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Export Diversification and Ecological Footprint: A Comparative Study on EKC Theory among Korea, Japan, and China

Hongbo Liu [1,*], Hanho Kim [2], Shuanglu Liang [1] and Oh-Sang Kwon [2]

1 School of Economics, Yunnan University, Kunming 650091, China; shlliang@ynu.edu.cn
2 Department of Agricultural Economics and Rural Development, Research Institute of Agriculture and Life Science, Seoul National University, Seoul 08826, Korea; hanho@snu.ac.kr (H.K.); kohsang@snu.ac.kr (O.-S.K.)
* Correspondence: hongboliu@ynu.edu.cn; Tel.: +86-158-2927-7130

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Abstract: This study examines the Environmental Kuznets Curve (EKC) hypothesis by adopting a country's ecological footprint as an indicator of environmental degradation in three East Asian countries: Japan, Korea, and China. During the development process, countries intend to balance between stabilizing export demand and maintaining sustainable economic improvement in the context of deteriorating global warming and climate change. The Environmental Kuznets Curve (henceforth, EKC) was originally developed to estimate the correlation between environment condition and economic development. In this paper, we started from the EKC model and adopted an Error Correction Methodology (henceforth, ECM) to estimate the EKC relationships in Japan, Korea (two developed countries), and China (a developing country) over the period of 1990 to 2013. Besides this, instead of only using Gross Domestic Product (henceforth, GDP), two subdivisions of trade diversification—export product diversification and export market diversification—are introduced as proxy variables for economic development in rectification of the EKC. The results demonstrate that both Korea and Japan satisfy the EKC theory by demonstrating an inverted U-shaped relationship between economic development and ecological footprint, while analysis based on data from China does not display the same tendency. For both export product diversification and market diversification, the more diversified the country's export is, the bigger its ecological footprint. The policy implications of this econometric outcome are also discussed.

Keywords: Environmental Kuznets Curve; ecological footprint; Herfindahl–Hirshman Index (HHI); export product diversification; export market diversification; error correction model (ECM)

1. Introduction

In 2018, Korea, Japan, and China experienced a heatwave starting in the middle of July and lasting to the beginning of August. This unprecedented heatwave killed 65 people in Japan in a week; record-breaking temperatures in South Korea killed 29 people; and according to empirical research from Massachusetts Institute of Technology (MIT), the north China plain is threatened by rising temperatures [1]. All these extreme climate disasters are closely connected with human activities and economic development.

China, Korea, and Japan are important countries in the international export market, share close geographical relationships, and are trade partners. Since the end of 1980s, both Korea and China have undergone rapid economic growth. With the reduction of trade and investment barriers after the signing of the Sino-Korea Free Trade Agreement (FTA) in 2015, the communication of technology, human capital, and natural resources accelerated. However, despite economic development, the issues of global warming and air pollution have not been effectively addressed. Against this background, we wish to investigate whether there is any relationship between trade development and pollution in these three closely interacting countries.

The Environmental Kuznets Curve is well understood and applied as the inverted U-shaped relationship between pollution and economic development. The pioneering work on the EKC by Krueger and Grossman in 1991 tested the relationship between trade and the environment [2]. Much attention has been paid to the relationship between international trade and environmental pollution since then. On the one hand, some economists agreed that international trade is able to encourage efficient acceleration in the production and consumption of most goods and services [3]; however, side effects represented by "Pollution Havens" arose in response to trade globalization, which indicated that trade will transfer pollution-concentrating industry from developed countries who have stringent pollution legislation to developing countries. Therefore, discussions on the relationship between trade and environment have not reached an agreement, and it is meaningful to do further analysis on this regime.

The contradictory opinions on the Environmental Kuznets Curve are due to the fact that the connection between economic development and the environment is both subtle and complex [4]. This can be partly explained by three effects which were proposed by Grossman and Krueger, who decomposed the changes in pollution into three fundamental forces: scale effects, composition effects, and technique effects [2]. Trade liberalization has demonstrated ability to increase the productivity of a certain nation, which will lead to a scale effect. However, this will possibly stimulate various types of economic activity because of composition effects [2,5,6]. Besides this, changes caused by trade liberalization could encourage the government to make stricter environmental policies which will finally lead to the appearance of technique effects. By decomposing the influences of trade and economic development on pollution into scale effects, composition effects, and technique effects, we can observe how different types of shocks influence pollution emission through common and divergent effects [4].

In this research, we intend to focus on the relationship between Ecological Footprint and economic development; besides this, we propose to introduce trade diversification as an extra proxy variable of economic development. Due to the reasons stated above, apart from the inverted U-shaped curve described by the Environmental Kuznets Curve, we are also interested in the empirical outcome of the effect of trade diversification.

This paper contributes to a number of strands in the recent literature concerning sustainable development and international trade. First, collecting and reorganizing a relatively complex time series database including economic development indices, export diversification, and ecological footprint allows us the possibility of analyzing the complicated relationship between export diversification and sustainable development [7–10]. Second, by taking advantage of a reduced-form EKC model, the current study does not rely on strong theoretical assumptions that are indispensable in models that use the structural form [11–13]. Lastly, this present research is supposed to function as a reminder to policy-makers: when it comes to sustainable development, compared with economy volume (which has long been the focus [14–16]), economic structures such as export diversification need better attention.

The rest of the paper is organized as follows. Section 2 gives a literature review on the Environment Kuznets Curve and related econometric technologies. Section 3 explains the theoretical model and the econometric methodology. Section 4 provides a detailed description of data and an empirical model application. Section 5 examines the empirical results and discussions. Section 6 presents conclusions with further research recommendations.

2. Literature Review

The Environment Kuznets Curve is a widely used theory for estimating the relationship between environmental degradation and economic development. Grossman and Selden's study revealed some rules for the relationship between economic development and environment condition in developed countries [6,17]. Their conclusion was that, from the current data available, the implementation of a North American Free Trade Agreement (NAFTA) agreement will cause the United States and Canada to pay more attention to physical and human capital investment to protect the local environment. Trade intensity was adopted in that article as a proxy of trade freedom. Heil and Selden [3] extended Grossman's work by expanding the database to panel data for 132 countries from 1950 to 1992. Their analysis reflected the outcome that increased trade intensity boosts carbon emissions in lower-income countries while decreasing carbon pollution in higher-income ones, which certifies that economic development is beneficial to the environment after reaching a certain "turning point". Besides this, import ratio to Gross Domestic Product, trade openness, and total trade value were also included as independent variables in the EKC analysis [18,19]. China is a developing country and is growing at an average growth rate of 6% annually; therefore, we need up-to-date study in this discipline.

There exists a large body of literature on EKC analysis which are organized in Table 1; for example, single-country analysis such as of China, Austria, and Turkey [20–22]; for international institutions like Organization for Economic Co-operation and Development (henceforth, OECD) countries [3,23]; and panel data estimation [24–26]. However, little has been done on comparison of three neighboring countries like China, Japan, and Korea as an emerging market and developed countries, respectively. One of the contributions of the current research is to achieve comprehensive research focusing on China, Japan, and Korea, and on their sustainable development conditions.

The literature on trade diversification itself explains the structure of international trade, and it is widely believed that higher trade diversification could decrease the risks of international trade and have a strong relationship with economic development. Olivier Cadot is a specialist on trade diversification; he proved in his work that lower-income countries tend to have undiversified exports. With a more developed economy, they first diversify, then reconcentrate after reaching a certain turning point [27]. More specifically, economic development shows a striking nonmonotonicity pattern, which can be described as an export diversification Kuznets curve [28]. Dutt provided evidence for a causal link between export diversification and development: the extensive margin works more effectively in raising per capita income than does the intensive margin of exports [29]. Export diversification is regarded as a valuable index in economic analysis because it is believed to be the only way a less-developed country can transform into a modern economy in terms of producing and exporting goods [30]. After various studies by different scholars, it seems that, across countries and time, there exists a robust inverted U-shaped relationship between export diversification and economic development [27,31]. Trade diversification has been frequently used in economic analysis to describe economic development conditions; however, there exist few studies which connect trade diversification and environment evaluation.

The idea of introducing Kuznets Curve of export diversification was originally proposed by Cadot [28]; however, his article was more focused on theory description without empirical analysis. In 2016, Gozgor tested the relationship between export product diversification and pollution based on data on Turkey from 1971 to 2010 using Kuznets curve empirically and came to the conclusion that higher export product diversification leads to more intensive CO_2 emissions [32]. Gozgor tested export product diversification, while export diversification includes both export market diversification and export product diversification. Luciana Juvenal proved in their paper that for a given market, export market diversification reduces firms' demand risks and therefore increases incentives for them to invest in expanding productivity [33], while export product diversification and lower export diversification could induce higher international trade risks. To the best of our knowledge, adopting export diversification in a three-country Environmental Kuznets curve analysis has not been performed yet.

Table 1. A summary of literature on the Environmental Kuznets Curve (EKC).

Author	Dependent Variable(s)	Independent Variable(s)	Type of Function	Regression Method	Turning Point	Country
MARK T. HEIL and THOMAS M.SELDEN (2001)	Per capita carbon emissions	Per capita GDP, Trade intensity	Income squared	Country fixed effect	USD 7000	132 countries from 1950 to 1992
Birgit Friedl, Michael Getzner (2003)	CO_2 emissions per capita	Per capita GDP, deviation of GDP from trend GDP, value added in the service sector nominal ratio to GDP, imports as a ratio to GDP, time dummy	Income cubed	Cointegrating regression		Austria from 1960 to 1999
Stern and Common (2001)	Per capita emission of sulfur	Per capita GDP, per capita GDP square, both with purchasing power parity	Income squared	Fixed and random	$101,166	World, OECD countries, non-OECD countries
Junyi Shen, Yoshizo Hashimoto (2004)	Per capita pollutant emission	per capita GDP, share of the secondary industry, population density, time trend	Income cubed	Random	69,071 CNY for dust fall case	China
Xiaozi Liu (2006)	Pollution index: Total Suspended Particulate (TSP), SO_2, NO_X, Nemerow index	Per capita GDP, per capita GDP square	Income cubed	Random	Monotonic relation, no turning point	Shenzhen, China from 1989 to 2003
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	No turning point in China case, Japan had in SO_2	China and Japan from 1975 to 1999
Tao SONG (2007)	Waste gas emission	Per capita GDP, per capita GDP square, per capita GDP cubed	Income cubed	Panel cointegration	29,017 RMB	China
X.D. Diao (2009)	Sulfur oxide discharge, soot discharge, industrial dust discharge	Per capita GDP, per capita GDP square, per capita GDP cubed, environmental policies/investment strategies/contribution of industry to GDP	Income cubed		23,218 RMB for soot discharge	Zhejiang Province, China
Victor BRAJER, Robert W. MEAD, Feng XIAO	Concentration of SO_2, TSP, and NO_2, Nemerow index, pollution index1, pollution index2 (epidemiological index)	Real per capita gross city product (PPP in 2004), population density, city location dummies, time trend	Income	Random effect Tobit model	For SO_2, 10,663 RMB; For TSP, 120,000 RMB; For NO_2, two turning points of 26,754 and 42,902 RMB respectively	139 cities in China from 1990 to 2006
Usama Al-mulali el.	Ecological footprint	GDP growth	GDP growth	Fixed effect and generalized method of moments	Inverted U-shaped relationship between Ecological Footprint (EF) and GDP growth	93 countries
Y wang	Ecological footprint of consumption, income and biocapacity	Economic growth	Economic growth	Ordinary Least Square (OLS) and spatial Durbin model	No evidence of inverted U-shaped EKC curve	China

Note: OECD countries refers to Organization for Economic Co-operation and Development member countries.

3. Data and Empirical Model

The independent variables used in this study were selected through analysis of theoretical and empirical literature. The dataset comprised data for Japan, Korea (two developed countries), and China (a developing country) over the period of 1990 to 2013.

3.1. Ecological Footprint Per Capita

Ecological footprint is measured based on a calculation of how much human beings demand from nature and how much nature is able to supply. From the demand perspective, ecological footprint functions as an indicator quantifying how much is required from the ecological system to support consumption by a given population, for example, plant-based food. Further, the ability of the environment to absorb the population's waste, especially air pollution emissions, is also considered when calculating ecological footprint. From the supply perspective, the biocapacity of a given city or nation indicates how productive its ecological credit is, for example, grazing land, cropland, and built-up land. Ecological footprint data was collected from the Global Footprint Network [26,34,35].

3.2. Real GDP Per Capita

GDP is an indicator of the comprehensive output of goods and services produced within a given state in a certain time period. GDP per capita is the value of GDP divided by the population of the target state. Our study adopted the real GDP per capita calculated in consistent 2011 US Dollar as a measure for real income. GDP data is available from the World Bank, which gives GDP per capita based on purchasing power parity [36].

3.3. Real GDP Per Capita Squared

Based on the former EKC studies, the real GDP per capita squared is expected to be negatively related with pollution emissions in order to reflect the inverted U-shape curve. From the literature summary form, we learn that this term was also widely utilized in former studies.

3.4. Export Diversification

Data on export diversification represented by the Herfindahl–Hirshman Index (HHI) index, for both product diversification and market diversification, were acquired from World Integrated Trade Solution (WITS), World Bank. The HHI index ranges from 0 to 1, with a value close to 0 indicating higher diversification. Separately speaking, the HHI product index is a method of estimation for the dispersion degree of trade value across a country's exportation, which is an indicator of the exporter's vulnerability to trade shocks. The HHI market index, on the other hand, is an indicator of the dispersion of trade value among a country's partners in exportation [27,28]. A country focusing on few trade destinations shows an index close to 1. Therefore, it is a measure of how an exporter is dependent on its trading partners and the danger it could face when their trade partners lift trade barriers.

The normalized Herfindahl index ranging between 0 and 1 is given by

$$H = \frac{\sum_k (S_k)^2 - \frac{1}{n}}{1 - \frac{1}{n}} \tag{1}$$

where

$$S_k = \frac{X_k}{\sum_{k=1}^{n} X_k}$$

S_k is the share of export line k (with amount exported in total exports X_k), n is the number of export lines, and k is the share of line k in total exports. Commodities use 4-digit Harmonized System Code (HS codes).

4. Empirical Model

Possible functional forms of the EKC for trade diversification and air emissions have typically taken the following form:

$$ln(EF)_t = \alpha_1 lnY_t + \alpha_2 (lnY_t)^2 + lnH_t + \varepsilon_t \quad (2)$$

EF refers to ecological footpint per capita, while *Y* refers to GDP per capita. In order to broaden the concept of the EKC, we added export diversification into the relationship with pollution emissions. H_t is the export Herfindahl–Hirschman index, better known as the Herfindahl index or HHI, and functions as a useful measurement of concentration or dispersion. The Herfindahl index can be used to measure concentration in a variety of contexts. For instance, Heil testified the effect of trade intensity on carbon emissions [3], while Grossman and Krueger examined the influence of trade intensity on ambient concentrations of sulfur dioxide [6].

This equation is in logarithmic form due to the reason that taking the logarithm can not only smoothen out the outliers in the dataset but could also provide elasticity through its coefficients [14].

Before doing regression, there are four main possible biases we need to consider in the econometric analysis of the EKC: heteroscedasticity, simultaneity, omitted variables bias, and cointegration issues [37].

There may be stationarity and structural breaks in the time path of all five variables.

Inspired by former studies, will follow a step-by-step process in this analysis [38]:

Step 1: Confirm the unit root.

In order to scrutinize the time series properties of the variables adopted in this study, we proposed performing a nonstationary test.

The stationarity of both dependent and independent variables in the time series was detected through an Augmented Dickey–Fuller (from now on ADF) test, which has been commonly adopted in former studies [20]. However, studies have detected that an improved methodology based on the ADF technique proposed by Elliot, Rothenberg, and Stock [39] exerts greater power than the traditional augmented Dickey–Fuller test. This could be explained by the fact that through this improved approach, the time series undergoes a GLS transformation before the ADF estimation. The improvement of the methodology is of great use in the current research and is fit for our purposes. This process was performed to testify to the characteristics of the time series in the target estimation. In this estimation process, the Ecological Footprint (EF) was designated as the dependent variable, while GDP per capita and export diversification (both export product diversification and export market diversification) were specified as the explanatory variables.

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

$$\Delta y_t = \alpha_0 + \partial y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-1} + \varepsilon_t \quad (3)$$

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, and p refers to the optimal lag length.

The ADF estimation is able to test the unit root; the null hypothesis argues that there exists a unit root, which means the target variables are nonstationary. Therefore, acceptance of the null hypothesis illustrated that there exists a unit root in the series. On the contrary, rejection of the null hypothesis indicates stationary properties of the series without a unit root.

The outcome of this improved ADF test is shown in Table 2.

Table 2. The outcome of the Augmented Dickey–Fuller (ADF) test.

Variables	DF-GLS Tau Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
ln_EF_Korea	−1.355	−3.770	−3.476	−2.932
ln_hhi_product_Korea	−1.163	−3.770	−3.476	−2.932
ln_hhi_market_Korea	−0.035	−3.770	−3.476	−2.932
ln_gdp_Korea	−0.605	−3.770	−3.476	−2.932
ln_gdp2_Korea	−0.620	−3.770	−3.476	−2.932

The outcome of the China, Korea, and Japan case demonstrated that there is a unit root in this dataset.

After some experimentation, we decided to use 1 lag in the improved Dickey–Fuller regression. The choice of lag length tends to be as much art as science [38]; due to the fact that our data is yearly data and limited from 1996 to 2015, we decided to use lag 1. The result of the regression was not obviously sensitive to the choice of lag length. The test statistics were not smaller than any of the critical values at lag 1 at the 1% critical value, so we accepted the null hypothesis that there is a unit root.

Step 2: Identify the number of lags.

In order to transform the Vector Auto –Regression (VAR) that represents our variables into the Error Correction Model (VECM) representation form, we have to decrease the number of lags by 1. That is, we go from

$$\boldsymbol{y_t = \mu + \sum_{i}^{p} \Phi_i y_{t-i} + \varepsilon_t} \tag{4}$$

$$\Delta y_t = \gamma + \tau t + \alpha(\beta' y_{t-1} + \nu + \rho t) + \sum_{i}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t \tag{5}$$

with $(p-1)$-many lags of Δy_t.

It turns out that it is possible to use a likelihood ratio test to find the proper lag number.

As is shown in Table 3, the Schwarz's Bayesian information criterion (SBIC), Hannan and Quinn's Information Criteria (HQIC), Akaike's Information Criterion (AIC), and the likelihood ratio test statistics indicate that 4 lags are more suitable for this research; however, the Final Prediction Error (FPE) favors 3 lags. In detail, the star signal * appears in the Lag 4 row in Table 3 for AIC, HQIC, SBIC and LR, while for FPE, it shows in the Lag 3 row. HQIC and SBIC outcomes support the validity of a consistent estimation of true lag length [26,40], while the FPE and AIC results tend to provide overestimated lag length even with infinite samples to estimate. To conclude, we decided to use 4 lags in the following estimation process.

Table 3. The outcome of lag selection.

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	39.2527				4.80×10^{-7}	−6.04211	−6.08699	−5.92089
1	77.3431	76.181	9	0	4.00×10^{-9}	−10.8905	−11.0701	−10.4056
2	92.7421	30.798	9	0	2.10×10^{-9}	−11.957	−12.2712	−11.1084
3	323.447	461.41	9	0	1.00×10^{-24} *	−48.9078	−49.3566	−47.6956
4	1118.14	1589.4 *	9	0		−180.357 *	−180.357 *	−178.902 *

Step 3: Identify the number of cointegration relationships.

In empirical time series studies, the nonstationary property of target data will lead to estimation inefficiency in the calculation process. Trustworthy estimation results cannot be achieved without correcting the nonstationary issue. Therefore, in this research, we proposed to adopt the Johansen cointegration test to avoid possible inefficiency caused by nonstationarity. After making sure the data is stationary, we are able to perform long-run analysis among the variables in the EKC model.

Rectification of the cointegration is similar to the lag length selection process, which also includes multiple procedures. In the maximum eigenvalue approach, we proposed to perform a likelihood ratio test; in this test, the null hypothesis indicates that exactly r-many cointegration relationships exist, versus the alternative hypothesis that $(r + 1)$ many cointegration relationships exist.

The results demonstrated in Table 4 is explained as follows. The cointegration test demonstrated evidence of cointegration among the variables, because * appeared when f equals 0; we could then possibly test the long-run equilibrium relation among variables without the danger of spurious regression.

Table 4. Johansen tests for cointegration.

f	Parms	LL	Eigenvalue	Trace Statistic	5% Critical Value
0	12	60.83		29.1381 *	29.68
1	17	69.4	0.70619	11.9906	15.41
2	20	73.86	0.47135	3.0666	3.76
3	21	75.39	0.19671		

Step 4: Fit a VECM (vector error correction model).

After the three steps above, we have sufficient statistical guidance specifying how we are going to perform the analysis, so we are now prepared to fit VECMs.

The long-run estimation results for the ECM are reported in Table 5. The error correction model captures the short-run dynamics of the EKC model. The coefficients are thus the short-run elasticities [26,41].

Table 5. Results of the vector error correction model.

Log EF Per Capita	Export Product Diversification			Export Market Diversification		
	China	Japan	Korea	China	Japan	Korea
Error correction term	0.749 *** (0.00)	0.299 (1.68)	−0.157 (−0.56)	0.945 *** (4.42)	0.387 ** (2.11)	−0.288 (−1.09)
Δlagged Log real gdp per capita	−0.872 *** (−3.00)	3.461 (1.03)	4.996 * (1.79)	−0.826 * (−2.04)	3.318 (0.76)	7.336 ** (2.67)
Δlagged Log real gdp per capita sq	0.073 *** (4.13)	−0.183 (−1.12)	−0.233 (−1.69)	0.074 *** (3.14)	−0.173 (−0.80)	−0.354 ** (−2.57)
Δlagged Log HHI	−0.028 (−0.09)	−0.110 ** (−2.30)	−0.134 (−1.32)	0.018 (0.19)	0.073 (0.83)	0.272 ** (2.36)
Cons_	0.123 *** (3.58)	−15.068 (−0.88)	−25.178 * (−1.78)	2.602 (1.57)	−14.050 (−0.63)	−35.041 ** (−2.65)
Adj R-squared	0.9870	0.7968	0.7871	0.9773	0.7494	0.8216
observations	21	23	23	21	23	23

Notes: Standard errors are shown in parentheses. * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

The coefficient of the error correction term is explained as the speed of adjustment. Take China's export product diversification as an example: the imbalance is corrected in the first period with 74.9%. For China, Japan, and Korea, their HHI coefficients are negative for export product diversification and positive for export market diversification, but not all significant.

GDP per capita functions as the most significant variable in determining ecological footprint among China, Japan, and Korea, as indicated by the fact that their respective coefficients have the biggest absolute values. Ecological footprint and GDP constitute an inverted U-shaped curve, while ecological footprint was positively related with export diversification. From a policy perspective, besides other trade indicators, export diversification functions as a significant factor affecting economic development condition [27]; in this study, export diversification is positively related to ecological footprint, which reflects the fact that in order to alleviate their ecological footprint, Korea and China should concentrate on the exportation of cleaner categories.

5. Results and Discussion

This study examines the Environmental Kuznets Curve (EKC) hypothesis by adopting a country's ecological footprint as a proxy variable to evaluate the environmental degradation condition. Three countries with different development situations were examined. This paper addresses the topic in the context of Japan, Korea, and China and, more importantly, adopted both export market diversification and export product diversification as proxy variables in the EKC model. Multiple time series techniques were used to formulate an error correction model (ECM) in order to fix the spurious regression problem.

The evidence presented here indicates that GDP per capita and export diversification had a robust relationship with ecological footprint; therefore, the EKC hypothesis holds in Korea, Japan, and China in the long run. As aforementioned, GDP per capita plays a pivotal role in determining ecological footprint in both Korea and China as indicated by the income effect being statistically significant ($p < 0.01$). Export product diversification exerts a negative effect on ecological footprint with negative coefficients of −0.028, −0.110, and −0.134 for China, Japan, and Korea, respectively; meanwhile export market diversification exerts a positive effect on ecological footprint with positive coefficients of 0.018, 0.073, and 0.272, respectively. The development tendency of these three countries are graphically demonstrated in Appendix A.

For Korea, there is an inverted U-shaped EKC curve between GDP per capita and ecological footprint. As shown in Table 5, the coefficients of GDP and GDP squared in export product diversification are 4.996 and −0.233, respectively (positive in GDP and negative in GDP squared), confirming the existence of an inverted U-shaped relationship. The same is true for export market diversification; therefore, for both export product diversification and market diversification, the more diversified the country's export is, the bigger its ecological footprint. This could possibly be explained by the fact that with more diversified export, a country's export basket is bigger, and the scale effect then dominates the pollution situation.

A similar outcome could be found in Japan: the coefficients of GDP and GDP squared in export product diversification are 3.461 and −0.183, respectively (positive in GDP and negative in GDP squared). However, overall, the statistical outcome of the data for Korea was more significant than that for Japan, especially for export market diversification.

As for China, the inverted U-shaped EKC hypothesis is invalid during the examined period. In detail, the coefficients of GDP and GDP squared in export product diversification are −0.872 and 0.073, respectively (negative in GDP and positive in GDP square). Besides this, we observed a positive relationship between export diversification and ecological footprint, which indicates that in order to alleviate the deteriorating ecological footprint in China, it is better to encourage export concentrating on clean industries instead of diversifying.

So far, controlling one's ecological footprint is not a legal requirement [42] and, thus, different countries have implemented environmental policies in accordance with their own interests and development pathways. Since it is difficult to implement any international measures and enforce them, voluntary efforts are necessary for Japan, Korea, and China for sustainable development. Besides this, since the three countries are all active exporters in the world market, it is suggested that they should pay more attention to the constitution of their exports to concentrate on less-polluting categories.

6. Conclusions

This study comparatively analyzed environmental development in three East Asian countries: Japan, Korea, and China. During the development process, countries intend to balance between stabilizing export demand and maintaining sustainable economic improvement in the context of deteriorating global warming and climate change. The Environmental Kuznets Curve (EKC) was originally developed to model the relationship between pollution and economic development. In this paper, we started by building an EKC model and adopting error correction methodology (ECM) to estimate the EKC relationships in Japan, Korea (two developed countries), and China (a developing country) over the period of 1990 to 2013. Besides this, instead of only using GDP per capita, two subdivisions of trade diversification—export product diversification and export market diversification—were introduced as proxy variables for economic development in refinement of the EKC. The results demonstrated that both Korea and Japan satisfy the EKC theory by demonstrating an inverted U-shaped relationship between economic development and ecological footprint, while analysis based on data from China does not display the same tendency.

Further research is suggested to expand the dataset from three countries to larger country groups with different development levels. Besides this, other econometric methodologies such as instrumental variables are suggested, as they could serve as an explanation of the causal nature embedded in the relationships we observed in the current analysis.

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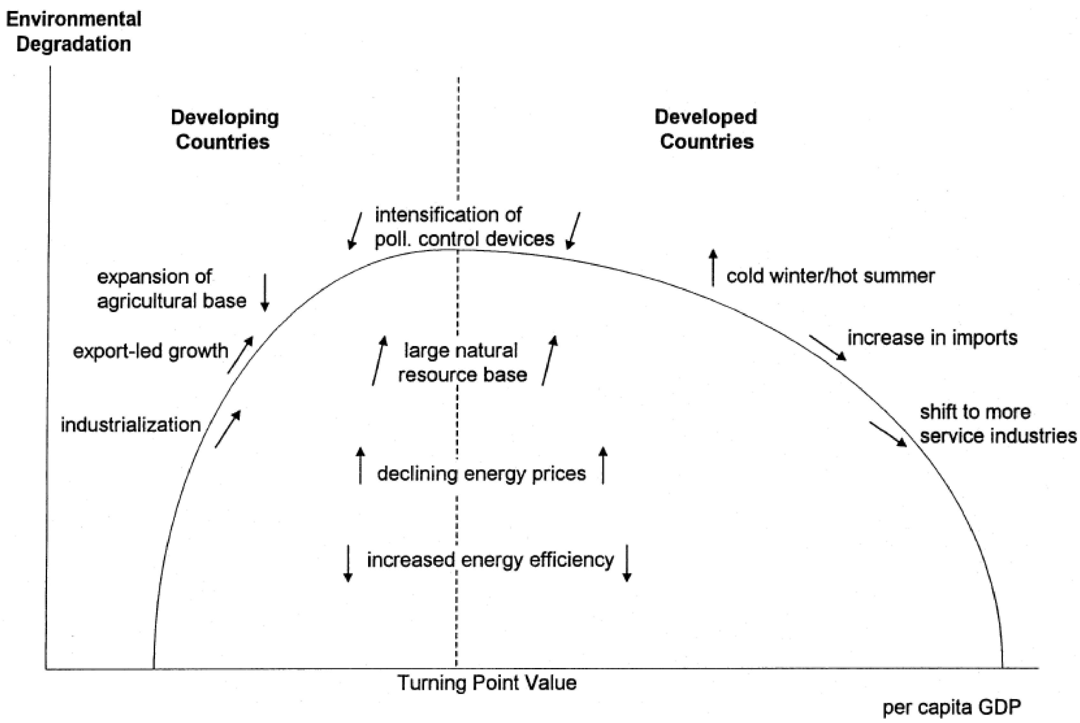
Appendix A. Depiction of the Environmental Kuznets Curve

In our current research, our outcome indicates that China as a developing country is still in the phase before the turning point, while Korea and Japan are after the turning point.



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