Method Moment (GMM) with the GMM three least square (3SLS) approach. According to Baltagi, 3SLS GMM is used to form simultaneous equations with two or more equations that structurally relate to each other. The assumptions of GMM 3SLS are winitial option, wmatrix, and instrument. Winitial assumes an independent residual between equations and the two homos-capacity models. Wmatrix controls the weight matrix based on parameters in the first step before continuing to the second estimation. While the instrument is for emphasizing both variables used in two estimation equations. The 3SLS error is assumed to be homosexedastic in the instrument variable, after estimating the measurement of direct, indirect, and total effect using the method in [12] as follows:

$$Direct = \frac{\partial \ln(E)}{\partial \ln(FDI)} \quad \text{.....(1)}$$

$$Indirect = \quad \text{.....(2)}$$

$$Total = Direct + Indirect \quad \text{.....(3)}$$

Econometrical Procedure

After completing the two stages model estimation using 3SLS GMM, simultaneous panel data equations analysis requires econometrical procedure, namely identification of simultaneous equations, GMM specifications testing, and unit root panel. The entire calculation processes related to the econometric procedure was completed using STATA 13 software.

The GMM specification test is done to determine the model's validity. The validity of each additional instrument is verified using the Sargasen tests while the Hansen test is for the over-identifying restrictions. Unit root testing with unit root is used in panel data researches. The statistical test used in the unit root panel is a modification of the Augmented Dickey-Fuller (ADF) and Philips-Perron (PP) tests, which is common unit root consisted of Levin, Lin a Chu (LLC) test and Breitung's test. The use of the LLC test method is more relevant for panel data because it provides more accuracy in unit root panel compared to other tests.

Data and Variables

Based on the model used, there are seven research variables consisted of two endogenous variables and five exogenous variables. Endogenous variables are per capita income and CO_2 emissions, while exogenous variables are FDI, GDP^2, trade openness, energy consumption, and total population.

First, FDI is the flow of foreign direct capital per capita with 2010 (US $) as the base year in economic reporting. The flow is calculated from the amount of asset capital, income reinvestment, and other capital. FDI is obtained from dividing nominal FDI with deflator, using 2010 (US $) as the base year starting from 1998-2014. Second, per capita income with 2010 (US $) as the base year is measured as the amount of GDP per capita divided by the mid-year population. Third, GDP^2 per capita is the squared amount of per capita income with 2010 as the base year in US $ to see if there is an EKC effect. Fourth, CO_2 emission is the result of total combustion from fossil fuels and cement manufacture. CO_2 emission is calculated per capita in metric tons ($MtCO_2$ per capita).

Fifth, Trade Openness (TRADE OPENNESS) shows the amount of trade from export and import activities measured as part of GDP (%). Sixth, energy consumption shows primary energy usage before it's transformed to other end users. Energy consumption is calculated as kg equivalent to oil per capita. Seventh, the total population shows the total population based on de facto status. The total population is calculated from the total population regardless of legal status or citizenship with the end of the year as the estimated value.

III. Result

Model Analysis

LLC unit root test is used in this study to test the stationarity of panel data from four groups of countries. Table 1 shows that all variables are statistically significant under the LLC test. Before the model is estimated, a specific test is performed for the simultaneous equations. First, identification of simultaneous equations is done to determine the model validity using Hansen test.

Table 1. Levin-Lin-Chu Unit Root Test.

Variable	Statistic (adjusted)	P > t	Description
FDI	-8,81	0,0000	Stationary
CO_2 Emission	-2,55	0,0053	Stationary
GDP	-3,91	0,0000	Stationary
GDP^2	-2,71	0,0033	Stationary

Population	-8,95	0,0000	Stationary
Energy Consumption	-24,58	0,0000	Stationary
Trade Openness	-5,00	0,0000	Stationary

Estimation Result

The 3SLS GMM test result shows that in model 1 FDI, population and trade openness significantly impact per capita income in low income countries. In model 2, per capita income, squared per capita income and energy consumption impact CO_2 emissions in low income countries. Furthermore, the estimation result for lower-middle income countries shows that FDI and trade openness significantly impact per capita income. While the estimation of model 2 shows that FDI, per capita income, and per capita income significantly impact CO_2 emissions.

In model 1, per capita income in upper-middle income countries is influenced by FDI, population and trade openness. In model 2, FDI, per capita income and per capita income significantly impact CO_2 emissions. While, FDI has a significant effect on the level of 1% with a coefficient of 0.16 in high income countries. This result indicates that FDI has a positive effect on per capita income, which means an increase in FDI will increase per capita income.

Results of the global panel shows that, first, in model 1, FDI has a significant p-value of 0,000 at the level of 1% with a coefficient of 0.55. Second, on global level, the population does not significantly impact per capita income. Third, trade openness has a coefficient of -0.001 and is significant at the level of 5%. In model 2, per capita income, squared per capita income, and energy consumption significantly impact CO_2 emissions while FDI is not significant.

Table 2. Estimation Result.

Low income			
Variable	**Coefficient**	**Variable**	**Coefficient**
Model 1 (lnGDP as dependent variable)		Model 2 (lnE as dependent variable)	
cons	11,1***	**cons**	-210,9***
lnFDI	0,08**	**lnFDI**	0,03
lnPOP	-0,32***	**lnGDP**	62,56***
TRADEOPP	-0,01**	**$(lnGDP)^2$**	-4,76***
		lnEnergy	0,71***
Lower Middle Income			
Cons	8,04***	**Cons**	-130,1**
lnFDI	0,23***	**lnFDI**	0,19***
lnPOP	-0,01	**lnGDP**	35,47**
TRADEOPP	-0,002**	**$(lnGDP)^2$**	-2,39**
		lnEnergy	-0,03
Upper Middle Income			
cons	9,73***	**Cons**	-164***
lnFDI	0,18***	**lnFDI**	-0,15**
lnPOP	-0,07**	**lnGDP**	38,03***
TRADEOPP	-0,009**	**$(lnGDP)^2$**	-2,17***
		lnEnergy	0,03
High Income			

cons	7,84***	**Cons**	-125,15***
lnFDI	0,16***	**lnFDI**	-0,018
lnPOP	0,09***	**lnGDP**	24,35***
TRADEOPP	-0,0001	**(lnGDP)^2**	-1,16***
		lnEnergy	0,14***
Global Panel			
Cons	5,66***	**Cons**	-24,03***
lnFDI	0,55***	**lnFDI**	-0,01
lnPOP	0,016	**lnGDP**	5,01***
TRADEOPP	-0,001**	**(lnGDP)^2**	-0,24***
		lnEnergy	0,03**

*Notes: *** 1%, significance ** 5%, significance * 10% significance*

IV. Discussion

FDI's Direct Effect on CO_2 Emission

The simultaneous relationship of FDI and CO_2 emissions are categorized into three groups, namely direct, indirect, and total effect. According to [14] the indirect effect refers to the pollution haven hypothesis which states that developing countries have a comparative advantage in production sectors that tend to create pollution. Meanwhile the direct effect through the porter effect pathway explains that FDI increases the competition among domestic producers, thereby encourage domestic producers to use advanced technology.

Table 3 shows the direct, indirect, and total effect of FDI on CO_2 emissions. First, the direct effect of FDI on CO_2 emissions in low-income countries is not significant. This is because the flow of FDI in low income countries leads to agriculture, food and beverages, and equipment. According to [15] in IPA Survey, agricultural sector is the most promising profitable sector in low income countries such as the majority of Africa. In addition, FDI inflow in low income countries has the lowest portion compared to other countries, counts for 10 billion USD in 2014 or 1% of total Global FDI in 2014.

Table 3. FDI's Effect on CO_2 Emission Estimation Result.

Countries	Direct Effect	Indirect Effect	Total
Low income	0,03	5,00***	5,03
Lower middle income	0,19***	8,15**	8,34
Upper middle income	-0,15**	6,84***	6,69
High income	-0,018	3,89***	3,87
Global Panel	-0,01	2,76***	2,75

*Notes: *** 1%, significance ** 5%, significance * 10% significance*

Second, FDI in lower-middle income countries has a direct effect on the increase of CO_2 emissions level. This result is consistent with [11] which states that in lower income countries such as Indonesia and the Philippines, FDI is the driving force of economic growth. This result proves that the Pollution haven hypothesis and EKC hypothesis were found. The EKC hypothesis proves economic growth is associated with environmental degradation. [7] support that the EKC hypothesis was found in lower middle-income countries. Based on the income-forming structure, lower-middle income countries have a

high share in the industry. For example, the dominant sector in Kenya is agriculture, tourism, and industry (primary sector), in India it's manufacturing and agriculture, and ino Vietnam it's services, manufacturing and agriculture [16].

Third, the direct effect of FDI in upper-middle income is consistent with [6,17,12] which found that FDI inflows reduce CO_2 emissions. FDI management regulations are continuously updated to accommodate the impacts, just like how Algeria improved investment policies and improved oil production after 2015. In addition, several countries have attempted to reduce primary energy intensity, upper-middle income countries managed to reduce from 9.22 MJ / $ 2011 in 1990 to 5.55 MJ / $ 2011 in 2015 [18].

Fourth, in high income countries FDI does not significantly impact CO_2 emissions. The flow of FDI in high-income countries on average is absorbed directly by the service sector, consistent with the studies of [19,20,21,17]. This proves that high income countries are starting to put attention in the service sector. Based on the GDP structure, high income countries began to form a downward trend in the manufacturing sector and shot up in the service sector.

Fifth, globally, FDI does not directly impact CO_2 emissions. The results are explained by [13] that the effect of investment is known through the relationship of economic growth with CO_2 emissions based on EKC. This means that FDI does not directly impact several countries, but impacts indirectly by improving the economy. In addition, the effect of FDI on CO_2 emissions are taking sectors that become investment objectives as considration, which means there are various factors that impact CO_2 emissions.

3.3.2. FDI's Indirect Effect on CO_2 Emission

Indirect effects consist of scale effects, technique effects, and composition effects on CO2 emissions [14]. [12] defines scale effect as the magnitude of industrial scale and economic activity. Scale effect provides increased environmental protection due to economic growth that occurs. Technique effect is technological capability in a production. The composition effect shows the production sector's composition. It means that if a sector uses more labor, then it is categorized as labor intensive instead of capital intensive.

First, in low income countries, FDI has a positive effect on CO_2 emissions. The estimated result in low income countries shows that 1% increase in FDI will increase CO_2 emissions by 79.76%. The result is consistent with the study of Kivyiro and Arminen (2014). Second, the indirect effect of FDI on CO_2 emissions in lower-middle income countries is positive. This result is consistent with the study of [11,13].

Third, the indirect effect of FDI on CO_2 emissions in upper-middle income countries has a positive coefficient. This result is consistent with the study of [13] which found that there is a positive effect of per capita income on CO_2 emissions in the upper-middle income economies. The indirect effect of economic growth has begun to lead to an increase of technical effect because some countries are starting to evaluate the FDI flows on the industrial sector [22]. Fourth, the indirect effect of FDI on CO_2 emissions in high income countries has a coefficient of 3.89. This result consistent with the study of [13]. This result indicates that 1% increase in per capita income will increase CO_2 emissions, but the magnitude of the effect is smaller than other countries.

FDI's Total Effect on CO_2 Emission

Global FDI has increased rapidly in recent years and foreign affiliate sales for MNEs have multiplied in value compared to the value of exports of goods and non-services. The effect of FDI flows is still a debate, which causes countries to implement a race-to-the-bottom regulation to attract investors or strategies to utilize investment. [13] found the relationship

between FDI and pollution intensity depends on the source of the pollutants and regional impact. The effect of total FDI on CO_2 emissions is the accumulation of direct and indirect effect. Globally, the effect of FDI on CO_2 is positive. Meanwhile, low income, lower-middle income, upper-middle income and high income countries have the same direction on the effect. Therefore, to see a greater impact, the magnitude should be considered. The highest magnitude found in lower-middle income countries followed by upper middle income, low income, high income and global panel.

Table 3 shows the total effect on four groups of countries. FDI has a positive total effect on CO_2 emissions in all groups. This result is consistent with the study of [13,23,24,25] suggested a redesign of environmental regulations to reduce environmental degradation.

V. Conclusion

The statistical test results concluded that FDI has a direct effect on CO_2 emissions in lower-middle income and upper-middle income countries, but does not significantly impact low income, high income, and global panels. Then, FDI has an indirect positive effect on CO_2 emissions in country groups based on GNI, namely low income, lower-middle income, upper-middle income, high income, and global panel. Based on the effect of total, FDI has a positive effect on carbon dioxide (CO_2) emissions in country groups based on GNI, namely all income categories and global panel.

As a closing note, this study has several limitations. First, the data used is total data not sectoral data so that it does not represent economic sectors that contribute greatly to CO_2 emissions. Second, data on CO_2 emissions is limited to total emissions as a residual production process, so it cannot measure the danger level of CO_2 emissions for human health. In addition, it has not been able to measure the threshold of the ambient capacity. This study recommends further studies of the effect of FDI on CO_2 emissions by taking the FDI objective sectors into account because each sector has different effects. The use of sectoral data will represent a direct source of CO_2 emissions.

Appendix

No	***Low Income Country***	***High Income Country***
1.	Haiti	Spain
2.	Nepal	Switzerland
3.	Tanzania	America
4.	Benin	Uruguay
5.	Zimbabwe	Singapore
6.	Congo	Saudi Arabia
7.	Eritrea	Sweden
8.	Mozambique	Slovenia
9.	Senegal	Japan
10.	Togo	Australia
11.	Tajikistan	New Zealand
12.	Yemen	Qatar
No	***Lower Middle Income Country***	***Upper Middle Income Country***
1.	Kenya	Albania

2.	Myanmar	Algeria
3.	Pakistan	Argentine
4.	Philipine	Brazil
5.	Sri Lanka	Bulgaria
6.	Vietnam	China
7.	Indonesia	Colombia
8.	Cambodia	Thailand
9.	India	Turkey
10.	Bangladesh	Venezuela
11.	Mongolia	Peru
		South Africa
		Malaysia

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