Ph.D. Dissertation of Economics

Essays on Trade and Sustainable Development

무역 과 지속 가능한 개발에 관한 연구

August 2018

Graduate School of Agriculture Economics and Rural Development
Seoul National University
Agriculture Economics Major

Liu Hongbo

Abstract

Essays on Trade and Sustainable D evelopment

Liu Hongbo

Dept. of Agriculture Economics & Rural Development

The Graduate School

Seoul National University

This dissertation comprises two essays, namely essay1 Export diversification, CO_2 emissions and EKC: panel data analysis of 125 countries, essay2 Ecological Footprint, FDI and GDP: Evidence from Belt& Road Initiative (BRI) countries, These essays are included to analyze theory and applications of trade and sustainable development from distinctive perspectives.

Chapter 1 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. A regression model with Driscoll and Kraay

Standard Errors is employed 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.

Chapter 2 examines the environmental issues embedded in BRI project, to be more specific: testify which of these three hypothesis (Pollution Havens Hypothesis, Pollution Halo Hypothesis, Environmental Kuznets Curve) is in accordance with the current development condition of BRI counties; whether there exists a bi-directional relationship among environmental resilience (Ecological Footprint), Gross Domestic Production (GDP), Foreign Direct Investment (FDI), as well as Total Factor Production (TFP) in BRI member countries. In this paper, Panel Vector Auto-regression (PVAR) is utilized to analyze a dataset of 44 member countries in this initiative, ranges from 1990 to 2016, to empirically testify the environmental evaluation of this project. Results are analyzed on both long-run and short-run cases through Orthogonalized Impulse-Response functions. Our findings display a great heterogeneity among different target variables, for FDI and Carbon Ecological Footprint, there does not exist a bi-directional relationship, only Carbon Footprint demonstrates robust influence on FDI. In addition, Pollution Havens

Hypothesis is true for FDI and TFP, while Pollution Halo hypothesis is valid on GDP, among BRI member countries.

The two essays follow a logic from worldwide panel data analysis to regional analysis and finaly conclude to a singel country. It is possible to observe that relationship between trade and sustainable development displays obvious heterogeneity in terms of target objective region, proxy variables, as well as time.

Contents

List of Tables

List of Figures

Introduction

Environmental challenges such as 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. Besides being a natural phenomenon, climate change has been more related with human activity and economic development. Two essays of this dissertation discuss economic development and environmental condition from CO_2 emissions and Ecological Footprint perspectives, to shed implications on sustainable development.

Essay 1 proposed to adopt an intermediate approach, using panel database to analyze the reduce-form relationship 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.

Essay 2 introduced environmental resilience as well economic resilience into consideration, which enables us to evaluate an important strategy for analyzing BRI member countries as a special region. What is more, it is empirical to analyze the pollution issue embedded in BRI from both country level and regional level, doing a comparison between the two directions and find out whether it is empirically applicable. Apart from the above mentioned, filling the gap in the literature concerning analyzing the relationship between environmental resilience and GDP, FDI in BRI member countries is considered as one of the contributions of this work. In addition, by confirming which of these hypothesis (Pollution Havens, Pollution Halo, EKC) is valid for BRI countries is practically instructive for this region for further policy consideration concerns sustainable development.

Essay1. Export diversification, CO2 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 an empirical regression equation incorporating Driscoll and Kraay standard errors to rectify the possible problems of heteroscedasticity as well as auto-correlated issues. 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 keep an 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 gas emissions in order to deal with deteriorating global warming circumstances. International Panel Conference on Climate Change (IPCC) fifth assessment report pointed out that human activities exert great influence on climate system obviously (Özokcu and Özdemir, 2017). Besides being a natural phenomenon, climate change is claimed to relate to human activity and economic development. CO_2 emissions are commonly regarded as one of the major source of global warming, due to the large amount of CO_2 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 controlling anthropogenic Greenhouse gas emissions (Holtz-Eakin and Selden, 1995). In order to prohibit further destabilization of biosphere, CO_2 emissions should be under urgent and serious control (Jayanthakumaran et al., 2012). In order to balance the relationship between the speed of economic advancement and environmental degradation, especially greenhouse gas emissions, we are in need of innovative mechanism to observe possible correlations between two factors.

Environment Kuznets Curve (hereafter EKC) is one of the most influential models for analyzing the relationship between environmental condition and economic development. EKC simulate a hypothesized inverted U-shaped correlation between diversified indices of environmental degradation and social 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, composition effect and technique effect. “Scale effect” has the definition as an increase in a certain type of pollution emissions is supposed to relate to a higher income level, under the background of holding other factors constant. In detail, scale effect measures the degree of an increase of economic size on pollution. “Technique effect” is characterized as the transformation in emission intensity due to adaptation of advanced technologies, for example clean production mechanism. “Composition effect” is designated as a change in pollution emission, due to the adjustment in the percentage of pollution intensive production in GDP. Composition effect functions as a measure to test the influence of a transformation in industrial composition (Cole, 2004; Copeland and Taylor, 1995).

Among empirical tests of EKC, two groups of variables are needed, pollution indices 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.

This study proposed to use an intermediate approach, which adopted panel database to analyze a reduce-form relationship between per capita GDP, export diversification and CO_2 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 neglected. 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 dealing with pollution related issues.

In order to further enrich the research of EKC, especially in trade discipline, the present work is proposed to incorparate export product diversification and market diversification into existing EKC model. Put it another way, understanding whether trade structure and pollution are correlated within EKC hypothesis 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).

It is believed that this paper contributes to a number of strands in recent literatures concerning sustainable development and trade. First, by collecting and reorganizing a relative complex panel database including economic 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 reduced-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, this present research is supposed to function as a reminding to policy makers: when it comes to sustainable development, compared 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 have attracted much attention among scholars from 1960s to now. Among the large amount of EKC studies, empirical works enjoy the majority while fewer papers are focus on theory analysis and literature review (Hartman and Kwon, 2005; Stern, 2017). During decades of development, EKC studies witnessed transformations through various perspective: for instance, indicators used in EKC studies proceed from the initial GDP exclusively, to trade related proxies, population and so on; econometric methodologies that is currently adopted broadened from static OLS to more comprehensive dynamic ones. Accordingly, outcomes of empirical EKC studies displays great heterogeneity, such as inverted U-shaped curve, N-shaped curve, some outcomes of the studies do not even support EKC theory.

Considering the large amount, literature review will be organized into 5 parts, in line with indicators adopted, functions used to explain the theory, dataset used to analysis, econometric methodologies performed to estimate, as well as outcome heterogeneity.

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 ambiguity (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 indices are also popular indicators for estimating 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). The other necessary variable in EKC study is economic development indicator, the indices 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 is also a factor that showed up in some recent EKC studies (Lee et al., 2009). In this work, population density is negatively correlated with CO_2 emissions, which means higher population density is beneficial to pollution alleviation. This result is distinctive 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 helps comprising the power inequality factors in exiting researches (Torras and Boyce, 1998).

Literature concerning trade diversification will be briefly discussed as it is a new variable proposed to add into EKC model. In former researches, diversification of market destinations and export products is deemed as a channel to meet the challenges of economic risks, for example: unemployment (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 who first adopted 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 CO_2 emissions (Gozgor and Can, 2016b).

2.2 Functions

Basically, a large proportion of empirical EKC researches could be concluded into reduced-form analysis, in which the endogenous variables are described as a function of exogenous variables, usually without the structure or primitive policy-invariant behavioral parameters (Sims, 1980). Independent variables in squared (Yaguchi et al., 2007), in cubed type (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 added to the existing EKC model to function as an improvement that 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 function as another inspiring point belonging to related research regime, 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 analysis (Heil and Selden, 2001; Shafik and Bandyopadhyay, 1992), panel data researches (Lee et al., 2009; Liddle, 2015; Nemati et al., 2016; Niu et al., 2011; Perman and Stern, 2003; Sirag et al., 2018), a single country (Gozgor and Can, 2017; Halicioglu, 2009; Saboori et al., 2012, 2016; Shen and Hashimoto, 2004), a city or a group of cities (Diao et al., 2009; Liu et al., 2007), and provincial level (Wang et al., 2013) are common 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 enables controlling for variables that cannot be certified such as cultural factors or variations in business practices across countries; or factors that adjustment over time but not across entities (Hsiao, 2014). Estimation results from different dataset demonstrated evident 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 effect estimation (Brajer et al., 2011), and CGE model (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). Lee reexamined the rationality of EKC through dynamic panel data approach (DPM) and observe evidences to support EKC hypothesis for CO_2 emissions through a global database. Their outcome claimed that with higher trade openness degree, pollution emission will decrease in high-income countries while increase 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 literatures on EKC demonstrated that CO_2 emissions increase perpetually in accordance with per capita income (Selden and Song, 1994; Shafik and Bandyopadhyay, 1992; Song et al., 2008). Despite the fact EKC model essentially functioning as an empirical analysis, not all estimates of EKC models estimated by so far displayed validity. In some researches, no meaningful EKC relationships can be found in global sphere, while several robust relationships between income and emissions can be discovered in individual countries. Heterogeneities among different pollution indices display the fact that, there is still no consistent agreement on the drivers of changes in emission (Stern, 2015). EKC hypothesis advocates that pollution increase initially as a country improves in economic performance; and then declines after reaching turning-point, which is a certain level of social development degree. Pollution deteriorates at early stage of economic development, which is partly due to 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 (Chronologically organized)

Author	Dependent variable(s)	Independent variable(s)	Type of function	Regression method	Turning point	Country and time
(Grossman and Krueger, 1991)	SO_2, Dark matter, suspended particles	Per capita GDP	GDP cubed, plus site dummies	Random effect	Around 4,000 USD for the first two pollutants	42 countries
(Shafik and Bandyopadhyay, 1992)	SPM, SO_2, Deforestation etc.	GDP in logarithm, trade openness, interaction dummies, time trend	Linear, squared, cubed	regression	3,670 per capita USD for SO_2	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, SO_2, NO_2, CO	Per capita GDP, population density, time	GDP squared	Fixed, random effects	Around 10,292 USD	68 countries from 1979 to

		dummies				1984
(Grossman and Krueger, 1995)	SO_2, smoke, heavy particles	Income, lagged income, dummies, populatio n density	Lagged GDP cubed	GLS	Around 8,000 USD	42 countries
(Cole et al., 1997)	SPM, SO, NO, CO	Per capita income	Logarith m squared	OLS and GLS	5,700 USD to 25,000 USD	1970 to 1992, OECD countries
(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
(Agras and Chapman, 1999)	CO_2 emissions	Per capita GDP, lagged variables, energy price	Income squared	Dynamic model	13,630 USD	33 countries and region 1991
MARK T. HEIL and THOMAS M.SELDEN(2001)	Per capita Carbon Emissions	Per capita GDP, Trade intensity, interactio n terms 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
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.,	CO_2	GDP,	Income	Random	8,570 to	89

2009)	emissions per capita	population density, exports and imports relative to GDP, energy use	cubed	and fixed	17,620 USD	countries from 1960 to 2000
(Özokcu and Özdemir, 2017)	CO_2 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 determine the results, the conditions of the data availability 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 literature 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. This research thus adopts export product diversification and market diversification as two innovative proxy variables for economic development, in order to capture the structural specialties of international trade in EKC study.

3. Theoretical model

EKC started from pollution and economic growth, and then developed into pollution and trade, this present research extends the existing logic of EKC study into more detail, and explores the embedded functions in this new logic.

This section describes theoretical models of EKC in line with the logic of the movement of this theory: from analyzing the correlation between pollution and economic growth, to pollution and trade, and then discussing the hypothesized theory of EKC relationship between pollution and export diversification.

3.1 Pollution and economic growth

The pollution demand is denoted as

$$z = \bar{e}x(p, \overline{\tau, K, L}) \ , \qquad \text{(Equation 1. 1)}$$

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 $I = G(p, K, L, z)$, (Equation 1. 2)

Where z is determined endogenously by (1.1).

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

$$\hat{z} = \varepsilon_{XK} \hat{K} \quad , \qquad \text{(Equation 1. 3)}$$

And

$$\hat{I} = s_r \hat{K} + s_\tau \hat{z} \, , \qquad \text{(Equation 1. 4)}$$

$s_r > 0$ 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:

$$\hat{z} = \frac{\varepsilon_{XK}}{s_r + s_\tau \varepsilon_{XK}} \hat{I} \quad . \qquad \text{(Equation 1. 5)}$$

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,

$$\hat{z} = \varepsilon_{XL} \hat{L} \quad . \qquad \text{(Equation 1. 6)}$$

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:

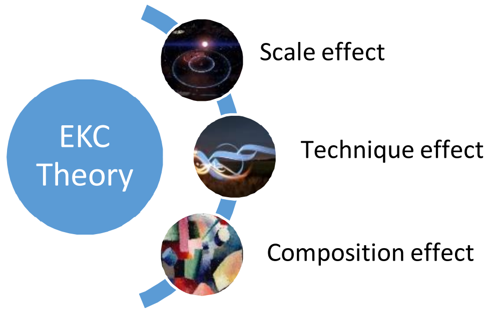
$$\hat{I} = s_w \hat{L} + s_\tau \hat{z} = (s_w + \varepsilon_{XL})\hat{L} \quad \text{(Equation 1. 7)}$$

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 is recommended (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 building a set of regression models to reflect changes of environmental condition to the degree of economic and social development, in other words, this model is proposed to display the changes of human influence on environment (Stern, 2015). And therefore, the standard EKC regression model is:

$$Pollution_{it} = \alpha_i + \gamma_t + \beta_1 GDP_{it} + \beta_2 GDP_{it}^{2} + \varepsilon_{it} .$$

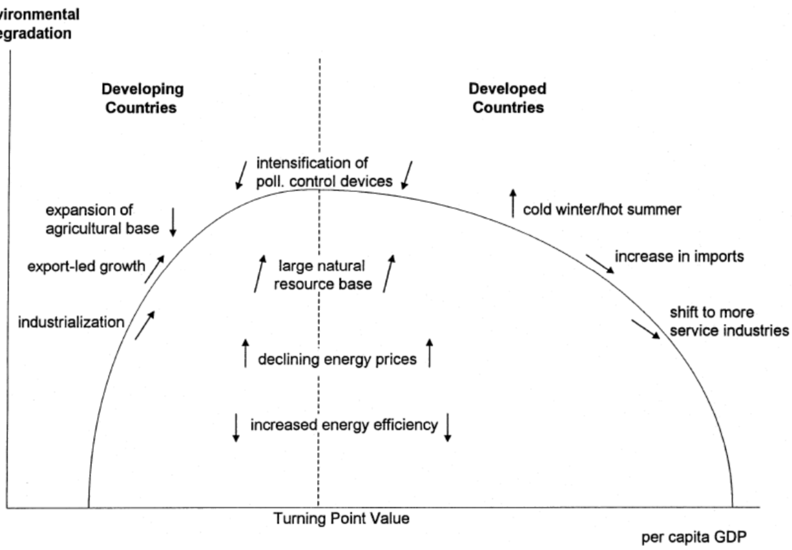
(Equation 1. 8)

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* represents 125 countries and t as an indicator of time. It is possible to observe the "turning point" level of GDP, and export diversification (Stern, 2015), the location of turning point is shown as τ in equation 1.9.

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

(Equation 1. 9)

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 (Stern et al., 1996). The effects of time-related factors differ from the development status of countries, for accelerating middle-income ones, the scale effect, which overpower the time effect. However, for developed countries, growth is slower and the environmental degradation effect can overwhelm the scale effect. This process explains the origin of EKC theory (Stern, 2004).

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

$$\frac{S_{it}}{P_{it}} = \gamma_i \frac{Y_{it}}{P_{it}} A_t \frac{E_{it}}{Y_{it}} \prod_{j=1}^{J} \left(\frac{y_{jit}}{Y_{it}}\right)^{\alpha_j} \sum_{k=1}^{K} \frac{e_{kit}}{E_{it}} \varepsilon_{it}, \qquad \text{(Equation 1. 10)}$$

where S denotes 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. In addition, the complexity of the inverted U-shaped EKC curve can be explained by the five effects measured in the above equations.

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 model and a dynamic one. Static models are those who treat economic growth (in current research changes of GDP) as changes in the level of output volumes, while dynamic models is able to capture the changing rate and evolution process of economic growth and pollution emission. To conclude, the major difference between static EKC model and dynamic EKC model lies in the point that whether it is possible to reflect elasticity of transformation (Pasten and Figueroa, 2012). Different from the traditional static EKC models, the dynamic one:

$$y_{i,t} - y_{i,t-1} = (\alpha - 1)y_{i,t-1} + \beta' X_{i,t} + \eta_i + \phi_t + \varepsilon_{i,t} \quad , \qquad \text{(Equation 1. 11)}$$

Where $y_{i,t} - y_{i,t-1}$ is the growth rate of per capita CO_2 emissions.

$$y_{i,t} = \alpha y_{i,t-1} + \beta' X_{i,t} + \eta_i + \phi_t + \varepsilon_{i,t} \quad , \qquad \text{(Equation 1. 12)}$$

By take the first differences of the above equation, get

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

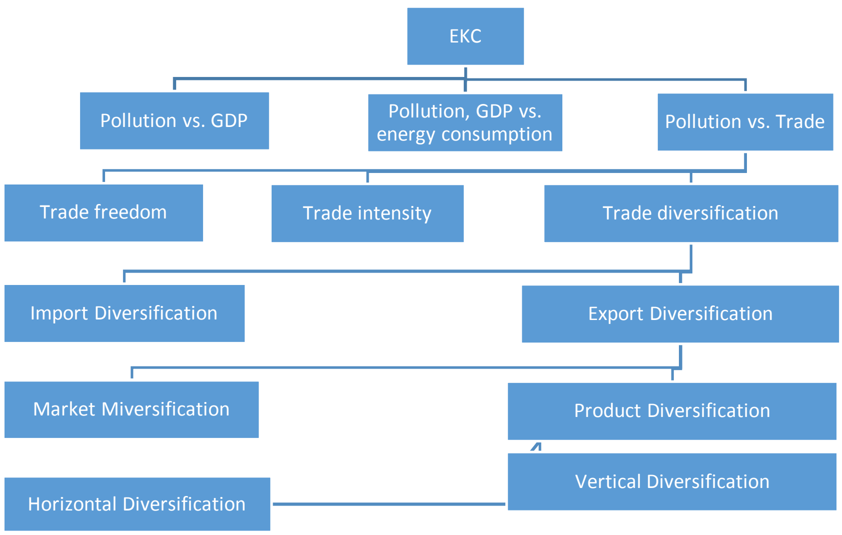
(Equation 1. 13)

There exists an example of using dynamic models (which is presented in equation 1.13) to regress EKC theory, by using panel data, certification of EKC hypothesis for CO_2 emissions was illustrated through a worldwide data set, their outcome claimed that with increasing level of international trade openness, pollution emission will decrease in high-income countries while get increased in low-income countries (Lee et al., 2009).

3.3 Pollution and export diversification

The relationship between export diversification and CO_2 emissiosns can be explained through subdividing export diversification into export market diversification and export product diversification (Cadot et al., 2013).

Figure 1. 3 Logics of export diversification



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 (Hummels, 2009). On the other hand, export product diversification, it could be further subdivided into vertical diversification and horizontal diversification (Ali et al., 1991).

Horizontal diversification appears within the scope of same sectors (primary, secondary or tertiary), that is to say, horizontal diversification facilitates transformation in the country's export variety by adding new products on existing export lines within the same sector, with the function to incorporate adverse social economical influence and political risks. Similarly, vertical enables adjustments outside a certain industrial sector, for example, from the primary to the secondary or tertiary sector. It entails extracting further process for existing products through value-added technologies, marketing or other related services. Vertical diversification is able to broaden market opportunities for raw material and help speed up growth and increase economic stability (Samen, 2010b).

To conclude, horizontal diversification means more varied export lines, while vertical diversification leads to building further uses for existing and innovative products through value-added process; 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).

Vertical diversification 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. To be more specific, one million USD value of corn exported from China to South Korea may have a dramatically different emissions component compared to a million USD value of corn exported to United Kingdom (market diversification). The export of one million worth of corn without any procession and cereal after deep processing by one million value of corn will have different CO_2 emission volumes (vertical product diversification).

Table 1. 2 Dimensions of export diversification

	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 or processed forms in both international and domestic markets	Add new commodities based on their flexibility to be marketed in raw and processed forms, and to serve international and domestic market	Introduce or expand value-added activities and import substitution	Choose new commodities based on value-added and import substitution potential	

Source: Ali et al., 1991

4. Data and empirical model

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. 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 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:

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

(Equation 1. 14)

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:

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

(Equation 1. 15)

$$Pollutant_{i,t} = \alpha_{i,t} + \beta_1 HHI_{it} + \beta_2 HHI_{it}^2 + \beta_3 GDP_{it} + \beta_4 GDP_{it}^2 + \beta_5 GDP_{it} * HHI_{it} + \beta_6 GDP_{it}^2 * HHI_{it}^2 + \mu_{it} \quad ,$$

(Equation 1. 16)

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

(Equation 1. 17)

Usually, this model is analyzed with panel data, by most commonly the fixed effects estimator, however cross-section or time-series methodologies have also been utilized (Bekhet and Yasmin, 2013; Dijkgraaf and Vollebergh, 2001; Kaufmann et al., 2011). Findings of those models are diverse according to econometric method being used.

There are several econometric issues that could influence EKC estimation: integrated variables, omitted value bias, , the problem of spurious regression as well as the recognition of time influence (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 outcome and Driscoll-Kraay estimation is made in table 1.6 to demonstrate whether Driscoll-Kraay standard error term exert higher robustness level.

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). What is more, regarding tests of the idiosyncratic component for a unit root, CADF is appropriate for unit root, especially when cross-sectional inter-dependence caused by a single common index as well as power are inversely influenced by a second prevalent 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 (Özokcu and Özdemir, 2017). These tests suggest that fixed effect analysis is suitable for the current study of 124 countries in general, 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 in table 1.5 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). 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 existing regression analysis provides extensive understanding of the interactive effects among the variables in the model. 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 changes of one variable are connected with another variable. Interaction effects can be frequently observed in regression analysis, for example ANOVA (analysis of variance), and in 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

Results of this research will be demonstrated both inclusively and in accordance with the income levels of country groups; in addition, comparison will be made with and without interaction terms which shed great heterogeneity in terms of outcome robustness.

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

[1] Country list is available in appendix 1.3

	(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***	1.414**	0.985**	2.093**
	(3.63)	(2.41)	(2.41)	(2.93)
Ln_gdp2	-0.092***	-0.092***	-0.072***	-0.118***
	(-4.78)	(-3.14)	(-3.55)	(-3.32)
Ln_hhi	0.406***	0.406***	-0.061	-0.268***
	(5.46)	(3.97)	(-1.13)	(-5.40)
Ln_hhi2	0.062***	0.062***	-0.006	-0.038***
	(5.79)	(4.79)	(-0.79)	(-6.30)
Cons_	-5.560***	-5.560*	-4.008*	-10.879**
	(-2.85)	(-1.97)	(-1.95)	(-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***	2.676***	1.276***	2.378***
	(13.09)	(15.25)	(11.29)	(15.29)
Ln_gdp2	-0.102***	-0.138***	-0.094***	-0.108***
	(-16.27)	(-18.99)	(-15.31)	(-15.91)
Ln_hhi	-0.284	0.924	0.715***	-0.407*
	(-1.57)	(1.70)	(5.08)	(-1.59)
Ln_hhi2	-0.054*	0.254**	0.057***	0.127***
	(-1.93)	(2.73)	(4.40)	(5.66)
LN_HHI*gdp	0.027	-0.085	-0.086***	0.087***
	(1.42)	(-1.40)	(-5.31)	(3.08)
LN_HHI2*gdp2	0.00052**	-0.024**	-0.00079***	-0.00055***
	(1.99)	(-2.21)	(-4.96)	(-2.06)
Cons_	-6.927***	-14.182***	-5.334***	-13.668***
	(-12.24)	(-13.90)	(-10.11)	(-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: for example in table 1.9. Therefore, it is still possible to draw meaningful conclusions that economic development displays inverted U-shaped relationship with CO_2 emissions (Frost, 2013; Frost, 2014; Vogt and Johnson, 2011).

Incorporating interaction terms to regression models can greatly broaden understanding of the relationships among the variables as well as facilitate more hypotheses to be estimated. Therefore, it is helpful to add interaction terms to the existing EKC model to capture the interaction effect among countries.

As we can learn from these 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 connected to the response value. 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

Applied economists often adopt interaction terms to display how the effect of one independent variable on the changes of dependent variable depends on the magnitude of another independent variable (Ai and Norton, 2003). Heil 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).

$$(CO_2)_{it} = \alpha_{it} + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_3 HHI_{it} + \beta_4 HHI_{it}^2 + \beta_5 GDP_t * HHI_{it} + \beta_6 GDP_{it}^2 * HHI_{it}^2 + \mu_{it}$$

(Equation 1. 18)

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	Fixed effect	Driscoll_Kraay standard error (random

		effect)		effect)
Ln_gdp	1.415*** (112.86)	3.032*** (38.87)	1.276*** (11.29)	2.378*** (15.29)
Ln_gdp2	-0.096*** (-15.88)	-0.160*** (-140.75)	-0.094*** (-15.31)	-0.108*** (-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

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 in table 1.10 displayed 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).

Displayed in table 1.10, GDP per capita in logarithm is the variable that exert most powerful explanatory ability 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 functions as a major factor to speed up 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, different countries implement environmental policies in accordance with their own interests and development pathway without worldwide unanimous regulations. 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 the world market, it is suggestive for them to pay more attention on the constitution of the exportation, to concentrate on 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 this study. Therefore, our research should be regarded as one of the empirical analysis.

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 recent literature concerning sustainable development and trade, by taking advantage of a reduced-form EKC model, the current study do not rely on strong theoretical assumptions that are indispensible in models that 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, compared to economy volome which has long been the focus, economic structure such as export diversification needs better attention.

6. Conclusions and discussions

In this study, the relationship between economic development and CO_2 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.

Further researches on the relationship between export diversification and pollution emission focusing more on transportation aspect may shed applicable results. Apart from this, further analysis which is able to collect data from more diversified sources and make comparison is of great value. Finally, dynamic econometric methodologies are proposed to modulate the structure transformation and to capture valuable policy instruction.

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.

Hartman, R., and Kwon, O.-S. (2005). Sustainable growth and the environmental Kuznets curve. *Journal of Economic Dynamics and Control* **29**, 1701-1736.

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.

Hummels, D. (2009). How Further Trade Liberalization Would Change Greenhouse-Gas Emissions from International Freight Transport. *In* "NBER Working Paper, Prepared for Global Forum on Trade and Climate Change".

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.

Sims, C. A. (1980). Macroeconomics and reality. *Econometrica: Journal of the Econometric Society*, 1-48.

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

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

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 $s_r > 0$ 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:

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

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).

Appendix 1.2 Calculation of Herfindahl-Hirshamn Index

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

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

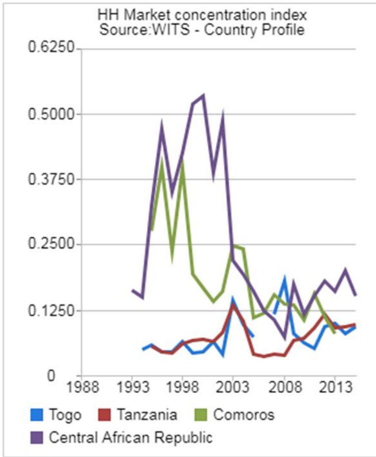
S_k is the share of export line k（with amount exported in total exports X_k）, and n is the number of export lines, k is the share of line k in total exports, n is the number of export lines, commodity use 4-digit HS code

Appendix 1.3 Country list

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

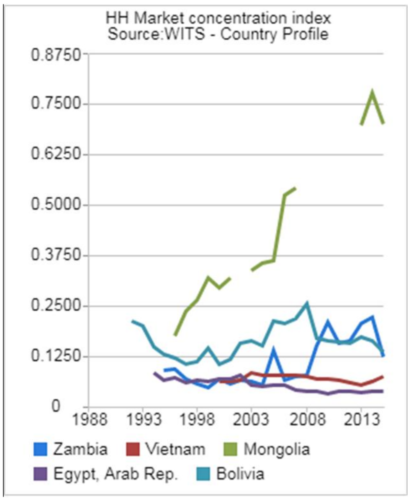
Low income countries ($1045 or less)

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.



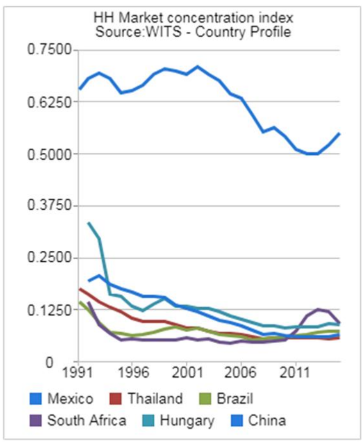
Lower middle income countries ($1046–$4125)

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.



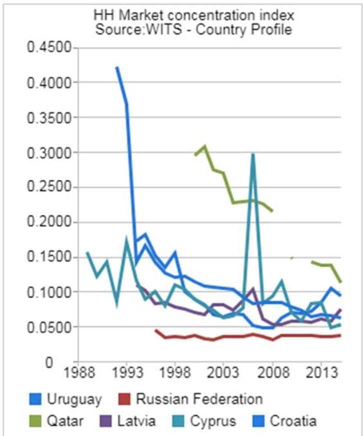
Upper middle income countries ($4126–$12,745)

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.



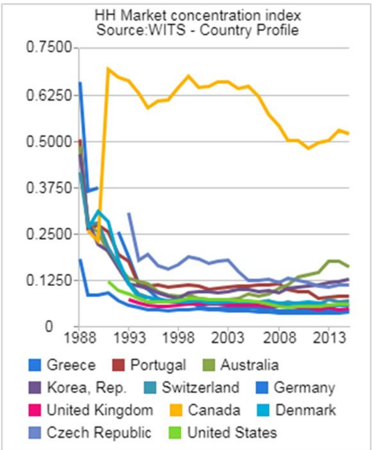
High income countries (Non-OECD) ($12,746 or more)

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.



Essay 2. Ecological Footprint, FDI and GDP: Evidence of Belt& Road Initiative (BRI) countries

Abstract:

Belt& Road Initiative (BRI), on the one hand is a constructive infrastructure development program with distinct commitment of regional and sub-regional social economic development, on the other, imperative environmental challenges involved in this plan should not be neglected. Under this background, the present research is employed to examine the environmental issues embedded in BRI project, to be more specific: testify which of these three hypothesis (Pollution Havens Hypothesis, Pollution Halo Hypothesis, Environmental Kuznets Curve) is in accordance with the current development condition of BRI counties; whether there exists a bi-directional relationship among environmental resilience (Ecological Footprint), Gross Domestic Production (GDP), Foreign Direct Investment (FDI) in BRI countries. In this paper, Panel Vector Auto-regression

(PVAR) is utilized to analyze a dataset of 44 member countries in this initiative, ranges from 1990 to 2016, to empirically testify the environmental evaluation of this project. In order to emphasize the interaction effect among BRI countries, this paper adds weighted terms comprising cross-section averages of foreign parameters into the existing PVAR model. Results are analyzed on both long-run and short-run cases through Orthogonalized Impulse-Response Functions. This research display a great heterogeneity among different target variables, FDI as a main variable of interest does not expose a bi-directional relationship with Ecological Footprint, only Ecological Footprint demonstrates robust influence on FDI. In addition, Pollution Havens Hypothesis is true for FDI and GDP among BRI member countries.

Keywords: Belt&Road Initiative, Regional Resilience, Ecological Footprint, Foreign Direct Investment, Panel Vector Auto-regression (PVAR)

1. Introduction

In 2013, Chinese government declared ambitious Multi-Billion-Dollar regional integration initiatives, called the “Belt&Road Initiatives” (from now on BRI). BRI regions include a range of more than 60 countries: within this region, member countries enjoy economic and technique communication through closer exchanges; outside the region, these countries act both individually or collectively as a group to connect with the rest of the world. Under this project, China underwriting billions of dollars of infrastructure investment projects in nations along the old Silk Road connecting it with Europe (Yu, 2017). China is spending roughly 150 billion

USD a year in this project to support or communicate with its member countries who have signed up to the scheme, the Chinese government is now exceptionally supporting Chinese entrepreneurs to transfer excess production capacity worldwide, especially with the countries who are members of the BRI. This project is purported to encourage regional economic advancement and social development as well as being a boost of multi-lateral cooperation among and beyond its members. Meanwhile, many regional and international environmental institution shows special concern over the possible condition, that BRI project is going to take advantage of this specific international project to green their own industries by relocating pollution intensive productions and resource extracting sectors to developing countries through Pollution Havens Hypothesis (PHH) (Tracy et al., 2017).

Large amount of investments (financially and technologically) as well as coordination projects are in progress, these initiating global ambitions is functioning as a major motivation for regional economic advancement; meanwhile, it also could possibly lead to environmental concerns through overloaded economic growth: water shortage, non-recycling energy expiration, as well as particle air pollution. In addition, environmental experts have also pointed out that China as a world leader, together with other fast developing nations, is generating nearly half of all global carbon dioxide emission (Harashima and Morita, 1998; Levi, 2015). In order to make a step further into sustainable development scheme, China as one of the major advocate in this project has set a concrete aim which is, to reduce carbon concentration level by 40% by the year 2020, in comparison with the 2005 levels (Stroik, 2016).

China's sustainable development target functions as a direction of an individual country, however, as a leader of the Belt&Road Initiatives, comprehensive strength and strategies are needed urgently more than ever before. Belt and Road Initiative member countries include both developed and developing countries: for the less developed countries' case, in order to speed up the transfer process of technology from developed economic entities, they are especially striving for more foreign direct investment, to their own development process; comparing to greening their economy, growing is in general more in need. However, for developed ones, their target is more multi-layered, to keep leading stage in economic development while satisfying citizens' increasing desire for clean environment, which will encourage them to invest more on the R&D of green technologies.

Therefore, it is empirically necessary to modulate the environmental evaluation of this project. In terms of analyzing the possible correlation between sustainable development and Foreign Development Investment, there are three major hypotheses: FDI Halo Hypothesis, Pollution Havens Hypothesis, and Environmental Kuznets Curve. According to FDI Halo hypothesis, FDI is hypothesized to exert positive environmental spillover effects, because FDI is deemed to be able to transfer advanced technologies from developed countries to under-developed ones (Doytch, 2012). Pollution Halo Hypothesis argue that multinational companies and transboundary plants function as a dissemination of superior knowledge from developed nations to the developing ones, which applies to the environmental area while improving the environmental performance of domestic industries (Doytch and Uctum, 2011).

Besides being a technology spillover mechanism, frequent economic exchanges among BRI countries themselves as well as with other nations in the world, could possibly lead to Pollution Havens Hypothesis (PHH), which implies that BRI members due to the fact that most of them belong to developing countries, they could become environmental victims during frequent economic exchanges (Birdsall and Wheeler, 1993; Jenkins, 2003; Zarsky, 1999). Concerns about environment encourage us to ask if increasing FDI as well as other economic exchanges among countries are associated with higher CO_2 emissions, more serious degradation, decreasing ecological resilience and higher ecological footprint. In addition, deceitful economic bubbles will screen the real development targets and result in consumption escalation, which will force the impoverish residents to damage the ecological system to seek for survival (Arango Vieira, 2009). Concerns about environment encourage us to ask if increasing FDI as well as other economic exchanges among countries are associated with higher CO_2 emissions, more serious degradation, decreasing ecological resilience and higher ecological footprint.

Dichotomy hypothesis of FDI's environmental function is displayed through the explanations of Pollution Havens Hypothesis and Halo Hypothesis. While EKC theory compromises the two to some extent, EKC is a hypothesized U-shaped relationship between economic development and pollution emission, which means pollution emission increases at first with economic development, after reaching a turning point it decreases with further economic advancement. Therefore, in this research, it is proposed to study that in BRI member countries, FDI will facilitate sustainable development or not, in addition, is there exiting a bi-directional relationship between the two variables, in detail, to decompose the cause an effect and describe the dynamic relationship between FDI and environment. Bidirectional relationship between ecological footprint and FDI is theoretically certified, however no studies have proved this empirically (Sassi and Gasmi, 2017). Therefore, this current study seeks to fill the gap between literatures and empirical theory in this regime, which elucidate the ambiguous causality correlation between ecological footprint and FDI among BRI member countries.

In addition to the hypothesized bidirectional relationship between environmental protection and FDI, comparison analysis between long-run and short-run as well shed academic significance. From the perspective of inner property and direction of how environment are correlated with economic increase: in the short-run, environment protection may decrease economic development speed due to more stringent environmental regulations, and in turn, pollution will also pessimistically influence economy through shortening life expectance and labor quality; In the long-run, it is expected that environment protection and economic development will encourage each other through escalation of resource efficiency and better allocation of social capital, which will lead to the so called “Sustainable Development” goals.

Based on this theoretical background, practical analysis on Belt&Road Initiative member countries will be implemented under the analysis framework of Panel VAR models. This paper provides an overview of PVAR methodology suited for macroeconomic practices and environmental issues to clarify a variety of practical issues to sustainable development. Panel VAR enjoys special properties that are suitable of solving academic problems, for example, PVAR is able to modulate both static and dynamic properties of interdependent models; it facilitates connecting heterogenetic units in an unrestricted mode; time variations which is common and be of great interest in most environment economic studies could be incorporated in PVAR model and exogenous shocks could be tested through affiliated technology such as Orthogonalized IRF; more importantly, cross sectional heterogeneities is able to detect (Canova and Ciccarelli, 2013). Special attention will be paid on the orthogonalized Impulse-Response Functions (IRF), which functions as a demonstration of the response of Ecological footprint to an orthogonal shock to another variable for example FDI, GDP or to itself. By orthogonalizing the responses, it is possible to diagnose the effect of one shock at a time, through keeping other shocks stable (Love and Zicchino, 2006; Mutascu et al., 2012).

However, PVAR model has limitations in analyzing interaction effects among different countries in the target group. In order to emphasize the interaction among BRI countries, this paper adds weighted cross-contry averages of foreign variables into the existing PVAR model. In detail, weight variable comprises the average of each variable of all countries except the target one. By applying weight variables, country specific of BRI members as well as a particular structure on the spillover effect present in the panel data. This could contribute to existing PVAR studies as an improvement, where the weight terms are specifically designed to account for the interaction effects among countries. This paper emphasizes the multi-country dimension of the problem by including foreign variables as weights in the panel, which intends to remedy the common issues of ignoring cross-country spillover effect in papers that solely using PVAR.

The main theoretical advances of this research relate to the fact that environmental resilience was included into consideration, which enables us to evaluate an important strategy for analyzing BRI member countries as a special region. What is more, it is empirical to analyze the pollution issue embedded in BRI from both country level and regional level, doing a comparison between the two directions and find out whether it is empirically applicable. Apart from the above mentioned, analyzing the relationship between environmental resilience and GDP, FDI in BRI member countries is considered as one of the contributions of this work. In addition, by confirming which of these hypothesis (Pollution Havens, Pollution Halo, EKC) is valid for BRI countries is practically instructive for this region for further policy consideration concerns sustainable development.

The remainder of the current study is organized in the following structure. Section 2 displays a brief literature review of environmental resilience, FDI, development conditions of BRI countries, panel VAR model. Section 3 outlines the theoretical description and estimation methodology. Results are in section 4 through both data and graph. Section 5 presents conclusions and policy implication.

2. Literature review

Both Chinese and foreign scholars began to realize the environment issue embedded in Belt&Road Initiative after its release, opinions on BRI's environmental influence varies largely among scholars, some of them being positive while others concern about its adverse effects. Professor Zhang Ning claimed in his letter published in Science, that substantial energy consumption will be required during the application process of BRI, in specific, mining and power plants, roads, bridges, as well as workshops for manufacturing sector. Although BRI is supposed to contribute to global and regional prosperity, it also could be a possible reason of surging carbon footprint (Zhang et al., 2017). Besides being a leading carbon-trading system, China's function as a global leader in climate responsibility was as well recognized, BRI proposes a plan for global cooperation which is projected to emphasize China's leadership in climate responsibility (Wang and Wang, 2017). There is an argument, that insists, BRI will become a new environmental threat across the entire Eurasian continent, those who had poor record in pollution regulation governance, including former Soviet Republics needs special attention in further research (Tracy et al., 2017). In the process of advancing BRI, China became one of the world's leading source of FDI (Foreign Direct Investment), in 2015, China ranked the second place after US in outward FDI, which made China one of the net capital exporter worldwide (Yu, 2017). Limited literatures on issues of environmental risks embedded in BRI project are restricted in condition description with little empirical analysis. Therefore, this research is proposed to employ up-to-date dataset to make up this gap.

2.1 Three hypothesis on FDI and pollution

As one of the pioneering scholar that departure from orthodox theoretical economic research, Hymer argued that, FDI is more complicated than a simple process people regarded to exchange assets internationally which comprises international production as well. He characterized FDI to a more extensive theory that includes industrial organization, which could be explained as a package in which capital, management, as well as new technologies are incorporated (Hymer, 1976).

Contradictive effects of FDI’s environmental spillover effect were displayed in the Table 2.4, where Pollution Havens Hypothesis and Halo Hypothesis display contradicting viewpoints, while EKC theory compromises the two to some extent. To be more specific, Pollution Havens Hypothesis (PHH) advocates that, under the circumstance of increasing globalization and trade liberalization, developing economies may attract more pollution intensive industries due to its relatively lax environmental regulations. Neo-liberal global regime represented by world-wide process of liberalization has become major sources of higher emission, water source pollution as well as increasing income inequality which will indirectly force the impoverished poor people to damage the environment in order to increase income (Arango Vieira, 2009; He, 2006). On the contrary, FDI Halo hypothesis argues that, FDI exert positive influence on sustainable development through demonstration effect, labor turnover mechanism as well as competition effect among different industries and nations (Cheung, 2010; Gao and Zhang, 2013). Examinations had been performed to display how competition between upstream industries and downstream ones encourage technology improvement by means of imitation, improvement of human resource quality, learning in doing effect. Similarly, He testified the path relationship between FDI and environmental efficiency by utilizing structural equation models and came into a results that certifies Pollution Halo Hypothesis which means FDI have a positive influence on local environmental efficiency (He, 2006).

By so far, most analysis on comparing Pollution Havens Hypothesis and Pollution Halo Hypothesis are restricted to theory description, therefore, in order to make up this gap, the current study will do empirical analysis by employing up-to-date data from BRI countries to testify the existence of these two-dichotomy hypothesis.

2.2 Other hypothesis related to FDI and pollution

In addition to the three hypothesis concerning FDI and environment, spillover effect of FDI could reflect the environment condition transformation according to production, consumption and trade. Based on Javorcik's firm-level empirical analysis, there is a positive productivity spillover effect from FDI spillover effect being effective through foreign institutions and their local suppliers in upstream sectors (Smarzynska Javorcik, 2004). As for production sector, through horizontal spillover effect, technical knowledge among different production sectors that would benefit pollution procession, this process, is among the classical cases of FDI influence environment. It is worth mentioning the importance of buyer-supplier relationships among foreign and domestic enterprises to pay attention on spillovers effects among sectors. Dunning argued the motivation for foreign industries to share general technical knowledge through spillover effect with firms in upstream and downstream affiliates, firms tend to influence on both product quality of the material supplied (Dunning, 2012). Theoretical models have been built to model the effects of correlations between foreign industries and domestic ones (Kneller and Pisu, 2007). The effect of FDI on economy is multi-folded, on the one hand, competition coming along with FDI project in the product and factor markets inclined to decrease profits of local economy, on the other, FDI's linkage effects to supplier entrepreneurs could possibly levy profits by cutting input expenditure (Kneller and Pisu, 2007; Markusen and Venables, 1999).

Table 2. 1 Literature summary concerning FDI and environment

Author	Dependent Variable	Independent variable	Region	Time	Method
(Hoffmann et al., 2005)	CO_2, SO_2 Emission	FDI	112 countries	1990-2005	Granger causality analysis
(Girma, 2005)	Changes in TFP	FDI, absorptive capacity (ABC)	UK	1989 - 1999	Endogenous threshold model, input Cobb–Douglas
(Wei and Liu, 2006)	TFP	R&D, export, FDI spillover	China	1998–2001	Cobb–Douglas production function
(Zheng et al., 2010)	Housing Price	Productivity, geography, quality of life	35 major Chinese cities	1991-2006	Hedonic regression
(Bekhet and bt Othman, 2011)	Electricity Consumption	CPI, GDP and FDI	Malaysia	1971 - 2009	VECM
(Pao and Tsai, 2011)	CO_2 Emissions	Energy consumption, FDI, Economic Growth	BRIC	1980-2005	Panel cointegration
(Jiang, 2015)	Pollution emission	FDI,output, capital stock, human capital	China, 28 provincia	1997–2012	OLS, Panel data

		stock, labor input	l-level		
(Doytch and Narayan, 2016)	Energy consump tion	GDP, FDI, net FDI capital inflow share of GDP	74 Countries	1985–2012	Dynamic panel estimation

According to Jiang, there are three channels to explain the influence of FDI on environment: technique effect, scale effect and finally income effect (Jiang, 2015). In fact, FDI is influencing sustainable development from various dimensions, which implies the environmental consequences of FDI could be effective through multiple approaches, for example technique effect, FDI is supposed to improve environment quality by helping domestic entrepreneurs to introduce advanced technology which are more environmental friendly. This could be a result of spillover effect by FDI. It is discovered that FDI outside the region but belong to the same industry has a negative impact on production technology, this is explained by increased competition within the same sector (Driffield and Taylor, 2000). Unlike the above mentioned studies, this research intends to adopt FDI (Foreign Direct Investment) to proxy the international exchanges among countries and within our target region: Betl&Road Initiative member countries.

At the empirical analysis, studies have been focused on spillovers for over 20 years, notwithstanding, many researches suffer from omitted variables or data incomplete. The vast majority of researches use a single equation OLS model to estimate the correlation between FDI and GDP (Bevan and Estrin, 2004; Borensztein et al., 1998; Hansen and Rand, 2006), FDI and labor productivity (Noorbakhsh et al., 2001), as well as FDI and environment (He, 2006; Hoffmann et al., 2005; Xing and Kolstad, 2002). The possible bi-directional relationship between FDI and environment, FDI and GDP, GDI and Total Factor Productivity are therefore ignored. More researches needed to perform in order to facilitate the understanding the spillover effect of FDI, to help evaluate the inner mechanism, especially in nations or regions with fragile ecological environment while in pursuit of more frequent international exchanges such as Belt and Road member countries.

2.3 Ecological Resilience and Economic Resilience

Explanations of ecological resilience as well as its connections with ecological footprint will be observed through the following literature. In one of benchmark article for our study, Chelleri examines a set of trade-offs between regional resilience and social-ecological vulnerabilities: regional environmental change is in accordance to complicated dynamics of nested adjusted mechanisms (Chelleri et al., 2016). The global interconnections among countries and regions where resources are extracted and where they are manufactured and supplied to consumers are increasing at an unique acceleration (Webster, 2014), this is changing public understanding about environmental change and regional sustainable development. Two types of resilience will be discussed in this study, namely engineering resilience and socio-ecological resilience (Clifton, 2010; Peterson et al., 1998; Walker et al., 2006).

Engineering resilience refers to the ability of a system recover from a strike to its original ascending growth path, while socio-ecological resilience specifies the ability of a mechanism to continue to function effectively even when being exposed to sudden shocks (Clifton, 2010). In his work, Clifton combines Ecological Footprint Analysis into the well-known I=PAT equation, where I represents human being's ecological influence (ecological footprint), P functions as a population proxy, A is consumption/production per capita, and T is technologies adopted in the process of consumption/production.

Inspired by Clifton's work, ecological footprint is introduced in this work as a proxy for environmental resilience. Further evidence to support this idea could be found in Wackernagel's work, in which he explains the mechanism of a standardized footprint computation methodology (Wackernagel and Yount, 1998). Ability to recover from shocks and vulnerability are the results of a series of interdependent social and natural evolution process.

Utilization of ecological footprint in sustainable development analysis enjoys multiple theoretical and empirical advantages. There exist multiplied studies which use CO_2 emission, SO_2 emission, water pollution, and energy consumption as environment condition indexes (Chen, 2009; Heil and Wodon, 1997; Hummels, 2009; Opoku, 2013; Pao and Tsai, 2011), compared to which, Ecological Footprint is a relatively wide-covered index for environment measurement. Ecological Footprint can be applied to human activity at different levels (Wackernagel and Rees, 1998; Wackernagel and Rees, 1997). National bio capacity, for example, is measured according to the yield-adjusted resource productivity of a certain square of forest, fisheries, cropland, grazing land and built-up areas inside the target country territory (Hornborg, 2009). Carbon Footprint functions as one of the measurements of CO_2 emissions related to fossil fuel use. In Ecological Footprint calculation process, these amounts are transformed into biologically productivity for attracting this amount of CO_2. Carbon Footprint is added to the Ecological Footprint due to the reason that, global warming has become increasingly severe and attracting attention from environmental related scientists. Increasing CO_2 concentrations in the atmosphere is regarded as one of the source of increasing ecological burden for earth atmosphere and human. In certain researches, carbon footprint calculation displays there measurement outcomes in certain unit, for example tomes released per month, which was not converted into local amount (Khan, 2017). Two distinct categories of footprint index should be realized: the first group is compiled using industry-product relationships embodied in input-output tables and hence are closely related to methodology of consumption-based indicators. The other group are formed on the relationships from Life-Cycle Assessment (LCA) which track particular products through supply chains (Nations, 2014). Ecological Footprint measures appropriate bio-capacity across five distinct land use category. This is contrasted with six demand types, which could be explained by that two demand systems: forest products and carbon sequestration, compete for the same bio-capacity category: forest land (Borucke et al., 2013).

2. 4 Literatures on different target regions

Literatures on spillover effect of FDI could be organized according to research target regions, for instance, researches about BRIC countries which are referred as China, Brazil, India and Russian Federation. These related researches revealed that, during the period from 1980 to 2005, there existed strong bidirectional causality correlations between pollution emissions and Foreign Direct Investment.

Furthermore, from a decomposed perspective, unidirectional obvious causality functions from output to FDI, which is in accordance with both pollution haven and halo effects (Pao and Tsai, 2011). Researches concerning developed countries such as United Kingdom also exert academic value: production progress with the increase of FDI through attracting innovative technologies and until some threshold level (Girma, 2005). Inspired by this research, it is proposed to further this study to check whether the same is applicable for other countries or regions with different development conditions, in this case, the BRI countries.

Apart from country level studies, provincial level empirical work also shed meanings. According to a research targeted on 28 provincial-level data in China, conclusion came out in this: FDI function as one of the sources to more serious pollutions among industrialized sectors, production process exert influence on natural resources (Jiang, 2015).

Researches concerning on FDI's spillover effect have paid attention mostly on firm level analysis or sector classification in one country or region (He, 2006; Moran, 2005; Wei and Liu, 2006). Studies from different region and countries demonstrate various relationships among FDI and regional sustainable development, which encourage us to perform an innovative research targeting on Belt&Road Initiative member countries.

2.5 Literatures on Panel VAR

Panel data Auto-regression (PVAR) was first initiated by Holtz-Eakin, Newey and Rosen, they estimated Vector Autoregression coefficients in panel data and analyzed the dynamic relationship between wages and hours worked by using American males' dataset (Holtz-Eakin et al., 1988). In this pioneering work, attention was paid on allowing for nonstationary individual effects and the estimation was done by applying instrumental variables, as well as lag length selection. Followed by this research, Love and Zicchino (2006) applied this methodology into empirical scheme, he employed the Euler-equation methodology and displayed the fact that financing constraints are more severe in nations who struggled with less developed financial condition (Love and Zicchino, 2006; Sassi and Gasmi, 2017). PVAR functions as a useful alternative in solving dilemmas of DSGE model through designing a panel dataset among interdependent economies. Besides, shock identification property of PVAR model encompasses more policy implications than its counterparts including DSGE and other VAR models such as SVAR, TVAR (Brana et al., 2012; Canova and Ciccarelli, 2009, 2013).

Until recent years, Vector Autoregression was mostly utilized in estimating macroeconomic questions with time series data (Ang and Piazzesi, 2003; Enders and Sandler, 1993; Toda and Phillips, 1994). Literature concerning PVAR methodology also include testifying the dynamic relationship between of public investment on private investment and economic growth (Canh and Phong, 2018), by adopting a panel VAR framework, the author performs Modified Dickey-Fuller test, Augmented Dickey-Fuller test as well as Unadjusted Dickey-Fuller test. Matheus analyzed the nexus between energy consumption, economic growth and urbanization with a panel of 21 Caribbean and Latin American countries since 1980 to 2014 by using Panel data Vector Autoregressive (Koengkan, 2017). PVAR was as well adopted by Ramadhani in his work of testifying the correlation between value added and CSR (Ramadhani et al., 2017). The spillover effect of FDI could reflect the environment condition transformation according to production, consumption and trade. According to Javorcik's firm-level empirical analysis, there is a positive productivity spillover effect from FDI spillover effect being effective through connecting with foreign companies and communicating resource with their local suppliers (Smarzynska Javorcik, 2004).

PVAR is one type of VAR models; this study will discuss other VAR models about their characteristics, and come to a conclusion that PVAR, compared to other VAR models is more suitable to our research target and data availability.

Table 2. 2 Demonstration and comparison among different types VAR models

VAR Types	Characteristics
VAR	a. Provide general description of linear dynamic relationship (Dovern et al., 2010)
SVAR (Structural VAR)	a. Estimate and interpret IRFs b. Dynamic multipliers c. Forecast FEVDs (Forecast Error Variance Decomposition) (Christopher F Baum) d. Identify structural shocks by imposing contemporaneous restrictions (Dovern et al., 2010)
GVAR (Global VAR)	a. Analyze interactions in global macroeconomic b. Be able to function with extended cross-section and large time dimensions c. Be able to deal with common factor interdependencies (Dees et al., 2007)
PVAR (Panel	a. Capture static and dynamic interdependencies; b. Be able to link across units, decompose cause and effect

VAR)	to certify single direction or bi-directional relationships (Lof and Malinen, 2014); c. Include time changes as well as shocks; d. Show cross-section dynamics (Canova and Ciccarelli, 2013) e. Capture the positive shock in macroeconomic regime with distinguishing development level (Love and Zicchino, 2006)
TVAR (Threshold VAR)	a. Distinguish regime-specific effects (Metiu et al., 2014) b. Enables observation of regime-specific spillovers

PVAR model is empirically utilized by multiple researches for diversified purpose of solving various social academic questions, mostly in the field of financial market analysis, however, recently, it is employed to model international trade and global imbalance (Xiaoling, 2008; Zhan-mei, 2008). Therefore, PVAR displays well adjustment for policy analysis and simulation exercised in which the consequences of specific oscillation can be detected. In this present research, environmental pollution issue will be analyzed by employing the estimation mechanism of PVAR model. Unlike the above works being discussed, whose attention was on firm-level estimation, in this study, we intend to empirically testify the spillover effect of FDI among BRI member countries, whether the knowledge and technique spillovers among these countries exert bi-directional relationship with environment resilience (ecological footprint) or not.

Table 2. 3 PVAR model applications in former literature

PVAR	Energy consumption, financial development, economic growth

applications	(Sadorsky, 2010)
	Financial development, investment decisions (Love and Zicchino, 2006)
	Corruption and inflation (Sassi and Gasmi, 2017)
	External shocks (commodity price, natural disaster, international economy) to output instability (Raddatz, 2007)
	The influence of global excess liquidity on commodities and asset prices (Brana et al., 2012)
	Two-dimension analysis between economic growth and pollution (Li et al., 2015)

Improvements have been made in current work concerning both empirically and theoretically. PVAR model is a dynamic panel analysis mechanism that comprises fixed effect outcomes. Generalized Method of Moments is performed to get regression fitness. Before that, time-series effects are precluded by using the average equation in constructing GMM estimators, in addition, forward difference method is used to eliminate individual effects (Arellano and Bover, 1995; Baltagi, 2008).

According literature review, there exits few FDI studies focusing on Belt&Road Initiative member countries, where environmental degradation and international trade as well as FDI play significant role in their social economic development. FDI had a long history of being used as a meaning instrument in analyzing spillover effects across countries, in this proposed research, we will keep adopting this variable, however, from an initiative perspective: The spillover effect of FDI could reflect the environment condition transformation according to production, consumption and trade. As for production sector, through horizontal spillover effect, sector-specific technical knowledge that would benefit pollution procession, this process, is among the classical cases of FDI influence environment.

Therefore, whether it is possible to observe a bi-directional relationship between sustainable development and Foreign Direct Investment in target country groups, while none of the studies have been focused on BRI countries, therefore, this important gap along with the need to consider the different effect of factors that influence regional environmental resilience motivate this research.

3. Theoretical analysis

The theoretical session of this work will generally be divided into two sections, the first one is theoretical background including Halo Hypothesis, Pollution Havens Hypothesis, and Environmental Kuznets Curve, to explain the correlation between FDI and environment, the second one is explaining PVAR model used to estimate this correlation.

3.1 Correlation between FDI and environment

Being regarded as a regional economic development booster, BRI is supposed to provide more liberal trade environment for its members, attracting more Foreign

Direct Investment, taking advantages of technology spillover effect. This study organizes three major hypotheses on explaining FDI's environmental spillover effect, which are Pollution Havens Hypothesis (PHH), FDI Halo Hypothesis, as well as Environmental Kuznets Curve.

Table 2. 4 Three major hypothesis on FDI's environmental spillover effect

Name of the H ypothesis	Meaning	Literature
Pollution Havens Hypothesis (PHH)	Local government tend to make lax environmental standards in order attract more FDI and obtain relative advantages in regional economic development	(Hu et al., 2018) (Cole, 2004) (Birdsall and Wheeler, 1993)
FDI Halo Hypothesis	FDI is hypothesized to exert positive environmental spillover effects, because FDI is supposed to be able to transfer advance technologies from developed countries to under-developed ones.	(Doytch, 2012) (Mabey and McNally, 1998) (Brucal et al.)
EKC Hypothesis	Economic development influences environment through scale, composition and technique effect which leads to an inverted U-shaped relationship between the two variables.	(Grossman and Krueger, 2008) (Stern, 2017)

Three major hypotheses are most frequently employed when analyzing the relationship between sustainable development and Foreign Development Investment, FDI Halo Hypothesis, Pollution Havens Hypothesis, Environmental Kuznets Curve. According to FDI Halo hypothesis, FDI is hypothesized to exert positive environmental spillover effects, because FDI is supposed to be able to transfer advanced technologies from developed countries to under-developed ones. Pollution Havens Hypothesis advocates that frequent economic exchanges and communications among economies could largely lead to pollution transformations from developed countries into developing ones. The validity of this hypothesis is able to be explained through the fact that less developed countries tend to have less stringent environmental regulations which could facilitate both finance and concrete investment from abroad. Concerns about environment encourage us to ask if increasing FDI as well as other economic exchanges among countries are associated with higher CO_2 emissions, more serious degradation, decreasing ecological resilience and higher ecological footprint. Besides, deceitful economic bubbles will screen the real development targets and result in consumption escalation, which will force the impoverish residents to damage the ecological system to seek for survival (Arango Vieira, 2009). Dichotomy hypothesis of FDI's environmental spillover effect is displayed through the explanations of Pollution Havens Hypothesis and Halo Hypothesis.

While EKC theory compromises the two to some extent, EKC is a hypothesized U-shaped relationship between economic development and pollution emission, which means pollution emission increases at first with economic development, after reaching a turning point it decreases with further economic advancement. In order to certify which of these three hypothesis is the suitable one to describe BRI member countries, in addition, is there exiting a bi-directional relationship between the two variables, it is proposed to conduct this research. It displays that the bidirectional relationship between ecological footprint and FDI has been testified theoretically but no studies have proved this empirically. Therefore, this present paper seeks to fill the gap in literature and elucidate the ambiguous causing correlation between ecological footprint and FDI among BRI member countries.

In addition, spillover effect from FDI could be organized into two categories (Blyde et al., 2004): horizontal (intra-industry spillover), and vertical (inter-industry spillovers). Both horizontal and vertical spillovers from FDI are regarded to transfer benefit to host nations directly through inter connections, help alleviate unemployment, R&D contributions expansion, indirectly through spillover effects for example technology externality influence. Through analyzing the two sphere of spillover property, it is possible to connect FDI and environment: vertical spillover is the extent they contain general rather than sector-specific technological knowledge; horizontal spillovers tend to adopt sector-specific technical knowledge that would favor competitors. Through this comparison, it is obvious that, there exists greater trade-offs for the MNE to prevent spillovers of certain types (Kneller and Pisu, 2007).

3.2 Panel VAR model specification

Panel Vector Autoregression (from now on PVAR) is built under the same logic of standard VAR model, but the difference is that PVAR comprises a cross country dimension. This enables PVAR to be a much more powerful tool to policy makers, since it could detect transportation of shocks across countries (Canova and Ciccarelli, 2013). PVAR technique is applied to test empirically whether the relationship between Environmental resilience and FDI, Environmental resilience and GDP are bidirectional or not. One advantage of PVAR is that it enables model to take advantage of Vector Autoregression even for panel data groups (Sassi and Gasmi, 2017).

In order to investigate the dynamics of the correlation among regional resilience, GDP and FDI, it is proposed to adopt a Panel Vector Auto-regression (PVAR) methodology. To the best of our knowledge, this specific investigation had not been performed in the subject of pollution spillover effect among Belt&Road Initiative member countries by so far. Different from Computable General Equilibrium model and time-series econometric models, PVAR model is regarded to be able to subject to long-term relationship that is consistent with economic theory. Furthermore, PVAR is demonstrated to modulate cross-country spillover effect, since individual country trade models are linked together. Compared to Panel VAR, Programs that is built for estimating time-series vecter auto regression models could be found in many statistical projects, such as SAS and STATA, PVAR on the other hand usually comprises programming dexterity (Abrigo and Love, 2015). The advantages of adopting panel dataset include panel data facilitates controlling of variables that is unable to be observed or measure, for instance culture proxies, their heterogeneity account in empirical researches. Apart from which, panel data enables higher accuracy in terms of parameter inference (Hsiao, 2007, 2014). Another advantage of PVAR is that it is able to treat multiple variables as endogenous, which enables the estimation bidirectional effects (Lof and Malinen, 2014), in present case, the bidirectional relationship between Ecological Footprint and FDI, Ecological Footprint and GDP.

Here is a k-variate panel VAR of order p with panel-specific fixed effects represented by the following system of linear equations:

$$Y_{it} = Y_{it-1}A_1 + Y_{it-2}A_2 + \cdots + Y_{it-p+1}A_{p-1} + Y_{it-p}A_p + X_{it}B + \mu_{it} + \varepsilon_{it}$$

$$i \in \{1,2,..., N\}, t \in \{1,2,...T_i\}$$ (Equation 2. 1)

Where, Y_{it} is a (1*k) vector of dependent variables; X_{it} is a (1*k) vector of exogenous covariates; μ_{it} and ε_{it} are (1*k) vectors of dependent variable-specific fixed-effect and idiosyncratic errors, respectively. The (k*k) matrices (A_1, A_2 …, A_{p-1}, A_p) and the (l*k) matrix B are parameters to be estimated. It is assumed that the formulations have the following characteristics (Abrigo and Love, 2015):

$$E[e_{it}] = 0 \text{ , } E[e'_{it}e_{it}] = \sum \text{ , } E[e'_{it}e_{is}] = 0 \text{ for all t>s}$$ (Equation 2. 2)

The parameters above are capable of being estimated jointly with the fixed effects or, alternatively, independently of the fixed effect after some transformation, using equation-by-equation ordinary least squares (OLS). (Abrigo and Love, 2015)

For these specific research purposes, this study specified a second order panel VAR model as follows:

$$Z_{it} = \Gamma_0 + \Gamma_1 Z_{it-1} + \Gamma_2 Z_{it-2} + \mu_i + d_{c,t} + \varepsilon_t$$ (Equation 2. 3)

Where Z_{it} is a three-variable vector ($\ln EF, \ln GDP, \ln FDI$), using i to index countries and t to index time, Γ is the parameters and ε is white noise error term.

In order to facilitate the VAR model into panel data, we are supposed to impose restrictions, to ensure the underlying structures is in accordance with each cross-sectional units, in our case, the different member countries of BRI project (Love and Zicchino, 2006).

Empirically, PVAR model is a dynamic panel analysis mechanism that comprises fixed effect outcomes. Generalized Method of Moments (GMM) is performed to achieve regression fitness. Before that, time-series effects are precluded by using the average equation in constructing GMM estimators (Arellano and Bover, 1995).

4. Data description

Data of ecological footprint, Foreign Direct Investment, as well as GDP are collected through various sources from 44 Belt and Road member countries, ranges from 1990 to 2016. Actually, by so far, the number of BRI members is 73 including China. However, due to data availability, as well as balancing the horizontal and vertical axis of the dataset, only 44 countries are included in this research.

Ecological Footprint: in this paper, EF refers to Ecological Footprint with a unit of GHA (Global Hectare) per capita. Ecological Footprint measures appropriate bio-capacity across five distinct land use categories. This is contrasted with six demand types, which could be explained by the existing two types of demand systems (Borucke et al., 2013). Ecological footprint measurement is a technical mechanism through which environmental pressures are attributed to domestic demand. Ecological Footprint values are illustrated in mutually exclusive units of area necessary to annually provide such ecosystem services (Monfreda et al., 2004). In this current research, both total ecological footprint as well as carbon footprint will be analyzed and comprised into PVAR models, this is because total ecological footprint demonstrate general descriptions of environmental condition while carbon ecological footprint specializes on displaying the degree of global warming.

Gross Domestic Product: GDP data came from World Bank, annual percentage growth rate of GDP, log change at market prices based on constant local currency. Aggregates are based on constant 2010 U.S. dollars. In order to avoid the common characteristic of the GDP which is instability, we directly adopt the log change form. GDP itself comprises the sum of gross value added by all resident producers in the economy as well as comprising any product taxes and minus any subsidies (Bank, 2000).

Foreign Direct Investment (Foreign direct investment, net inflows BoP), current US dollars. FDI is supposed to bring composition and technique effect as well as scale effect on environment condition (Doytch and Narayan, 2016). Foreign Direct Investment belongs to cross-border economic exchange regime, which is associated with the condition of an enterprise in one country interacting with another economic entity.

Table 2. 5 A summary of dataset

Variables	Observations	Mean	Standard Deviation	Minimum	Maximum
Ecological Footprint (Carbon)	1017	1.6899	1.284045	.021174	6.704063
Ecological Footprint (Total)	1017	3.0032	1.821681	.4308162	9.314663
GDP	1538	3.1564	8.1022	-99.2	60.3
FDI	1030	7.13e+09	2.45e+10	-2.09e+10	2.91e+11

The database this research adopted for analyzing is panel data set, one preliminary advantage of adopting panel data over a simple cross-sectional data base is that it facilitates us to control for the country-specific fixed effects, this is especially meaningful for this research since our data set are countries with different development conditions. By utilizing panel data, it could avoid potential bias lead by data, and more importantly figure out latent effects that are caused by auto-correlation with explanatory variables. However, this does not mean that panel data can solve all econometric issues, actually it also could be a possible complication factor for future analysis (Cole and Neumayer, 2004). Based on this statement, it is recommended to decide a suitable econometric methodology for our specific database, in order to avoid as much spurious issue (or any other factors that could influence robustness) as possible.

5. Econometric analysis and results

5.1 Model specification

By utilizing PVAR as the main analyzing technology for our topic, it enables us to overcome the limitations causing by simply using VECM or Granger-causality analysis separately. The empirical model of this study is a combination of Abrigo's PVAR theoretical model and Doytch's applicable one (Abrigo and Love, 2015; Doytch and Narayan, 2016; Love and Zicchino, 2006), adjustments are made in order to suit data characteristics and research topic. In addition, in order to modulate interaction effect among countries in BRI program, weight terms are added into exiting PVAR model.

In this research, PVAR models consists of six variables: Ecological Footprint and GDP, FDI, and the weight of respective factor $\begin{bmatrix} \mathrm{EF}_{it} \\ GDP_{it} \\ FDI_{it} \\ (\mathrm{EF\_w})_{it} \\ (\mathrm{GDP\_w})_{it} \\ (\mathrm{FDI\_w})_{it} \end{bmatrix}$.

Where the weights are cross-section averages of foreign variables, could be calculated as follows:

$$EF_{-w_{it}} = \frac{\sum_{t=1990,i=1}^{t=2016,i=44} EF_{it} - \sum_{t=1990}^{t=2016} EF_{it}}{43} \qquad \text{(Equation 2. 4)}$$

Similar is true for GDP_w, and FDI_w. They represent country-specific weights, typically constructed using data on foreign data.

The structural form of VAR models is as follows:

$A\Delta y_t = \sum_{i=1}^{p} A_i \Delta y_{t-1} + D_t + B\varepsilon_t$ (Equation 2. 5)

Where p denotes the maximum lag length, y_t is a (6*1) vector of endogenous variables, y_{t-1} is a (6*1) vector of lagged values of endogenous variables, D_t is (6*1) deterministic variables such as Constant, Linear trend, seasonal dummies, and Impulse dummies. In addition, A_i is a (6*6) autoregressive coefficients matrix, A indicates the instantaneous correlationship between the observed factors of Δy_t, ε_t represents a (6*1) vector of random error of the disturbance terms, which could also be referred as Orthogonalized Shocks.

Before analyzing the Panel VAR, it is necessary to estimate the reduced form of VAR, which can be obtained by multiplying A^{-1} to both sides of Equation 2.6

$\Delta y_t = \sum_{i=1}^{p} \theta_i \Delta y_{t-1} + \mu_t$ (Equation 2. 6)

Where $y_t$is a (6*1) vector of endogenous variables , $\theta_i$is a (6*6) coefficients matrix which is achieved by multiplying $A^{-1}A_i$ $(I - 0,1 \ldots 6)$, and μ_t represents (6*1) vector of error terms in reduced form VAR. Matrix A is a lower triangular matrix with ones on the diagonal and matrix B is a diagonal matrix. Matrix A and B are displayed as follows:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 \\ a_{21} & a_{21} & 1 & 0 & 0 & 0 \\ a_{21} & a_{21} & a_{21} & 1 & 0 & 0 \\ a_{21} & a_{21} & a_{21} & a_{21} & 1 & 0 \\ a_{21} & a_{21} & a_{21} & a_{21} & a_{21} & 1 \end{bmatrix} * \begin{bmatrix} \mu_T^{EF} \\ \mu_T^{GDP} \\ \mu_T^{FDI} \\ \mu_T^{EF\_w} \\ \mu_T^{GDP\_w} \\ \mu_T^{FDI\_w} \end{bmatrix} = \begin{bmatrix} b_{11} & 0 & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & b_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & b_{66} \end{bmatrix} * \begin{bmatrix} \varepsilon_T^{EF} \\ \varepsilon_T^{EF} \\ \varepsilon_T^{EF} \\ \varepsilon_T^{EF\_w} \\ \varepsilon_T^{GDP\_w} \\ \varepsilon_T^{FDI\_w} \end{bmatrix}$$

(Equation 2. 7)

By further transformation process, $\mu_t = A^{-1}B\varepsilon_t$ could help display the relationship between reduced form disturbances and the structural form shocks.

$$\begin{bmatrix} \mu_T^{EF} \\ \mu_T^{GDP} \\ \mu_T^{FDI} \\ \mu_T^{EF\_w} \\ \mu_T^{GDP\_w} \\ \mu_T^{FDI\_w} \end{bmatrix} = \begin{bmatrix} \lambda_{11} & 0 & 0 & 0 & 0 & 0 \\ \lambda_{21} & \lambda_{22} & 0 & 0 & 0 & 0 \\ \lambda_{31} & \lambda_{32} & \lambda_{33} & 0 & 0 & 0 \\ \lambda_{41} & \lambda_{42} & \lambda_{43} & \lambda_{44} & 0 & 0 \\ \lambda_{51} & \lambda_{52} & \lambda_{53} & \lambda_{54} & \lambda_{55} & 0 \\ \lambda_{61} & \lambda_{62} & \lambda_{63} & \lambda_{64} & \lambda_{65} & \lambda_{66} \end{bmatrix} * \begin{bmatrix} \varepsilon_T^{EF} \\ \varepsilon_T^{GDP} \\ \varepsilon_T^{FDI} \\ \varepsilon_T^{EF\_w} \\ \varepsilon_T^{GDP\_w} \\ \varepsilon_T^{FDI\_w} \end{bmatrix}$$

(Equation 2. 8)

This research employs recursive identification through the Cholesky decomposition to regulated contemporaneous structural shocks in PVAR model for analyzing the impact of target variables.

$$\begin{pmatrix} \ln\_\,EF_{it} \\ \ln\_\,GDP_{it} \\ \ln\_\,FDI_{it} \\ \ln\_(EF\_w)_{it} \\ \ln\_(GDP\_w)_{it} \\ \ln\_(FDI\_w)_{it} \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{pmatrix} + \Gamma_1 \begin{pmatrix} \ln\_\,EF_{it-1} \\ \ln\_\,GDP_{it-1} \\ \ln\_\,FDI_{it-1} \\ \ln\_(EF\_w)_{it-1} \\ \ln\_(EF\_w)_{it-1} \\ \ln\_(EF\_w)_{it-1} \end{pmatrix} + \Gamma_2 \begin{pmatrix} \ln\_\,EF_{it-2} \\ \ln\_\,GDP_{it-2} \\ \ln\_\,FDI_{it-2} \\ \ln\_(EF\_w)_{it-2} \\ \ln\_(EF\_w)_{it-2} \\ \ln\_(EF\_w)_{it-2} \end{pmatrix} + \mu_i + d_{c,t} + \varepsilon_t$$

$i \in \{1,2,\ldots,N\}$, $t \in \{1,2,\ldots,T_i\}$

(Equation 2. 9)

The parameters above are capable of being estimated integratedly with the fixed effects or, instead, through fixed effect after some model conversion, adopting equation-by-equation Ordinary Least Squares (OLS). Where i is used to proxy countries from BRI and t to index time which ranges from 1990 to 3016, Γ is the parameters and ε is white noise the error term.

Restrictions are imposed to facilitate the VAR model into panel data as well as to ensure the underlying structures is in accordance with each cross-sectional units (Love and Zicchino, 2006), in our case, the different member countries of BRI project.

5.2 Estimation procedure

Estimation procedures of PVAR are decomposed into four steps: panel data unit root test, lag length selection, cointegration test as well as PVAR granger causality test.

5.2.1 Unit root test

Testing a unit root in Ecological Footprint using all countries observation over 20 years in this sample will be performed through ADF (Augmented Dickey-Fuller) process (Engle and Granger, 1987). As before, it is not suggested to include a trend in our analysis procedure, therefore, no specification on the “trend” option in STATA command, nevertheless, “drift” option was added due to specific data condition. And it is proposed to use 2 lags in ADF regressions, which will remove cross-sectional means by using “demean” option. In order to detect the stationarity in panel data of the dependent and independent variables, ADF was the most common method carried on (Friedl and Getzner, 2003). Different from Friedl’s argument, Elliot has demonstrated that an improved test based on the Dickey-Fuller approach, which is believed to be more powerful than traditional rectification

(Elliot et al., 1996). The reason is that, in this innovated approach, time series data set undergoes a GLS conversion process before performing ADF. The target of this process is to test the exclusiveness of the time series with ecological footprint (EF) as the dependent variable and GDP per capita, Foreign Direct Investment (FDI), as the explanatory variables.

The ADF test for unit root requires the estimation of equation of the form:

$$\Delta y_t = \alpha_0 + \partial y_{t-1} + \sum_{i=1}^{P} \beta_i \Delta y_{t-1} + \varepsilon_t \qquad \text{(Equation 2. 10)}$$

Where, y_t is a vector for the time series variables in a particular regression, in our case, the variables under consideration, ε_t is the error term, p refers to the optimal lag length.

The two hypothesis of unit root test in our specific research topics are as follows,

H_o: all panels contain unit roots

H_a: at least one panel is stationary

Table 2. 6 Result of Unit root test

Variables	Inverse chi-squared	Inverse normal	Inverse logit	Modified inverse Chi-squared
EF (Carbon)	268.94(0.00)[2]	-9.87(0.00)	-10.42(0.00)	13.64(0.00)
EF (Total)	273.16(0.00)	-10.05(0.00)	-10.68(0.00)	13.96(0.00)
GDP	725.05(0.00)	-21.04(0.00)	-26.46(0.00)	40.47(0.00)

[2] Values in parentheses are p-values

FDI	156.98(0.00)	-6.13(0.00)	-5.89(0.00)	6.09(0.00)
EF(Carbon)_w	486.11(0.00)	-13.96(0.00)	-17.27(0.00)	24.64(0.00)
EF(Total)_w	488.03(0.00)	-14.26(0.00)	-17.41(0.00)	24.77(0.00)
GDP_w	725.05(0.00)	-21.03(0.00)	-26.45(0.00)	40.46(0.00)
FDI_w	302.32(0.00)	-9.35(0.00)	-10.31(0.00)	12.47(0.00)

All of the tests strongly reject the null hypothesis that all the panels contain unit roots, rejection of the null hypothesis implies the series is stationary without unit root. For every variable in this model. 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 calculated from 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.

Here, it is necessary to make further explanation on stability of GDP: in the ordinary course of events, GDP datasets tend to display instability property, the reason why GDP is stable in our estimation is that, the GDP data adopted is the logarithm form of GDP changes, to be more specific, it is the annual percentage growth rate of GDP, log change at market prices.

5.2.2 Lag length selection

In order to converting the VAR representation of our variables into the VECM representation, it suggests to decrease the number of lags by one.

$$y_t = \mu + \sum_{i}^{p} \Phi_i y_{t-i} + \varepsilon_t \qquad \text{(Equation 2. 11)}$$

With p lags of y_t to

$$\Delta y_t = \gamma + \tau t + \alpha(\beta' y_{t-1} + \nu + \rho t) + \sum_{i}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t \qquad \text{(Equation 2. 12)}$$

With p-1 lags of Δy_t

It turns out that it is possible to use likelihood-ratio test to find the proper lags number. The Akaike's information criterion (AIC) (Akaike, 1969), Hannan and Quinn's information criteria (HQIC) (Hannan and Quinn, 1979), Schwarz's Bayesian information criterion (SBIC) (Schwarz, 1978) as well as the likelihood-ratio test statistics now favor four lags, and the final prediction error (FPE) indicates lag 3. According to Lutkepohl, HQIC and SBIC outcome provide consistent estimation of true lag length, while the FPE and AIC statistics overestimate lag length even in infinite estimation samples (Lütkepohl, 2005). It is planned to apply panel autoregression (PVAR) technique to test empirically whether the interaction between Ecological Footprint (EF) and GDP, EF and FDI are bidirectional. The advantage of this methodology is that it facilitates benefiting from advantages of Vector Autoregression (VAR) from the advantage of panel techniques with only two typical econometric restrictions, stationary issue and lag selection (Sassi and Gasmi, 2017).

Table 2. 7 Lag selection outcome between Ecological Footprint and GDP

Lag	Interactions between EF (Carbon) and GDP					Interactions between EF (Total) and GDP				
	CD	J	MBIC	MAIC	MQIC	CD	J	MBIC	MAIC	MQIC
1	0.99	11.5	-68.7	-12.5	-34.1	0.99	15.2	-65.0	-8.8	-30.4
2	0.99	7.0	-46.4	-8.9	-23.4	0.99	8.6	-44.8	-7.4	-21.8
3	0.99	3.3	-23.5	-4.7	-11.9	0.99	4.6	-22.2	-3.5	-10.6

Table 2. 8 Lag selection outcome between Ecological Footprint and FDI

Lag	Interactions between EF (Carbon) and FDI					Interactions between EF (Total) and FDI				
	CD	J	MBIC	MAIC	MQIC	CD	J	MBIC	MAIC	MQIC
1	0.99	11.82	-68.3	-12.18	-33.76	0.992	13.26	-66.9	-10.74	-32.32
2	0.99	6.98	-46.4	-9.02	-23.41	0.993	6.33	-47.1	-9.67	-24.05
3	0.98	3.67	-23.0	-4.33	-11.52	0.984	1.08	-25.6	-6.92	-14.11

Table 2. 9 Lag selection outcome between Ecological Footprint_w and GDP_w

Lag	Interactions between EF_w(carbon)and GDP					Interactions between EF_w(total) and GDP				
	CD	J	MBIC	MAIC	MQIC	CD	J	MBIC	MAIC	MQIC
1	0.99	18.18	-61.98	-5.23	-27.40	0.99	0.18	-63.88	-7.73	-29.31
2	0.99	10.99	-42.45	-5.01	-19.39	0.97	0.28	-43.58	-6.14	-20.53
3	-1.52	3.34	-23.38	-4.66	-11.86	-9.49	0.33	-22.11	-3.39	-10.58

Table 2. 10 Lag selection outcome between Ecological Footprint_w and FDI_w

Lag	Interactions between EF_w(carbon) and FDI	Interactions between EF_w(total) and FDI_w

	CD	J	MBIC	MAIC	MQIC	CD	J	MBIC	MAIC	MQIC
1	0.999	15.02	-63.79	-8.98	-30.15	0.999	16.41	-62.40	-7.59	-28.76
2	0.999	11.73	-40.82	-4.27	-18.39	0.999	5.73	-46.82	-10.27	-24.39
3	0.978	6.86	-19.41	-1.34	-8.19	0.974	8.93	-17.35	0.93	-6.13

Estimation results of the Hansen's J statistics (J) is higher at one lag, for the case of EF (Carbon) and GDP, however, for the rest of the cases, J statistics are higher at two lags. As for MBIC, MAIC, and MQIC estimations are lower at one lag. To conclude, the evidence suggests using lag 2 in the following estimation process is appropriate.

5.2.3 Cointegration test

Only a cointegration series can lead further long run relationship (Asafu-Adjaye, 2000). If the model consists with the more than three variables (multi-variate model) and I (1) variables are bonded by more than one cointegration vector, it is not suitable to apply Engle and Granger procedure. The nonstationary in time series data causes estimation inefficiency to empirical estimation and data analysis. Running a least squares regression without correcting nonstationary could possibly leads to spurious regression outcome. Therefore, this study adopted cointegration test in our research which is expected to enable us to observe the long-run relationship among the variables in PVAR model (Sigmund et al., 2017).

Tests for the number of cointegration relationships, similar to lag length, involve multiple tests (Becketti, 2013). In the maximum eigenvalue approach, a likelihood-ratio test was performed between the null hypotheses of exactly r cointegration relationships versus the alternative hypothesis that r+1 cointegration exist. However, this approach is not capable of revising the multiple test issue; nominal sizes of the tests will not correspond to the actual size of the test when multiple tests are conducted.

5.2.4 PVAR granger causality test

PVAR model is estimated by Granger Causality Wald tests for each equation. STATA's built-in test command is capable of doing such analysis. Panel VAR-Granger causality Wald test will be demonstrated as follows,

H_o: Excluded variable does not Granger-cause Equation variable

H_a: Excluded variable Granger-causes Equation variable

It is proposed to use panel granger causality test to testify which of these hypothesis is true.

Table 2. 11 Panel granger test results

Equation/excluded		Chi2	DF	Prob>chi2
Total	GDP	0.708	1	0.400
	Total_w	4.238	1	0.040
	GDP_w	7.560	1	0.006
	ALL	11.803	3	0.008
GDP	Total	3.935	1	0.047
	Total_w	0.005	1	0.942
	GDP_w	28.961	1	0.000
	ALL	32.361	3	0.000

Total_w	Total	15.524	1	0.000
	GDP	0.532	1	0.466
	GDP_w	243.276	1	0.000
	ALL	259.348	3	0.000
GDP_w	Total	0.436	1	0.509
	GDP	8.576	1	0.003
	Total_w	6.739	1	0.009
	ALL	65.064	3	0.000

Results of the Granger causality test above shows that Ecological Footprint does not Granger-causes GDP, but GDP Granger-causes Ecological Footprint (Total) at the 5% confidence levels, which confirms the existence of a single directional relationship between pair variables, instead of a bi-directional one. The same is true for Carbon Ecological Footprint, who demonstrate robust single directional relationship from GDP to Ecological Footprint (Carbon).

This research first checks the stability condition of the estimated panel VAR through Impulse-Response Function. The resulting table and graph of eigenvalues confirm that all variables under this estimation are stable (Abrigo and Love, 2015).

5.3 Results of PVAR and corresponding FEVD

In order to utilize VAR estimation procedure into Panel data, restrictions needed to be added to ensure the underlying structure is in accordance with each cross-sectional unit. In order to avoid the possible violation of this constraint in empirical analysis, there exists one reasonable solution to grant individual heterogeneity in the levels of variables by employing fixed effect factors (Love and Zicchino, 2006). In fact, the impulse response functions are adopted to estimate the impact of one variable shock on the present and future values of endogenous parameters while the null hypothesis will be suspended (Henriques and Sadorsky, 2008). In order to overcome the shortage of auto-correlation, it is suggested to perform a shock Orthogonalization process to separate similar components from residuals to each variable using Cholesky decomposition (Sassi and Gasmi, 2017).

5.3.1 Results of PVAR

This section presents the results of PVAR model, Eigenvalue Stability Condition, Granger Causality Wald test, Forecast-Error Variance Decomposition (FEVD) and Impulse-response function. Table 2.7 shows the outcomes of PVAR model with one lag.

Here is the equation under estimation,

$$Z_{it} = \Gamma_0 + \Gamma_1 Z_{it-1} + \Gamma_2 Z_{it-2} + \mu_i + d_{c,t} + \varepsilon_t \qquad \text{(Equation 2. 13)}$$

Where Z_{it} is a six-variable vector (lnEF, lnGDP, lnFDI, lnEF_w, lnGDP_w, lnFDI_w), we use i to index countries in BRI project and t to index time (1990 to 2016), Γ is the parameters and ε is white noise.

In order to facilitate the VAR model into panel data, it is suggested to impose restrictions, to ensure the underlying structures is in accordance with each cross-sectional units, in our case, the different member countries of BRI project (Love and Zicchino, 2006).

Table 2. 12 Result of PVAR

Response of	Response to					
	D(Ln_EF)	D(Ln_GDP)	D(Ln_FDI)	D(Ln_EFw)	D(Ln_GDPw)	D(Ln_FDIw)
Mode1. Ecological Footprint (Total) and GDP, FDI, and their weights						
D(Ln_EF)	0.811***(1.57e+09)	0.0614***(8.28e+08)	3.46e-12***(1.01e+09)	-2.636***(-2.64e+09)	-0.0141***(-1.95e+08)	4.94e-11***(2.12e+09)
D(Ln_GDP)	3.581***(6.94e+09)	0.678***(9.14e+09)	-7.21e-13***(-2.10e+08)	-26.21***(-2.63e+10)	0.0286***(3.95e+08)	3.38e-10***(1.45e+10)
D(Ln_FDI)	1.40061e+11***(2.71e+20)	1.04015e+10***(1.40e+20)	0.617***(1.80e+20)	-3.87654e+11***(-3.89e+20)	-5.47628e+09***(-7.57e+19)	3.556***(1.53e+20)
D(Ln_EFw)	0.444***(8.60e+08)	0.0681***(9.19e+08)	6.35e-13***(1.85e+08)	-1.844***(-1.85e+09)	-0.0252***(-3.48e+08)	1.86e-11***(8.02e+08)
D(Ln_GDPw)	1.283***(2.49e+09)	0.443***(5.97e+09)	9.69e-12***(2.83e+09)	-20.10***(-2.02e+10)	0.188***(2.60e+09)	2.21e-10***(9.52e+09)
D(Ln_FDIw)	-2.97315e+09***(-5.76e+18)	170742516.5***(2.30e+18)	0.0389***(1.13e+19)	-1.87642e+10***(-1.88e+19)	91458329.2***(1.26e+18)	1.551***(6.68e+19)
Mode2. Ecological Footprint (Carbon) and GDP, FDI and their weights						
D(Ln_EF)	1.102***(1.76e+09)	0.0570***(7.44e+08)	2.23e-13***(50206354.89)	-2.084***(-1.27e+09)	-0.0367***(-4.70e+08)	2.39e-11***(6.79e+08)
D(Ln_GDP)	5.685***(9.11e+09)	0.727***(9.48e+09)	-1.65e-11*** (-3.73e+09)	-34.81***(-2.13e+10)	-0.131***(-1.68e+09)	4.09e-10***(1.16e+10)
D(Ln_FDI)	1.93382e+11***(3.10e+2	1.24327e+10***(1.62e+20)	0.200***(4.50e+19)	-4.22109e+11***(-	-9.22652e+09***(-	3.267***(9.30e+19)

	0)			2.58e+20)	1.18e+20)	
D(Ln_EFw)	0.293***(4.69e+08)	0.0334***(4.35e+08)	-1.18e-13***(-2.65e+07)	-1.196***(-7.31e+08)	-0.0132***(-1.69e+08)	1.32e-11***(3.77e+08)
D(Ln_GDPw)	1.901***(3.05e+09)	0.395***(5.14e+09)	4.80e-***(1.08e+09)	-28.31***(-1.73e+10)	0.151**(1.94e+09)	3.13e-10***(8.91e+09)
D(Ln_FDIw)	-.44728e+09***(-3.92e+18)	157904209.5***(2.06e+18)	0.0336***(7.56e+18)	-2.66911e+10***(-1.63e+19)	-10858833.7***(-1.39e+17)	1.602***(4.56e+19)

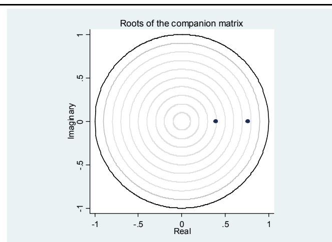
Above results demonstrate robustness under 1% level in general, which means strong robustness, especially, all variables displays obvious correlation to itself, for example 0.811 for Total Ecological Footprint and 0.617 for FDI in model 1. Nonetheless, in model 2, Carbon Footprint exhibit positive self-correlation, which is in accordance with the case of Total Footprint. Even though both model 1 and model 2 illustrate significance in 1% level, their respective self-correlation is divergent among variables.

It is obvious from table 2.12 that, response from changes of GDP to Ecological Footprint is sensitive, and a country with higher GDP is more likely to have higher Ecological Footprint which certifies the validity of Pollution Havens Hypothesis. While the cases for FDI are the same, response of Total Ecological Footprint is positively correlated with FDI, which imply Pollution Havens Hypothesis is true for these variables.

In detail, as for Carbon Ecological Footprint, similar tendency could also be observed: FDI, it exposed positive relationship with Ecological Footprint, which implies that higher total factor productivity and foreign direct investment evoke higher environmental risks in terms of ecological footprint.

Next step is to check the stability condition of PVAR model by adopting Eigenvalue Stability Condition. Table 2.11 demonstrates the graph and tables of eigenvalue stability condition.

Table 2. 13 Eigenvalue stability condition

Eigenvalue			**Graph**
Real	Imaginary	Modulus	
0.7595	0	0.7595	
0.3917	0	0.3917	

The Eigenvalue test indicated that the PVAR model is stable because all eigenvalues are inside of unity circle.

5.3.2 Results of the FEVD (Forecast-Error Variance Decomposition) estimates

Forecast-Error Variance Decomposition (from now on FEVD) was calculated through STATA command, based on a Cholesky decomposition of the residual covariance matrix of the underlying PVAR model. Standard errors and confidence intervals based on Monte Carlo estimation be calculated instead (Winkler et al., 2014). The analysis of nexus between ecological footprint, GDP, and FDI, complements the literature. The results of preliminary tests indicate the existence of low multi-collinearity, cross-section dependence, and unit roots.

Table 2. 14 Forecast-error variance decomposition results (FDI/Carbon EF)

Response variable and forecast horizon		Impulse variable		Response variable and forecast horizon		Impulse variable	
		FDI	Carbon			Carbon	FDI
FDI	0	0	0	Carbon	0	0	0
	1	1	0		1	1	0
	2	0.64	0.36		2	0.9977	0.0022
	3	0.55	0.45		3	0.9974	0.0025
	4	0.49	0.51		4	0.9972	0.0028
	5	0.47	0.53		5	0.9971	0.0029
	6	0.45	0.55		6	0.9971	0.0030
	7	0.43	0.57		7	0.9970	0.0030
	8	0.43	0.57		8	0.9970	0.0030
	9	0.42	0.58		9	0.9970	0.0030
	10	0.41	0.58		10	0.9970	0.0031
Carbon	0	0	0	FDI	0	0	0
	1	0.11	0.894		1	0.106	0.894
	2	0.088	0.911		2	0.415	0.585
	3	0.084	0.916		3	0.513	0.487
	4	0.083	0.918		4	0.565	0.435
	5	0.082	0.919		5	0.595	0.405
	6	0.081	0.919		6	0.614	0.386
	7	0.080	0.920		7	0.626	0.374
	8	0.080	0.920		8	0.634	0.366
	9	0.079	0.920		9	0.640	0.360
	10	0.079	0.920		10	0.643	0.357

Results of FEVD are displayed in table 2.13. Due to the reason that standard errors are relatively large, the forecast error variance of Carbon Ecological Footprint is not obviously different from zero. Based on results of this test, it is possible to observe which variable exert stronger explaining power to our target variable: both FDI and carbon footprint explain better to their own changes, which are 63% and 99% respectively; as for the interactive influence, the explanatory power of Carbon Footprint to FDI is stronger than vice versa. These results demonstrate the fact that the bidirectional relationship between FDI and Carbon Footprint is not valid.

The variance decompositions display the significance of the total effect. Development of Ecological Footprint was explained by the fluctuation of GDP and FDI. The result of the variance decomposition analysis for Ecological Footprint is demonstrated in Table 2.12, it is obvious that Total Ecological Footprint was negatively explained by GDP for 34% with robustness.

5.3.3 Impulse Response Functions

Through observing the outcome of Impulse Response Functions (from now on IRFs) estimation obtained from the PVAR estimation, it is possible to find how endogenous variables react to certain structural shocks over time. In this research, IRF outcomes are demonstrated in a 10-quarter period graph with 95% confident intervals. As it could be observed in Figure 2.1, the shaded area means a 95% confidence intermission.

Figure 2. 1 IRFs Results of Ecological Footprint (Carbon), GDP, and FDI

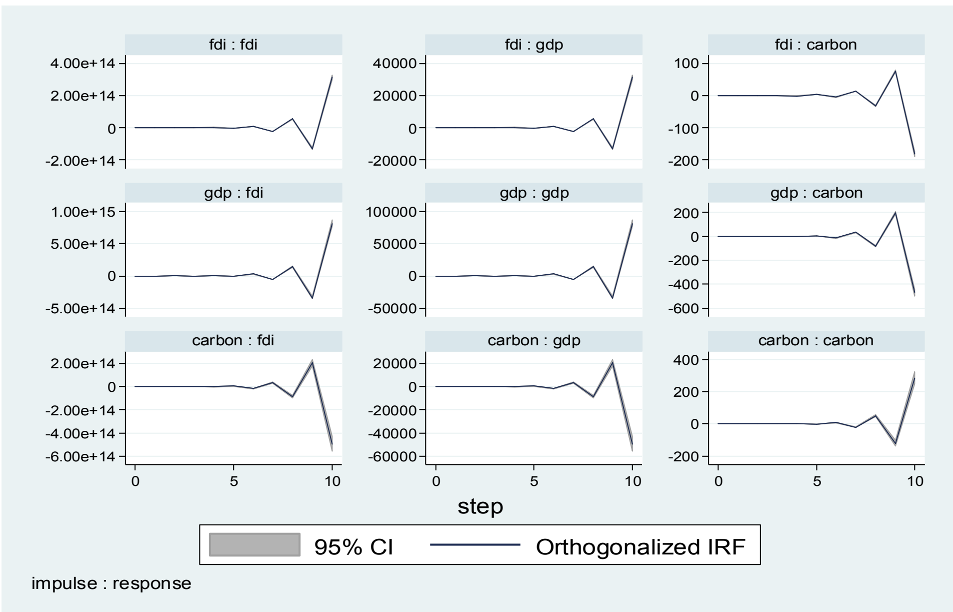


Figure 2.1 illustrated the structural IRFs of the endogenous variables to the shock of variables including themselves. IRF depicts the evolution of the variable Ecological Footprint, GDP, FDI along the time period 1990 to 2016, after a shock in a given point (Pesaran and Shin, 1998). In this research, the first graph means response of FDI to FDI shock; confidence intervals are modulated using Gaussian estimation based on Monte Carlo collected from the estimated PVAR model. At the same time, Orthogonalized IRF are also estimated based on Cholesky decomposition (Abrigo and Love, 2015). Response of Ecological Footprint to FDI exposed a clear decreasing trend after a relatively stable period, which certifies the Pollution Halo Hypothesis: increasing trade and international investment deteriorate countries' environment situations and makes poor countries into a pollution haven for their richer counterpart. The similar is true for the relationship between Ecological Footprint and GDP.

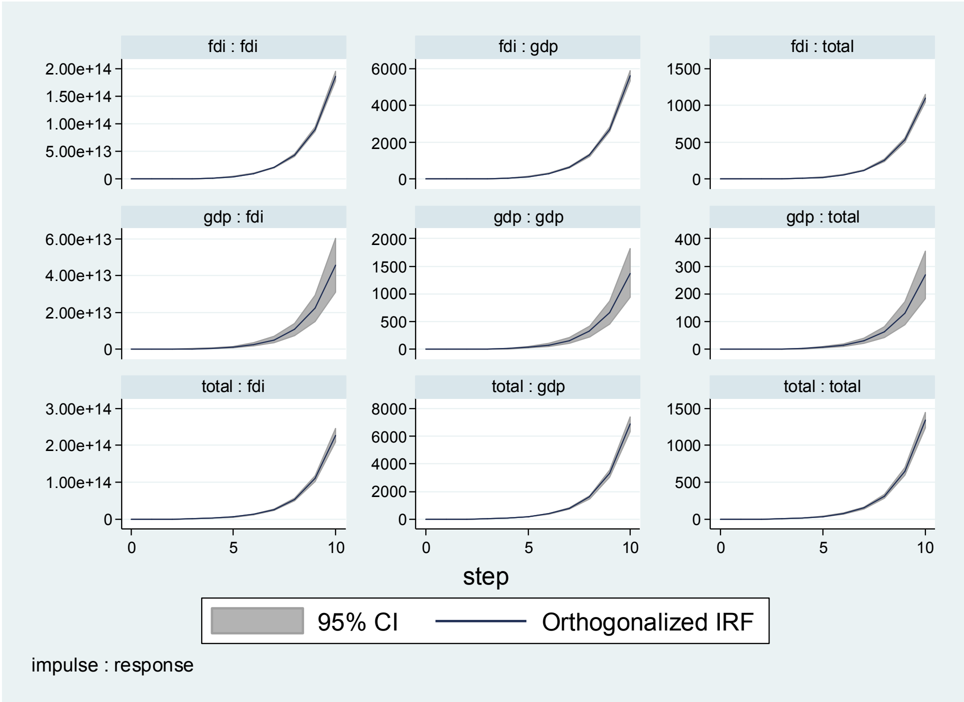
However, as for weight values, the outcome is more complicated than a simple one direction trend: it decreased at first and increased before further decline. When observing the Impulse Response Functions (IRFs) after accomplishing PVAR analysis, it is obvious to observe that endogenous variables response to certain structural shocks over the target time. Figure 2.1 illustrates the structural of the endogenous variables to the shocks of GDP, FDI respectively.

Table 2. 15 Forecast-error variance decomposition results (FDI/Total EF)

Response variable and forecast horizon		Impulse variable		Response variable and forecast horizon		Impulse variable	
		FDI	Total			Total	FDI
FDI	0	0	0	Total	0	0	0
	1	1	0		1	1	0
	2	0.64431	0.35568		2	0.84227	0.15772
	3	0.64360	0.35639		3	0.86560	0.13439
	4	0.56646	0.43353		4	0.84762	0.15237
	5	0.54406	0.45593		5	0.85058	0.14941
	6	0.51133	0.48866		6	0.84656	0.15343
	7	0.49292	0.50707		7	0.84647	0.1535242
	8	0.4747	0.52521		8	0.84512	0.15487
	9	0.46164	0.53835		9	0.844684	0.15531
	10	0.45001	0.54998		10	0.84404	0.15595
Total	0	0	0	FDI	0	0	0
	1	0.00163	0.99998		1	0.00001	0.99998
	2	0.15927	0.84728		2	0.35497	0.64502
	3	0.13610	0.86389		3	0.35636	0.64363
	4	0.15439	0.84560		4	0.43366	0.56633
	5	0.15154	0.84845		5	0.45636	0.54363
	6	0.15568	0.84431		6	0.48925	0.51074
	7	0.15583	0.84416		7	0.50782	0.49217
	8	0.15724	0.8425		8	0.52607	0.47392
	9	0.15772	0.84227		9	0.53931	0.46068
	10	0.15839	0.84160		10	0.55101	0.44898

Based on results of this test displayed in Table 2.14, it is possible to observe which variable exert stronger explaining power to our target variable: both FDI and Total Footprint explain better to their own changes, which are 64.4% and 84.2% respectively; as for the interactive influence, the explanatory power of Total Footprint to FDI is stronger than vice versa, the comparison are 54.9% to15.6%. These results demonstrate the fact that the bidirectional relationship between FDI and Total Footprint is not valid.

Figure 2. 2 Results of Ecological Footprint (Total), GDP, FDI

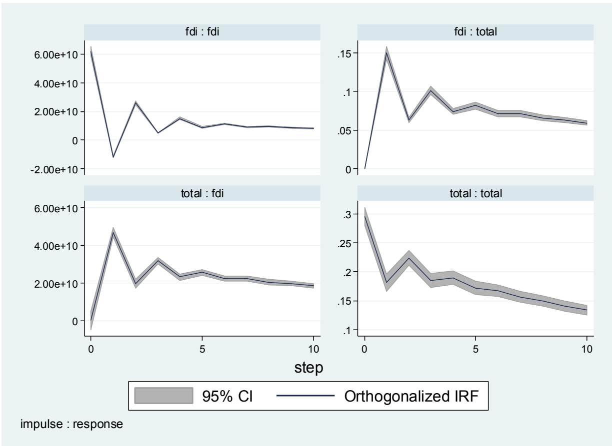


The above graph displays the structural IRF of a shock in FDI, GDP and Total Footprint on FDI, GDP and itself respectively. It indicates that, in this model a positive shock to FDI causes a steady increase. Although some of the impulse responses differ sharply, the response of FDI and Total demonstrates similar Footprint shock across the two orderings. FDI and Total Footprint display increasing trend in structural IRF test, which certifies Pollution Havens Hypothesis which is in opposite to Carbon Ecological Footprint.

The IRF results with GDP, FDI as well as with Ecological Footprint as proxy variables of regional resilience certify the dynamic correlation in line with the Pollution Havens Hypothesis we made in the beginning of this research. The empirical estimation displays that the interrelationship between Ecological

Footprint and GDP, ecological footprint and FDI are robust among subsamples of Total Ecological Footprint and carbon ecological footprint.

Figure 2. 3 Results of Ecological Footprint (Total), FDI



Since FDI is of main interest in this research, a separate Impulse Response Function is performed to assistant detailed analysis and facilitates comparison. It is observed that, even though FDI and Total Footprint are comprised in both IRF test, there still exits great heterogeneity. In Figure 2.2, Total Footprint response to shocks of FDI positively, and the same is true when Total Footprint becomes the response variable. However, in Figure 2.3, the IRF correlation between FDI and Total Footprint demonstrates oscillation. Similar comparisons have been done to GDP and TFP, which could be observed in Appendix.

Overall, this investigation demonstrates that there exists a strong and robust causal relationship from FDI to regional resilience and vice versa. Such conclusion can be made on GDP unidirectional relationship could be observe from Ecological Footprint to TFP. This results is in accordance with former research findings, where Tiwari certified unidirectional causality directed from energy consumption to GDP among Europe and Eurasian countries (Tiwari, 2011). In this current research, further comparison between Carbon Footprint and Total Footprint sheds some intriguing phenomenon; in general, Total Footprint exhibits higher robustness and stronger correlations among variables.

6. Discussion and policy implications

This research analyzed the environmental challenges on BRI project, with a special interest over Foreign Direct Investment and interaction effect among its member countries. Current research is employed to examine the environmental issues embedded in BRI project, to be more specific: testify which of these three hypothesis (Pollution Havens Hypothesis, Pollution Halo Hypothesis, Environmental Kuznets Curve) is in accordance with the current development condition of BRI counties; whether there exists a bi-directional relationship among environmental resilience (Ecological Footprint), Gross Domestic Production (GDP), Foreign Direct Investment (FDI) in BRI member countries. In this paper, Panel Vector Auto-regression (PVAR) is utilized to analyze a dataset of 44 member countries in this initiative, ranges from 1990 to 2016, to empirically testify the environmental evaluation of this project. Results are analyzed on both long-run and short-run cases through Orthogonalized Impulse-Response Functions. Results of this research display a great heterogeneity among different target variables, FDI as a main variable of interest does expose a bi-directional relationship with Ecological Footprint, only Ecological Footprint demonstrates robust influence on FDI. In addition, Pollution Havens Hypothesis is true for FDI and GDP among BRI countries, after adopting weight values into PVAR estimation.

Using a Panel Vector Autoregression model on two subsamples with different Footprint calculation directions, this study provides robust evidence that the relationships between regional resilience and GDP, FDI do not display bi-directional tendency, heterogeneity appear among different target variables. In fact, the analysis of Orthogonalized Impulse responses Functions provides evidence that the relationship between ecological Footprint and GDP is not unidirectional and the causality is bilateral. It is clear that FDI is simultaneously a cause and a consequence of Ecological Footprint changes. This relationship is robust but heterogeneous across subsamples with different footprint column. Our findings suggest that for BRI member countries, in order to boost regional resilience economic development, especially the spillover effect conveyed by FDI and other economic indexes should be paid proper attention.

Results of the variance decompositions are in accordance with IRF analysis. It is evident that GDP is a major determinant of Ecological Footprint both Total Ecological Footprint and Carbon Ecological Footprint. GDP indicators explain, on average, between 34% and 37% of the Ecological Footprint over 16 years. Thus, GDP is a major channel of spillover effect of ecological resilience and political-economic instability of the Ecological Footprint. However, the magnitude of the reverse causal impact from Ecological Footprint to GDP is rather small. It explains around 7% to 8% of Ecological Footprint both Carbon and Total, respectively.

Findings of this research are economically significant because there appears a bilateral nexus in theoretical predictions. For the case of FDI, the relationships are in general a positive one, just the opposite of GDP's results. By applying weight variables, country specific of BRI members as well as a particular structure on the interdependencies present in the panel data. This could contribute to existing PVAR studies as an improvement, where the weight terms are specifically designed to account for the interaction effects among countries. This paper emphasizes the multi-country dimension of the problem by including foreign variables as weights in the panel, which intends to remedy the common issues of ignoring cross-country spillover effect in papers that solely using PVAR.

Difference between FDI and GDP in forming Pollution Havens Hypothesis and Pollution Halo Hypothesis respectively could be explained by the special property of the proxy variable of GDP and international trade, instead of using GDP volume, this research introduces the annual growth rate of GDP and FDI inflow value. In addition, complexity between FDI and GDP is also proposed to explain this discrepancy. In the short-run, environment protection may decrease economic development speed due to more stringent environmental regulations, and in turn, pollution will also pessimistically influence economy through shortening life expectance and labor quality; In the long-run, it is expected that environment protection and economic development will encourage each other through escalation of resource efficiency and better allocation of social capital, which will lead to the so called "sustainable development" goals.

It is worth emphasizing that this analysis is preliminary due to a lack of primary data and the fact that we have just begun the process of model parameterization. Further researches of this discipline are recommended to modify the measure of Ecological Footprint; make comparisons among country groups in different income levels. Besides, after adopting weight terms in existing PVAR model, heterogeneity between Carbon EF and Total EF in PVAR results disappears. In addition, by comparing results with and without weight terms, it is observed that, adding weight terms in PVAR model could increase convergence when performing IRF estimation. In accordance with most non-experimental analysis procedures, the current research is unable to provide confirmative evidence of causality. Further researches may fulfill this gap through more complexed methodologies such as instrumental variables, which could serve as an explanation of the causal nature embedded in the relationships we observed in current analysis. Apart from which, more detailed comparison between countries within BRI project and those who geographically connected but are not in the BRI group may exhibit consequential results.

To conclude, empirical outcomes of this study emphasize multiple essential policy significance to sustainable development in BRI member countries. First, due to the certification of FDI contribute to Pollution Havens Hypothesis in BRI countries, it is suggested for this initiative to pay more attention to the constitution of the FDI, when strive to economic development; balance between increasing the quantity of FDI and the possible pollution embedded in it. Second, this result is in consistent with increasing consciousness among countries in sustainable development trends, more stringent environmental policies are suggested to made to reduce ecological degradations; foreign investment should go through strict inspection before being approved. Lastly, most of BRI countries are developing ones or middle income nations, it is recommended for these countries to reconsider their industry constitution, emphasize on renewable resource.

References:

Abrigo, M. R., and Love, I. (2015). Estimation of panel vector autoregression in Stata: A package of programs. *manuscript, Febr 2015 available on http://paneldataconference2015. ceu. hu/Program/Michael-Abrigo. pdf*.

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.

Akaike, H. (1969). Fitting autoregressive models for prediction. *Annals of the institute of Statistical Mathematics* **21**, 243-247.

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.

Ang, A., and Piazzesi, M. (2003). A no-arbitrage vector autoregression of term structure dynamics with macroeconomic and latent variables. *Journal of Monetary economics* **50**, 745-787.

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.

Arango Vieira, L. C. (2009). The impact of foreign direct investment on developing economies and the environment. *Revista Ingenierías Universidad de Medellín* **8**, 111-128.

Arellano, M., and Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of econometrics* **68**, 29-51.

Asafu-Adjaye, J. (2000). The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. *Energy economics* **22**, 615-625.

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

Baltagi, B. (2008). "Econometric analysis of panel data," John Wiley & Sons.

Bank, T. W. (2000). "World Development Indicators 2000," Oxford University Press, USA.

Becketti, S. (2013). "Introduction to time series using Stata," Stata Press College Station, TX.

Bekhet, H. A., and bt Othman, N. S. (2011). Causality analysis among electricity consumption, consumer expenditure, gross domestic product (GDP) and foreign direct investment (FDI): Case study of Malaysia. *Journal of economics and international finance* **3**, 228.

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.

Bevan, A. A., and Estrin, S. (2004). The determinants of foreign direct investment into European transition economies. *Journal of comparative economics* **32**, 775-787.

Birdsall, N., and Wheeler, D. (1993). Trade policy and industrial pollution in Latin America: where are the pollution havens? *The Journal of Environment & Development* **2**, 137-149.

Blyde, J., Kugler, M., and Stein, E. (2004). "Exporting vs. outsourcing by MNC subsidiaries: which determines FDI spillovers?," University of Southampton.

Borensztein, E., De Gregorio, J., and Lee, J.-W. (1998). How does foreign direct investment affect economic growth? 1. *Journal of international Economics* **45**, 115-135.

Borucke, M., Moore, D., Cranston, G., Gracey, K., Iha, K., Larson, J., Lazarus, E., Morales, J. C., Wackernagel, M., and Galli, A. (2013). Accounting for demand and supply of the biosphere's regenerative capacity: The National Footprint Accounts' underlying methodology and framework. *Ecological Indicators* **24**, 518-533.

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.

Brana, S., Djigbenou, M.-L., and Prat, S. (2012). Global excess liquidity and asset prices in emerging countries: A PVAR approach. *Emerging Markets Review* **13**, 256-267.

Brucal, A., Javorcik, B., and Love, I. Pollution Havens or Halos? Evidence from Foreign Acquisitions in Indonesia.

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.

Canh, N. T., and Phong, N. A. (2018). Effect of Public Investment on Private Investment and Economic Growth: Evidence From Vietnam by Economic Industries. *Applied Economics and Finance* **5**, 95-110.

Canova, F., and Ciccarelli, M. (2009). Estimating multicountry VAR models. *International Economic Review* **50**, 929-959.

Canova, F., and Ciccarelli, M. (2013). Panel Vector Autoregressive Models: A Survey☆ The views expressed in this article are those of the authors and do not necessarily reflect those of the ECB or the Eurosystem. *In* "VAR Models in Macroeconomics–New Developments and Applications: Essays in Honor of Christopher A. Sims", pp. 205-246. Emerald Group Publishing Limited.

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

Chelleri, L., Minucci, G., and Skrimizea, E. (2016). Does community resilience decrease social–ecological vulnerability? Adaptation pathways trade-off in the Bolivian Altiplano. *Regional Environmental Change* **16**, 2229-2241.

Chen, S. (2009). "Energy consumption, CO2 emission and sustainable development in Chinese industry."

Cheung, K. Y. (2010). Spillover Effects of FDI via Exports on Innovation Performance of China's High-Technology Industries. *Journal of Contemporary China* **19**, 541-557.

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

Clifton, D. (2010). A sustainable world: an ecological footprint and I= PAT perspective.

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., and Neumayer, E. (2004). Examining the impact of demographic factors on air pollution. *Population & environment* **26**, 5-21.

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.

Dees, S., Mauro, F. d., Pesaran, M. H., and Smith, L. V. (2007). Exploring the international linkages of the euro area: a global VAR analysis. *Journal of applied econometrics* **22**, 1-38.

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.

Dovern, J., Meier, C.-P., and Vilsmeier, J. (2010). How resilient is the German banking system to macroeconomic shocks? *Journal of Banking & Finance* **34**, 1839-1848.

Doytch, N. (2012). FDI halo vs. pollution haven hypothesis.

Doytch, N., and Narayan, S. (2016). Does FDI influence renewable energy consumption? An analysis of sectoral FDI impact on renewable and non-renewable industrial energy consumption. *Energy Economics* **54**, 291-301.

Doytch, N., and Uctum, M. (2011). Globalization and the Environmental Spillovers of sectoral FDI. *Unpublished manuscript*.

Driffield, N., Munday, M., and Roberts, A. (2002). Foreign direct investment, transactions linkages, and the performance of the domestic sector. *International journal of the economics of business* **9**, 335-351.

Driffield, N., and Taylor, K. (2000). FDI and the labour market: a review of the evidence and policy implications. *Oxford Review of Economic Policy* **16**, 90-103.

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.

Dunning, J. H. (2012). "International Production and the Multinational Enterprise (RLE International Business)," Routledge.

Elliot, B., Rothenberg, T., and Stock, J. (1996). Efficient tests of the unit root hypothesis. *Econometrica* **64**, 13-36.

Enders, W., and Sandler, T. (1993). The effectiveness of antiterrorism policies: A vector-autoregression-intervention analysis. *American Political Science Review* **87**, 829-844.

Engle, R. F., and Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: journal of the Econometric Society*, 251-276.

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**.

Gao, X., and Zhang, W. (2013). Foreign investment, innovation capacity and environmental efficiency in China. *Mathematical and Computer Modelling* **58**, 1040-1046.

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.

Girma, S. (2005). Absorptive capacity and productivity spillovers from FDI: a threshold regression analysis. *Oxford bulletin of Economics and Statistics* **67**, 281-306.

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.

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.

Grossman, G. M., and Krueger, A. B. (2008). The inverted-U: what does it mean? *Environment and Development Economics* **1**, 119-122.

Haberl, H., Erb, K.-H., and Krausmann, F. (2001). How to calculate and interpret ecological footprints for long periods of time: the case of Austria 1926–1995. *Ecological economics* **38**, 25-45.

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

Hannan, E. J., and Quinn, B. G. (1979). The determination of the order of an autoregression. *Journal of the Royal Statistical Society. Series B (Methodological)*, 190-195.

Hansen, H., and Rand, J. (2006). On the causal links between FDI and growth in developing countries. *The World Economy* **29**, 21-41.

Harashima, Y., and Morita, T. (1998). A comparative study on environmental policy development processes in the three East Asian countries: Japan, Korea, and China. *Environmental Economics and Policy Studies* **1**, 39-67.

Hartman, R., and Kwon, O.-S. (2005). Sustainable growth and the environmental Kuznets curve. *Journal of Economic Dynamics and Control* **29**, 1701-1736.

He, J. (2006). Pollution haven hypothesis and environmental impacts of foreign direct investment: The case of industrial emission of sulfur dioxide (SO2) in Chinese provinces. *Ecological Economics* **60**, 228-245.

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.

Henriques, I., and Sadorsky, P. (2008). Oil prices and the stock prices of alternative energy companies. *Energy Economics* **30**, 998-1010.

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

Hoffmann, R., Lee, C. G., Ramasamy, B., and Yeung, M. (2005). FDI and pollution: a granger causality test using panel data. *Journal of international development* **17**, 311-317.

Holtz-Eakin, D., Newey, W., and Rosen, H. S. (1988). Estimating vector autoregressions with panel data. *Econometrica: Journal of the Econometric Society*, 1371-1395.

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

Hornborg, A. (2009). Zero-sum world: challenges in conceptualizing environmental load displacement and ecologically unequal exchange in the world-system. *International Journal of Comparative Sociology* **50**, 237-262.

Hsiao, C. (2007). Panel data analysis—advantages and challenges. *Test* **16**, 1-22.

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

Hu, J., Wang, Z., Lian, Y., and Huang, Q. (2018). Environmental Regulation, Foreign Direct Investment and Green Technological Progress—Evidence from Chinese Manufacturing Industries. *International journal of environmental research and public health* **15**, 221.

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.

Hummels, D. (2009). How Further Trade Liberalization Would Change Greenhouse-Gas Emissions from International Freight Transport. *In* "NBER Working Paper, Prepared for Global Forum on Trade and Climate Change".

Hymer, S. H. (1976). "International operations of national firms."

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.

Jiang, Y. (2015). Foreign direct investment, pollution, and the environmental quality: a model with empirical evidence from the Chinese regions. *The International Trade Journal* **29**, 212-227.

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.

Khan, M. I. (2017). DO INCOME GROWTH AND TRADE EXPANSION REALLOCATE THE ECOLOGICAL FOOTPRINTS? A CASE STUDY OFPAKISTAN, Department of Environmental Economics, Pakistan Institute of Development Economics.

Kneller, R., and Pisu, M. (2007). Industrial linkages and export spillovers from FDI. *The World Economy* **30**, 105-134.

Koengkan, M. (2017). The nexus between energy consumption, economic growth, and urbanization in Latin American and Caribbean countries: An approach with PVAR model. *Revista Valore* **2**, 202-219.

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.

Levi, M. (2015). Go East, Young Oilman. *Foreign Aff.* **94**, 108.

Li, Q., Hu, H., Luo, H., Lin, L., Shi, Y., Zhang, Y., and Zhou, L. (2015). "Two-way coupling relationship between economic growth and environmental pollution-Regional difference analysis based on PVAR model."

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.

Lof, M., and Malinen, T. (2014). Does sovereign debt weaken economic growth? A panel VAR analysis. *Economics Letters* **122**, 403-407.

Love, I., and Zicchino, L. (2006). Financial development and dynamic investment behavior: Evidence from panel VAR. *The Quarterly Review of Economics and Finance* **46**, 190-210.

Lütkepohl, H. (2005). "New introduction to multiple time series analysis," Springer Science & Business Media.

Mabey, N., and McNally, R. (1998). Foreign direct investment and the environment. *World Wildlife Foundation.*

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

Markusen, J. R., and Venables, A. J. (1999). Foreign direct investment as a catalyst for industrial development. *European economic review* **43**, 335-356.

Metiu, N., Hilberg, B., and Grill, M. (2014). Financial Shocks, Credit Regimes, and Global Spillovers.

Monfreda, C., Wackernagel, M., and Deumling, D. (2004). Establishing national natural capital accounts based on detailed ecological footprint and biological capacity assessments. *Land Use Policy* **21**, 231-246.

Moran, T. H. (2005). How does FDI affect host country development? Using industry case studies to make reliable generalizations. *Does foreign direct investment promote development*, 281-313.

Mutascu, M. I., Estrada, F., and Tiwari, A. K. (2012). Taxation and political stability.

Nations, U. (2014). "System of Environmental-Economic Accounting 2012," Rep. No. 9211615755. The World Bank.

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.

Noorbakhsh, F., Paloni, A., and Youssef, A. (2001). Human capital and FDI inflows to developing countries: New empirical evidence. *World development* **29**, 1593-1610.

Opoku, E. E. O. (2013). Effects of Trade Openness and Economic Growth on Carbon Dioxide (Co2) Emissions in Ghana, Department of Economics, Kwame Nkrumah University of Science and Technology.

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.

Pao, H.-T., and Tsai, C.-M. (2011). Multivariate Granger causality between CO2 emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product): Evidence from a panel of BRIC (Brazil, Russian Federation, India, and China) countries. *Energy* **36**, 685-693.

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, H. H., and Shin, Y. (1998). Generalized impulse response analysis in linear multivariate models. *Economics letters* **58**, 17-29.

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

Peterson, G., Allen, C. R., and Holling, C. S. (1998). Ecological resilience, biodiversity, and scale. *Ecosystems* **1**, 6-18.

Raddatz, C. (2007). Are external shocks responsible for the instability of output in low-income countries? *Journal of Development Economics* **84**, 155-187.

Ramadhani, N. Q., Saraswati, E., and Fuad, A. (2017). SOCIAL RESPONSIBILITY AND VALUE ADDED CREATION.

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.

Sadorsky, P. (2010). The impact of financial development on energy consumption in emerging economies. *Energy Policy* **38**, 2528-2535.

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.

Sassi, S., and Gasmi, A. (2017). The Dynamic Relationship Between Corruption–Inflation: Evidence From Panel Vector Autoregression. *The Japanese Economic Review* **68**, 458-469.

Schwarz, G. (1978). Estimating the dimension of a model. *The annals of statistics* **6**, 461-464.

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.

Sigmund, M., Ferstl, R., and Unterkofler, D. (2017). Panel Vector Autoregression in R: The panelvar Package.

Sims, C. A. (1980). Macroeconomics and reality. *Econometrica: Journal of the Econometric Society*, 1-48.

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.

Smarzynska Javorcik, B. (2004). Does foreign direct investment increase the productivity of domestic firms? In search of spillovers through backward linkages. *American economic review* **94**, 605-627.

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.

Stroik, P. C. (2016). "Technology, Trade and the Environment," University of California, Irvine.

Tiwari, A. K. (2011). Comparative performance of renewable and nonrenewable energy source on economic growth and CO2 emissions of Europe and Eurasian countries: A PVAR approach. *Economics Bulletin* **31**, 2356-2372.

Toda, H. Y., and Phillips, P. C. (1994). Vector autoregression and causality: a theoretical overview and simulation study. *Econometric reviews* **13**, 259-285.

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

Tracy, E. F., Shvarts, E., Simonov, E., and Babenko, M. (2017). China's new Eurasian ambitions: the environmental risks of the Silk Road Economic Belt. *Eurasian Geography and Economics* **58**, 56-88.

Vačkář, D. (2012). Ecological footprint, environmental performance and biodiversity: a cross-national comparison. *Ecological Indicators* **16**, 40-46.

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.

Wackernagel, M., and Rees, W. (1998). "Our ecological footprint: reducing human impact on the earth," New Society Publishers.

Wackernagel, M., and Rees, W. E. (1997). Perceptual and structural barriers to investing in natural capital: Economics from an ecological footprint perspective. *Ecological economics* **20**, 3-24.

Wackernagel, M., and Yount, J. D. (1998). The ecological footprint: an indicator of progress toward regional sustainability. *Environmental Monitoring and Assessment* **51**, 511-529.

Walker, B., Salt, D., and Reid, W. (2006). In Resilience Thinking: Sustaining People and Ecosystems in a Changing World. Washington DC: Island Press.

Wang, C., and Wang, F. (2017). China can lead on climate change. *Science* **357**, 764-764.

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.

Webster, F. (2014). "Theories of the information society," Routledge.

Wei, Y., and Liu, X. (2006). Productivity spillovers from R&D, exports and FDI in China's manufacturing sector. *Journal of international business studies* **37**, 544-557.

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

Winkler, A. M., Ridgway, G. R., Webster, M. A., Smith, S. M., and Nichols, T. E. (2014). Permutation inference for the general linear model. *Neuroimage* **92**, 381-397.

Xiaoling, Y. W. Y. (2008). The Effect of Foreign Trade and FDI on Environmental Pollution: An analysis based on the Impulse Response Function of Time Series in China: 1982~ 2006 [J]. *World Economy Study* **12**, 012.

Xing, Y., and Kolstad, C. D. (2002). Do lax environmental regulations attract foreign investment? *Environmental and Resource Economics* **21**, 1-22.

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.

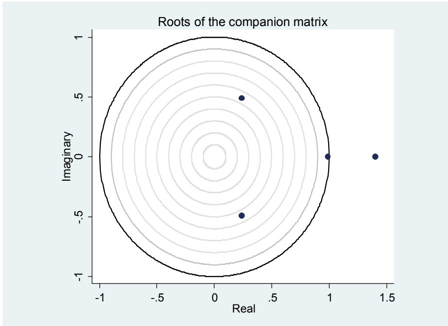
Yu, H. (2017). Motivation behind China's 'One Belt, One Road'initiatives and establishment of the Asian infrastructure investment bank. *Journal of Contemporary China* **26**, 353-368.

Zhan-mei, Q. J.-z. Z. (2008). Relationship between Financial Development and International Trade in China——Based on the Data of 1991-2005 [J]. *Journal of International Trade* **1**, 016.

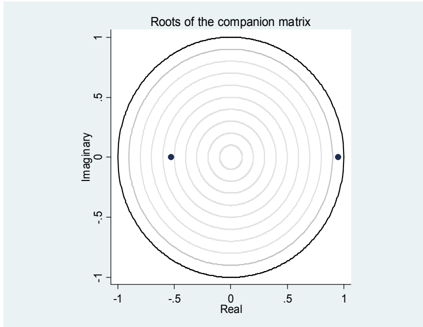
Zhang, N., Liu, Z., Zheng, X., and Xue, J. (2017). Carbon footprint of China's belt and road. *Science* **357**, 1107-1107.

Zheng, S., Kahn, M. E., and Liu, H. (2010). Towards a system of open cities in China: Home prices, FDI flows and air quality in 35 major cities. *Regional Science and Urban Economics* **40**, 1-10.

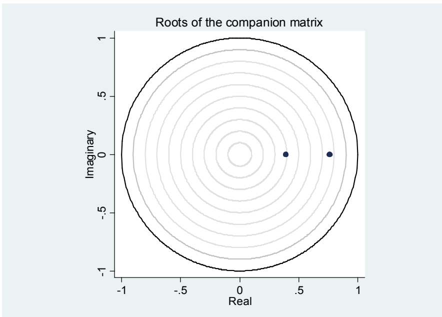
Appendix 2.1. Results of unit root test



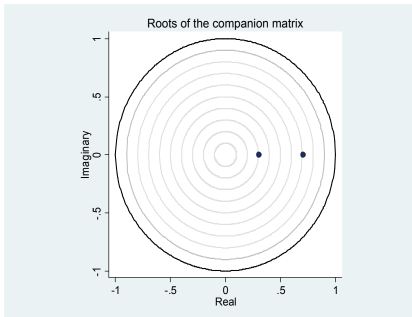
1.1 Ecological footprint (Total), GDP, FDI, Total_w



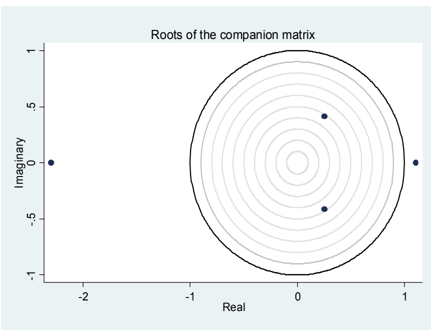
1.2 Ecological Footprint (Total) and FDI



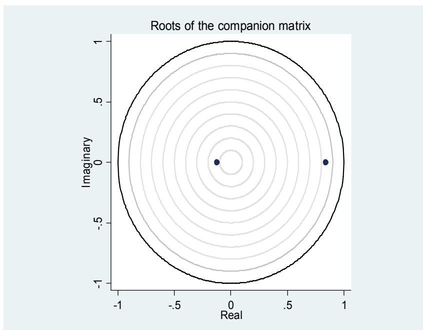
1.3 Ecological Footprint (Total) and GDP



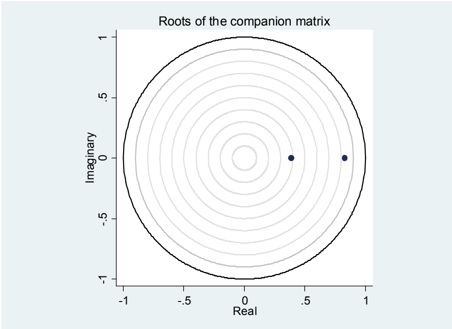
1.4 Ecological Footprint (Total) and Total_w

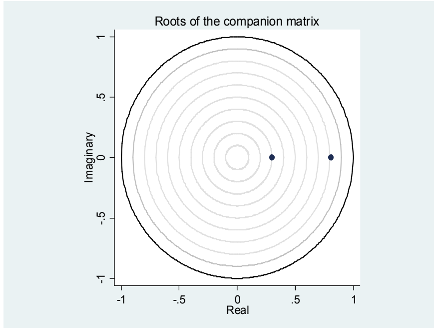


1.5 Ecological Footprint (Carbon), GDP, FDI, Carbon_w

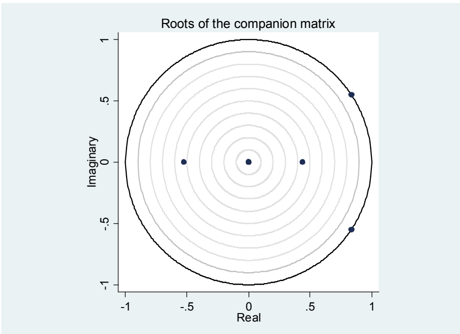


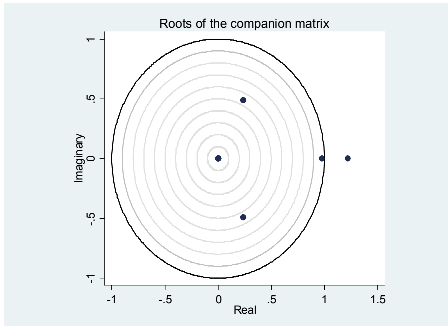
1.6 Ecological Footprint (Carbon) and FDI





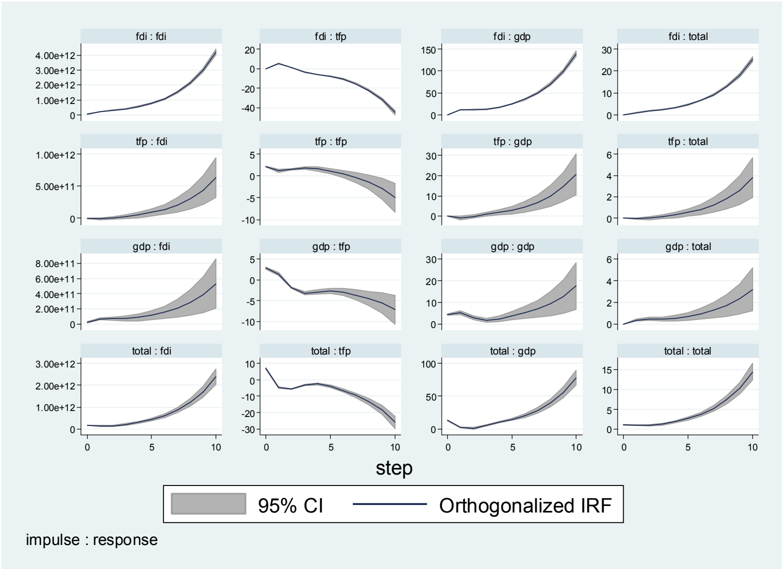
1.7 Ecological Footprint (Carbon) and GDP 1.8 Ecological Footprint (Carbon) and Carbon-w



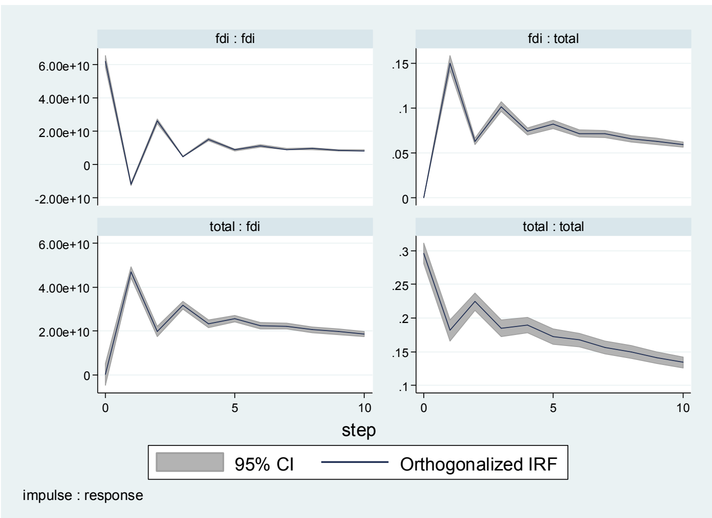


1.9 Unit root test comprises weight values (total) 1.10 Unit root test comprises weight value (carbon)

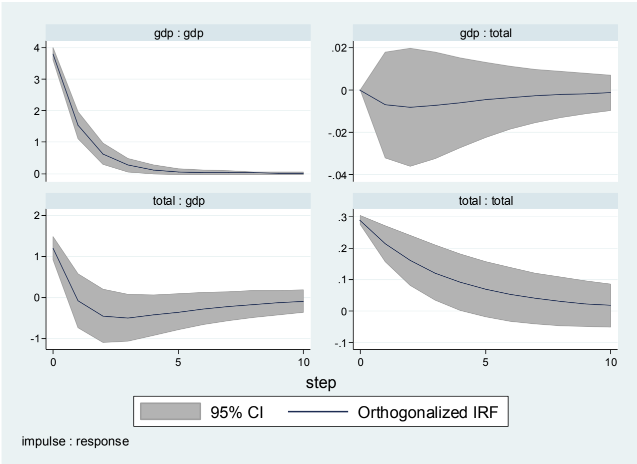
Appendix 2.2. Results of the FEVD estimates (Total Footprint)



2.1 Ecological Footprint, GDP, FDI, TFP



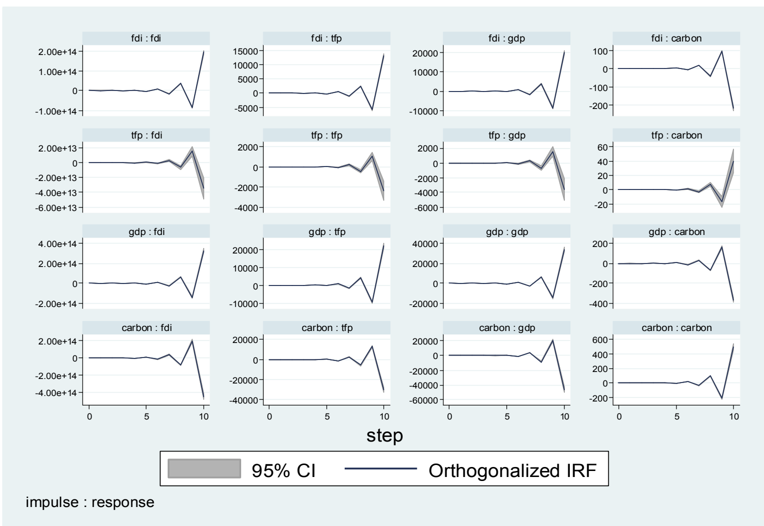
2.2 Ecological Footprint and FDI



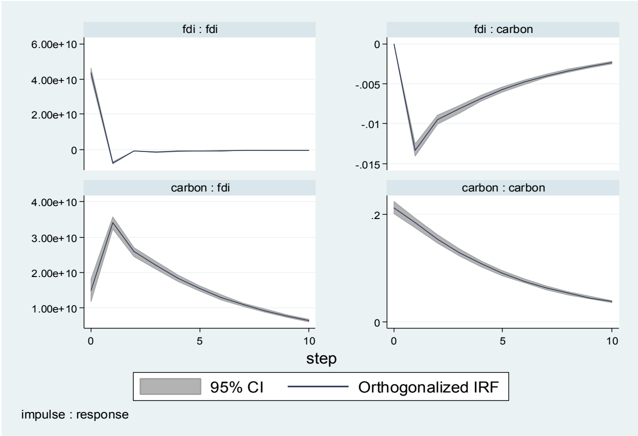
2.3 Ecological Footprint and GDP

Appendix 2.3. Results of the FEVD estimates (Carbon Footprint)

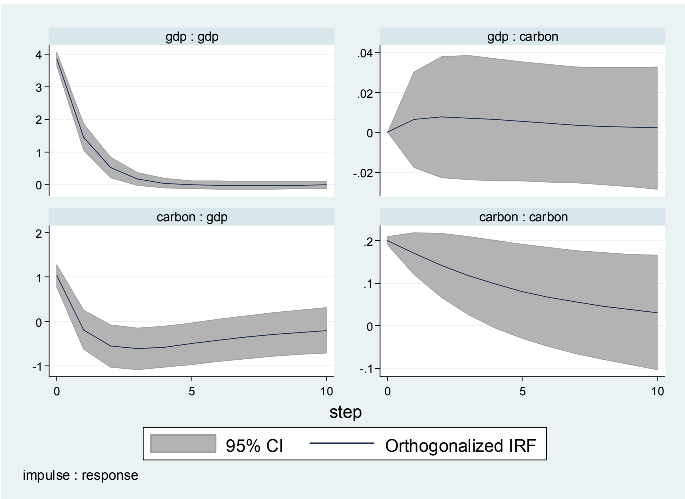
3.1 Ecological Footprint, GDP, FDI, TFP



3.2 Ecological Footprint and FDI



3.3 Ecological Footprint and GDP



Appendix 2.4 Results of the FEVD estimates （Forecast-error variance decomposition）

4.1 FEVD results response from Total Ecological Footprint to other variables

		Total	GDP	FDI	Total_w	GDP_w	FDI_w
Total	0	0	0	0	0	0	0
	1	1	0	0	0	0	0
	2	.2729872	.3113742	.1904543	.0559764	.1024007	.0162377
	3	.1042024	.2590105	.0746439	.0754784	.0620527	.0074815
	4	.0503231	.2311534	.0345107	.0573566	.0547333	.0085252
	5	.0507172	.2302332	.0269293	.0455589	.0501147	.0080496
	6	.0524706	.2224286	.0231806	.0434394	.0462321	.0072384
	7	.0538884	.2199838	.022402	.0428509	.0450956	.0070641
	8	.0544239	.2191629	.0221126	.0425863	.044692	.0069989
	9	.0546112	.2188358	.0220114	.0425053	.044547	.0069752
	10	.054685	.2187308	.021981	.0424776	.0444977	.0069675

4.2 FEVD results response from GDP to other variables

		Total	GDP	FDI	Total_w	GDP_w	FDI_w
GDP	0	0	0	0	0	0	0
	1	.5803802	.4196198	0	0	0	0
	2	.2960931	.4130535	.1940907	.0100347	.0466805	.0114994
	3	.2056349	.2879183	.1873958	.015766	.0411985	.0167622
	4	.1364163	.2440374	.1135423	.03444	.0491563	.0159092
	5	.0764843	.2368277	.0427532	.0354312	.04693	.0092217
	6	.0574348	.216825	.0237428	.0414286	.0434009	.0069177

	7	.0557434	.2185673	.0225232	.0423138	.0443466	.007009
	8	.0549465	.2185257	.0219544	.0423719	.0443564	.0069473
	9	.0547751	.2185597	.0219416	.0424481	.0444277	.0069567
	10	.0547484	.2186496	.02196	.0424557	.0444587	.0069618

4.3 FEVD results response from FDI to other variables

		Total	GDP	FDI	Total_w	GDP_w	FDI_w
FDI	0	0	0	0	0	0	0
	1	.3923546	.4005113	.0907443	0	0	0
	2	.215026	.3464602	.2273232	.0010855	.0634985	.0277523
	3	.228313	.3308179	.2334994	.0010356	.0635267	.0310513
	4	.2274611	.3214023	.2249864	.0034546	.0609543	.0299885
	5	.2222104	.3144613	.222342	.0034222	.0608899	.0296872
	6	.2236479	.3055883	.2098522	.0038	.0581065	.0282042
	7	.1989613	.2761485	.1723641	.0071741	.0502627	.0233663
	8	.13535	.2343416	.0949496	.0223688	.0425361	.0145486
	9	.0791403	.2175597	.0381161	.035672	.0413326	.0083966
	10	.0603904	.2154625	.023771	.0407164	.0426275	.0069747

4.4 FEVD results response from Total Ecological Footprint weight to other variables

		Total	GDP	FDI	Total_w	GDP_w	FDI_w
Total_w	0	0	0	0	0	0	0
	1	.5798764	.2451898	.0697621	.073704	0	0
	2	.3227322	.2936386	.2428648	.0327497	.04847	.0150644
	3	.2840617	.2900498	.2588234	.0275094	.0718941	.0292734

	4	.2236199	.2875167	.1884545	.0238179	.060882	.0214839
	5	.1288141	.2211411	.0919521	.0395862	.0441483	.0117798
	6	.0746816	.2223146	.0387449	.0416383	.0450886	.0084859
	7	.0580627	.2179335	.0238557	.0418764	.0438804	.0070334
	8	.0553997	.2180903	.022205	.0423937	.0442652	.0069637
	9	.0549365	.2185673	.0219966	.0424195	.0444026	.0069593
	10	.0547727	.2185882	.021945	.0424516	.0444327	.0069569

4.5 FEVD results response from GDP_w to other variables

		Total	GDP	FDI	Total_w	GDP_w	FDI_w
GDP_w	0	0	0	0	0	0	0
	1	.0587837	.2363376	.0164409	.0437329	.2316438	0
	2	.1780399	.2084704	.0813591	.1251542	.0650408	.0002897
	3	.0923775	.1580604	.0271952	.0768084	.0306546	.0005893
	4	.0607027	.1992721	.0228974	.0493401	.0435409	.0069037
	5	.0573754	.2201142	.0234538	.0421934	.0452801	.0072447
	6	.0550688	.2177749	.0217253	.0424681	.0441055	.0068639
	7	.0549094	.2183572	.0219344	.042514	.0443592	.0069464
	8	.0547901	.2185965	.0219449	.0424563	.0444316	.0069574
	9	.0547411	.2186307	.021952	.0424608	.044454	.0069603
	10	.0547322	.2186589	.0219605	.0424621	.0444647	.0069623

4.6 FEVD results response from FDI_w to other variables

		Total	GDP	FDI	Total_w	GDP_w	FDI_w
GDP_w	0	0	0	0	0	0	0
	1	.0017691	.3957767	.0325533	.0178445	.1265757	.011514

2	.0466656	.2538268	.0307276	.0455623	.0565016	.0053304
3	.054623	.2236274	.0221681	.043589	.0445038	.0061264
4	.0532808	.2186349	.0214142	.0421125	.0448085	.0069024
5	.0543636	.2197206	.0222199	.0421252	.0449794	.0070586
6	.0545773	.2190187	.0220189	.0423565	.0446001	.0069782
7	.0546678	.2187463	.0219771	.0424497	.0445048	.0069665
8	.0547073	.2187033	.0219708	.0424597	.0444839	.0069651
9	.0547176	.2186799	.0219649	.0424624	.0444741	.0069636
10	.0547222	.2186726	.0219636	.0424633	.0444709	.0069631

Conclusion and Discussion:

Two essays of this thesis are logically connected: they follow the logic from worldwide panel data analysis to regional analysis and finaly conclude to a singel country. It is possible to observe that relationship between trade and sustainable development displays obvious heterogeneity in terms of target objective region, proxy variables, as well as time. In the first study, the relationship between economic development and CO_2 emission is examined under three circumstances.

The first analysis is performed for 125 countries during the time period 2000 to 2015. 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. 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.

The second research analyzed the environmental challenges on BRI project, with a special interest over Foreign Direct Investment and interaction effect among its member countries. Current research is employed to examine the environmental issues embedded in BRI project, to be more specific: testify which of these three hypothesis (Pollution Havens Hypothesis, Pollution Halo Hypothesis, Environmental Kuznets Curve) is in accordance with the current development condition of BRI counties; whether there exists a bi-directional relationship among environmental resilience (Ecological Footprint), Gross Domestic Production (GDP), Foreign Direct Investment (FDI) in BRI member countries.

국문초록

무역 및 지속 가능한 개발에 관한 연구

서울대학교 대학원

농경제사회학부 농업·자원경제학전공

홍보리우

이 논문은 2 장으로 구성되어있다. 제 1 장수출 다양화, 이산화탄소 배출량 및환경 쿠즈네츠 곡선: 125 개국의 패널 데이터 분석. 제 2 장: 생태 발자국 및 외국직접 두자, 국내 총생산: 일대 일로 국가 대상 으로 연구. 이 두 연구는 지속 가는한 개발 이론과 응용및 무역의 상관 관계에 대한 연구이다.

1 장에서는 2000 년에서 2014 년까지 125 개국의 수출 다양화에 관한 자료를 사용하여 국제 무역 및 이산화탄소 배출량에 대한 다국가 회귀 분석 이다.가능한 조항을 탐색한다. HS4 코드로 사용했다. 규모 효과, 기술 효과 및 구성 효과를 통해 오염 배출과의 상관 관계를 정당화하기 위해 수출 다양화는 수직적, 수평 적 다각화로 세분화된다. 이분 산성 및 자기 상관 오차 문제를 위해 Driscoll 과 Kraay 표준 오차를 이용한 회귀 모델을 사용한다. 연구결과는 수출 다양화 및 제품 다양 화는이산화탄소 배출 저감에게 긍정적인 영향을 미친다. 한편, 경제 개발 및 수출 다각화의 상호

작용 조건은 다른 소득 수준 간 비교를 용이하게한다: 저소득 국가는 경제 발전과 이산화탄소 배출량 사이의 U 자형 관계를 보여 주지만, OECD 국가는 여전히 125 개국의 결과와 일치 인 역 U 자형 EKC 곡선을 유지한다

2 장에서는 일대 일로국가에 포함 된 환경 문제를 검토한다.오염 된 하벤스 가설, 오염 된 헤일로 가설, 환경 적 쿠즈네츠 곡선 총 세가지을 통해서 현재 “일대 일로” 국가에 발전 조건에 부합한 이론을 통해서 환경 회복력 및 GDP, FDI 간의 상관관계를 존재하는지에 대한 연구한다. 환경 탄력성 사이에 양방향 관계가 존재하는지 여부. 본연구에서는 PVAR (Panel Vector Auto-regression)을 사용하여, 1990 년부터 2016 년까지 44 개 회원국의 데이터를 이용한 분석 이다. 연구 결과는외국인 직접 투자 와 탄소 생태 발자국에 대해 서로 다른 목표 변수간에 큰 이질성을 보여 주며 양방향 관계가 존재하지 않으며 탄소 발자국 만외국인 직접 투자 에 강력한 영향을 미친다. 또한 오염 헤이븐 가설은 외국인 직접 투자 와 총 요소 생산 에 해당하며, 오염 헤일로 가설은 BRI 회원국인 중국내 총생산 에 유효하다.

두연구는 글러버패널 분석에서 지역패널분석으로 두 단계로 진행했다. 무역과 지속 가능한 개발 사이의 관계는 목표 대상 지역, 대리 변수, 시간뿐만 아니라 시간의 측면에서 화실한 이질성을 보여 주는 것을 관찰 되었다.

주제어: 지속 가능한 개발, 무역, 수출 다양화, 일대 일로국가

학　번: 2015-31360

Dedication

Dedicate this work to my past grandfather, without whom I could not accomplish a PhD degree