Export diversification, CO_2 emissions and EKC: panel data analysis of 125 countries

Abstract

This study explores the applicable stipulation of cross-country regression analysis of international trade and carbon emissions using data on export diversification across 125 countries from 2000 to 2014 at the HS4 digit of disaggregation. Export diversification is subdivided into vertical and horizontal diversification in order to justify its correlation with pollution emission through scale effect, technique effect as well as composition effect. We use a regression model with Driscoll and Kraay standard errors to rectify the possible problems of heteroskedastic and autocorrelated error structure. Results demonstrate that both export market diversification and product diversification help CO_2 emission mitigation in 125 countries. Besides, interaction terms of economic development and export diversification facilitate the comparison among different income levels: low income countries illustrate U-shaped relationship between economic development and CO_2 emissions, while OECD countries still maintain inverted U-shaped EKC curve which is unanimous with the outcome of 125 countries in general.

Keywords

Environmental Kuznets Curve (EKC), Herfindahl-Hirschman Index (HHI), Export Product Diversification, Export Market Diversification, Carbon Dioxide (CO_2) emissions, Driscoll and Kraay standard errors

1. Introduction

Global warming and climate change exert great challenges to world environment in the 21st century (Saboori et al., 2016). The 2015 Paris conference on climate change acted as a threshold to encourage reducing greenhouse gases emission in order to deal with deteriorating global warming circumstances. The

International Panel on Climate Change (IPCC) fifth assessment report pointed out that human activities influence climate system obviously (Özokcu and Özdemir, 2017). Besides being a natural phenomenon, climate change has been more related with human activity and economic development. CO2 emissions are commonly regarded as one of the major source of global warming, due to the large amount of CO2 released into the atmosphere that came from fossil energy consumption (Friedl and Getzner, 2003). Potential threats deriving from climate change has created a debate on how to balance the expenditure and benefit of reducing anthropogenic greenhouse gases emissions (Holtz-Eakin and Selden, 1995).

Environment Kuznets Curve is one of the most influential model for analyzing the relationship between environment and economic development. EKC simulate a hypothesized inverted U-shaped relationship between various indicators of environmental degradation and economic development: pollution emission at first rises with economic growth, after going through a certain turning point, the trend reverses, with further economic development, environment condition gets improved. The correlation between pollution and trade could be explained by the renowned three effects theory: scale effect, technique effect and composition effect. “Scale effect” is defined as: an increase in emissions related to a higher income, holding everything else constant (e.g., production mix of goods). In detail, the scale effect measures the effect on pollution of an increase in the economic size that results from income-driven growth in production. “Technique effect” is characterized as the change in emission intensity due to access to new technologies (e.g., cleaner technologies). Technique effect is correlated with the transformation in the production technology of a given industrial sector (Cole, 2004; Copeland and Taylor, 1995). “Composition effect” is designated as a change in emission due to the adjustment in the share of dirty goods production in GDP. Composition effect measures the influence of a change in industrial composition, unlike technique effect or income effect, composition effect could be either positive or negative (Garetti and Taisch, 2012).

In the empirical test of EKC, two groups of variables are needed, pollution indexes and economic development ones. Pollution itself is a conceptually simple idea, however, the choice of pollutants could be perplexed due to its wide scope and uncertain adaptation to economic analysis (Brajer et al., 2011). EKC concludes what is well understood and applied as the inverted U-shaped relationship between pollution and economic development: environmental deterioration first increases as a country's economic development increases, then after reaching a turning point, environment situation starts to improve. The pioneering work upon environment EKC by Krueger and Grossman in 1991, tested the relationship between trade and environment. In order to analyze the mechanism behind this U-shaped relationship, the influence of trade on environmental degradation was decomposed into three perspectives: scale effect, compositon effect and technique effect (Grossman and Krueger, 1991).

We adopt an intermediate approach, using panel database to analyze the reduce-form relationshp between per capita income, export diversification and emissions. The employment of export diversification into the existing vast majority of explorations of EKC studies permits the testification of possible relationship between trade structure and pollution, especially under the background that most former researches focusing on economic volumes (GDP, trade volume) as main indicators for economic development. Export diversification is an important reflection of the structure of trade and economic development, therefore in a research concerning analyzing the relationship between economic development and pollution, export diversification should not be negalected. Apart from theoretical implications, estimating the correlation between diversification and pollution is supposed to remind policy makers to diverse part of their attention on the quantity of trade and GDP to the structure perspective when dealling with pollution related issues. In order to further enrich the research of EKC, especially in trade discipline, the present work is proposed to adopt export product diversification and market diversification in analysis process. Put it another way, understanding whether trade structure and pollution are correlated within EKC hypothsis both theoretically and empirically will be one of the themes of this research. Distinctive to structural models, reduced-form analysis does not require a priori knowledge on parameters that will be adopted (Holtz-Eakin and Selden, 1995).

We believe that this paper contributes to a number of strands in the recent literatures concerning sustainable development and trade. First, by collecting and reorganizing a relative complex panel database including economin development proxies, export diversification as well as pollution emission, it enables the possibility of analyzing the complicated relationship between export diverisifcation and sustainable development. Second, by taking advantage of a reduce-form EKC model, the current study do not rely on strong theoretical assumptions tht are indispensible in models tht use the structural form. Third adoptation of interaction terms does not facilitate boosting estimation robustness and model efficiency, but also, enables comparison among countries groups based on income discrepancy. Lastly, present research is supposed to function as a reminding to policy makers: when it comes to sustainable development, compares to economy volomes which has long been the focus, economic structure such as export diversification need better attention.

The rest of the paper is organized as follows. Section 2 displays literature review concerning former studies of EKC theory and related econometric technology. Section 3 explains theoretical model, and the econometric methodology. Section 4 provides the data description and an empirical model application. Section 4 examines the empirical results and suggests policy implications. Section 5 presents conclusions.

2. Literature review

Discussions regarding the relationship between economic growth and environmental quality attract much attention among scholars from 1960s to now. Considering the large amount, literature review will be organized into 5 parts.

2.1 Indicators

Two necessary variables are needed in the empirical estimation of EKC study, pollution indexes and economic development ones. Pollution itself is a conceptually simple idea, however, the choice of pollutants could be perplexed due to its wide scope and uncertain adaptation to economic analysis (Brajer et al., 2011). As is shown in table 1, single pollution emission indicators such as sulfur dioxide, soot discharge or nitrogen dioxide emissions are adopted in existing EKC studies (Heil and Selden, 2001; Stern and Common, 2001;

Yaguchi et al., 2007). Besides emission volume, ambient pollution intensity as well as nemerow index are also popular indicators for proximating pollution in recent EKC studies (Bekhet and Yasmin, 2013; das Neves Almeida et al., 2017; Liu et al., 2007; Stern and Zha, 2016). With the development of data accessability, scholars tend to choose variables that is capable of concluding more information in one data list, for example, ecological footprint (Al-Mulali et al., 2015; Caviglia-Harris et al., 2009). Another necessary variable in EKC study is economic development indicator, the indexes that have been analyzed so far include: per capita GDP, trade intensity, trade openness, import export volume, the percentage of trade volume in GDP (Copeland and Taylor, 2004; Cui et al., 2016; Grossman and Krueger, 1991; Selden and Song, 1994).

Population density also is a factor that showed up in some recent EKC studies (Lee et al., 2009). In this work, population density is negatively correlated with CO2 emissions, which means higher population density is benefitial to pollution alleviation. This result is distintive with most EKC research and also opposite to the essence of scale effect. GINI index is a cutting-edge independent variable in EKC study, which help comprising the power inequality factors in exiting researches (Torras and Boyce, 1998).

As a new variable we intend to add into EKC model, literatures concerning trade diversification will be briefly discussed. In former researches, diversification of export products and markets destination is regarded as means to meet the challenges of unemployment and lower growth in many developing countries, such as China, Chile, Pakistan, Costa Rica, Mauritius (Akbar et al., 2000; Ali et al., 1991; Amurgo-Pacheco, 2008; Ferreira and Harrison, 2012; Juvenal and Santos Monteiro, 2013; Rondeau and Roudaut, 2014; Samen, 2010a; Seetanah et al., 2012; Xuefeng and Yaşar, 2016). The reason could be stemmed from the fact that, developing countries are heavily dependent on export. There was one scholar first adopt export product diversification in EKC study, by using a dataset of Turkey, he came to a conclusion that: in the long run, greater product diversification leads to higher CO2 emissions (Gozgor and Can, 2016b).

2.2 Function

Independent variables in squared (Yaguchi et al., 2007), three dimensions (Lee et al., 2009) cases are most common in EKC research. Squared terms are indispensable to EKC studies, both inverted U-shaped curve or U-shaped curve are prospected to be emulated through squared terms in regression. Cubed terms are improvements scholars made to expand the heterogeneity of EKC research and to test whether two turning points will appear or not.

Interaction terms introduced by Heil and Selden is another inspiring point belongs to function sphere, which enjoyed the advantage of enabling the comparison among countries in different income levels, especially in cross-sectional analysis (Heil and Selden, 2001).

2.3 Data set

Cross-country (Heil and Selden, 2001; Shafik and Bandyopadhyay, 1992), panel data (Lee et al., 2009; Liddle, 2015; Nemati et al., 2016; Niu et al., 2011; Perman and Stern, 2003; Sirag et al., 2018), single country (Gozgor and Can, 2017; Halicioglu, 2009; Saboori et al., 2012, 2016; Shen and Hashimoto, 2004), city (Diao et al., 2009; Liu et al., 2007), provincial level (Wang et al., 2013) are commonly used data scopes in EKC related studies, among the published journal papers, panel data is becoming a more popular choice for most scholars, which could be explained by the advantages of panel data itself. Panel data allows controlling for variables that cannot be observed or measured like cultural factors or difference in business practices across companies; or variables that change over time but not across entities (Hsiao, 2014).. Estimation results from different dataset demonstrated exert great divergence.

2.4 Estimation methods

Estimation methods used in EKC research can be organized into static ones and dynamic ones. Fixed effect (Heil and Wodon, 1997), random (Brajer et al., 2011), CGE (Copeland and Taylor, 2005) are concluded into the static group. For some cases, comparison among different methodologies are available in EKC research (Stern and Common, 2001; Yaguchi et al., 2007). The choice among different estimation methods is in accordance with data availability and function entity.

Apart from the above mentioned static estimation methodologies, dynamic research on EKC is also worth mentioning (Agras and Chapman, 1999; Dinda, 2008; Lee et al., 2009; Saboori et al., 2016; Sirag et al., 2018). In Agras's work, long-run models were used to estimate the relationship between environmental degradation and income, the result displayed no significant evident for the existence of an EKC relationship based on their data base. Lee reexamined the rationality of EKC through dynamic panel data approach (DPM) and found evidence of EKC hypothesis for CO_2 emissions through a global data set. Their outcome claimed that as international trade openness increases, environmental quality will increase in high-income countries while deteriorate in low-income countries. Cointegration test among single country's time series data in EKC sphere is another research perspective, cointegration test allows both long-term and short-term causality test by using ARDL (Auto Regressive Distributed Lag) methodology.

2.5 Outcome

The results of studies on EKC theory are disputed. Most of the literature on EKC demonstrated that the level of CO_2 emissions usually increase monotonically with per capita income (Selden and Song, 1994; Shafik and Bandyopadhyay, 1992; Song et al., 2008). Fewer studies have focus on estimations of EKCs for carbon emissions for a panel date set of OECD countries and individual time-series regressions for each of the countries in the panel (Dijkgraaf and Vollebergh, 2001). Though EKC theory is an essentially empirical phenomenon, not all estimates of EKC models estimated by so far are statistically robust. In some researches, no meaningful EKC can be found in global sphere while several robust relationships between income and emissions can be discovered in individual countries. While concentrations of some local pollutants have clearly declined in developed countries and so have emissions of some pollution factors, there is still no consent agreement on the drivers of changes in emission (Stern, 2015). EKC hypothesis advocates that pollution increases initially as a country improves in economic performance; and then declines after reaching a certain level of economic progress, a turning point. Pollution deteriorates at early stage of economic development, which is partly due to the reason that polluting industries' setting up in this phase (Jayanthakumaran et al., 2012). The existence and value of turning point also varies in terms of dataset, estimation methods etc. (Grossman and Krueger, 1995; Shafik and Bandyopadhyay, 1992; Stern, 2017)

Table 1. 1 A summary of literatures on empirical EKC research

Author	Dependent variable(s)	Independent variable(s)	Type of function	Regression method	Turning point	Country and time
(Grossman and Krueger, 1991)	So2, Dark matter, suspended particles	Per capita GDP	GDP cubed, plus sites dummies	Random effect	Around 4,000 USD for the first two pollutants	42 countries
(Shafik and Bandyopadhyay, 1992)	SPM, SO2, Deforestation etc.	GDP in log, trade openness, interaction dummies, time trend	Linear, squared, cubed	regression	3,670 per capita USD for SO2	149 countries from 1960 to 1990
(Panayotou, 1993)	Deforestation	Income per capita, population, interaction term	Interaction term, GDP	Cross section	800 to 1,200 USD per capita	68 developing countries and developed ones
(Selden and Song, 1994)	SPM, SO2, NO2, CO	Per capita GDP, population density, time dummies	GDP squared	Fixed, random effects	Around 10,292 USD	68 countries from 1979 to 1984
(Grossman and Krueger, 1995)	SO2, smoke, heavy particles	Income, lagged income, dummies, population density	Lagged GDP cubed	GLS	Around 8,000 USD	42 countries
(Cole et al., 1997)	SPM, SO, NO, CO	Per capita income	Logarithm squared	OLS and GLS	5,700 USD to 25,000 USD	1970 to 1992, OECD countries
MARK T. HEIL and THOMAS M.SELDEN(2001)	Per capita Carbon Emissions	Per capita GDP, Trade intensity, interaction term of trade and GDP	Income squared	Country Fixed Effect	7,000 USD	132 countries from 1950 to 1992

Stern and Common (2001)	Per capita emission of Sulfur	Per capita GDP with ppp	Income squared	Fixed and Random	101,166 USD	World , OECD countries, non OECD countries
(Agras and Chapman, 1999)	CO2 emissions	Per capita GDP, lagged variables, energy price	Income squared	Dynamic model	13,630 USD	33 countries and region 1991
(Torras and Boyce, 1998)	SO, smoke, heavy particles, fecal coliform	Per capita income, power inequality variables	Income cubed	OLS	4,000 to 15,000 USD	Low-income countries
YUE YAGUCHI, TETSUSHI SONOBE (2007)	SO_2, CO_2 emission per area	Per capita GDP, per capita GDP square, three time dummies	Income squared	Fixed plus Random	Japan had in SO_2	China and Japan from 1975 to 1999
(Lee et al., 2009)	CO2 emissions per capita	GDP, population density, exports and imports relative to GDP, energy use	Income cubed	Random and fixed	8,570 to 17,620 USD	89 countries from 1960 to 2000
(Özokcu and Özdemir, 2017)	CO2 emission	Per capita income, per capita energy use	Income cubed	Driscoll-Kraay standard error	none	78 countries, from 1980 to 2010

Via this brief form, we could clearly observe the evolution and development of empirical EKC research. Specifically, independent variables expand from single GDP per capita to energy price, energy consumption even GINI index.

The five parts of literature review are logically connected with each other: the choice of indicators, data set as well as function determines the results, the conditions of the data available influence which analyzing function to employ. Innovations are made during all years of development on EKC hypothesis, expansion of dataset from single countries into panel data including various countries and broaden time ranges.

Among all literatures concerning EKC theory, most studies, including the aforementioned, use GDP or trade volume as proxy variables for economic development, as a result, the structure of trade and a decomposition of economic development are ignored. Our proposed research thus adopts export product diversification and market diversification as two innovative proxy variables for economic development, in order to capture the structure characteristics of international trade in EKC study.

3. Theoretical model

EKC hypothesis advocates that pollution increases initially as a country improves in economic performance; and then declines after reaching a certain level of economic progress, a turning point. Pollution deteriorates at early stage of economic development, partly due to the reason that polluting industries' setting up in this phase (Jayanthakumaran et al., 2012).

3.1 Pollution and growth

The pollution demand is denoted as

$$z = \bar{e}x(p, \overline{\tau, K, L}) \qquad (1.1)$$

Where, $\tau = \bar{\tau}$ which is the fixed pollution tax; $\bar{e}$ is fixed emission intensity; p is the world prices; K represents capital; L is labor

Income is $I = G(p, K, L, z)$

Where z is determined endogenously by (1.1).

After the determinant of pollution demand and income, now consider growth via capital accumulation alone. Then differentiating (1.1), (1.2) holding L constant, yields

$$\hat{z} = \varepsilon_{XK} \hat{K} \tag{1.3}$$

And

$$\hat{I} = s_r \hat{K} + s_\tau \hat{z} \tag{1.4}$$

$s_r > 0$ and $s_\tau > 0$ are the shares of capital and emission charges in national income, $\hat{z} = dz / z$ and so on, and $\varepsilon_{XK} > 0$ is the elasticity of X output with respect to the endowment of capital, which is positive by Rybczinski theorem. Through 1.3 and 1.4, here came the result:

$$\hat{z} = \frac{\varepsilon_{XK}}{s_r + s_\tau \varepsilon_{XK}} \hat{I} \tag{1.5}$$

This equation contributed to understand that there is a positive, monotonic relation between pollution and income when growth occurs through the factor used intensively in the pollution intensive sector.

Alternatively, suppose growth occurs via accumulation of human capital, then we have,

$$\hat{z} = \varepsilon_{XL} \hat{L} \tag{1.6}$$

Where, $\varepsilon_{XL} < 0$ is the elasticity of X output with respect to the endowment of human capital. Note that $\varepsilon_{XL} < 0$ follows from the Rybczinski theorem of international trade: human capital accumulation stimulates the clean industry Y, which squeeze resources out of the dirty industry X and lowers pollution. The effect of human capital accumulation on income is:

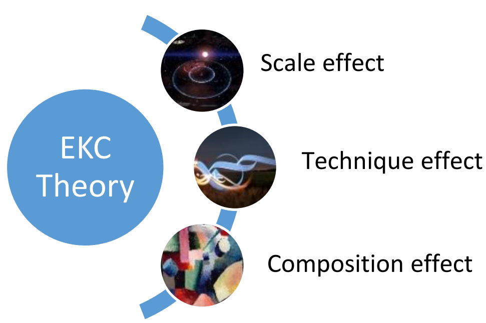
$$\hat{I} = s_w \hat{L} + s_\tau \hat{z} = (s_w + \varepsilon_{XL}) \hat{L} \tag{1.7}$$

Where $s_w > 0$ is the share of human capital in national income. Although the coefficient of $\hat{L}$ has both a positive and negative term, the increase in the supply of labor must raise national income, despite the drop in pollution. This follows from looking at the net production frontier, and so on, given prices and the fixed emissions intensity, income must increase (Copeland and Taylor, 2013).

3.2 Pollution and trade

The correlation between pollution and trade could be explained by the renowned three effects theory: scale effect, technique effect and composition effect. “Scale effect” is defined as: an increase in emissions related to a higher income, holding everything else constant (e.g., production mix of goods). In detail, the scale effect measures the effect on pollution of an increase in the economic size that results from income-driven growth in production. Beside production section, scale effect had also been empirically estimated by Managi that there is a positive relationship between trade openness on CO2 emissions for non-OECD countries, offering suggestive evidence for scale effect from trade-driven increases in industrial production (Managi et al., 2009).

Figure 1. 1 Three effects embedded in EKC theory



“Technique effect” is characterized as the change in emission intensity due to access to new technologies (e.g., cleaner technologies). Specifically speaking, technique effect is correlated with the transformation in the production technology of a given industrial sector. Ceteris paribus, imagine that a producer introduces more environmental friendly production technique, thus reducing energy consumption or pollution emissions per unit of economic activity within the sector (Cole, 2004; Copeland and Taylor, 1995).

“Composition effect” is designated as a change in emission due to the adjustment in the share of dirty goods production in GDP. Composition effect measures the influence of a change in industrial composition, unlike technique effect or income effect, composition effect could be either positive or negative. For instance, a shift in an economy from relatively clean industry (e.g., tertiary industry) towards relatively polluting intensive industries such as food processing and cement production are regarded as a composition effect, which will induce an increase in energy consumption as well as pollution emission. On the other side, composition effect could also be positive if the transformation is turned backward. Input-output table is very useful in deciding what the effect would be of an increase in the demand for one production sector. Searching deeper from this sector, not only does the output of this certain sector will increase, but also, all of the inputs into supply chain of a product of this sector will finally lead to an increase in pollution emission (Garetti and Taisch, 2012).

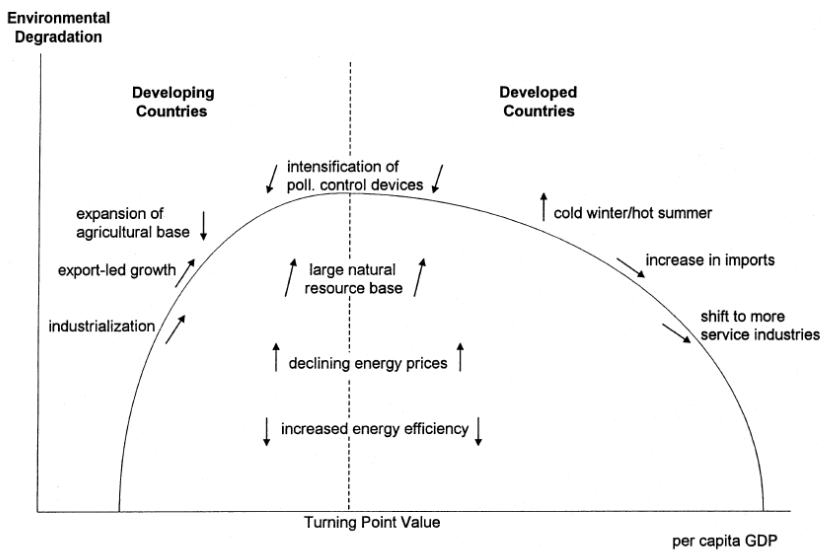
To integrate the four explanations of EKC assumption, there came out the idea that regressions that allow levels of environmental impact to become zero or negative are not suitable unless in the case of the net rates of change of the stock of renewable resources. And therefore, the standard EKC regression model is:

$$Pollution = \alpha_i + \gamma_t + \beta_1 GDP + \beta_2 GDP^2 + \varepsilon_{it} .$$

Where, pollution is the emission of CO_2, to measure the air pollution degree; GDP is the domestic product per capita; ε_{it} is a random error term. i indexes countries and t as time indicator. The first two terms on the right-hand side of the equation are country and time effects. The assumption is that, though the level of emissions per capita may differ over countries at any particular income level, the elasticity of emissions with respect to income is the same in all countries at a given income level (Proops and Safonov, 2004). The time effects are intended to account for time varying omitted variables and stochastic shocks that are common to all countries. It is possible to observe the "turning point" level of income, τ, where emissions or concentrations are at a maximum as follows (Stern, 2015),

$$\tau = \exp(-\beta_1 / 2\beta_2)$$

Figure 1. 2 A detailed graph of EKC (Agras and Chapman, 1999)



Besides scale effect, technique effect and composition effect, time effect is also proposed to be considered when analyzing the credentials EKC effect. Time-related effects, aimed to modulate technological transformation to all countries, reduce environmental impacts in all states at all levels of income (Stern et al., 1996). The effects of time-related factors differ from the development status of countries, for rapidly growing middle-income ones, the scale effect, which overpower the time effect. However, for wealthy countries, growth is slower and pollution reduction effect can overwhelm the scale effect. This process explains the origin of EKC theory (Stern, 2004).

As an example, Stern introduced the following econometric model to decompose sulfur emissions in 64 countries:

$$\frac{S_{it}}{P_{it}} = \gamma_i \frac{Y_{it}}{P_{it}} A_t \frac{E_{it}}{Y_{it}} \prod_{j=1}^{J} \left(\frac{y_{jit}}{Y_{it}}\right)^{\alpha_j} \sum_{k=1}^{K} \frac{e_{kit}}{E_{it}} \varepsilon_{it} \,,$$

where S is sulfur emissions and P is population

The RHS decomposed per capita emissions into five different aspects: scale effect, time effect, energy intensity, output mix and input mix. What is more, the contribution of the five effects to changes in global emissions at the global level varies among countries, which leads to the complexity of the EKC curve.

Apart from the above explanations, in the most recent literature of Stern, he came up with an innovative direction of analyzing EKC theory: a static one and a dynamic one. Static models that designates economic growth as simply shifts in the level of output; dynamic ones that model the economic growth process as well as the evolution of emissions or environmental quality. In detail, the static direction could be decomposed into two types: the one that advocates the EKC relationship is derived by changes in the elasticity of substitution as the economy develops; the other one is that the EKC is primarily encouraged by transformation of the elasticity of marginal utility (Pasten and Figueroa, 2012). Different from the traditional static EKC models, the dynamic one:

$$y_{i,t} - y_{i,t-1} = (\alpha - 1) y_{i,t-1} + \beta' X_{i,t} + \eta_i + \phi_t + \varepsilon_{i,t}$$

Where $y_{i,t} - y_{i,t-1}$ is the growth rate of per capita co2 emissions.

$$y_{i,t} = \alpha y_{i,t-1} + \beta' X_{i,t} + \eta_i + \phi_t + \varepsilon_{i,t}$$

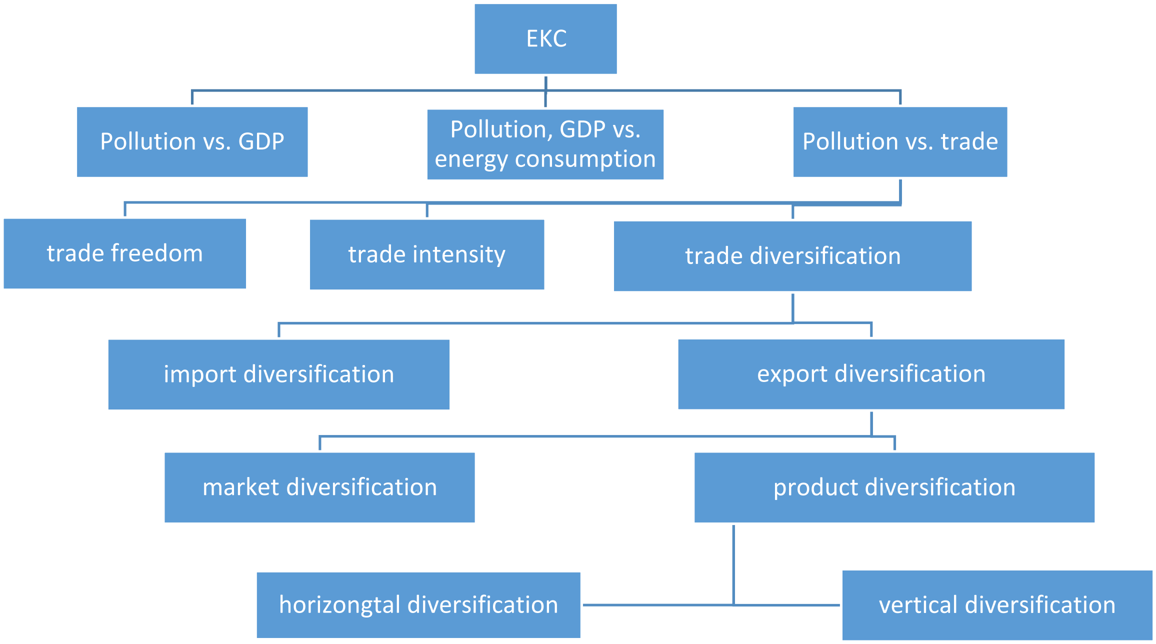
By take the first differences of the above equation, get

$$y_{i,t} - y_{i,t-1} = \alpha (y_{i,t-1} - y_{i,t-2}) + \beta' (X_{i,t} - X_{i,t-1}) + (\eta_i - \eta_{i-1}) + (\phi_t - \phi_{t-1}) + (\varepsilon_{i,t} - \varepsilon_{i,t-1})$$

The dynamic researches were represented by Chien-Chiang Lee, who reexamined the rationality of EKC through dynamic panel data approach (DPM). They found evidence of EKC hypothesis for CO_2 emissions through a global data set, their outcome claimed that as international trade openness increases, environmental quality will increase in high-income countries while deteriorate in low-income countries.

3.3 Pollution and export diversification

Figure 1. 3 Logics of export diversification



The relationship between export diversification and CO_2 emissiosn can be explained through subdividing export diversification into export market diversification and export product diversification (Cadot et al., 2013). In terms of export market diversification, higher market diversification means one country trade with more partners, its products are exported to more destinations, which in turn implies intensive transportation and pollution. On the other hand, export product diversification, it could be further subdivided into vertical diversification and horizontal diversification (Ali et al., 1991). Horizontal diversification takes place within the same sector (primary, secondary or tertiary), and entails adjustment in the country's export mix by adding new products on existing export baskets within the same sector, with the hope to mitigate adverse economic (to counter international price instability or decline) and political risks (Samen, 2010b). Vertical diversification into processing of domestic manufactured goods entails a shift from the primary to the secondary or tertiary sector. It entails contriving further uses for existing products by means of increased value added activities such as processing, marketing or other services.

Vertical diversification can expand market opportunities for raw material and help enhance growth and stability since processed goods generally have greater price stability than raw commodities.

Vertical diversification leads to contriving further uses for existing and new innovative commodities by means of value-added ventures; horizontal one means more varied export lines. Higher vertical diversification implies less pollution through "learning by doing" effect: in which the accumulation of knowledge about innovative methods of production are unintended by-products, such as capital accumulation and new production mechanism (Al-Marhubi, 2000). The above mentioned process is supposed to alleviate pollution through technique effect; however, horizontal diversification is expected to increase pollution with bigger "basket", which could be explained by scale effect that leads to higher pollution emission levels. Put another way, one million USD value of corn exported from China to South Korea may have a dramatically different emissions component than a million USD value of corn exported to United Kingdom (market diversification); the export of one million of corn exported without any further procession and cereal produced by one million value of corn will have different CO2 emission volumes (vertical product diversification).

Table 1. 2 Dimensions of export diversification (Ali et al., 1991)

	Stability-oriented		Growth-oriented		
	Based on existing commodities	Add new commodities	Based on existing commodities	Add new commodities	
Horizontal Diversification	Adjust export shares based on covariation of export earnings from individual commodities	Add new commodities based on covariation of export earnings from individual commodities	Adjust export shares based on growth rate of export earnings from individual commodities	Add new commodities base on growth rate of world prices	Add new commodities based on market niche
Vertical Diversification	Adjust export shares based on a commodity's ability to be marketed in raw	Add new commodities based on their flexibility to be marketed in raw and	Introduce or expand value-added activities	Choose new commodities based on value-added and import substitution potential	

	or processed forms in both international and domestic markets	processed forms, and to serve international and domestic market	and import substitution

4. Data and empirical model

Many factors may influence CO_2 emissions, while in our study, two main variables will be considered, GDP per capita and export diversification.

Carbon dioxide emission, the CO2 emission data that is adopted in this analysis came from world bank, CO_2 emission kg per GDP, ppp of 2011 in US dollars. Due to data availability, only year 2000 to 2014 could be utilized.

GDP per capita, GDP data also is available in world bank, GDP per capita based on purchasing power parity. A number of previous studies discovered a non-linear relationship between pollution emission or other environment situation index with per capita GDP, which may in turn imply the relationship between co2 emission and GDP as well as trade index.

Export diversification, as a key factor in this research, a comprehensive study was performed before deciding which index to use to represent export diversification.

Table 1. 3 Three types of diversification evaluation methods

Type name	Example
Concentration ratio	Herfindahl-Hirschman Index, Gini index, Theil index, Diversification Index (Rodgers, 1957)

CSCEEF(Commodity specific cumulative export experience function)	Commodity-specific cumulative export experience function, Commodity-specific traditionalist index (CSTI), Variance of CSTI
The absolute deviation	Average absolute deviation, Median absolute deviation etc.

Among those choices, it is proposed to utilize Herfindahl index, both export product diversification and market diversification are available on WITS. The calculating method for Herfindahl index can be found in Appendix1.The resulting sample is an uneven panel of 1693 observations from 125 countries spanning the time period from 2000 to 2015.

Table 1. 4 Data summary

Variable	ObsERVATIONS	Mean	Std. Dev.	Min	Max
gdp	1,996	17989.68	19070.25	440.3526	141947
co2	1,738	.2660579	.1740697	.0278142	1.360246
hhi_p	1,939	.1147231	.1589935	.0028	.9872
hhi_m	1,937	.1526063	.1406415	.0036	.921

In this analysis, the EKC model was determined in reference to relatively recent literatures, instead of only using GDP per capita as the proxy of economic development, export diversification of product and market are also regarded as unneglectable factors. Therefore, an empirical model of the EKC hypothesis is as follows:

$$\ln(pollu\tan t)_{it} = \alpha_1 \ln Y_{it} + \alpha_2 (\ln Y_{it})^2 + \ln H_{it} + \ln(H_{it})^2 + \varepsilon_{it}$$

Usually, this model is estimated with panel data, by most commonly the fixed effects estimator. But time-series or cross-section data have also been utilized (Bekhet and Yasmin, 2013; Dijkgraaf and Vollebergh, 2001; Kaufmann et al., 2011). On the theoretical basis, the assumption of most static models that pollution externalities are optimally internalized over the process of economic progress cannot be certified through empirical estimation. Findings of those models are diverse according to econometric method being used.

Data on pollution and environmental issues are notoriously erotic in terms of data coverage as well as quality (Stern et al., 1996). Therefore, further data procession and model rectification including data loss corrections should be paid extra attention.

5. Empirical methodology

In this analysis, the EKC model was determined in reference to relatively recent literatures, instead of only using GDP per capita as the proxy of economic development, export diversifications of product and market are also regarded as unneglectable factors. Therefore, an empirical model of the EKC hypothesis is as follows:

$$Pollutant_{i,t} = \alpha_{i,t} + \beta \bullet HHI_{i,t} + \mu_{i,t} \quad (1)$$

$$Pollutant_{i,t} = \alpha_{i,t} + \beta_1 \bullet HHI_{i,t} + \beta_2 \bullet HHI_{i,t}^2 + \mu_{i,t} \quad (2)$$

$$Pollutant_{i,t} = \alpha_{i,t} + \beta_1 HHI + \beta_2 HHI^2 + \beta_3 GDP + \beta_4 GDP^2 + \beta_5 GDP * HHI + \beta_6 GDP^2 * HHI^2 + \mu_{it} \quad (3)$$

$$Ln\_Pollutant_{i,t} = \alpha_{i,t} + \beta_1 (Ln\_HHI_{i,t}) + \beta_2 (Ln\_HHI_{i,t}^2) + \mu_{i,t} \quad (4)$$

Usually, this model is estimated with panel data, by most commonly the fixed effects estimator. But time-series or cress-section data have also been utilized (Bekhet and Yasmin, 2013; Dijkgraaf and Vollebergh, 2001; Kaufmann et al., 2011). On the theoretical basis, the assumption of most static models that pollution

externalities are optimally internalized over the process of economic progress cannot be certified through empirical estimation. Findings of those models are diverse according to econometric method being used.

There are several econometric issues that could influence EKC estimation: omitted variables bias, integrated variables, the problem of spurious regression as well as the identification of time effects (Stern, 2017). Besides econometric issues, hypothesis testing and estimation in EKC analysis are needed, the assumption of unidirectional causality from economic growth to environmental quality, the assumption that whether transformations in trade relationships connected to development had influence on environmental condition (Stern et al., 1996). In order to correct the potential bias caused by data or model, it is proposed to adopt unit root test, Driscoll-Kraay standard error estimation methodology. comparison between fixed effect and Driscoll-Kraay estimation is made to demonstrate whether Driscoll-Kraay error term is more suitable for this data set and expose higher efficient outcome.

First, the second generation unit root test, Pesaran's CADF (Cross-sectional Augmented Dickey-Fuller) is implemented to all variable in order to ensure stability (Özokcu and Özdemir, 2017). Pesaran CADF test runs the t-test for unit roots in heterogeneous panels with cross-section dependence, first proposed by Pesaran (Pesaran, 2007). What is more, regarding tests of the idiosyncratic component for a unit root, CADF is appropriate for unit root, especially when cross-sectional dependence is due to a single common factor and size as well as power are inversely influenced by a second common factor (Gengenbach et al., 2009). The results of Pesaran's CADF test with 1 lag for our dataset illustrated that: besides, ln_gdp2, other variables are stationary.

Table 1. 5 Results of stationary test

Variable Name	Lag1		Lag0	
	Z[T-bar]	p-value	Z[T-bar]	p-value
LN_CO2	-5.532	0.000	-6.897	0.000

LN_GDP	-0.828	0.204	-2.056	0.020
LN_GDP2	-0.484	0.314	-1.501	0.067
LN_P	-0.041	0.484	-2.204	0.014
LN_P2	-1.827	0.034	-3.474	0.000
LN_M	-2.713	0.003	-5.821	0.000
LN_M2	-2.431	0.008	-4.837	0.000

Second, Hausman test was adopted to determine appropriateness of random effect test and fixed effect test. Hausman principle is an effective mechanism to assist hypothesis testing procedure, in which if two estimators are available, the first one is efficient under the alternative while the other one is consistent under any hypothesis. According to Cameron and Trivedi (Cameron and Trivedi, 2009), the "sigmamore" command in Stata is helpful for efficient executing of Hausman test, this is because this option denotes that both covariance matrices are based on the same estimated variance from the efficient estimator (Özokcu and Özdemir, 2017). These tests suggest that fixed effect is suitable for the case of 124 countries as a whole, while random effect is applicable for low income country group and OECD country group respectively.

Thirdly, after determining the applicability of fixed effect model for our data, we can adopt a modified Wald test for heteroscedasticity in the fixed effect model. The outcome demonstrated the rejection of the null hypothesis of homoscedasticity.

Fourthly, we propose to do the serial correlation test, due to the reason that serial correlation in linear panel-data equations tend to bias the standard errors which leads to less efficient results (Antonie et al., 2010). According to this test, the probability of the null hypothesis being true is less than 0.01%, which implies there is no first order autocorrelation. Therefore, it is meaningful to reject this hypothesis and came to a conclusion that there is auto correlation in our data.

There are two issues needed to be fixed before further estimation, which are serial correlation and heteroscedasticity. Driscoll-Kraay standard errors for coefficients estimated by fixed-effects regression are suitable for this data description (Driscoll and Kraay, 1998). They proposed a nonparametric covariance matrix estimator which produces heteroscedasticity consistent standard errors that are robust to general forms of dependence. According to the outcome of serial correlation test, the next step is to fix the problem of auto correlation in order to do regression. Based on this, Driscoll and Kraay estimator is supposed to be more efficient than pooled OLS and fixed effects regression, therefore, a comparison between the outcomes of two estimation approaches was performed.

Fixed effect and Driscoll-Kraay standard errors are all demonstrated in the three tables of 125 country group, the low-income country group and OECD country group.

Lastly, besides the aforestated methodologies, this research adopted an interaction term in regression to make a separate comparative group. The fact is that, besides the accuracy that interaction terms bring, there still exist potential issues: there are a number of difficulties in interpreting such interactions, and various problems could as well arise.

This study focused on interactions between categorical variables and continuous ones, adding interaction terms to a regression analysis provides expanded understanding of the relationships among the variables in the model and facilitates more hypotheses to be tested. In regressions with multiplicative terms, the model coefficients reflect conditional relationships. In general, models with interaction terms should not ignore the main effects of the variable that forms the interaction term, even if these variables are not robust in regression (Williams, 2015), therefore, main effects of the variable and the interaction term can avoid confounded effect. What is more, if main effects are ignored, arbitrary transformation in the zero point of the existent variables can lead to important changes in the obvious influences of the intersection terms. Interaction effects occur when the effect of one variable depends on the value of another variable. Interaction effects are common in regression analysis, ANOVA (analysis of variance), and designed experiments (Brambor et al., 2005). In a work related to trade and pollution, Heil and Selden argued that by adding interaction terms (GDP multiplied Trade intensity), it is possible to analyze whether international trade increases pollution at some income levels and reduces it at others (Heil and Selden, 2001).

5.1 Results without interaction term

Table 1. 6 Analysis results for 125 countries [1]

Ln_co2	Market diversification		Product diversification	
	Fixed Effect	Driscoll-Kraay Standard Errors	Random Effect	Driscoll-Kraay Standard Errors
Ln_gdp	1.050*** (9.25)	2.838*** (80.80)	1.145*** (9.67)	2.973*** (40.58)
Ln_gdp2	-0.075*** (-12.10)	-0.148*** (-40.27)	-0.078*** (-11.94)	-0.156*** (-40.02)
Ln_hhi	0.061** (2.23)	0.076*** (3.22)	-0.012 (-0.44)	0.229*** (21.00)
Ln_hhi2	0.012* (1.76)	0.022*** (3.06)	0.002 (0.43)	0.039*** (22.71)
Con_	-4.642*** (-8.99)	-14.821*** (-42.60)	-5.423*** (-10.17)	-15.162*** (-42.11)
F-test or Wald chi2	191.57	0.0000	606.25	0.0000

[1] Country list is available in appendix 1.3

R-squared		0.2845		.02949
observations	1692	1692	1693	1693
countries	125	125	125	125

Table 1. 7 Low income countries, 16 in total

Ln_co2	Market diversification		Product diversification	
	Fixed effect	Driscoll-Kraay standard errors (fixed effect)	Random effect	Driscoll-Kraay standard error (random effect)
Ln_gdp	-4.094***	-4.094***	-4.227***	-0.810
	(-4.33)	(-6.85)	(-4.41)	(-0.16)
Ln_gdp2	0.293***	0.293***	0.299***	0.071
	(4.37)	(7.00)	(4.42)	(0.19)
Ln_hhi	0.017	0.0172	0.013	-0.267
	(0.17)	(0.40)	(0.21)	(-1.67)
Ln_hhi2	-0.013*	-0.0127	0.008	-0.005
	(-0.42)	(-0.79)	(0..67)	(-0.11)
_cons	11.961***	11.961***		
	(3.60)	(5.69)		
F-test or Wald chi2	6.35	0.0000	21.23	0.0000
R-squared				0.1395

observations	208	208	209	209
countries	16	16	16	16

Table 1. 8 OECD countries, 35 in total

Ln_co2	Market diversification		Product diversification	
	Fixed effect	Driscoll-Kraay standard errors (fixed effect)	Random effect	Driscoll-Kraay standard error (random effect)
Ln_gdp	1.414*** (3.63)	1.414** (2.41)	0.985** (2.41)	2.093** (2.93)
Ln_gdp2	-0.092*** (-4.78)	-0.092*** (-3.14)	-0.072*** (-3.55)	-0.118*** (-3.32)
Ln_hhi	0.406*** (5.46)	0.406*** (3.97)	-0.061 (-1.13)	-0.268*** (-5.40)
Ln_hhi2	0.062*** (5.79)	0.062*** (4.79)	-0.006 (-0.79)	-0.038*** (-6.30)
Cons_	-5.560*** (-2.85)	-5.560* (-1.97)	-4.008* (-1.95)	-10.879** (-2.96)
F-test or Wald chi2	186.49	0.0000	674.09	0.0000
R-squared				.1567
observations	490	490	490	490

countries	35	35	35	35

Table 1. 9 Regression results after adopting interaction terms

Ln_co2	Market diversification		Product diversification	
	Fixed effect	Driscoll-Kraay standard errors (fixed effect)	Fixed effect	Driscoll-Kraay standard error (random effect)
Ln_gdp	1.538*** (13.09)	2.676*** (15.25)	1.276*** (11.29)	2.378*** (15.29)
Ln_gdp2	-0.102*** (-16.27)	-0.138*** (-18.99)	-0.094*** (-15.31)	-0.108*** (-15.91)
Ln_hhi	-0.284 (-1.57)	0.924 (1.70)	0.715*** (5.08)	-0.407* (-1.59)
Ln_hhi2	-0.054* (-1.93)	0.254** (2.73)	0.057*** (4.40)	0.127*** (5.66)
LN_HHI*gdp	0.027 (1.42)	-0.085 (-1.40)	-0.086*** (-5.31)	0.087*** (3.08)
LN_HHI2*gdp2	0.00052** (1.99)	-0.024** (-2.21)	-0.00079*** (-4.96)	-0.00055*** (-2.06)
Cons_	-6.927*** (-12.24)	-14.182*** (-13.90)	-5.334*** (-10.11)	-13.668*** (-15.18)

F-test or Wald chi2	0.0000	0.0000	0.0000	0.0000
R-squared	0.0303	0.2952	0.0292	0.3686
observations	1,815	1,815	1,816	1,816
countries	125	125	125	125

Results demonstrated above illustrated low R-square values, however, low R-square is not necessarily a bad case, especially when we have statistically significant predictors, we can still draw meaningful conclusions about how changes in the predict values are associated with changes in the independent variables. Regardless of the R-squared, the significant coefficients still represent the mean change in the response for one unit of change in the predictor while holding other predictors in the model constant. Obviously, this type of information can be extremely valuable (Frost, 2013; Frost, 2014; Vogt and Johnson, 2011).

Adding interaction terms to a regression model can greatly expand understanding of the relationships among the variables in the model and allows more hypotheses to be tested. It would be useful to add an interaction term to the model if there is a need to test the hypothesis that the relationship between GDP and export diversification both market diversification and product diversification and also their square terms.

As we can learn from this empirical results, even though the significance of each variable is relatively high, with decent p-values, however, the R-squares are not that robust as expected. According to literature review concerning econometrics (Hu et al., 1999; Jaccard and Turrisi, 2003; Jin et al., 2001), low R-square is not inherently bad, especially when there exit statistically significant predictors, an important conclusion about how changes in the predictor values are associated with changes in the response value could be made. Regardless of the R-squared, the significant coefficients still represent the mean change in the response for one unit of change in the predictor while holding other predictors in the model constant. Obviously, this type of information can be extremely valuable. Since the purpose of our research is not to produce predictions that are reasonably precise, a low R-square value can still help us make reasonable explanations.

The use of interaction terms is not limited to cases in which the associations between the dependent variables and independent variables vary between countries. In principle, it can be applied in all situations where one variable is associated with the dependent variable changes according to the value of another one. The connection among independent variables may, as an example, depend on the develop condition of each individual country. Under such situation, we can empirically create interaction terms by multiplying GDP and export diversification proxies as well as their square terms.

5.2 Comparison between the outcome with and without interaction term

Interaction terms are used widely in applied econometrics, and the correct way to interpret them is known by many econometricians and statisticians, most applied researchers misinterpret the coefficient of the interaction term in nonlinear models. Applied economists often estimate interaction terms to infer how the effect of one independent variable on the dependent variable depends on the magnitude of another independent variable (Ai and Norton, 2003). Heil insisted that relationship between international trade and the environment is more complicated than as described as pollution havens hypothesis, he argued that interaction terms should be added to observe whether international trade increases pollution at some income levels and reduces it at others (Heil and Selden, 2001).

$$CO_2 = \alpha_{it} + \beta_1 GDP + \beta_2 GDP^2 + \beta_3 HHI + \beta_4 HHI^2 + \beta_5 GDP * HHI + \beta_6 GDP^2 * HHI^2 + \mu_{it}$$

In this model, GDP*HHI refers to a variable calculated as the simple observation-by-observation product of GDP and HHI, the independent terms GDP and HHI are referred as “main terms”, and the product of the main terms, their multiplier, as the “interaction term”, which brings to first simple observations:

1. In a regression with interaction terms, the main terms should always be included. Otherwise, the interaction effect may be significant due to left-out variable bias. (the multiplier term is by construction likely to be correlated with the main term.

2. The partial derivative of the dependent variable with respect to GDP is $\beta_1 + 2\beta_2 GDP + \beta_5 HHI$. The interpretation of β_1 is the partial derivative of CO_2 emission with respect to GDP. A t-test for $\beta_1 = 0$ is therefore, a test of the null of no effect of GDP. To test for no effect of GDP, it is needed to test if $(\beta_1, \beta_5) = (0,0)$ using, for example, an F-test(Balli and Sørensen, 2013),

3. After determining that our regression must be estimated as a fixed effects model, next is to examine whether the interaction term could increase the explanatory power of the regression compared to the case that included only direct effect. This is proposed to be accomplished through F-test.

The empirical meaning of interaction terms in this study lies on the fact that, because of the interaction term, the effect of having more GDP is different according to the level of export diversification. Another way of illustrating this is that the slopes of the regression lines between GDP and CO_2 emission is different from the different categories of export diversification. β_5 is capable of showing how different those slopes are shaped.

Table 1. 10 A comparison of results with and without interaction terms

	WITHOUT INTERACTION TERMS		**WITH INTERACTION TERMS**	
Ln_co2	Fixed effect	Driscoll_Kraay standard errors (fixed effect)	Fixed effect	Driscoll_Kraay standard error (random effect)
Ln_gdp	1.415*** (112.86)	3.032*** (38.87)	1.276*** (11.29)	2.378*** (15.29)
Ln_gdp2	-0.096***	-0.160***	-0.094***	-0.108***

	(-15.88)	(-140.75)	(-15.31)	(-15.91)
Ln_hhi	-0.021 (-0.80)	0.24*** (16.69)	0.715*** (5.08)	-0.407* (-1.59)
Ln_hhi2	-0.002 (-0.36)	0.040*** (22.05)	0.057*** (4.40)	0.127*** (5.66)
LN_HHI*gdp			-0.086*** (-5.31)	0.087*** (3.08)
LN_HHI2*gdp2			-0.00079*** (-4.96)	-0.00055*** (-2.06)
Cons_	-6.344*** (-12.81)	-15.40*** (-38.36)	-5.334*** (-10.11)	-13.668*** (-15.18)
F-test or Wald chi2	0.0000	0.0000	0.0000	0.0000
R-squared	0.3701	0.2918	0.0292	0.3686
observations	1,816	1,816	1,816	1,816
countries	125	125	125	125

6. Conclusions and discussions

In this study, the relationship between economic development and CO2 emission is examined under three circumstances. The first analysis is performed for 125 countries during the time period 2000 to 2015. The results illustrated that, for these 125 countries, there is an inverted U-shaped relationship between GDP and CO_2 emission, what is more, both export market diversification and export product diversification demonstrate negative relationship with pollution, which means, trade diversification help CO_2 emission alleviation.

EKC (EKC) was originally developed to model the relationship of pollution and economic development. In this paper, we started from EKC model and adopt a regression model to estimate the EKC relationship among 125 countries over the period 2000 to 2015. Unlike most EKC (EKC) studies which focus on narrow measures of GDP per capita or trade volume as proxies for development, export diversification is introduced as one of the proxy variables for economic development in rectification of EKC in our research. Results demonstrate that both export market diversification and export product diversification help CO_2 emission alleviation in 125 countries panel data analysis. Besides, low income countries illustrated U-shaped relationship between economic development and CO_2 emissions, while OECD countries still maintained inverted U-shaped EKC curve which was unanimous with the outcome of 125 countries as a whole.

After analyzing the data from 125 countries as a whole, further subdivision was made, these countries are organized into 5 group according to income levels: Low income countries ($1045 or less), Lower middle income countries ($1046–$4125), Upper middle income countries ($4126–$12,745), High income countries (non-OECD) ($12,746 or more), High income countries ($12,746 or more) (Can and Gozgor, 2016). In order to highlight comparison, it is proposed to choose the lowest income group and highest income groups. The outcome was that, low income countries illustrated U-shaped relationship between economic development and CO_2 emissions, while OECD countries still maintained inverted U-shape EKC curve which was unanimous with the outcome of 125 countries as a whole.

Besides the EKC outcome, there is another interesting finding worth mentioning. The outcome of 125 countries estimation and OECD countries estimation are more significant than low income country group, this, according to Hoechle, is partly because Driscoll-Kraay estimation method is more suitable for data set which contains a large cross-section (Hoechle, 2007).

GDP per capita is the most significant variable in determining CO_2 emission in the panel data analysis in 125 countries, due to the fact that its coefficient has the biggest absolute value respectively. CO_2 and GDP constitute an inverted U-shaped curve, while CO_2 were positively related with export diversification. From a policy perspective, export diversification appears as a key element of the economic development process (Cadot et al., 2011), in this study, export diversification is positively related to CO_2, which reflect the fact that in order to alleviate CO_2 emissions, countries are supposed to concentrate on the exportation of cleaner categories. By so far, controlling CO_2 is not a legal requirement (Choi et al., 2010), and thus, different countries implement environmental policies in accordance with their own interests and development pathway. Since it is difficult to implement any international measures and enforce them, voluntary efforts are necessary for countries for sustainable development. Besides, with increasing globalization, countries are become more active participants in world market, it is suggestive for them to pay more attention on the constitution of the exportation, to concentrate on the less polluted categories.

Due to the increasing concerns on global climate change issues, researches on EKC theory related with CO_2 emission surged in recent years. However, the outcome of all those studies are varied, partly due to the selection of pollutants, the choice of country (which country, or how big a country group as well as the development condition of them), as well as the econometric methodologies that is adopted in the study. Therefore, our research should be regarded as one of the empirical analysis even though our results are in accordance with the EKC theory.

Results of this research, especially the ones concerning the relationship between exporting diversification and pollution emissions are not rigidly consistent with EKC theory, however, this is in accordance with some previous studies, which, as presented in literature review, are not all perfect EKC certifications. We believe that this paper contributes to a number of strands in the recent literatures concerning sustainable development and trade, by taking advantage of a reduce-form EKC model, the current study do not rely on strong theoretical assumptions tht are indispensible in models tht use the structural form. As for policy implications of the present research, it is supposed to function as a reminding to policy makers: when it comes to sustainable development, compares to economy volomes which has long been the focus, economic structure such as export diversification need better attention.

Further researches on relationship between export diversification and pollution emission focusing more on transportation aspect may shed applicabel results.

References:

Agras, J., and Chapman, D. (1999). A dynamic approach to the Environmental Kuznets Curve hypothesis. *Ecological Economics* **28**, 267-277.

Ai, C., and Norton, E. C. (2003). Interaction terms in logit and probit models. *Economics letters* **80**, 123-129.

Akbar, M., Naqvi, Z. F., and Din, M.-u. (2000). Export Diversification and the Structural Dynamics in the Growth Process: The Case of Pakistan [with Comments]. *The Pakistan Development Review*, 573-589.

Al-Marhubi, F. (2000). Export diversification and growth: an empirical investigation. *Applied economics letters* **7**, 559-562.

Al-Mulali, U., Weng-Wai, C., Sheau-Ting, L., and Mohammed, A. H. (2015). Investigating the environmental Kuznets curve (EKC) hypothesis by utilizing the ecological footprint as an indicator of environmental degradation. *Ecological Indicators* **48**, 315-323.

Ali, R., Alwang, J. R., and Siegel, P. B. (1991). "Is export diversification the best way to achieve export growth and stability?: a look at three African countries," World Bank Publications.

Amurgo-Pacheco, A. (2008). "Patterns of export diversification in developing countries," World Bank Publications.

Antonie, M. D., Cristescu, A., and Cataniciu, N. (2010). A panel data analysis of the connection between employee remuneration, productivity and minimum wage in Romania. *In* "Proceedings of the 11th WSEAS Int. Conf. MCBE", pp. 134-139.

Balli, H. O., and Sørensen, B. E. (2013). Interaction effects in econometrics. *Empirical Economics* **45**, 583-603.

Bekhet, H. A., and Yasmin, T. (2013). Exploring EKC, trends of growth patterns and air pollutants concentration level in Malaysia: A Nemerow Index Approach. *In* "IOP Conference Series: Earth and Environmental Science", Vol. 16, pp. 012015. IOP Publishing.

Brajer, V., Mead, R. W., and Xiao, F. (2011). Searching for an Environmental Kuznets Curve in China's air pollution. *China Economic Review* **22**, 383-397.

Brambor, T., Clark, W. R., and Golder, M. (2005). Understanding interaction models: Improving empirical analyses. *Political analysis* **14**, 63-82.

Cadot, O., Carrère, C., and Strauss-Kahn, V. (2011). Export diversification: What's behind the hump? *Review of Economics and Statistics* **93**, 590-605.

Cadot, O., Carrere, C., and Strauss - Kahn, V. (2013). Trade diversification, income, and growth: what do we know? *Journal of Economic Surveys* **27**, 790-812.

Cameron, A. C., and Trivedi, P. K. (2009). "Microeconometrics using stata," Stata press College Station, TX.

Can, M., and Gozgor, G. (2016). Dynamic relationships among CO2 emissions, energy consumption, economic growth, and economic complexity in France.

Caviglia-Harris, J. L., Chambers, D., and Kahn, J. R. (2009). Taking the "U" out of Kuznets. *Ecological Economics* **68**, 1149-1159.

Choi, E., Heshmati, A., and Cho, Y. (2010). An empirical study of the relationships between CO2 emissions, economic growth and openness.

Choi, I. (2001). Unit root tests for panel data. *Journal of international money and Finance* **20**, 249-272.

Cole, M. A. (2004). Trade, the pollution haven hypothesis and the environmental Kuznets curve: examining the linkages. *Ecological economics* **48**, 71-81.

Cole, M. A., Rayner, A. J., and Bates, J. M. (1997). The environmental Kuznets curve: an empirical analysis. *Environment and development economics* **2**, 401-416.

Copeland, B. R., and Taylor, M. S. (1995). Trade and transboundary pollution. *The American Economic Review*, 716-737.

Copeland, B. R., and Taylor, M. S. (2004). Trade, growth, and the environment. *Journal of Economic literature* **42**, 7-71.

Copeland, B. R., and Taylor, M. S. (2005). Free trade and global warming: a trade theory view of the Kyoto protocol. *Journal of Environmental Economics and Management* **49**, 205-234.

Copeland, B. R., and Taylor, M. S. (2013). "Trade and the environment: Theory and evidence," Princeton University Press.

Cui, J., Lapan, H., and Moschini, G. (2016). Productivity, Export, and Environmental Performance: Air Pollutants in the United States. *American Journal of Agricultural Economics* **98**, 447-467.

das Neves Almeida, T. A., Cruz, L., Barata, E., and García-Sánchez, I.-M. (2017). Economic growth and environmental impacts: An analysis based on a composite index of environmental damage. *Ecological Indicators* **76**, 119-130.

Diao, X. D., Zeng, S. X., Tam, C. M., and Tam, V. W. (2009). EKC analysis for studying economic growth and environmental quality: a case study in China. *Journal of Cleaner Production* **17**, 541-548.

Dijkgraaf, E., and Vollebergh, H. R. (2001). "A note on testing for environmental Kuznets curves with panel data." Nota di Lavoro, Fondazione Eni Enrico Mattei.

Dinda, S. (2008). EKC: static or dynamic? *International Journal of Global Environmental Issues* **9**, 84-88.

Driscoll, J. C., and Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of economics and statistics* **80**, 549-560.

Dumitrescu, E.-I., and Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Economic Modelling* **29**, 1450-1460.

Ferreira, G. F., and Harrison, R. W. (2012). From Coffee Beans to Microchips: export diversification and economic growth in Costa Rica. *Journal of Agricultural and Applied Economics* **44**, 517-531.

Friedl, B., and Getzner, M. (2003). Determinants of CO 2 emissions in a small open economy. *Ecological economics* **45**, 133-148.

Frost, J. (2013). Regression analysis: How do I interpret R-squared and assess the goodness-of-fit. *The Minitab Blog* **30**.

Frost, J. (2014). How to Interpret a Regression Model with Low R-squared and Low P values. *Minitab Inc.(ed) Getting Started with Minitab* **17**.

Garetti, M., and Taisch, M. (2012). Sustainable manufacturing: trends and research challenges. *Production Planning & Control* **23**, 83-104.

Gengenbach, C., Palm, F. C., and Urbain, J.-P. (2009). Panel unit root tests in the presence of cross-sectional dependencies: comparison and implications for modelling. *Econometric Reviews* **29**, 111-145.

Gozgor, G., and Can, M. (2016a). Effects of the product diversification of exports on income at different stages of economic development. *Eurasian Business Review* **6**, 215-235.

Gozgor, G., and Can, M. (2016b). Export product diversification and the environmental Kuznets curve: evidence from Turkey. *Environmental Science and Pollution Research* **23**, 21594-21603.

Gozgor, G., and Can, M. (2017). Does export product quality matter for CO2 emissions? Evidence from China. *Environmental Science and Pollution Research* **24**, 2866-2875.

Granger, C. W. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica: Journal of the Econometric Society*, 424-438.

Grossman, G. M., and Krueger, A. B. (1991). "Environmental impacts of a North American free trade agreement." National Bureau of Economic Research.

Grossman, G. M., and Krueger, A. B. (1995). Economic growth and the environment. *The quarterly journal of economics* **110**, 353-377.

Halicioglu, F. (2009). An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey. *Energy Policy* **37**, 1156-1164.

Heil, M. T., and Selden, T. M. (2001). International trade intensity and carbon emissions: a cross-country econometric analysis. *The Journal of Environment & Development* **10**, 35-49.

Heil, M. T., and Wodon, Q. T. (1997). Inequality in CO2 emissions between poor and rich countries. *The Journal of Environment & Development* **6**, 426-452.

Hoechle, D. (2007). Robust standard errors for panel regressions with cross-sectional dependence. *Stata Journal* **7**, 281.

Holtz-Eakin, D., and Selden, T. M. (1995). Stoking the fires? CO2 emissions and economic growth. *Journal of public economics* **57**, 85-101.

Hsiao, C. (2014). "Analysis of panel data," Cambridge university press.

Hu, P. J., Chau, P. Y., Sheng, O. R. L., and Tam, K. Y. (1999). Examining the technology acceptance model using physician acceptance of telemedicine technology. *Journal of management information systems* **16**, 91-112.

Jaccard, J., and Turrisi, R. (2003). "Interaction effects in multiple regression," Sage.

Jayanthakumaran, K., Verma, R., and Liu, Y. (2012). CO 2 emissions, energy consumption, trade and income: a comparative analysis of China and India. *Energy Policy* **42**, 450-460.

Jin, R., Chen, W., and Simpson, T. W. (2001). Comparative studies of metamodelling techniques under multiple modelling criteria. *Structural and multidisciplinary optimization* **23**, 1-13.

Juvenal, L., and Santos Monteiro, P. (2013). Export market diversification and productivity improvements: theory and evidence from Argentinean firms.

Kaufmann, R. K., Kauppi, H., Mann, M. L., and Stock, J. H. (2011). Reconciling anthropogenic climate change with observed temperature 1998–2008. *Proceedings of the National Academy of Sciences* **108**, 11790-11793.

Lee, C.-C., Chiu, Y.-B., and Sun, C.-H. (2009). Does one size fit all? A reexamination of the environmental Kuznets curve using the dynamic panel data approach. *Review of Agricultural Economics* **31**, 751-778.

Liddle, B. (2015). What are the carbon emissions elasticities for income and population? Bridging STIRPAT and EKC via robust heterogeneous panel estimates. *Global Environmental Change* **31**, 62-73.

Liu, X., Heilig, G. K., Chen, J., and Heino, M. (2007). Interactions between economic growth and environmental quality in Shenzhen, China's first special economic zone. *Ecological Economics* **62**, 559-570.

Lopez, L., and Weber, S. (2017). Testing for Granger causality in panel data. *Stata Journal* **17**, 972-984.

Managi, S., Hibiki, A., and Tsurumi, T. (2009). Does trade openness improve environmental quality? *Journal of environmental economics and management* **58**, 346-363.

Nemati, M., Hu, W., and Reed, M. (2016). Are Free Trade Agreements Good for the Environment? A Panel Data Analysis. *In* "2016 Annual Meeting, July 31-August 2, 2016, Boston, Massachusetts". Agricultural and Applied Economics Association.

Niu, S., Ding, Y., Niu, Y., Li, Y., and Luo, G. (2011). Economic growth, energy conservation and emissions reduction: A comparative analysis based on panel data for 8 Asian-Pacific countries. *Energy policy* **39**, 2121-2131.

Özokcu, S., and Özdemir, Ö. (2017). Economic growth, energy, and environmental Kuznets curve. *Renewable and Sustainable Energy Reviews* **72**, 639-647.

Panayotou, T. (1993). "Empirical tests and policy analysis of environmental degradation at different stages of economic development." International Labour Organization.

Pasten, R., and Figueroa, E. (2012). The environmental Kuznets curve: a survey of the theoretical literature. *International Review of Environmental and Resource Economics* **6**, 195-224.

Perman, R., and Stern, D. I. (2003). Evidence from panel unit root and cointegration tests that the environmental Kuznets curve does not exist. *Australian Journal of Agricultural and Resource Economics* **47**, 325-347.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross - section dependence. *Journal of Applied Econometrics* **22**, 265-312.

Proops, J. L., and Safonov, P. (2004). "Modelling in ecological economics," Edward Elgar Publishing.

Rodgers, A. (1957). Some aspects of industrial diversification in the United States. *Economic Geography* **33**, 16-30.

Rondeau, F., and Roudaut, N. (2014). What Diversification of Trade Matters for Economic Growth of Developing Countries? *Economics Bulletin* **34**, 1485-1497.

Saboori, B., Sulaiman, J., and Mohd, S. (2012). Economic growth and CO2 emissions in Malaysia: a cointegration analysis of the environmental Kuznets curve. *Energy policy* **51**, 184-191.

Saboori, B., Sulaiman, J., and Mohd, S. (2016). Environmental Kuznets curve and energy consumption in Malaysia: A cointegration approach. *Energy Sources, Part B: Economics, Planning, and Policy* **11**, 861-867.

Samen, S. (2010a). Export development, diversification and competitiveness: how some developing countries got it right. *World Bank Institute*.

Samen, S. (2010b). A primer on export diversification: key concepts, theoretical underpinnings and empirical evidence. *Growth and Crisis Unit World Bank Institute*, 1-23.

Seetanah, B., Sannassee, R., and Lamport, M. (2012). Export Diversification and Economic Growth: The Case Of Mauritius. *In* "4th World Trade Organization Annual Conference", pp. 1-2.

Selden, T. M., and Song, D. (1994). Environmental quality and development: is there a Kuznets curve for air pollution emissions? *Journal of Environmental Economics and management* **27**, 147-162.

Shafik, N., and Bandyopadhyay, S. (1992). "Economic growth and environmental quality: time-series and cross-country evidence," World Bank Publications.

Shen, J., and Hashimoto, Y. (2004). Environmental Kuznets curve on country level: evidence from China. *Discussion Papers in Economics and Business*, 04-09.

Sirag, A., Matemilola, B. T., Law, S. H., and Bany-Ariffin, A. N. (2018). Does environmental Kuznets curve hypothesis exist? Evidence from dynamic panel threshold. *Journal of Environmental Economics and Policy* **7**, 145-165.

Song, T., Zheng, T., and Tong, L. (2008). An empirical test of the environmental Kuznets curve in China: A panel cointegration approach. *China Economic Review* **19**, 381-392.

Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. *World development* **32**, 1419-1439.

Stern, D. I. (2015). The environmental Kuznets curve after 25 years. *Journal of Bioeconomics*, 1-22.

Stern, D. I. (2017). The environmental Kuznets curve after 25 years. *Journal of Bioeconomics* **19**, 7-28.

Stern, D. I., and Common, M. S. (2001). Is there an environmental Kuznets curve for sulfur? *Journal of Environmental Economics and Management* **41**, 162-178.

Stern, D. I., Common, M. S., and Barbier, E. B. (1996). Economic growth and environmental degradation: the environmental Kuznets curve and sustainable development. *World development* **24**, 1151-1160.

Stern, D. I., and Zha, D. (2016). Economic growth and particulate pollution concentrations in China. *Environmental Economics and Policy Studies* **18**, 327-338.

Torras, M., and Boyce, J. K. (1998). Income, inequality, and pollution: a reassessment of the environmental Kuznets curve. *Ecological economics* **25**, 147-160.

Vogt, W. P., and Johnson, R. B. (2011). "Dictionary of statistics & methodology: a nontechnical guide for the social sciences: a nontechnical guide for the social sciences," Sage.

Wang, P., Wu, W., Zhu, B., and Wei, Y. (2013). Examining the impact factors of energy-related CO 2 emissions using the STIRPAT model in Guangdong Province, China. *Applied Energy* **106**, 65-71.

Williams, R. (2015). Interaction effects between continuous variables.

Xuefeng, Q., and Yaşar, M. (2016). Export Market Diversification and Firm Productivity: Evidence from a Large Developing Country. *World Development* **82**, 28-47.

Yaguchi, Y., Sonobe, T., and Otsuka, K. (2007). Beyond the environmental Kuznets curve: a comparative study of SO 2 and CO 2 emissions between Japan and China. *Environment and Development Economics* **12**, 445-470.

Appendix 1.1. Theory explanation from Copeland

The pollution demand is denoted as

$$z = \bar{e}x(p, \overline{\tau, K, L}) \qquad (1.1)$$

Where, $\tau = \bar{\tau}$ which is the fixed pollution tax; $\bar{e}$ is fixed emission intensity; p is the world prices; K represents capital; L is labor

Income is $I = G(p, K, L, z)$

Where z is determined endogenously by (1.1).

After the determinant of pollution demand and income, now consider growth via capital accumulation alone. Then differentiating (1.1), (1.2) holding L constant, yields

$$\hat{z} = \varepsilon_{XK} \hat{K} \qquad (1.3)$$

And

$$\hat{I} = s_r \hat{K} + s_\tau \hat{z} \qquad (1.4)$$

$s_r > 0$ and $s_r > 0$ are the shares of capital and emission charges in national income, $\hat{z} = dz / z$ and so on, and $\varepsilon_{XK} > 0$ is the elasticity of X output with respect to the endowment of capital, which is positive by Rybczinski theorem. Through 1.3 and 1.4, here came the result:

$$\hat{z} = \frac{\varepsilon_{XK}}{s_r + s_\tau \varepsilon_{XK}} \hat{I} \qquad (1.5)$$

This equation contributed to understand that there is a positive, monotonic relation between pollution and income when growth occurs through the factor used intensively in the pollution intensive sector.

Alternatively, suppose growth occurs via accumulation of human capital, then we have,

$$\hat{Z} = \varepsilon_{XL} \hat{L} \tag{1.6}$$

Where, $\varepsilon_{XL} < 0$ is the elasticity of X output with respect to the endowment of human capital. Note that $\varepsilon_{XL} < 0$ follows from the Rybczinski theorem of international trade: human capital accumulation stimulates the clean industry Y, which squeeze resources out of the dirty industry X and lowers pollution. The effect of human capital accumulation on income is:

$$\hat{I} = s_w \hat{L} + s_\tau \hat{z} = (s_w + \varepsilon_{XL}) \hat{L} \tag{1.7}$$

Where $s_w > 0$ is the share of human capital in national income. Although the coefficient of $\hat{L}$ has both a positive and negative term, the increase in the supply of labor must raise national income, despite the drop in pollution. This follows from looking at the net production frontier, and so on, given prices and the fixed emissions intensity, income must increase (Copeland and Taylor, 2013).

Appendix 1.2 Calculation of Herfindahl-Hirshamn Index

The normalized Herfindahl index, ranges between zero and one is given as follows

$$H_t = \frac{\sum_k (S_k)^2 - \frac{1}{n}}{1 - \frac{1}{n}} \qquad S_k = \frac{X_k}{\sum_{k=1}^{n} X_k}$$

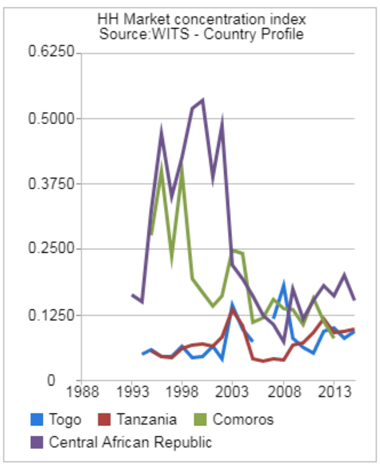
S_k is the share of export line k （with amount exported in total exports X_k）, and n is the number of export lines, k is the share of line k in total exports, n is the number of export lines, commodity use 4-digit HS code

Appendix 1.3 Country list

Country list of different developing stages (Gozgor and Can, 2016a)

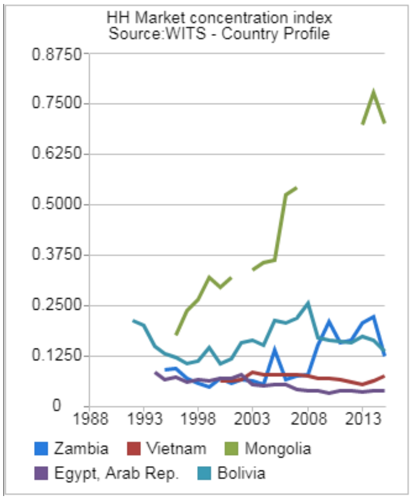
Low income countries ($1045 or less)

Bangladesh, Benin, Burkina Faso, Burundi, Cambodia, the Central African Republic, Chad, Comoros, Congo Democratic Republic, Ethiopia, the Gambia, Guinea, Guinea–Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mozambique, Nepal, Niger, Rwanda, Sierra Leone, Tajikistan, Tanzania, Togo, Uganda, and Zimbabwe.



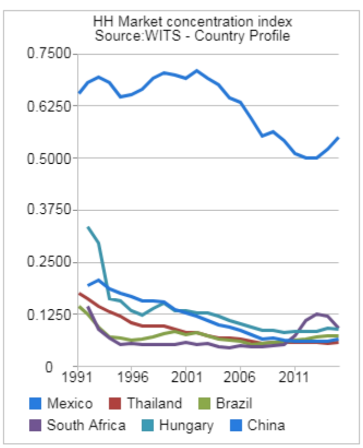
Lower middle income countries ($1046–$4125)

Armenia, Bolivia, Cameroon, Cape Verde, Congo Republic, Cote D'Ivoire, Djibouti, Egypt, El Salvador, Georgia, Ghana, Guatemala, Honduras, India, Indonesia, Kyrgyz Republic, Lao PDR, Mauritania, Moldova, Mongolia, Morocco, Nigeria, Pakistan, Paraguay, the Philippines, Sao Tome and Principe, Senegal, Sri Lanka, Sudan, Syria, Ukraine, Uzbekistan, Vietnam, Yemen, and Zambia.



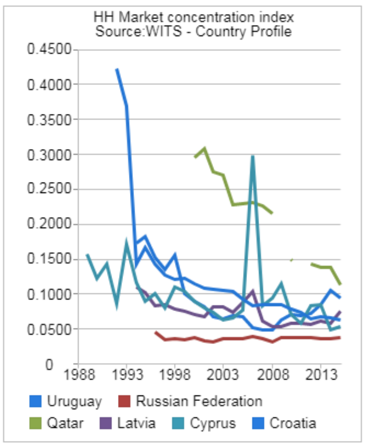
Upper middle income countries ($4126–$12,745)

Albania, Angola, Argentina, Azerbaijan, Belarus, Belize, Bosnia and Herzegovina, Brazil, Bulgaria, China, Colombia, Costa Rica, Dominica, the Dominican Republic, Ecuador, Fiji, Gabon, Grenada, Hungary, Iran, Iraq, Jamaica, Jordan, Kazakhstan, Lebanon, Macedonia FYR, Malaysia, Maldives, Mauritius, Mexico, Panama, Peru, Romania, Serbia, South Africa, St. Lucia, St. Vincent and the Grenadines, Suriname, Thailand, Tunisia, Turkey, Turkmenistan, and Venezuela.



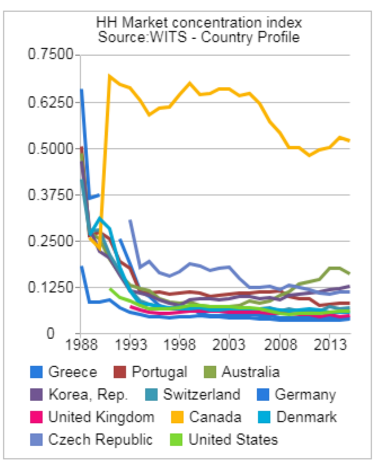
High income countries (Non-OECD) ($12,746 or more)

Antigua and Barbuda, the Bahamas, Bahrain, Barbados, Bermuda, Croatia, Cyprus, Equatorial Guinea, Hong Kong SAR, Kuwait, Latvia, Lithuania, Macao SAR, Malta, Oman, Qatar, Russia, Saudi Arabia, Singapore, St. Kitts and Nevis, Trinidad and Tobago, and Uruguay.



High income countries (OECD members) ($12,746 or more)

Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea Republic, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, the United Kingdom, and the United States.



Appendix 1.4 Extended calculations and proofs: Granger Causality Test for panel data

In one of his research, Granger initiated a methodology for analyzing causal relationships between time series. Suppose x_t and y_t are two stationary series (Granger, 1969). Then the following model:

$$y_t = \alpha + \sum_{k=1}^{K} \beta_k y_{t-k} + \sum_{k=1}^{K} \gamma_k x_{t-k} + \varepsilon_t$$

Can be used to test whether x causes y. The basic idea is that if past values of x are significant predictors of the current value of y even when past value of y have been included in the model, then x exert a causal influence on y. The null hypothesis is:

$$H_0 : \gamma_1 = ... = \gamma_K = 0$$

If H_0 is rejected, one can make the conclusion that causality from x to y exists. The x and y variables can be interchanged for causality test in the other direction, and it is possible to observe bidirectional causality.

Dumitrescu and Hurlin further extended this model to be capable of testing causality in panel data (Dumitrescu and Hurlin, 2012). The regression is illustrated as follows,

$$y_{i,t} = \alpha_i + \sum_{k=1}^{K} \beta_{ik} y_{i,t-k} + \sum_{k=1}^{K} \gamma_{ik} x_{i,t-k} + \varepsilon_{i,t}$$

Where $x_{i,t}$ and y_{it} are the observations of two stationary variables for individual i in period t. coefficients are allowed to differ across individuals and the panel must be balanced. The null hypothesis for the panel data case is,

$$H_0 : \gamma_{i1} = ... = \gamma_{iK} = 0 \qquad \forall i = 1,...N$$

Which correspond to the absence of causality for all individuals in the panel.

The test assumes there can be causality for some individuals but not necessarily for all. The alternative hypothesis thus writes (Lopez and Weber, 2017):

$$H_1 : \gamma_{i1} = ... = \gamma_{iK} = 0 \qquad \forall i = 1,...N$$

$$\gamma_{i1} \neq 0 \text{ or...or } \gamma_{iK} \neq 0 \qquad \forall i = N_1 + 1,...N$$

If $N_1 = 0$, there is causality for all individuals in the panel.

For our own specific research and data status, before doing panel data granger test, missing values issue was fixed through replace the missing variable by the value of its n-1. Besides, in order to ensure the stability of the dataset, panel unit root test was applied for all the concerning variables, and here are the outcomes of unit root test:

Table 1. 11 Unit root test outcome

Variables	Inverse chi-squared	Inverse normal	Inverse logit	Modified inverse Chi-squared
CO_2	464.92(0.0000)[1]	-7.11(0.0000)	-7.09(0.0000)	9.61(0.0000)
GDP	610.43(0.0000)	-12.78(0.0000)	-13.16(0.0000)	16.12(0.0000)
HHI-product	715.71(0.0000)	-15.62(0.0000)	-16.23(0.0000)	20.83(0.0000)
HHI-market	714.41(0.0000)	-16.00(0.0000)	-16.52(0.0000)	20.77(0.0000)

Number of panels:125
Number of periods:16

The above is the Fisher-type unit root test, based on augmented Dickey-Fuller tests. The hypothesis is,

Ho: All panels contain unit roots

Ha: At least one panel is stationary

All four of the tests strongly reject the null hypothesis that all the panels contain unit roots for every variable in this model. Choi's simulation results suggest that the inverse normal Z statistic offers the best trade-off between size and power, and he recommends using it in applications (Choi, 2001). It is observed that the inverse logit L ∗ test typically agrees with the Z test. Under the null hypothesis, Z has a standard normal distribution and L ∗ demonstrated a t-distribution with 5N + 4 degrees of freedom. Low values of Z and L ∗ cast doubt on the null hypothesis.

The ADF test for unit root testifies the null hypothesis of unit root existing against the alternative that the variables are stationary. Therefore, acceptance of the null hypothesis identifies that the series has a unit root. On the contrary, rejection of the null hypothesis implies the series is stationary without unit root.

After accomplishing the unit root test, we now proceed to panel Granger test,

Table 1. 12 Granger test outcome

Causality direction (x to y)	W-bar	Z-bar	Z-bar tilde
CO_2 to GDP	2.9861	15.7018 (p-value = 0.0000)	10.4528 (p-value = 0.0000)
CO_2 to HHI_product	1.9896	7.8238 (p-value = 0.0000)	4.6799 (p-value = 0.0000)
CO_2 to HHI_market	2.6158	12.7738 (p-value = 0.0000)	8.3072 (p-value = 0.0000)
GDP to CO_2	2.7304	13.6801 (p-value = 0.0000)	8.9713 (p-value = 0.0000)
HHI_product to CO_2	2.0714	8.4702 (p-value = 0.0000)	5.1536 (p-value = 0.0000)
HHI_market to CO_2	2.1470	9.0678 (p-value = 0.0000)	5.5915 (p-value = 0.0000)

H_0: y does not Granger-cause x.

H_1: y does Granger-cause x for at least one panelvar (country) if P value < Significance level (0.05), then Null hypothesis would be rejected.

if P value > Significance level (0.05), then Null hypothesis cannot be rejected.

The above is the outcome of singe lag by default. In this case, the outcome of the test rejects the null hypothesis. After trying different lags options, the outcome is similar with the single lag. therefore, y does granger cause x at least for one panelvar, which means CO_2 and GDP, HHI have granger causality relationship.