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The relation between environmental pollution and trade: a panel data analysis

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Abstract: Human and environment relations began to change with agricultural revolution at first. This change was followed by the industrial revolution. As a result of the increase in the world's population, production, trade with the industrial revolution, environment has been effected negatively by accelerating the consumption of natural resources. Some of the factors such as industrialization, rapid population growth and excessive consumption of natural resources has been caused environmental pollution. In this context, this paper explains the dilemma between environmental pollution and trade for various countries with different income levels.
This study aims to analyze the relationship between environment, economic growth and Trade Openness Rate. For this reason, CO_2 emissions per capita, GDP and Trade Openness Rate have been used for the period from 1960 to 2010. The data has been obtained from the World Bank and analyzed by the Panel Data Method. To conclude, Trade Openness Rate of developed countries has a negative effect on the level of CO_2 emission while Trade Openness Rate of developing and less developed countries has positive effect. The results may be evidence that the Pollution Haven Hypothesis is still valid for the developing and/or less developed countries.

Keywords: environment, growth, trade, panel cointegration, causality.

Introduction

Researchers are discussing about the impact of trade liberalization and economic growth on the environment for years. There could be two opposing groups studying the relationship between trade and environment. Many environmentalists have thought that trade liberalization and economic growth would negatively affect environmental quality. According to the some of proponents' assumptions, trade

liberalization may lead to destruction and irrevocable impacts on the environment (Zaman, 2013:5-6).

Particularly after the industrial revolution, rapidly increasing human activities have caused deterioration on natural stability of the world. This rapid change in the world and increase in global economic activities have begun to create significant differences in the understanding of a livable environment.

Rapid developments occurring together with industrial revolution lead to change in the industrialization strategies. While watching the import substitution policies at the beginning of industrialization, in the process of industrialization are preferred the export-oriented strategy which is the purpose of economic growth and development with realization of export-oriented production.

Inadequate development as well as rapid industrialization leads to environmental problems. The main objective of economic development is to raise the living standards. Thus, the realization of sustainable development should be aimed instead of fast development. This can be done with the implementation of the least damaging industrialization strategy for the environment.

On the other contrary idea is that economic welfare can be improved with trade liberalization. Especially developing countries and less developed countries have low environmental standards and regulations. While income and trade activities rise, living conditions in these countries improve. Developing and less developed countries have desired higher environmental standards, clean environment, and clean technology with increasing income (Zaman, 2013:5). Therefore, environment will be more viable.

As mentioned in the studies of Quiroga *et al.* (2007) and Zaman (2013), there is a link between comparative advantage and environment. According to the Ricardian Theory and Heckscher-Ohlin Theorem, countries have used less or lax stringent environmental regulations to have a comparative advantages in pollution intensive industry. Free trade may shift the comparative advantages in favor of the countries having lower or lax stringent regulations. Therefore, countries having stricter environmental regulations could lose its comparative advantages.

Excessive liberalization generally directs the countries to implement low environmental standards in order to reduce costs. The presence of different environmental standards between countries would cause displacement of some branches of industry. Some countries having high environmental standards shift their polluting industries to the countries having lower environmental standards (Low and Yeats, 1992:18). In this study, the trade-environment interaction has been analyzed in the framework of the Pollution Haven Hypothesis. The Pollution Haven Hypothesis (PHH) states that pollution-intensive industries tend to move countries with lax environmental regulations. It has been expressed that trade liberalization leads to the movement of polluting industries from high income or stringent environmental regulation countries to low income or lax environmental regulation countries. Thus,

polluting industries will be relocated from developed countries to the developing countries (Cai *et al.*, 2004) and the countries having less stringent environmental regulations have comparative advantage at the pollution-intensive production (Cole, 2004). In addition, developed countries benefit from this relocation in terms of environmental quality while developing countries lose (Bekmez and Nakipoglu, 2011).

To explain this complex relation, we can evaluate the relationship between environment and economic growth as well as the relationship between environment and trade liberalization. The relationship between economic growth and the environment can be shown with the Environmental Kuznets Curve. The Environmental Kuznets Curve Hypothesis has claimed that there is an inverted U-shaped relationship between per capita income and environmental quality (Grossman and Krueger, 1994). Originally it has been described in the theory of income distribution developed by Simon Kuznets (1955) who found an inverted U relationship between income inequality and economic development. Economic literature has stated that an increase in per capita income leads to a decrease in the quality of life by creating an environmental pollution at first; but later on, it creates an increase in the quality of life (Islam et. al., 1996). Data has been analyzed according to cross-section or panel data techniques such as in Grossman *et al.* (1991), Shafik *et al.* (1992), Cole *et al.* (1997), Panayotou's (2003) studies. The findings about variables, terms and the countries lead different results for explaining the Environmental Kuznets Curve. For example Akbostancı *et al.* (2009) find N shaped relation between CO_2 emission and income while Basar *et al.* (2007) find invert N curve for the same variables in Turkey. While Grossman *et al.* (1994), Cole *et al.* (1997), Copeland *et al.* (2003), Stern (2004) find invert U, Selden *et al.* (1994) find inverted J relation for different countries.

This study consists of three main parts. In the first part, the theoretical information has been given about the relationship among pollution, economic growth and Trade Openness Rate. The relation between these variables is explained by Environmental Kuznets Curve and Pollution Haven Hypothesis. In the second part, model and data have been described. In the last part, Panel Data Method, Panel Cointegration Method and Panel Causality have been introduced. According to the results obtained, Trade Openness Rate of developed countries has a negative effect while Trade Openness Rate of developing and less developed countries has positive effect on the pollution. Thus, it can be asserted that the Pollution Haven Hypothesis is still valid for the developing and/or less developed countries. In the last part, political recommendations have been made for the countries with different income level.

Model and data

In accordance with the studies about impact of economic growth and Trade Openness Rate on pollution quality, the model is written as the following form:

$$lnCO_{2_{it}} = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 lnOPEN_{it} + \varepsilon_{it} \quad (1)$$

variables in the model are, respectively:
CO_2 : CO_2 Emissions (metric tons per capita)
GDP : Gross Domestic Product (2005 fixed prices, US $)
OPEN : Trade Openness Rate

Level of CO_2 emissions is affected by a number of complex processes such as urbanization, economic growth, trade openness, energy consumption and globalization. These relationships between variables have been remarkable subject of research in last decades. That is why the aim of this paper is to examine the relationship between environment, economic growth and trade openness. CO_2 emissions per capita, GDP and Trade Openness Rate have been used for the period from 1960 to 2010 because of the lack of available data, especially CO_2 emissions (metric tons per capita). The data for mentioned variables have been obtained from the World Bank. Countries are classified by income and development levels with the World Bank Atlas Method. The World Bank has grouped countries as low-income economies, lower-middle-income economies, upper-middle-income economies and high-income economies. In this study, lower-middle-income economies and upper-middle-income economies are combined and accepted as developing countries. Low-income economies and high-income economies are grouped as less developed countries and developed countries, respectively. There are 26 countries in the group of developed countries, 29 countries in the group of less developed countries and 13 countries in the group of developing countries. The list of the countries is provided in Appendix Table 1.

Methods and results

In this study, Panel Unit Root, Panel Cointegration Analysis and Panel Ganger Causality have been used for examination of the relationship among pollution, economic growth and trade liberalization. The empirical analysis consists of four steps: First, the stationary of the variables searched by panel unit root tests has been tested. Second, the cointegration relationship has been investigated. Third, long-run parameters of variables are estimated by Panel Fully Modified Ordinary Least Squares (FMOLS) method. Last step both the short-run and long-run causalities have been investigated.

Panel unit root tests

In this study, we utilize two panel unit root tests which are widely used in the literature to examine the stationary properties of variables.

These panel unit root tests are LLC (Levin *et al.*, 2002) and IPS (Im *et al.*, 2003) tests.

There are some differences between LLC and IPS tests. LLC unit root test has assumed that homogenous for all cross sections. But IPS unit root test has allowed heterogeneous values. For this reason two panel unit root tests are used in the model.

The maintained hypothesis of LLC unit root test is that;

$$\Delta y_{it} = \mu_i + \rho y_{i,t-1} + \sum_{L=1}^{k} \alpha_L \Delta y_{it-L} + \delta_i t + \theta_t + \varepsilon_{it} \quad (2)$$

where μ_i is unit specific fixed, θ_t is time effects, k is the lag length and Δ is the first difference. The null hypothesis of test is $\rho = 0$ for all *i* and the variable has a unit root. The alternative hypothesis is $\rho < 1$ and it shows that the variable is stationary.

IPS unit root test is;

$$\Delta y_{it} = \mu_i + \rho_i y_{it-1} + \sum_{L=1}^{k} \alpha_L \Delta y_{it-L} + \delta_i t + \theta_t + \varepsilon_{it} \quad (3)$$

The other difference of this test from LLC is alternative hypothesis. While alternative hypothesis of LLC unit root test examines that all i has a stationary process, alternative hypothesis of IPS unit root test examines that at least one *i* has a stationary process (Nazlioglu and Soytas, 2012).

The results of panel unit root tests are illustrated in Table 1. According to the unit root test results, the null hypothesis cannot be rejected clearly for the levels of variables. However, the null hypothesis is rejected strongly for first differences of the variables. The results have shown that variables are integrated at first differences. All variables are stationary at first difference for developed countries, developing countries and less developed countries. Thus, the variables are suitable for searching long-run relationship among pollution, economic growth and Trade Openness Rate.

Panel cointegration analysis

In this research, the panel cointegration test developed by Pedroni (1999) has been used to examine the existence of long-run relation among the variables for developed countries, developing countries and less developed countries. Pedroni Cointegration Test results are illustrated in Table 2.

The results have illustrated that with the exception of group rho-stat, all statistics has rejected null hypothesis which implies that there is no cointegration for developed countries. As shown in Table 2, except for panel v stat, the null hypothesis which implies that there is no cointegration can be rejected strongly for developing countries. Except for panel v and panel rho stats, all statistics have rejected null hypothesis which implies that there is no cointegration for less developing countries. The results strongly support evidence of long-run cointegration relationships.

Table 1 - Panel unit root tests.

	Developed Countries				Developing Countries				Less Developed Countries			
	LLC		IPS		LLC		IPS		LLC		IPS	
Variable	Constant	Constant& trend	Constant	Constant& trend	Constant	Constant& trend	Constant	Constant& trend	Constant	Constant& trend	Constant	Constant& trend
LCO_2	-13.387 (0.000)	-4.564 (0.000)	-7.860 (0.000)	-1.130 (0.129)	-4.213 (0.000)	-2.476 (0.007)	-2.820 (0.002)	0.197 (0.578)	-1.491 (0.068)	0.197 (0.578)	-1.232 (0.109)	-0.271 (0.393)
$LGDP$	-16.674 (0.000)	-3.305 (0.005)	-8.065 (0.000)	0.665 (0.747)	-2.694 (0.003)	-2.154 (0.016)	3.372 (0.999)	1.228 (0.890)	2.702 (0.996)	-0.165 (0.434)	5.516 (1.000)	2.353 (0.991)
$LTRADE$	-2.740 (0.003)	-3.906 (0.000)	0.415 (0.661)	-2.980 (0.001)	-1.144 (0.126)	-1.351 (0.089)	-1.669 (0.048)	-2.851 (0.002)	-2.641 (0.004)	-1.463 (0.072)	-2.309 (0.010)	-1.958 (0.025)
$\Delta LCO_2 2$	-28.249 (0.000)	-33.178 (0.000)	-28.171 (0.000)	-32.803 (0.000)	-17.313 (0.000)	-16. 719 (0.000)	-20. 812 (0.000)	-19. 850 (0.000)	-9.225 (0.000)	-7.481 (0.000)	-15.741 (0.000)	-14.440 (0.000)
$\Delta LGDP\Delta$	-18.488 (0.000)	-20.472 (0.000)	-17.600 (0.000)	-19.337 (0.000)	-16. 154 (0.000)	-16. 729 (0.000)	-16. 890 (0.000)	-16. 388 (0.000)	-9 522 (0.000)	-8.971 (0.000)	-12.918 (0.000)	-12.806 (0.000)
$\Delta TRADE\Delta$	-34.674 (0.000)	-34.448 (0.000)	-31.482 (0.000)	-30.542 (0.000)	-23.324 (0.000)	-21.717 (0.000)	-25.581 (0.000)	-23.722 (0.000)	-16.027 (0.000)	-15.436 (0.000)	-18.419 (0.000)	-17.567 (0.000)

ote: Numbers in brackets are p-values. is the first difference. Newey-West and Bartlett Kernel was used for LLC test. Schwarz Bayesian Criterion was used to optimal lag determination.

Table 2 - Panel cointegration test results

	Developed countries		Developing countries		Less developed countries	
	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.
Panel v	4.607	0.00	-0.433	0.67	-0.455	0.67
Panel rho	-8.450	0.00	-4.871	0.00	-0.979	0.16
Panel PP	-10.848	0.00	-7.204	0.00	-2.582	0.00
Panel ADF	-10.882	0.00	-6.814	0.00	-1.790	0.03
Group rho	-0.599	0.27	-2.485	0.01	-1.701	0.04
Group PP	-2.410	0.01	-5.005	0.00	-3.860	0.00
Group ADF	-2.726	0.00	-3.572	0.00	-2.959	0.00

Panel cointegration estimation

After determining the long-run relationship between variables, it has been used Fully Modified Ordinary Least Squares (FMOLS) estimator developed by Pedroni (2000) to find long-run coefficients of variables. Pedroni (2000) has compared various cointegration estimators in relatively small samples and argued that FMOLS estimator has more consistent results. Thus, in this study Panel FMOLS estimator has been used as a cointegration estimator. The results of Panel FMOLS estimator has estimated for three different country groups and 68 countries.

FMOLS estimation results for developed countries are displayed in Table 3. While environmental pollution is effected positively by GDP, pollution is affected negatively by Trade Openness Rate. According to the results of group panel, the effect of Trade Openness Rate on pollution is negative.

As a shown in Table 3, long-run coefficient on the Trade Openness Rate is significant and negative for developed countries. According to the results of group panel, the effect of Trade Openness Rate on pollution is -0.04. Trade Openness Rate has a negative relation with pollution in some countries such as Belgium, Denmark, Netherlands, Sweden, Trinidad & Tobago, Chile. GDP for these countries is relatively low compared to other developed countries. Denmark is considered one of the most successful countries in the production of biogas. Biogas is the clean and renewable energy resource and biogas plants do not produce carbon. Therefore, it plays an important role reducing in the emission of greenhouse. There is also negative relationship between trade openness and pollution in Sweden has strict environmental regulations. For these reasons, the effect of Trade Openness Rate on pollution is negative.

A 1% increase in Trade Openness Rate increases pollution by 3.84% in USA, 1.79% in Norway, 0.66% in France, 0.36% in South Korea. The effect of Trade Openness Rate on pollution is significant and positive in these countries. It is possible to assume that these countries are exporter countries in some industries which increase the rate of pollution.

According to the results of group panel, the effect of GDP on pollution is positive. A 1% increase in GDP increases pollution by 0.41. This result is expected that GDP affects pollution positively at the first stage.

The results of FMOLS estimator for developing countries are illustrated in Table 4. According to the results of group panel, the effect of Trade Openness Rate on pollution is positive. Long-run coefficient on the Trade Openness Rate is significant at 10 percent level and positive for developed countries. Long-run coefficient on the Trade Openness Rate is 0.18. That is, trade liberalization leads to the movement of polluting industries from high income or stringent environmental regulation countries to low income or lax environmental regulation countries. Thus, polluting

Table 3 - Estimated long-run coefficients for developed countries.

PANEL FMOLS						
COUNTRY	CONSTANT	T STAT.	LNGDP	T STAT.	LNOPEN	T STAT.
Australia	-10.02***	-6.78	0.52***	6.41	-0.37	-1.58
Austria	-11.03***	-3.52	0.56***	3.46	-0.35	-1.34
Barbados	-31.81***	-18.50	1.53***	24.20	-0.08	-0.72
Belgium	-3.63	-0.99	0.40**	2.02	-0.94***	-2.64
Canada	-3.07	-1.28	0.23*	1.94	-0.08	-0.37
Chile	-13.09***	-9.65	-0.66***	9.50	-0.60***	-4.94
Denmark	-5.87***	-3.23	0.54***	5.71	-1.35***	-7.23
Finland	-14.43***	-3.34	0.70***	3.10	-0.27	-0.66
France	15.79***	2.91	-0.58**	-2.40	0.66*	1.71
Greece	-25.48***	-6.68	0.99***	5.30	0.46	1.60
Iceland	3.20***	4.27	0.03	1.08	-0.43***	-3.54
Israel	-9.23***	-10.54	0.45***	11.88	-0.04	-0.47
Italy	-15.42***	-4.63	0.59***	4.00	0.20	0.80
Japan	-13.36***	-7.25	0.53***	8.05	0.09	0.48
Korea, Rep.	-17.08***	-27.15	0.65***	18.49	0.36***	3.50
Luxembourg	12.45***	5.81	-0.45***	-2.57	0.26	0.62
Netherland	-6.79***	-3.59	0.56***	4.92	-1.24***	-4.13
Norway	-18.05***	-5.97	0.48***	8.21	1.79***	3.25
Portugal	-26.71***	-22.19	1.12***	15.89	-0.15	-0.82
Singapore	-4.15	-0.62	0.48***	1.89	-0.95	-0.55
Spain	-21.74***	-3.15	0.87***	2.86	-0.09	-0.22
Sweden	2.65	0.32	0.12	0.30	-0.91*	-1.80
Trinidad	-26.87***	-9.78	1.40***	12.75	-0.57**	-2.48
United King.	9.45***	10.80	-0.25***	-6.11	-0.03	-0.26
United States	5.88*	1.94	-0.36	-0.21	3.84**	2.48
Uruguay	-2.94	-0.62	0.21	0.90	-0.37	-1.54
PANEL	-8.90***	-24.20	0.41***	27.76	-0.04***	-4.09

Note: ***,**,* indicate statistical significance at 1, 5 and 10 percent level respectively

industries may relocate from developed countries to the developing countries. A 1% increase in Trade Openness Rate increases pollution by 0.49% in Costa Rica, 5.70% in Gabon, 0.54% in Guatemala, 0.78% in Honduras, 0.15% in Indonesia, 0.15% in Mauritania, 0.78% in Senegal and 0.55% in Sudan.

A 1% increase in Trade Openness Rate decreases pollution by 0.14% in Argentina, 1.16% in Republic of Congo, 0.95% in Ecuador, 0.44% in Hungary, %0.21 in India, 0.35% in Mexico and 0.36% in South Africa. Mexico's trade deficit has increased with the crisis in Mexico and lived the recession in production. The crisis erupted in Mexico is reflected in some developing countries such as Argentina and Ecuador. Thus, it is possible to argue that due to the reduction in the volume of trade, trade and pollution have a negative relation. The effect of Trade Openness Rate on pollution is not significant for Turkey. This case may demonstrate that the production causing

Table 4 - Estimated Long-Run Coefficients for Developing Countries.

PANEL FMOLS						
COUNTRY	CONSTANT	TSTAT.	LNGDP	TSTAT.	LNOPEN	TSTAT.
Algeria	-23.16***	-6.97	1.02***	7.85	-0.35	-1.06
Argentina	-12.31***	-5.65	0.54***	5.94	-0.14*	-1.74
Brazil	-13.87***	-13.24	0.52***	11.11	0.06	0.52
Colombia	-2.96**	-2.17	0.17*	1.97	-0.27	-0.78
Congo Rep.	-4.14	-1.37	0.40***	2.55	-1.16***	-2.85
Costa Rica	-13.05***	-9.76	0.48***	5.02	0.49*	1.74
Cote d'lvoire	-13.60***	-3.66	0.70***	3.62	-0.83	-1.33
Dominican Rep.	-17.63***	-12.22	0.71***	8.75	0.30	1.43
Ecuador	-29.49***	-10.57	1.40***	9.35	-0.95***	-3.44
Fiji	-9.44***	-4.51	0.44***	3.38	0.02	0.04
Gabon	-29.40***	-2.69	0.20	0.46	5.70***	3.57
Ghana	-11.92***	-8.12	0.48***	6.84	-0.04	0.43
Guatemala	-10.96***	-11.24	0.36***	6.86	0.54***	5.51
Honduras	-8.51***	-7.29	0.21***	2.94	0.78***	6.70
Hungary	-6.07**	-2.46	0.39***	3.38	-0.44***	-3.18
India	-23.58***	-10.97	0.90***	9.60	-0.21*	-1.71
Indonesia	-18.88***	-27.47	0.71***	20.58	0.15**	2.15
Mauritania	-21.01***	-3.28	0.72**	2.07	1.15**	2.28
Mexico	-17.80***	-7.88	0.75***	7.70	-0.35***	-2.99
Nicaragua	-21.41***	-13.03	0.95***	12.34	-0.05	-0.71
Nigeria	-25.48***	-2.96	1.03***	2.65	-0.20	-0.47
Peru	-4.02	-1.66	0.12	1.21	0.31	1.54
Philippines	-4.74	-1.36	0.12	0.68	0.35	1.47
Senegal	-6.07**	-2.19	0.09	0.62	0.78***	3.55
South Africa	-5.68***	-3.46	0.36***	5.71	-0.36*	-1.91
Sri Lanka	-11.31***	-5.94	0.51***	5.03	-0.41	-1.20
Sudan	-3.75	-1.51	0.02	0.15	0.55***	3.41
Turkey	-19.83***	-9.12	0.79***	8.39	0.02	0.18
Venezuela	0.47	0.23	0.10	1.13	-0.33	-1.61
PANEL	-13.43***	-35.75	0.52***	29.32	0.18*	1.77

Note: ***,**,* indicate statistical significance at 1, 5 and 10 percent level respectively

pollution is not aimed for foreign trade in Turkey. According to the results of group panel, the effect of GDP on pollution is positive like in the developed countries.

The results of Panel FMOLS estimator for less developing countries are displayed in Table 5. According to the results of group panel, the effects of Trade Openness Rate and GDP on pollution are positive. Long-run coefficient on the Trade Openness Rate is 0.32 for less developing countries. Long-run coefficient on the Trade Openness Rate is positive in some countries such as Burkina Faso, Kenya, Nepal, Niger and Togo. Furthermore it is possible to claim that the Pollution Haven Hypothesis is still valid for the developing and less developed countries. Coefficient of Trade Openness Rate is negative for Democratic Republic of Congo. This country survived the civil war and the trade volume of Democratic Republic of Congo decreased. At the same time

Table 5 - Estimated Long-Run Coefficients for Less Developed Countries.

PANEL FMOLS						
COUNTRY	CONSTANT	T STAT.	LNGDP	T STAT.	LNOPEN	T STAT.
Benin	-27.44***	-13.42	1.16***	10.75	0.16	1.13
Burkina Faso	-18.75***	-13.72	0.55***	7.25	1.14***	7.04
Burundi	-25.04***	-6.08	1.10***	4.80	-0.33	-0.97
Central African Rep.	-6.72	-0.59	0.14	0.31	0.25	0.58
Chad	4.89	0.65	-0.51	-1.20	0.67	1.21
Congo Dem. Rep.	-44.84***	-4.18	1.91***	4.16	-0.60***	-2.72
Kenya	-2.91	-1.33	-0.05	-0.88	0.70*	1.91
Madagascar	-4.75	-0.48	0.17	0.35	-0.35	-0.93
Nepal	-28.50***	-7.51	1.09***	5.38	0.41*	1.81
Niger	0.38	0.05	-0.36	-0.91	1.34***	4.85
Rwanda	-23.93***	-4.03	0.92***	2.98	0.52	0.79
Sierra Leone	1.21	0.12	-0.18	-0.42	0.15	0.33
Togo	-21.71***	-11.28	0.87***	8.71	0.39*	1.87
PANEL	-15.53***	-17.14	0.54***	10.95	0.32***	4.45

Note: ***,**,* indicate statistical significance at 1, 5 and 10 percent level respectively

Democratic Republic of Congo has a hydroelectric potential. Hydroelectric is a clean and renewable energy resources. Therefore, it plays an important role reducing in the emission of greenhouse.

In summary, Trade Openness is estimated -0.04, 0.18 and 0.32 for developed, developing and less developing countries, respectively. As expected from the literature, this result supports Pollution Haven Hypothesis. According to the Pollution Haven Hypothesis, polluting industries may relocate to less stringent environmental regulations. Dirty industries migrate from developed countries to developing or less developing countries. Consequently, developing and less developing countries provide pollution haven for dirty industries.

Panel causality

Considering the cointegrated variables, Pesaran *et al.* (1999) has estimated Panel Vector Error Correction Model (VECM) to implement the Granger Causality Test (Apergis and Payne, 2010:1424). If the variables are cointegrated, Vector Error Correction Model should be estimated by implementing VAR model with one lagged error correction term (Agir, *et al.*, 2011:453). Engle and Granger (1987) have two stages. At the first stage, long term equation can be written to estimate residuals as follows (Apergis and Payne: 2010:1423-1424):

$$CO_{2_{it}} = \alpha_i + \delta_{it} + \gamma_{1i} GDP_{it} + \gamma_{2i} OPEN_{it} + \varepsilon_{it} \qquad (4)$$

where δ_i; refers deterministic trends and ε_{it} represent residuals. At the second stage, lagged residual is estimated as error correction model in the above equation. Dynamic

error correction model is estimated as follows (Apergis and Payne: 2010: 1423-1424):

$$\Delta CO_{2_{it}} = \alpha_{1j} + \sum_{k=1}^{q} \theta_{11ik} \Delta CO_{2_{it-k}} + \sum_{k=1}^{q} \theta_{12ik} \Delta GDP_{it-k} + \sum_{k=1}^{q} \theta_{13ik} \Delta OPEN_{it-k} + \gamma_{1i} \varepsilon_{it-1} + u_{1it} \quad (5)$$

$$\Delta GDP_{it} = \alpha_{2j} + \sum_{k=1}^{q} \theta_{21ik} \Delta CO_{2_{it-k}} + \sum_{k=1}^{q} \theta_{22ik} \Delta GDP_{it-k} + \sum_{k=1}^{q} \theta_{23ik} \Delta OPEN_{it-k} + \gamma_{2i} \varepsilon_{it-1} + u_{2it} \quad (6)$$

$$\Delta OPEN_{it} = \alpha_{3j} + \sum_{k=1}^{q} \theta_{31ik} \Delta CO_{2_{it-k}} + \sum_{k=1}^{q} \theta_{32ik} \Delta GDP_{it-k} + \sum_{k=1}^{q} \theta_{33ik} \Delta OPEN_{it-k} + \gamma_{3i} \varepsilon_{it-1} + u_{3it} \quad (7)$$

where Δ refers to first difference; *q* is the optimal lag length and *u* represents unrelated error term (Apergis and Payne, 2010:1424). These equations identify short-run and long-run causalities (Agir *et al*., 2011:453).

The results of Panel Causality for developed countries are illustrated in Table 6. GDP has a positive and statistically significant impact in the short-run on CO_2 whereas Trade Openness Rate is positive but statistically insignificant. The error correction term is statistically significant at the 1% level. The error correction term is statistically significant while the speed of adjustment toward long-run equilibrium appears much faster than in the case of GDP and Trade Openness Rate equations which are dependent variables.

Trade Openness Rate has a positive and statistically significant impact on GDP in the short-run. Additionally CO_2 is positive but statistically insignificant. The error correction term is statistically significant at the 5% level but the speed of adjustment toward long-run equilibrium appears relatively much slower.

GDP and CO_2 have a positive and statistically significant impact in the short-run on Trade Openness Rate. The error correction term is statistically significant at the 1% level, but with a relatively slow speed of adjustment to long-run equilibrium.

Table 7 reports the results of the short-run and long-run causality test for developing countries. GDP has positive and statistically significant impact in the short-run on CO_2 whereas Trade Openness Rate is a positive but statistically

Table 6 - Panel causality for developed countries.

	SHORT-RUN CAUSALITY			LONG-RUN CAUSALITY	
	lnCO2	lnGDP	lnOPEN	ECT(-1)	
ΔlnCO$_2$		103.60 (0.00)	4.19 (0.12)	-0.019***	(-7.45)
ΔlnGDP	1.25 (0.53)		8.12 (0.02)	-0.001**	(-2.33)
ΔlnOPEN	4.84 (0.09)	8.32 (0.02)		-0.006***	(-3.43)

Note: The p-values are in brackets and parentheses. ***, ** and * indicate the statistical significance at 1, 5 and 10 percent levels respectively.

Table 7 - Panel Causality for Developing Countries.

	SHORT-RUN CAUSALITY			LONG-RUN CAUSALITY	
	$\Delta lnCO_2$	$\Delta lnGDP$	$\Delta lnOPEN$	ECT(-1)	
$\Delta lnCO_2$		32.24 (0.00)	2.35 (0.31)	-0.018***	(-4.68)
$\Delta lnGDP$	3.14 (0.21)		12.25 (0.00)	-0.002**	(-2.36)
$\Delta lnOPEN$	9.14 (0.01)	0.22 (0.89)		-0.008***	(-3.12)

Note: The p-values are in brackets and parentheses. ***, ** and * indicate the statistical significance at 1, 5 and 10 percent levels respectively.

insignificant. The error correction term is statistically significant at the 1% level whereas the speed of adjustment toward long-run equilibrium appears much faster than in the case of GDP and Trade Openness Rate equations which are dependent variables.

CO_2 has a positive but statistically insignificant impact in the short-run on GDP. Trade Openness Rate is positive and statistically significant. The error correction term is statistically significant at the 5% level. However the speed of adjustment toward long-run equilibrium appears relatively more slowly.

CO_2 has a positive and statistically significant impact in the short-run on Trade Openness Rate while Trade Openness Rate is a positive but statistically insignificant. The error correction term is statistically significant at the 1% level. The speed of adjustment toward long-run equilibrium appears relatively slower than in the case of CO_2 equations.

The results of Panel Causality for less developed countries are illustrated in Table 8. GDP has a positive and statistically significant impact in the short-run on CO_2 whereas Trade Openness Rate is positive but statistically insignificant. The error correction term is statistically insignificant.

CO_2 has a positive and statistically significant impact in the short-run on GDP while Trade Openness Rate is a positive but statistically insignificant. The error correction term is statistically significant at the 10% level while the speed of adjustment toward long-run equilibrium appears relatively more slowly.

CO_2 has a positive but statistically insignificant impact in the short-run on Trade Openness Rate. GDP is a positive and statistically significant. The error correction term is statistically significant at the 1% level.

Table 8 - Panel Causality for Less Developing Countries.

	SHORT-RUN CAUSALITY			LONG-RUN CAUSALITY	
	$\Delta lnCO_2$	$\Delta lnGDP$	$\Delta lnOPEN$	ECT(-1)	
$\Delta lnCO_2$		7.67 (0.02)	2.57 (0.28)	-0.014	(-1.18)
$\Delta lnGDP$	10.79 (0.00)		0.59 (0.74)	-0.002*	(-1.95)
$\Delta lnOPEN$	0.27 (0.87)	11.27 (0.00)		0.018***	(5.56)

Note: The p-values are in brackets and parentheses. ***, ** and * indicate the statistical significance at 1, 5 and 10 percent levels respectively.

Conclusions

This study empirically investigates the relationship among the Environmental Pollution, Economic Growth and Trade Openness Rate for various countries with different income levels. According to the empirical results obtained from panel cointegration and panel causality tests, Trade Openness Rate of developed countries has a negative effect while Trade Openness Rate of developing and less developed countries has positive effect on the level of CO_2 emission.

GDP has positive and statistically significant impact in the short-run on CO_2 while CO_2 has positive and statistically significant impact in the short-run on GDP. However CO_2 has positive but statistically insignificant impact in the short-run on Trade Openness Rate.

The error correction term is statistically significant at the 1% level and the speed of adjustment toward long-run equilibrium appears much faster than in the case of GDP and CO_2 equations which are dependent variables.

As mentioned before, trade liberalization leads to the movement of polluting industries from high income countries to low income countries. Thus, polluting industries may relocate from developed countries to the developing countries. While developed countries benefit from this relocation in terms of environmental quality, developing countries lose. For this reason it is possible to say that the results may be evidence that the Pollution Haven Hypothesis is still valid for the developing and less developed countries. Additionally GDP effects these countries' pollutions positively at first stage.

Earth and its resources are the common property of mankind. Therefore, nations should jointly adopt environmental standards. Efficient environmental regulations and clean technologies can reduce the pollution. Thus, environmental quality can

increase. Many countries that implicitly pursue trade liberalization policies also tend to relax environmental regulations so as to attract investment from the private sector at the same time. For this reason more effective policies must be implemented and controlled in order to have a viable environment.

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Appendix *List of the Countries Included in the Analysis*

Developed Countries	Developing Countries	Less Developed Countries
Australia	Algeria	Benin
Austria	Argentina	Burkina Faso
Barbados	Brazil	Burundi
Belgium	Colombia	Central African Rep.
Canada	Congo Rep.	Chad
Chile	Costa Rica	Congo Dem. Rep.
Denmark	Cote d'lvoire	Kenya
Finland	Dominican Rep.	Madagascar
France	Ecuador	Nepal
Greece	Fiji	Niger
Iceland	Gabon	Rwanda
Israel	Ghana	Sierra Leone
Italy	Guatemala	Togo
Japan	Honduras	
Korea, Rep.	Hungary	
Luxemb.	India	
Netherland	Indonesia	
Norway	Mauritania	
Portugal	Mexico	
Singapore	Nicaragua	
Spain	Nigeria	
Sweden	Peru	
Trinidad	Philippines	
United King.	Senegal	
United States	South Africa	
Uruguay	Sri Lanka	
	Sudan	
	Turkey	
	Venezuela	

Source: Grouping is performed according World Bank Atlas Method