An empirical investigation of the Environmental Kuznets Curve from an international economics perspective: *Does the origin of FDI matter?*

DANG Phuong Thao*

(Abstract)

The Environmental Kuznets Curve (EKC) is a hypothesis of an inverted U-shaped relationship between environmental damage and income of a country, which means pollution tends to get worse as economic growth takes place, then starts to improve at a turning point over the course of development. Despite its complexity and controversy, the theory underlined by the EKC has been widely employed in empirical research on different economic elements in their relationship with growth and pollution. This research applies the EKC model to achieve two purposes: testing the EKC hypothesis and studying the environmental impacts of FDI (from developed and developing partners) and trade, the two important physical aspects of globalization. The most interesting question inspired the research is whether the origin of FDI affects environmental quality of host countries through the EKC. In the panel of 51 developed and developing countries and the subpanel of 23 developing economies for the period from 2001 to 2012, the two-way fixed effect econometric model verifies the EKC's existence. Furthermore, the country-of-origin factor of FDI, which is largely ignored in the literature, is proved to be important to understand the impact of international investment on the environment. FDI from developed countries shows robust halo effect which reduces carbon dioxide emissions through technology transfer and development. Whereas, developing-country FDI and trade openness are associated with more polluting economic activities. However, the model does not capture the pattern of developed country subpanel, which requires further research. The findings deliver important policy implications to national governments, especially in developing countries, and critical input to the international discussions on the linkage between environment and cross-border flows of capital and goods.

Keywords: Environmental Kuznets Curve, EKC, environment, growth, sustainable development, sustainability, FDI, trade, halo, pollution havens.

1. Introduction

Despite various conflicts and some heated parts, since the last half of the twentieth century, the world has been experiencing the most peaceful and stable period throughout history, providing the vital condition for continuous economic growth in many countries (Harari & Perkins, 2014). Growth has become a global norm and the main target of governments. However, according to the Intergovernmental Panel on Climate Change (IPCC), economic

* The Graduate School of East Asian Studies, Yamaguchi University

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activities are the main cause of global warming, the biggest environmental issue of our age, which in turn brings irreversible destructions to our ecological system. Lying at the center of the growth-environment nexus, the Environmental Kuznets Curve hypothesis (EKC) has become a key aspect of environmental economics literature. Originally, the term Kuznets curve, named after Simon Smith Kuznets (1901 – 1985), the 1971 Nobel-prize-winner economist refers to an inverted U-shaped relationship between income inequality and economic growth, which hypothesizes that income inequality first rises then falls along the development path (1955). In the field of environmental policy technical study, a very similar possible pattern between environmental degradation and income of a country has captured the attention of research community since Grossman & Krueger's remarkable article in 1991. The term "Environmental Kuznets Curve" (EKC) has become popular to indicate the hypothesis of an inverted U curve between environmental damage and income of a country, which means pollution tends to get worse as economic growth takes place, then starts to improve at a turning point over the course of development.

The emergence of the EKC theory has changed the domain of environmental talks because in the past environmentalists and associated scientists generally claimed income growth as a threat to the environment (Stern, 2004). It makes the idea of sustainable development, which is promoted in the report "Our Common Future" by the World Commission on Environment and Development in 1987 (Brundtland), become more achievable. In other words, if proved, it will answer the question whether economic growth and sustainability are compatible (Selepe, 2008). However, the EKC is a topic of debate from the beginning. Scientists argue about its shape (U-shaped or N-shaped), the level of income at the turning point and even its validity (Moomaw & Unruh, 1997; Tang & Tan, 2015; Yandle, Vijayaraghavan, & Bhattarai, 2002). A possible reason of this disagreement lies in the complicated nature of the EKC, which is the joint outcome of the environmental demand, the three income effects (namely scale, structure, and technology effects), and the dual impacts of international flows of trade and investment (Bo, 2011).

Despite its complexity and controversy, the theory underlined by the EKC has been widely employed in empirical research on different economic elements in their relationship with growth and pollution. In a literature review of 51 EKC studies in various countries by Al-Mulali, Saboori, & Ozturk (2015), the hypothesis is tested by various sets of variables and methodologies, but the majority of them include carbon dioxide emission, GDP per capita and GDP per capita squared in their models. While the EKC is verified by 39 out of 51 papers, in many cases, the main research interest is the impact of other explanatory variables in the growth – environment nexus, which is examined via EKC models. Although the validity of the EKC is debatable, its function forms are broadly accepted to represent the dynamics of economic development and environmental degradation, thus facilitating the research of other socio-economic factors in that matrix. Popular additional explanatory variables are trade openness, FDI, energy consumption, population, industrial output, financial capacity, and urbanization.

In this study, the EKC hypothesis will be investigated from an international economics perspectives by a panel of 51 countries, including 28 developed and 23 developing nations. The application of panel data analysis has a merit over a time series data or cross-sectional data set. It allows the unobserved characteristics of each country to be controlled. (Wooldridge, 2008). With an additional time variable in the two-way fixed effect model, the unobservable effect of each year is also captured. (Greene, 2011). Besides the basic variables of traditional EKC models (CO2, GDP per capita and GDP per capita square), the presence of foreign direct investment (FDI) and trade openness is important to deliver policy implications. They represent the necessity of evaluating the EKC from an international economics angle. As globalization has become an inevitable tendency, every country must define its position and strategy to integrate into the global market. Trade and FDI are the most dynamic factors of globalization, reflecting the flows of capital and goods worldwide. Through the scope of trade and FDI, an economy directly exerts its influence on the wealth and life quality of other nations. Moreover, FDI and trade share similar characteristics in the relationship with growth and environment, having either positive or negative impacts. Scholars disagree about the nature of these relationships, debating about whether these two economic indicators benefit or undermine the environment (Haisheng, Jia, Yongzhang, & Shugong, 2005). Nevertheless, they commonly acknowledge that trade and FDI are two of important mechanisms driving the EKC (Antweiler, Copeland, & Taylor, 2001; Bo, 2011).

Furthermore, whether the origin of FDI affects its influence on the environment is an interesting question. In the last decades, FDI from developing countries has been increasingly contributing to world investment. While rich economies dominated cross-border capital flow until the end of the twentieth century, emerging markets have been playing more and more important role since then. Increasing ten times in the last 15 years, developing-country FDI outflow now accounts for approximately one-third of global annual flow. Accordingly, their FDI overseas stock has risen steadily to more than 20% of global FDI stock. Although advanced economies still take the larger share, emerging countries have become significant investors outside their borders. Nevertheless, research on the differences between the two FDI sources is in its infancy. In order to understand the impacts of different investor groups on other countries' economic growth and environmental degradation through cross-border investment, this study will control both FDI from developed countries and FDI from developing countries in the empirical test. It will be the first time FDI flows from different sources have been treated separately in a pollution model. The country-of-origin factor has been largely ignored by previous researchers because most of the time all FDI flows are pooled altogether or distinguished by receiving economies (Blonigen & Wang, 2004). This paper argues that previous researchers have not given adequate attention to this aspect, and aims to fill the knowledge gap.

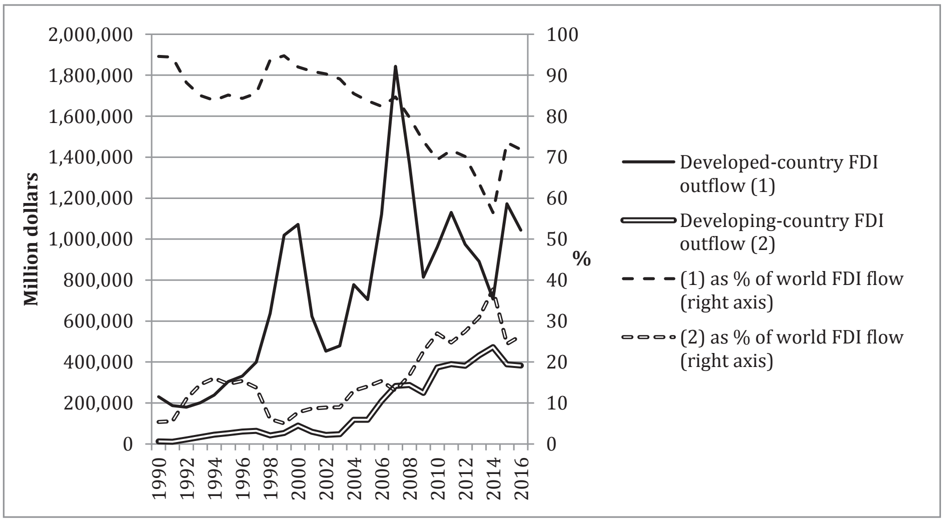

Figure 1. FDI outflows from developed and developing countries, 1990-2016. Source: UNCTAD.

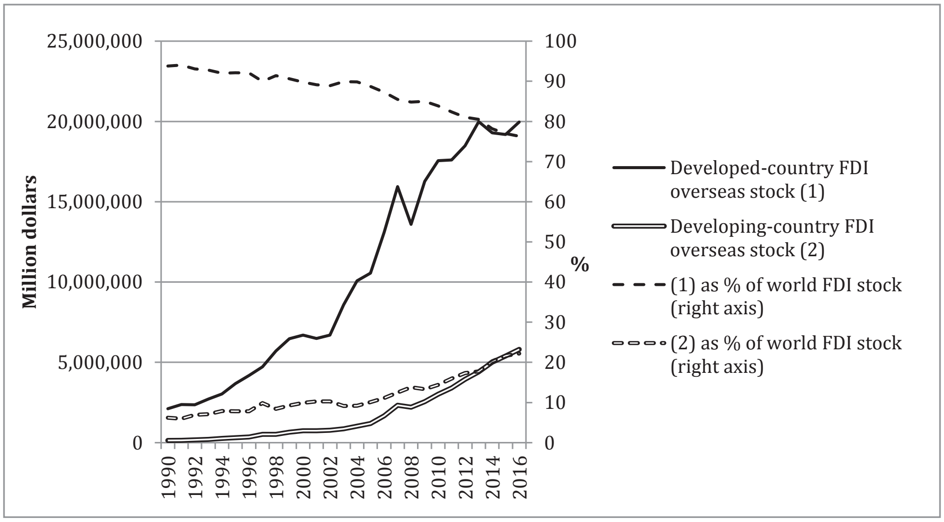

Figure 2. FDI overseas stocks of developed and developing countries, 1990 - 2016. Source: UNCTAD.

In short, the application of the EKC model in this paper serves two main purposes: to test the EKC hypothesis itself and to explore the roles playing by trade and FDI in environmental situations of host countries, especially regarding the origin factor of FDI. The same model will be run for the whole panel and then validated for each of the developed and developing countries subpanels to compare and discover more insights. While the novel consideration of FDI sources gives the study its originality to contribute to the literature, its model is simple but effective enough to answer the research questions. The findings are expected to provide crucial policy implications to national governments and critical input to the international discussions on the linkage between environment and cross-border economic activities. Policymakers may earn a great understanding of their country's position in the matrix of the globalization era, thus finding the way to achieve prosperity while minimizing their impact on environmental quality of not only they own country but also other countries and the global common. As Moomaw & Unruh (1997) stress that the transition into greener economic structure should not be taken for granted as a definite outcome of growth, and there does not exist a fixed level of income at the top of the curve for all nations, identifying the strategy to lower the turning point and reach it in the best manner with the lowest total cost is the most challenging task for governments. The remaining parts of this article are organized as follows: Section 2 is the methodology and model justifications. Section 3 presents the empirical result and discusses its interpretations. Finally, Section 4 covers conclusions and policy recommendations.

2. Methodology

This research employs the EKC model to achieve two purposes: testing the EKC hypothesis and studying the environmental impacts of FDI (from developed and developing partners) and trade, the two important physical aspects of globalization. The relevance of controlling FDI and trade in the EKC pollution function is well defined by literature. While considered as drivers of growth (Campos & Kinoshita, 2002; Frankel & Romer, 1999), FDI and trade have dual impacts on the environment. On one hand, they foster technology transfer and renovation. On the other hand, they are associated with the outsourcing of heavy polluting industries from rich to poor country and the rapid increase of the scale effect (Bo, 2011).

For FDI, its relationship with environment consists of two schools of thought, namely the pollution haven effect and the FDI halo effect. The pollution haven hypothesis states that FDI is harmful to the environment because multinational companies (MNCs) tend to seek for cost reduction by moving to countries with lower environmental standards. According to Cole and Elliott (2005), globalization has made the competitive position of a country become more sensitive to environmental regulations since trade barriers are falling down. Investigating the American FDI outflows, they state that "dirty" industries are likely to relocate to less developed countries with laxer pollution control. Kellenberg (2009) adds that the phenomenon also happens in relative "footloose" industries, such as electrical equipment and components, which are often associated with lower relocation cost and regarded as insignificant polluters. Furthermore, Poelhekke and Ploeg (2012) highlight that the enforcement of environmental regulation plays the more important role than the policy stringency itself. In alignment with this point, from the developing countries' perspective, Pao and Tsai (2011) suggest that pollution haven effects can happen in both active and passive processes. Not only are emerging economies relaxing environmental regulations to attract greater FDI inflow to fuel their growth, but also their governments don't have enough capacity to hold the enforcement up to the level established in policies. His point is supported by quite a few studies in rapidly expanding markets showing that FDI is positively correlated to carbon dioxide emissions (Haisheng, Jia, Yongzhang, & Shugong, 2005; Lau, Choong, & Eng, 2014; Sapkota & Bastola, 2017).

On the contrary, the halo effect advocates argue that FDI has pro-environmental spill-over effect as it is a mean of know-how transfer (Doytch, 2012). There is much evidence that FDI induces environment-friendly technology in emerging countries (Al-mulali & Foon Tang, 2013; Pao & Tsai, 2011). The effect even exerts itself on unaffiliated domestic firms thanks to the increasing mobility of workforce (Vera-Cruz & Dutrénit, 2005). Furthermore, Eskeland and Harrison (2003) suggest that foreign firms remarkably use cleaner energy with better efficiency comparing to their domestic peers. Doytch and Narayan (2016) prove the same point again in a panel of 74 countries from 1985 to 2012, showing that FDI encourages the use of renewable energy and discourages fossil fuel resources. Besides, the scale of FDI halo effect seems to greatly depend on the types of FDI and the host countries' context. FDI in service sector is environmentally friendly while FDI in heavy industries create pollution. FDI inflows to developed countries are greener than the flows going to less developed economies (Doytch & Uctum, 2011). Nevertheless, it is worth to note that the halo effect may still exist in low environment safeguard destinations. Some of giant MNCs have internal environmental standards higher than the requirement of the host country. In order to increase their own competitiveness, they want to gain public favors and participate in the rulemaking process to push domestic standards forward (Garcia-Johnson, 2000). To this point, it is not clear that which school, pollution or halo, has more credibility. Some scholars support both sides of the argument (Pao & Tsai, 2011; Poelhekke & Ploeg, 2012). To the best of the author's knowledge, the paper by Zeng and Eastin (2012) is the only research empirically considering the FDI origin factor in environmental impact. However, they merely control FDI from developing countries without taking into account the developed-country FDI. Their results show that MNCs from less developed regions tend to commit to voluntary pollution abatement practices ISO 14001 in their foreign operation. The prevailing theory and the FDI origin factor will be addressed later in this text.

For trade, the debate around the impact of trade on environment follows a similar path with FDI. Up to now, neoclassical economists have been embracing the idea that free trade would make everyone better-off. Even lower-income communities or groups who receive smaller pieces of the cake would be much poorer without export (Krugman, Obstfeld, & Melitz, 2015). In that sense, trade will ultimately help to raise living standards including environmental quality over time. The elaborate model developed by Antweiler, Copeland, and Taylor (2001) argue that trade has scale, composition and technology effects on pollution just like income. Because technology effect is greater than scale effect, negative impacts of trade will be outweighed; thus, freer trade is good for the environment. However, Daly (1996) point out that while highly closed protected economy suffers from outdated technologies and over-exploitation of natural resources, it does not mean that any freer degree of trade is better for all countries. He criticizes trade without barriers is pushing human economy beyond the ecological limit of the earth. It is the fact that carbon emissions related to trade have been increasing substantially. From 1990 to 2008, carbon dioxide emissions in exported good production increased by 80% worldwide. The average annual rate is 4.3%, faster than population growth (1.4%) and total global $CO2$ emissions (2%), but slower than the rise in the value of trade (Peters, Minx, Weber, & Edenhofer, 2011). Ecological economists and environmentalists have been demanding that the World Trade Organization (WTO) play a critical role in resolving the trade distortion caused by environmental cost externalization. However, at the pleasure of globalists and growth thirsty governments, WTO has been avoided the difficult task. It seems that WTO will not actively step into the heart of the environmental discussion until major polluters make the first move and bring back the climate change legislation to trade forums. Nonetheless, it is worth to note that the reluctance of WTO is partly due to the lack of concrete empirical evidence and the absence of a rational action agenda presented by climate economists. More research needs conducting to examine the environmental impact of trade from different angles in order to get globalists and environmentalists on the same page. The connection of trade and FDI with pollution explains their relevance to the EKC model while their complexity and controversy make them challenging research subjects. They are popular key variables of EKC studies.

Despite the sheer volume of the EKC literature, only a minority of studies involve panel data or cover a group of countries. Table 1 summarizes several critical EKC studies employing data analysis techniques. Based on methodologies, those studies can be divided into three groups. The first group are papers using conventional panel data approach, the fixed effect and random effect models (Atici, 2009; Neequaye & Oladi, 2015; Orubu & Omotor, 2011; Sapkota & Bastola, 2017; Zeng & Eastin, 2012). The second apply more sophisticated time series techniques expanding for panel data such as Autoregressive distributed lag model (ADRL) or Fully modified OLS (FLOLS) (Acaravci & Ozturk, 2010; Cho, Chu, & Yang, 2014). Last are studies which employ the alternative approach developed by Narayan and Narayan, comparing short-run and long-run income elasticity of pollutants (Jaunky, 2011; Narayan & Narayan, 2010). The second and third groups can verify the EKC hypothesis for each country in the sample but require a sufficient time series dimension. Whereas, conventional panel data analysis techniques of the first group answer the question whether or not the EKC is generally manifested for the whole panel. It is the better option for studies with a relatively short interval.

Table 1. Literature on the EKC with panel analysis

Article	Sample	Period	Key variables other than pollutants & GDP	Methodology	Results
Orubu and Omotor (2011)	47 African countries	1990-2012		OLS Fixed effect, Random effect	EKC: Yes
Zeng and Eastin (2012)	48 developed & developing countries	1990-2005	ISO14001, FDI, FDI from developing countries, exports	Fixed or random effect (Not specified)	EKC: Yes FDI from developing countries exhibits commitment to protect environment
Sapkota and Bastola (2017)	14 Latin American countries	1980-2010	FDI	Fixed effect, Random effect	EKC: Yes FDI: pollution havens effect
Neequaye and Oladi (2015)	27 developing countries		FDI, corruption	Two-way fixed effect	EKC: Yes FDI: halo effect
Atici (2012)	ASEAN	1970-2006	FDI, export, export to Japan, US, and China	Fixed effect, Random effect	EKC: Yes (N-shaped) FDI: Halo impact Export to Japan and US: No impact Export to China: Increase pollution
Cho, Chu, and Yang (2014)	22 OECD countries	1971-2000	energy	FMOLS Unit root tests, Cointegration,	EKC: Yes only in 15 countries
Acaravci and Ozturk (2010)	19 European countries	1960-2005	energy	ADRL, Granger causality	EKC: Yes only in Denmark and Italy
Narayan and Narayan (2010)	43 developing countries	1980-2004		Income elastic comparison, Unit root tests, Cointegration	EKC: Yes only for 35% of the sample and for Asian and Middle East panel
Jaunky (2011)	36 rich countries	1980-2005		Income elastic comparison, Unit root tests, Cointegration	EKC: Yes only in Greece, Malta, Oman, Portugal and the UK

(Note: GDP stands for GDP per capita)

The EKC theory implies that the environmental degradation is a function of GDP and square of GDP. In literature, most researchers prefer the linear logarithm quadratic model to perform the relationship between environmental indicator, economic growth, and other controlled variables. Thus, in this study, after duly considering other method options, the following two-way fixed effect model is proposed to test the EKC hypothesis:

$$Ln(CO_2)_{it} = \beta_0 + \beta_1 LnGDP_{it} + \beta_2(LnGDP_{it})^2 + \beta_3 LnFDI^{dved}{}_{it} + \beta_4 LnFDI^{dvig}{}_{it} + \beta_5 LnTRADE_{it} + \alpha_i + \theta_t + \varepsilon_{itt}$$

$$FDI^{dved} = \frac{\textit{FDI from developed countries}}{\textit{Gross domestic product}} \text{x}100\%$$

$$FDI^{dvig} = \frac{\textit{FDI from developing countries}}{\textit{Gross domestic product}} \text{x}100\%$$

$$TRADE = \frac{\textit{Import+Export}}{\textit{Gross domestic product}} \text{x}100\%$$

The annual carbon dioxide emission (CO2) is selected as the environmental pollution indicator. GDP stands for the gross domestic product per capita in real term (in constant 2010 USD). FDI^{dved} is the ratio of the FDI inflow stock from developed economies as a percentage of the gross domestic product in a given year for a country. Meanwhile, FDI^{dvig} refers to similar variable attributed to the developing investor group. TRADE measures the level of trade openness as a proportion of both import and export to the same denominator. For example, FDI^{dved} of China in 2001 is its FDI-to-income ratio calculated from the sum of bilateral FDI stocks invested by all developed countries in that year. All variables are transformed into natural logarithm form to encourage stability in the variance-covariance matrix (Chang, Fang, & Wen, 2001). Last, α_i represents the individual effect of each nation, θ_t stands for the time effect of each year, and ε denotes the random disturbance. The conversions of trade and FDI into percentages of income are important to eliminate the effect of inflation and to make all economies with various scales comparable. FDI stock is used instead of FDI annual flow because it reflects the real influence of existing foreign companies better. After an investment is made, it circulates in the economy and continuously come back to its owner to generate profit for years to come. Besides, the accumulated stock data less suffers from market fluctuation, business circle and other year specific factors.

Annual data are obtained for the period between 2001 and 2012 from the World Development Indicators (WDI), UNCTAD, and the UN Comtrade Database. The panel data of the study covers 51 countries, including 28 developed and 23 developing nations. The full list of countries is attached below. The classification of countries into developed and developing groups follows the grouping system of the IMF[1]. The same criteria are applied to defined the two FDI investor groups. The period is limited by the availability of bilateral FDI data published on UNCTAD statistics website. Besides, the time series of 4 developing countries (Macedonia, Nigeria, Pakistan and Papua New Guinea) are discontinuous because of missing trade records in some years. Therefore, this is an unbalanced panel with a total of 601 observations. While the time dimension of the panel is not so long, its cross-sectional dimension is wider than most samples in previous research. It is considered sufficient to deliver statistically reliable results.

[1] There are many country classification systems from different international organizations, that causes controversy. The author has considered between the two most popular grouping catalogs by the IMF and UNCTAD. However, the IMF designation is selected because it has clearer criteria and closer to common sense about who are developed and who are developing countries. The findings of this study are robust with both ways of classifications. For detailed results of the model in the UNCTAD grouping setting, please contact the author.

Table 2. List of countries

28 Developed countries	23 Developing countries	
Australia	Argentina	
Austria	Armenia	
Canada	Bangladesh	
Czechia	Bulgaria	
Denmark	Cambodia	
Estonia	China	
Finland	Croatia	
France	El Salvador	
Germany	Hungary	
Greece	Macedonia	(no trade data in 2008)
Hong Kong	Republic of Moldova	
Ireland	Nigeria	(no trade data in 2004 and 2005)
Italy	Pakistan	(no trade data in 2001 and 2002)
Israel	Papua New Guinea	(no trade data from 2005 to 2010)
Japan	Paraguay	
Latvia	Peru	
Macao	Philippines	
Netherlands	Poland	
New Zealand	South Africa	
Norway	Thailand	
Portugal	Turkey	
Republic of Korea	Uganda	
Singapore	Ukraine	
Slovenia		
Sweden		
Switzerland		
United Kingdom		
USA		

The econometric process employed to estimate the panel is the two-way fixed effect within model. Basically, it is the extension of fixed effect model method to include a time-specific effect. This is the most suitable panel data techniques for this research because the relatively short time dimension of the data, limited by the accessibility of bilateral FDI records, does not allow complicated time series based techniques. Besides, the income elastic comparison approach suggested by Narayan & Narayan (2010) is interesting but do not allow the inclusion of additional variables which is important to deliver policy implications. Random effect model option is also dropped because such technique is not available for unbalanced panel with two-way fixed effect in R environment for statistical computing.

The same model will be run for the whole panel of 51 countries, then estimated separately for the two subpanels of developed and developing economies. If the U-shaped EKC is likely to take place, the coefficient of GDP will be positive while the coefficient of GDP squared is negative. It implies that the CO2 growth pace will get slower when the GDP increases, and then turns into a downward trend after reaching the turning point. The signs of trade and two FDI variables decide their impacts on environment. The negative sign is halo effect, while the positive sign means increasing pollution.

3. Results

3.1. Estimation

The estimation result is displayed below:

Table 3. Estimation by two-way fixed effect within model

Unbalanced Panel: n=51, T=6-12, N=601

Residuals :

Min.	1st Quarter	Median	3rd Quarter	Max.
-0.5980	0.0475	-0.0034	0.0479	0.4095

Coefficients :

	Estimate	Standard Error	t-value	Pr(>|t|)
LnGDP	2.7092	0.2201	12.3093	< 2.2e-16 ***
$(LnGDP)^2$	-0.1108	0.0128	-8.6508	< 2.2e-16 ***
$LnFDI^{dved}$	-0.1016	0.0209	-4.8696	1.475e-06 ***
$LnFDI^{dvig}$	0.0257	0.0088	2.9391	0.0034 **
LnTRADE	0.0906	0.0370	2.4510	0.0146 *

Significance codes: p. < 0.001 '***' p. < 0.01 '**' p. < 0.05 '*' p. < 0.1 '.'

Total Sum of Squares: 10.208

Residual Sum of Squares: 5.6656

R-Squared: 0. 4450

Adjusted R-Squared: 0. 3764

F-statistic: 85.6349 on 5 and 534 DF, p-value: < 2.22e-16

Overall intercept: 4.3923 (se: 0.9944)

The coefficients of GDP and GDP squared receive positive and negative signs respectively, featuring an inverted U-shaped curve between income and pollutant level. Both estimations have the 0.1% significance levels, a confirmation of the EKC hypothesis. Interestingly, FDI from developed countries and FDI from developing countries receive adverse signs. The estimation of FDI^{dved} is -0.1016 (0.1% significance), while one of FDI^{dvig} is 0.0257 (1% significance). Although the estimation for FDI for less developed economies is somewhat less remarkable in both value and consistency, the concrete result from the wealthier counterparts states clearly that different groups of investors exert opposite impacts on the environment. FDI from rich countries shows halo effect, benefiting the environment of host countries. Whereas, FDI from lower income group is associated with more pollution. It is worth to note that, given the same amount of investment, the green impact of developed investors is about four times outweighed the negative impact of developing ones. Taking into account that the developed countries still dominate the bigger share of global investment, the inferior impact of developing countries seems to be not striking. By a 5% confidence level, trade openness stands on the opposite side of sustainability. The rapid increase of international trade invokes environmental degradation. The goodness-of-fit, measured the adjusted R-squared, implies that 37.64% of the total variation in CO2 explained by the regression model. This is a noteworthy level for panel data with wide cross-sectional dimension. F-statistic also has a near 0 p-value. Therefore, the null hypothesis that all the coefficients are equal to 0 is rejected. The extracted overall intercept is 4.3923 with a standard error (se) of 0.9944. The model now can be rewritten as:

$$Ln(CO_2)_{it} = 4.3923 + 2.7092\ LnGDP_{it} - 0.1108\ (LnGDP_{it})^2 - 0.1016 LnFDI^{dved}_{it} + 0.0257 LnFDI^{dvig}_{it} + 0.0906 LnTRADE_{it} + \alpha_i + \theta_t + \varepsilon_{itt} \quad (1)$$

However, calculated from equation (1), the level of GDP at the turning point where emission starts to decrease as income increase is very high, at 203,950 constant 2010 US Dollar. This figure is questionable because it is much higher than ones estimated by previous studies, which range from 15,500 to 68,900 US Dollar in 2010 price (Moomaw & Unruh, 1997; Yandle, Vijayaraghavan, & Bhattarai, 2002). It is possible that the EKC is strongly valid in a part of the panel but insignificant in the other part, misleading the estimation of the turning point for the whole panel. Therefore, the model and the turning point are then estimated for two subpanels, developed and developing country groups. Table 4 compares the main panel and two subpanels:

Table 4. Validity of the model in developed and developing subpanels

	51 countries	**Developed panel**	**Developing panel**
LnGDP	2.7092 ***	0.1635	3.4297 ***
(LnGDP)2	-0.1108 ***	0.0178	-0.1710 ***
$LnFDI^{dved}$	-0.1016 ***	0.0008	-0.1530 ***
$LnFDI^{dvig}$	0.0257 **	0.0172 .	0.0282 .
LnTRADE	0.0906 *	-0.0407	0.2445 ***
R-Squared	0. 4450	0.2155	0.4428
Adjusted R-Squared	0.3764	0.1000	0.3491
Turning point GDP (2010 US Dollar)	203,950	No turning point	22,660

Significance codes: p. < 0.001 '***' p. < 0.01 '**' p. < 0.05 '*' p. < 0.1 '.'

Both subpanels are suffered from the shrunk sample sizes, which undermine the adjusted R-squared and some confidence levels. However, there are remarkable differences between the developed and developing groups. Neither a U-shaped curve relationship nor a turning point is featured by the developed-country panel. There is no clear pattern between GDP and CO2 at any confidence level, either. In contrast, the developing panel demonstrates similar results to that of the whole sample. This result is surprising to many because the EKC is regarded as more likely to happen in rich regions. Comparing the two subsamples, a possible explanation is that developed countries have moved to the higher position on the development course where carbon emissions have been stable, and the growth rates have been slowed down, which make the fixed effect model difficult to capture the relationship at this sample size. The model bases its estimation on variations within each country from one year to the next. Because these variations are small for developed countries, it is difficult to observe the pattern of this subgroup. Besides, there is no explicit implication of trade and developed-country FDI for the environment of developed host economies. Only some adverse impacts of FDI from developing investors still exist in this subpanel (10% significance). However, it is hard to reach any solid conclusion because the goodness-of-fit of the model is humble with the modest value of the adjusted R-squared (0.1).

In comparison, the EKC hypothesis is confirmed in the developing panel. All variables keep the same signs as the aforementioned results. All of their coefficients are confident though significance levels of TRADE and FDI^{dvig} have changed. Nevertheless, the absolute values of the parameters of all three additional variables are higher than that of the whole sample. It seems that policy implications of the model are more applicable for developing countries. The environment in less developed regions is more sensitive to the impacts of FDI and trade. The technology gap between developed and developing countries make the later witness greater improvement when knowhow transfer is facilitated by FDI from advanced investors, but their institutional weaknesses constrain them to prevent adverse influences of globalization in the environment of their countries. The turning point for developing subgroup is 22,660 US Dollar, which is ten times lower than the estimation of the whole panel, and stays within the normal range of previous studies. It could be the complication of the developed-country pattern that has confused the turning point calculation for the all-country panel. However, even this more reasonable turning point is still high for many developing countries of lower income, which is difficult to be realized in near future. Moreover, it is necessary to note that this is only a prediction of the average GDP per capita at the turning point as there is no fixed level for all countries (Moomaw & Unruh, 1997). The lower income a developing country is, the greater political effort required to achieve the transformation point sooner.

The results, especially in the developing-country subgroup, well verify the case of China, reported by Deng and Song (2008). China, the biggest receiver of FDI from developed investors and the global giant exporter of commercial goods, has experienced the green impact of foreign investment but paid a heavy environmental cost for export escalation. Meanwhile, it contradicts Zeng and Eastin (2012) who state that MNCs from developing regions put extraordinary effort into voluntary pollution abatement practices (ISO14001). This paper argues that ISO14001 is not a good proxy for pollution reduction capacity of all developing investors. Because it is not conducted by every MNC, it does not represent the property of the whole population. Furthermore, the findings of FDI stock variables in this research are more concrete than that of studies controlling FDI flow regressors (Atici, 2012; Neequaye & Oladi, 2015) since the inflow variables are more prone to market fluctuation, business circle and other year specific factors.

3.2. Individual effect

The individual effect extracted for each country is correlated with the average carbon dioxide emission of that nation (after taking natural logarithm). The regression between them is illustrated in the following scatter diagram. The bigger amount of emission a country releases, the closer to zero its individual effect. With the goodness-of-fit denoted as R^2 at 0.71677, approximately 72% of this relationship can be explained by the OLS. Meanwhile, the time effect ranges from -4.3432 to -4.4411, that is not greatly varied over the years. It implies that after adjusted by individual effect, big emitters have their individual equation nearer to the core part of Model 1, which is decided by independent variables. In other words, the major polluters influence the panel estimator to greater extent. Apparently, the USA (-0.8096) and China (0.9220), the two global biggest emitters, most influence the estimation with the smallest absolute values of individual effect.

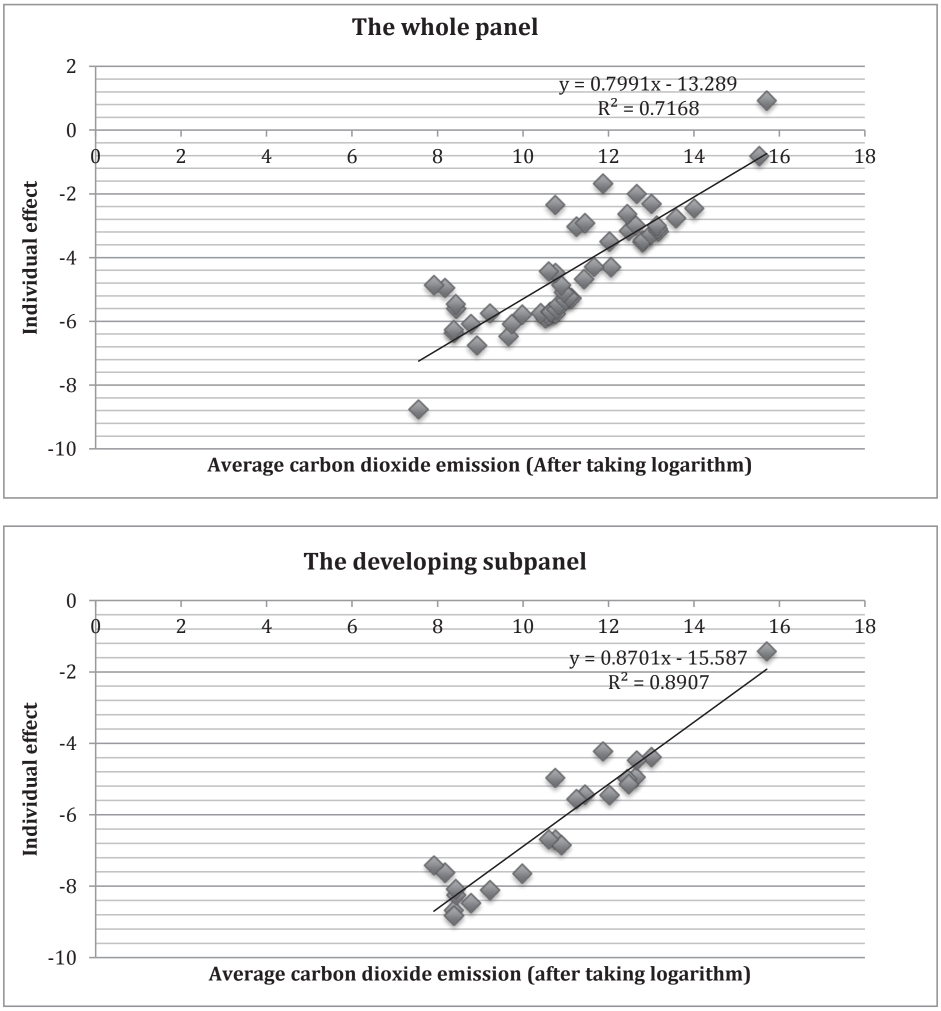

Figure 3. Country's individual effect and its average CO_2 emission.

Table 5. Country positions in comparison with the regression line in Figure 3

The whole panel			
Under the regression line		Above the regression line	
Australia	Israel	Argentina	Poland
Austria	Japan	Armenia	South Africa
Croatia	Latvia	Bangladesh	Thailand
Canada	Macao	Bulgaria	Turkey
Czechia	Netherlands	Cambodia	Uganda
Denmark	New Zealand	China	Ukraine
Estonia	Norway	El Salvador	**USA**
Finland	Portugal	Macedonia	
France	Republic of Korea	Republic of Moldova	
Germany	Singapore	Nigeria	
Greece	Slovenia	Pakistan	
Hong Kong	Sweden	Papua New Guinea	
Hungary	Switzerland	Paraguay	
Ireland	United Kingdom	Peru	
Italy		Philippines	

The developing subpanel			
Under the regression line		Above the regression line	
Argentina	Republic of Moldova	Bangladesh	Uganda
Armenia	Paraguay	Cambodia	Ukraine
Bulgaria	Peru	China	
Croatia	Poland	Nigeria	
El Salvador	South Africa	Pakistan	
Hungary	Thailand	Papua New Guinea	
Macedonia	Turkey	Philippines	

The individual effect also contains information of a country's economic structure. It explains the variation of each country from the regression line. If a country stays below the line, it seems to have greener economic structure than a country with the same level of emission but above the line. China, the only country with positive individual effect (0.9220), has similar emission scale to the USA. However, as China locates at a higher position in the graph, its economy more relies on heavily polluting industries. The two countries are dominating players in the model, but they belong to different development levels. While the rapid expansion of Chinese economies heavily relied on fossil fuel energy, thus boosting carbon dioxide emission, pollutant level of the USA is stable due to its slower growth rate and more energy-effective structure. Besides, the USA may have some merit over China because of its institutional and regulatory foundation. However, the USA itself has more heavy industries than other developed countries. In 29 countries under the regression line, 27 is developed countries (except Croatia and Hungary), whereas the USA is the only developed country marginally above the line. Macao (-8.7555) has the smallest value of individual effect because of not only its small scale but also its mostly-service-sector economy.

The same relationship can be illustrated for country effects of the developing subpanel. Among this group, countries locating under the regression line have relatively greener economic structures. Whereas, for the rest of the group (China, Bangladesh, Pakistan, Cambodia, Philippines, Nigeria, Papua New Guinea, Uganda and Ukraine), it may take greater effort to transform their economies toward environmentally friendly structures.

3.3. Robustness checks

Robustness check is the process examining how critical regression coefficients change when the model is altered, typically by adding or removing variables (Lu & White, 2014). Robustness checks are conducted for the whole panels and two subpanels. In Model 2 and Model 3, TRADE and FDI^{dvig} are dropped respectively. Then, TRADE is divided into $TRADE^{dved}$ (trade with developed countries) and $TRADE^{dvig}$ (trade with developing countries) in Model 4.

Table 6. Robustness checks

51 countries				
	Main model	**Model 2**	**Model 3**	**Model 4**
51 countries				
LnGDP	2.7092 ***	2.8427 ***	2.6017 ***	2.772 ***
$(LnGDP)^2$	-0.1108 ***	-0.1221 ***	-0.1055 ***	-0.1146 ***
$LnFDI^{dved}$	-0.1016 ***	-0.1012 ***	-0.0891 ***	-0.0977 ***
$LnFDI^{dvig}$	0.0257 **	0.0245 **		0.0255 **
LnTRADE	0.0906 *		0.0917 *	
$LnTRADE^{dved}$				0.0326
$LnTRADE^{dvig}$				0.0273
28 developed countries				
LnGDP	0.1635	-0.1256	-0.0004	0.1887
$(LnGDP)_2$	0.0178	0.0333	0.0253	0.0148
$LnFDI^{dved}$	0.0008	-0.0067	0.0074	0.0035
$LnFDI^{dvig}$	0.0172 .	0.0182 .		0.0172
LnTRADE	-0.0407		-0.0523	
$LnTRADE_{dved}$				-0.0016
$LnTRADE_{dvig}$				-0.0608
23 developing countries				
LnGDP	3.4297 ***	3.4349 ***	3.3362 ***	3.5345 ***
$(LnGDP)^2$	-0.1710 ***	-0.1798 ***	-0.1656 ***	-0.1796 ***
$LnFDI^{dved}$	-0.1530 ***	-0.1669 ***	-0.1339 ***	-0.1509 ***
$LnFDI^{dvig}$	0.0282 .	0.0413 *		0.0227
LnTRADE	0.2445 ***		0.2678 ***	
$LnTRADE^{dved}$				0.0633
$LnTRADE^{dvig}$				0.1519 ***

Significance codes: $p. < 0.001$ '***' $p. < 0.01$ '**' $p. < 0.05$ '*' $p. < 0.1$ '.'

For the whole panel and developing subpanel, all variables maintain their sign across model variations. Significance levels of GDP, GDP square, TRADE and FDI^{dved} are also unchanged. The estimations of FDI from developing regions are solid in the whole panel, but its significance level is altered among models in the developing subgroup panel. Meanwhile, there is still little meaningful result gained from the developed country subgroup. The robustness checks confirm that the aforementioned findings are robust against the alteration of model specifications, especially for the EKC, developed countries' FDI and trade openness in the main panel and developing subpanel.

4. Conclusions

By and large, the study confirms the validity of the EKC in a panel of 51 countries and its subpanel of 23 developing countries, taking into account the influence of FDI and the level of trade openness. The robustness of the model again specification alterations are also confirmed. Although this research is limited in explaining the pattern of the developed-country subgroup which requires further study, the concrete findings in the developing subgroup show that environment in countries of lower income is more sensitive to the globalization progression. Thus, the implications of this study are of great importance to their governments. The opposite effects of the two FDI flows explain why until now researchers have been confusing about the effect of cross-border investments. If incorporated into a single variable, they will neutralize the impact of each other, and the significance level will be undermined. On one hand, the greater magnitude of the regressors found in the developing subgroup supports Doytch and Uctum's argument that domestic factors of a host country influence the attitude of investors toward environment protection (2011). On the other hand, the study adds that the development stage of an investor country also has critical influence in the environmental orientation of its international investments. This is the most important contribution of the paper to literature. The findings on developing-country FDI and trade, though not as significant and robust as one on developed-country FDI, are interesting because they contradict Zeng and Eastin (2012) and the well-known Antweiler, Copeland and Taylor (2001). Although Zeng and Eastin argue that investors from developing economies tend to voluntarily commit to higher pollution abatement requirements in host countries, it seems that MNCs from those regions are still greatly hindered by their financial and regulatory competence. Besides, there is some doubt about Antweiler, Copeland and Taylor's conclusion that technical effect of trade outweighs scale effect to benefit the environment.

These results deliver important policy implications to governments, especially in developing countries. First, all countries should enhance the screening of FDI to limit harmful impacts of outdated techniques and promote know-how transfer. Policy makers, especially in developing countries, should bring up strategies to attract FDI from technical-intensive investors.

However, while the FDI from developed countries shows strong halo effect, that should not be interpreted that FDI from developing countries is totally undesirable. From an emerging economy's point of view, a better understanding is that their MNCs should respect the global standard of pollution abatement and commit to best environmental practices to make their investments become more attractive outside the border. Given the integration tendency among developing countries to enhance their political and economic positions, it is critical that the process should pay due attention to limit environmental adverse impact arising from trade and investment within the same group. Second, developing governments should carefully reexamine their FDI-led and export-led growth strategies. While the efficiency of these strategies is questioned by recent research (Herzer, Klasen, & Nowak-Lehmann D., 2008; Pao & Tsai, 2011), unsophisticated and indifferent pro-FDI and pro-trade policies can trigger long-term environmental costs. Third, international effort needs bringing up to address the trade distortion by environmental cost externalization, which is undermining the positive side of trade in contribution to sustainability. In other words, fair trade should be favored instead of free trade. Future multinational trade and investment agreements should include a carefully tailored environmental framework to facilitate the adoption of higher pollution abatement requirement and to limit the negative side of trade, especially in developing countries. Last but not least, from the individual effect analysis, every country can understand their position in the global environment-growth nexus and foresee the degree of challenge they will face to pursue sustainability. By and large, this paper agrees with Moomaw & Unruh (1997) that the turning point of the EKC is a political effort more than a conspicuous outcome of development.

The research pays the ways for further investigations. First, it suggests a new hypothesis that polluting industrial migrations might currently happen among developing countries at different levels of development, rather than between rich and poor nations as proposed by the original pollution haven hypothesis. Second, the inclusion of other factors such as corruption or environmental regulation stringency may provide more insights and implications. Third, the country-of-origin factor of FDI can be tested against the host-country factor to see how domestic setting affects FDI from different regions. Last, other models can be brought up to test the developed-country subpanel, which is not explained thoroughly by this research. All mentioned above is a source of inspiration for future studies.

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