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Economic Growth And Carbon Emission: A Dynamic Panel Data Analysis

Ibrahim BAKIRTAS[1], Seyhat BAYRAK[2], Atalay CETIN[3]

Abstract

The relationship between carbon dioxide emission (CO_2) and economic growth is one of the crucial topics in environmental economics. This study is aimed to investigate that problem. In this study, depending on the theory of Environmental Kuznets Curves (EKC), the impact of income in carbon dioxide emission has measured for 34 OECD and 5 BRICS countries with using Dynamic Panel Data Analysis. In this regard OECD countries are classified by income groups due to the average per capita income rate of OECD to solve the homogeneity problem among OECD countries. On the other hand EKC hypothesis analysed by short and long run income elasticity which will be using for an evident that a country reduces CO_2 emissions with the income increase in this study. According to the findings of the study, % 36 of the country sample coherent with the EKC hypothesis. The main encouragement for testing this relationship between economic growth and CO_2 emission is leading politicians to reconsider the environmental impacts which are arising from income increase when they are taking a decision to maximizes the economic growth.

Keywords: EKC; OECD; Dynamic Panel Data

1. Introduction

World population has rapidly increased since the beginning of 20th century. Due to rapidly increasing of world population, the world energy demand has also increased year by year. In this regard rapidly increasing use of fossil fuels (especially in the energy sector) is considered as an essential reason of environmental degredation (such as air pollution, ozone depletion), climate change and global warming. The reason behind all of them is induced progressive greenhouse gas (GHG) emission (especially carbon dioxide (CO_2)) due to an increasingly use of fossil fuels (Erdem, 2010; Toklu, 2013).

Kuznets (1955) expected that when per capita income increases, initially income inequality is also increases too. But after a turning point (TP) income inequality will begin to decline. In the literature, this relationship between per capita income and income inequality has represented by a bell-shaped curve (Kuznets, 1955). This economical

| [1]Corresponding Author: Aksaray University, Faculty of Economics and Administrative Science, Department of Economics, 68000 Aksaray, Turkey,
[2]Dumlupınar University, Faculty of Economics and Administrative Science, Department of Econometrics, 43000 Kütahya, Turkey.
[3]Aksaray University, Faculty of Economics and Administrative Science, Department of Economics, 68000 Aksaray, Turkey.

incident is mostly known as Kuznets Curve. In this regard, after 1990's, the same inverted U shaped relationship in Kuznets Curve has also been found between the level of environmental degradation and per capita income. Afterwards, the inverted U shaped curve which explains the relationship between measured indicators of degradation (such as the level of sulphur oxide (SO_2) or carbon dioxide (CO_2) emissions) and economic growth took the name of Environmental Kuznets Curve (EKC). Concordantly Figure 1 shows the EKC and the turning point (TP) of the bell-shaped curve. As it can be understood from the Figure 1, environmental pollution increases due to the increase in income per capita at the early stages of economic growth. Afterwards, along with per capita income increase, environmental pollution increases to the beyond of (until TP) the ecological threshold level. In that point (TP), environmental quality improves with higher income per capita. Consequently Figure 1 shows that long run relationship between per capita income and environmental quality (Dinda, 2004; Stern, 2004).

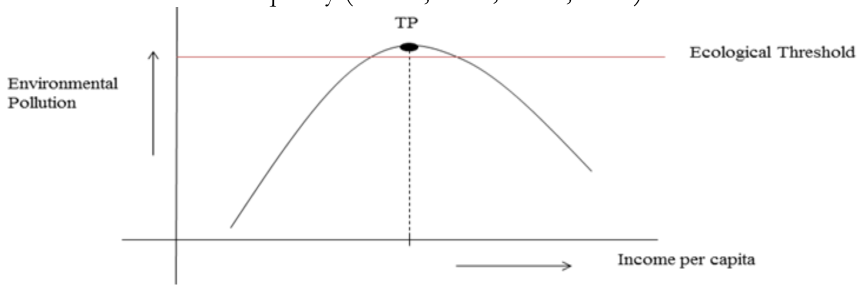

Figure 1. *Environmental Kuznet Curve (EKC) (Panayotou, 1997; Dinda, 2004).*

The main incentive which is lying behind at this study is to canalize the politicians attention to the consequences of economic growth decisions on environmental quality by the help of testing EKC. In this regard in the literature of EKC, per capita income, per capita income squared and per capita income cubed used as a determinant of environmental quality especially in several studies such as Grossman and Krueger (1995), Dinda et al. (2000), Perman and Stern (2003), Martinez-Zarzoso and Bengochea-Morancho (2004), Galeotti et al. (2006). However quite high correlation coefficients between income, income squared and income cubed induced an unreasonable TP such as \$3137 (Panayotou, 1993), \$3670 (Shafik, 1994). From this point of view Narayan and Narayan (2010), in their inspirational study, stated a significant problem of multi-collinearity (which was the reason of misspecification of TP) between per capita income, per capita income squared and per capita income cubed. Concordantly, the collinearity test among per capita income and per capita income squared and among per capita income squared and per capita income cubed applied in this study. According to the findings, the correlation coefficient between per capita income and per capita income squared has estimated to 0.9586 for lower income OECD countries sample, 0.9586 for higher income OECD countries sample and 0.9429 for BRICS countries sample. On the other hand the correlation coefficient between per capita income squared and per capita income cubed has estimated to 0.9773, 0.9709 and 0.9803 for lower and higher income OECD countries and BRICS countries panels, respectively.

As also pointed out in Narayan and Narayan (2010), EKC hypothesis can examine by the help of long run and short run income elasticity comparision. They proposed if the long run income elasticity smaller than income elasticity of short run, then this result implies CO_2 emissions will decrease due to the increase in per capita income over time. Therefore, the long run and short run income elasticities has tested both for panel groups and individual countries in this study.

According to the individual country findings of our study, the estimated long run income elasticies have found smaller than the short run income eleasticities in Czech Republic, Greece, Slovak Republic, Slovenia, Denmark, Germany, Iceland, Norway, Sweeden, Switzerland, United Kingdom (UK), Unites States of America (USA), China and Russian Federation. In other words % 36 of the sample coherent with the EKC hypothesis. Additionally the long run relationship between CO_2 emissions and income per capita has also investigated for three panel groups by using panel cointegration tests and error correction model (ECM). Initially, the reverse relation has found for three panel groups at the study. In this context, the countries which have statistically insignificant income elasticity results for short run and long run has excluded from the study. In this way, for two panels, the long run income elasticies have found smaller than the short run income elasticities.

This study is distributed into five main sections. At the following section, a general overview of EKC hypothesis has carried out by the help of selected studies in the literature. In section three, the econometric techniques which were used at this study, has argued. The information about panel data set and the results of the econometric analysis has given in the section four. Finally, some concluding remarks and suggestions has pointed out at the last section.

2. Literature

Although Grossman and Krueger (1991) firstly implicated the inverted U relationship between per capita income and environmental quality, Panayotou (1993) was the first one who entitled that bell shaped curve to EKC. After Grossman and Krueger (1991), the relationship between per capita income and environmental pollution has been argued by many studies in the literature. Early studies of EKC has been investigated by Shafik and Bandyopadhyay (1992), Shafik (1994), Panayotou (1993, 1997), Grossman and Krueger (1995), Selden and Song (1995). In this regard, they have reached an inverted U relationship between income and pollution correspondingly to the hypothesis of EKC accordingly to the findings of their studies.

Cross-section or panel data techniques were used in most studies on EKC literature. Dinda et al. (2000) testing the relationship between suspended particulate matter (spm) and SO_2 emissions and per capita income for 33 countries between the years of 1979-1990. They used income and income squared as determinants of environmental quality. In respect of the results, they couldn't find any evidence of EKC.

Dijkgraaf and Vollebergh (2001) researched the inverted U shaped relationship between CO_2 emissions and per capita Gross Domestic Product (GDP) for OECD countries between the years of 1960-1997 by the virtue of panel data analysis techniques. They also challenge the assumption of country homogeneity and reject the homogeneity hypothesis even for a small country groups. According to the findings of this study, eleven of the twenty four countries confirmed the EKC hypothesis.

Dinda and Coondoo (2002) estimated the casuality between per capita CO_2 emission and per capita GDP by using a cross country panel data set including 88 countries for the period of 1960-1990. They found a long run relationship between per capita CO_2 emission and per capita GDP for seven different country groups through unit root and cointegration tests and error correction model which were based on time series econometric techniques. They also discovered a bi- directional causality between income and CO_2 emissions more or less for all country groups.

Perman and Stern (2003) investigated the EKC hypothesis by using panel data set of SO_2 emissions and GDP for 74 countries during 31 years. In this regard individual and panel cointegration techniques were used in that study. Considering the results of the study, it was found that many countries have U shaped or monotonically increasing relationship between SO_2 emissions and GDP. Regard to the results did not prove the EKC for SO_2 emissions.

Martinez-Zarzoso and Bengochea-Morancho (2004) studied the relationship between CO_2 emissions and income per capita for 22 OECD countries during 1975-1998. They asserted the homogeneity problem of the countries. The pooled mean group estimator was used at the study to solve homogeneity problem in short run. Findings of the study were pointed to an N shaped relationship for almost all of the countries.

Galeotti et al. (2006) also analysed the relationship between CO_2 emission and per capita income, per capita income squared, income cubed with using two different CO_2 emission data set for OECD countries and non-OECD countries. They reached an inverted U relationship between per capita income and for both CO_2 emissions and found a reasonable turning point of per capita income (15.000$ for the first and 20.000$ for the second data set of CO_2 emissions) for OECD panel. However that relationship has characterized by an increasing concave for non-OECD panel.

Narayan and Narayan (2010) tested the short and long run income elasticity of 43 developing countries to examined the EKC hypothesis. They were propounded as an evidence of EKC that if the long run income elasticity is smaller than the short run income elasticity, then a country has reduced CO_2 emissions due to the increased in income. Additionally they also estimated the long run relationship between per capita CO_2 emissions and per capita income by the help of panel cointegration and unit root tests. According to the findings of the study, income elasticity in the long run was smaller than the short run only in two panels.

Even there is easy to find a study of EKC which cross section and panel data techniques were used, still single country studies were also examined by researches in the literature such as Carson et al. (1997), Akbostancı et al. (2009), Jalil and Mahmud (2009).

3. Methodology

In this study, the long run relationship between CO_2 emissions and per capita income has examined by using panel cointegration techniques. Following the studies of Pedroni (1999) and Westerlund (2007), the cointegration tests are applied to expose the long run relationship between the variables. The regression of panel cointegration is stated at below,

$$\ln CO_{2i,t} = \alpha_i + \beta_i \ln Y_{i,t} + \varepsilon_{i,t}$$
$$t = 1,......,T \; ; \; i = 1,......., N \qquad (1)$$

According to this equation, $\ln Y$ is expressing the natural logarithm of real GDP per capita and $\ln CO_2$ is implying the natural logarithm of per capita CO_2 emissions.

4. Data and Results

4.1. Data

Carbon dioxide emissions and real GDP per capita (measured in constant (2005 prices) US$) data for each countries are obtained from World Bank and The United States Department of Agriculture (USDA) respectively. Concordantly the data set is covered the period from 1990 to 2010. On the other hand differently from the other OECD examples in the literature, OECD countries has examined separately by the help of average real GDP per capita level considering the structural, technological and economic development differences among OECD countries. In this regard the average real GDP per capita has estimated as 27.504 US $ for 34 OECD countries over the sample period. In this way, depending on the level of the real GDP per capita of the countries below or above on average real GDP per capita, OECD countries has split into two panel groups such as higher income OECD country panel (19 countries) and middle upper income OECD country panel (15 countries). Except from these panel groups general OECD countries panel and BRICS countries panel are also examined at this study.

4.2. Panel Unit Root and Panel Cointegration Test Results

As mentioned previously, before applying the panel cointegration test, the existence of panel unit root in variables needs to be examined. In this regard panel unit root tests were estimated for all variables firstly. According to the panel unit root test results for each variable, the real GDP per capita and per capita CO_2 emissions are integrated of order one for all 38 countries. However because some data of variables are missing, unbalanced panel unit root tests such as IPS test, Fisher ADF test and Fisher PP test are estimated too. Concordantly panel unit root tests has examined for 4 panel groups. However, while panel unit root tests were estimating, cross-section dependency was investigated firstly. In this regard non-stationary on series have examined by the help of first generation and second generation panel unit root test results to expose the cross-section dependency. At this point cross-section dependency has tested by means of Pesaran, Friedman and Frees tests. According to the results the cross-section dependency has been found for each panel groups.

Table 1 show the panel unit root test results for each panel groups. The IPS test results are reported in Column 2 and Fisher-ADF and Fisher PP tests are reported in Column 3 and 4 respectively. Lastly Pesaran CADF tests are reported in Column 5. Additionally p values which are related to these unit root tests are reported beneath the test statistics in parenthesis. According to results in Table 1, it has found for each panel groups that series of per capita CO_2 emission and real GDP per capita are panel non-stationary on level. Although these two series are becoming panel stationary when first difference of them are considering in tests. Under the circumstances is there a long run relationship between per capita CO_2 emission and real GDP per capita? From this point of view, the long run relationship between per capita CO_2 emission and real GDP per capita has examined due to the panel cointegration tests. In this regard panel Pedroni and Westerlund cointegration test results for each panel group are given in Table 2.

Table 1. Panel Unit Root Test Results

Panel Groups	IPS		Fisher ADF		Fisher PP		Pesaran CADF	
	lnCO_2	**lnY**	**lnCO_2**	**lnY**	**lnCO_2**	**lnY**	**lnCO_2**	**lnY**
OECD	-0.2896 (0.3861)	1.5263 (0.9365)	70.7974 (0.3845)	38.5998 (0.9985)	83.9295* (0.0921)	32.6767 (0.9999)	0.976 (0.835)	-0.539 (0.295)
UpperMiddle Income OECD	-1.1422 (0.1267)	1.0567 (0.8547)	38.5165* (0.0890)	15.1332 (0.9770)	31.8968 (0.2787)	13.5561 (0.9901)	-0.114 (0.454)	-0.332 (0.370)
Higher Income OECD	0.5694 (0.7154)	1.1060 (0.8656)	32.2809 (0.8023)	23.4691 (0.9827)	52.0327* (0.0963)	19.1215 (0.9979)	2.344 (0.990)	-0.623 (0.267)
BRICS	0.3671 (0.6432)	4.9765 (0.9979)	9.4352 (0.4914)	1.0270 (0.9998)	13.9477 (0.1754)	0.4317 (0.9997)	-1.531* (0.063)	-1.583* (0.057)

Notes:, **,*** denote statistical significance at the 10 per cent, 5 per cent and 1 per cent leves, respectively.*

As it can be seen from the Table 2, for the OECD panel group, all of the four test statistics of Pedroni panel cointegration analysis support the long run relationship between per capita CO_2 emission and real GDP per capita at 1 per cent level of significance. On the other hand, according to the Westerlund cointegration test results for OECD panel group, three of the test statistics (G_t,P_t,P_a) support the panel cointegration between per capita CO_2 emission and real GDP per capita at 1 and 5 per cent level of significance. As it is shown in Table 2, for upple middle income OECD countries panel group, Pedroni panel cointegration test statistics are significant at 1, 5 and 10 per cent level and three of the four test statistics of Westerlund cointegration analysis are significant at 1 per cent level. Concordantly the long run relationship between per capita CO_2 emission and real GDP per capita supported for upper middle income OECD panel group by virtue of Pedroni and Westerlund panel cointegration analysis.

Table 2. Pedroni Panel and Westerlund Cointegration Test Results

	Pedroni Panel Cointegration Results				Westerlund Cointegration Results			
Panel Groups	**Panel PP**	**Panel ADF**	**Group PP**	**Group ADF**	G_t	G_a	P_t	P_a
OECD	-4.822*** (0.000)	-7.945*** (0.000)	-2.835*** (0.0023)	-5.623*** (0.000)	-2.618*** (0.000)	-5.551 (0.956)	-10.074** (0.049)	-6.259*** (0.004)
Upper Middle Income OECD	-0.772** (0.0201)	-2.366*** (0.0089)	-0.601* (0.0740)	-2.994*** (0.0014)	-3.907*** (0.000)	-7.292 (0.995)	-10.32*** (0.003)	-14.09*** (0.001)
Higher Income OECD	-5.207*** (0.000)	-7.754*** (0.000)	-3.194*** (0.007)	-4.827*** (0.000)	-2.594*** (0.000)	-5.939 (0.839)	-8.126** (0.048)	-6.659*** (0.007)
BRICS	0.282 (0.6111)	-1.499* (0.0669)	-0.235 (0.4070)	-1.878** (0.0302)	-3.717*** (0.000)	-10.767* (0.068)	-3.375 (0.445)	-5.159 (0.320)

Notes :,**,*** denote statistical significance at the 10 per cent, 5 per cent and 1 per cent levels, respectively.*

As it is pointed out in Table 2, for higher income OECD countries panel group, Pedroni panel cointegration test statistics are significant at 1 per cent level while three test statistics of Westerlund cointegration analysis are significant at 1 and 5 per cent level. In this view, the panel cointegration between per capita CO_2 emission and real GDP per capita is supported by cointegration analysis for higher income OECD countries panel group. Finally as can be seen in Table 2, Pedroni (two of the test statistics are significant at 5 and 10 per cent level) and Westerlund (two of the test statistics are significant at 1 and 10 per cent level) panel cointegration test results for BRICS countries panel group support the long run relationship between per capita CO_2 emission and real GDP per capita.

4.3. Panel and Individual Country Results

The long run effect of per capita income on per capita CO_2 emission is shown in Table 3 for each panel groups. Beginning with the results for OECD countries panel, 1 per cent increase in per capita income causes a 0,65 per cent increase at per capita CO_2 emission in the short run. However in the long run 1 per cent increase in per capita income reduces per capita CO_2 emissions by around 0,19 per cent. The short and long run income elasticity results for OECD countries panel are statistically significant at 1 per cent level. On the other hand, as it is shown in Table 3, both for upper middle income OECD countries and higher income OECD countries panels, it has found that income increase has a negative and statistically significant effect (-0,19 and -0,17 respectively) on CO_2 emission in the long run. Although long run income elasticity have found smaller than the short run income elasticity in both of the upper middle income OECD countries panel and higher income OECD countries panel coherent with EKC hypothesis.

Table 3. Long and Short-Run Income Elasticity for Panel Groups

Panel Groups	Long run	Short Run	ECT
OECD	-0.1910***	0.6528***	-0.3115***
	(-9.50)	(4.88)	(-6.70)
Upper Middle Income OECD	-0.1939***	0.7888***	-0.2395***
	(-8.02)	(4.91)	(-3.31)
Higher Income OECD	-0.1733***	0.5547***	-0.3661***
	(-5.31)	(2.79)	(-6.04)
BRICS	0.2525***	0.3619	-0.1806*
	(2.68)	(1.08)	(-1.78)

*Notes : t- statistics are given in parenthesis while *,**,*** denote statistical significance at the 10 per cent, 5 per cent and 1 per cent levels, respectively.*

In addition to that, as can be seen from Table 3, for BRICS countries panel, increase in per capita income has a statistically non significant effect on per capita CO_2 emission in the short run. Solely that relationship has found positive and statistically significant in the long run for BRICS countries panel.

Table 4. Long and Short Run Income Elasticity for Individual Countries

Country	Long run		Short run			
	Y		Change Y		ECM	
Upper Middle Income OECD Countries						
Chile	0.9174***	(4.50)	0.1175	(0.18)	-0.4282**	(-2.19)
Czech Republic	-0.2452***	(-2.86)	0.8997***	(3.03)	-0.5913***	(-3.27)
Greece	0.3181***	(2.67)	1.0539***	(2.87)	-0.5312*	(-1.91)
Hungary	-0.2268*	(-1.78)	0.2574	(1.29)	-0.3923*	(-1.89)
Israel	-0.0593	(-0.10)	-0.2104	(-0.30)	-0.2980*	(0.052)
Korea	0.6404***	(4.02)	1.2475***	(4.48)	-0.2056	(-1.50)
Mexico	0.4235***	(4.05)	0.3083	(1.50)	-0.5478**	(-2.24)
New Zealand	-0.5300	(-0.40)	0.7836*	(1.65)	-0.1353	(-0.77)
Poland	-0.1458	(-1.26)	0.0059	(0.02)	-0.3108	(-1.57)
Portugal	0.2385	(0.23)	1.1202*	(1.84)	-0.2158	(-0.99)
Slovak Republic	-0.1933***	(-6.18)	0.5535***	(3.18)	-0.9730***	(-5.45)
Slovenia	0.1793*	(1.78)	0.7212**	(2.53)	-0.4856***	(-2.65)
Spain	-3.7402	(-0.09)	2.2649***	(6.12)	-0.0167	(-0.11)
Turkey	0.9890***	(10.40)	0.3562	(1.47)	-0.4865**	(-2.33)
Higher Income OECD Countries						
Australia	0.0888	(1.22)	0.6833	(1.34)	-0.7023***	(-2.63)
Austria	0.1144	(0.70)	1.0568**	(1.99)	-0.4860**	(-2.46)
Belgium	-0.5456***	(-4.68)	0.6995	(1.32)	-0.6302***	(-3.31)
Canada	-0.7649	(-0.32)	0.5508	(1.46)	-0.0917	(-0.40)

Denmark	-0.9465***	(-4.09)	1.7999*	(1.84)	-0.9160***	(-4.35)
Estonia	0.1068	(1.55)	0.2491	(0.80)	-0.8461***	(-3.54)
Finland	0.1468	(1.26)	0.9909**	(1.98)	-0.9498***	(-4.03)
France	-0.6896***	(-4.05)	0.6566	(0.95)	-0.7192***	(-2.91)
Germany	-0.7203***	(-5.53)	0.6031**	(2.54)	-0.5103***	(-2.62)
Iceland	-0.1827***	(-3.25)	1.5292***	(4.52)	-0.9609***	(4.73)
Ireland	0.0819	(0.32)	0.5979***	(4.78)	-0.1254	(-1.31)
Italy	-0.2565	(-0.09)	1.3962***	(6.30)	-0.0441	(-0.37)
Japan	-0.0704	(-0.19)	1.0106***	(5.08)	-0.2978**	(-2.04)
Luxemburg	0.8374	(0.56)	0.6776	(1.16)	-0.1096	(-0.90)
Netherlands	-0.0983	(-1.61)	0.1186	(0.36)	-0.8668***	(-3.23)
Norway	0.7537***	(7.14)	0.8995***	(3.57)	-0.7835***	(-3.18)
Sweeden	-0.3774***	(-3.62)	0.9347**	(1.97)	-0.8728***	(-3.95)
Switzerland	-0.6510***	(-3.75)	-0.3345***	(-0.60)	-0.8050***	(-3.51)
United Kingdom	-0.4580***	(-2.88)	0.8118***	(2.76)	-0.2987**	(-1.85)
United States	-0.2558**	(-2.26)	0.9852***	(5.96)	-0.1731**	(-2.01)
BRICS Countries						
Brazil	0.8406	(1.57)	0.8978**	(1.99)	-0.1943	(-1.53)
China	0.7362***	(4.94)	1.5062**	(2.23)	-0.2001*	(-1.67)
India	0.7505***	(12.13)	-0.1924	(-0.63)	-0.4060***	(-2.78)
Russian Federation	0.2534**	(2.04)	0.2960*	(1.72)	-0.2748**	(-1.98)
South Africa	0.2693	(1.24)	-0.7868	(-1.26)	-0.5227**	(-2.55)

*Notes : t- statistics are given in parenthesis while *,**,*** denote statistical significance at the 10 per cent, 5 per cent and 1 per cent levels, respectively.*

Table 4 shows the long and short run income elasticity at the same time with one-period lagged error correction term for each of the countries which are in OECD and BRICS countries panel. As mentioned before OECD countries are grouped by an average income per capita of OECD. According to the results of upper middle income OECD countries in Table 4, in the short run, income per capita has a statistically significant and positive impact on per capita CO_2 emission in Czech Republic, Greece, Korea, Slovak Republic and Spain at 1 per cent level, Slovenia at 5 per cent level and New Zealand and Portugal at 10 per cent level. Although in the long run, 1 per cent increase in per capita income reduces per capita CO_2 emission by around 0,24 per cent at Czech Republic, 0,19 per cent at Slovak Republic and 0,22 per cent at Hungary, while income increase raises per capita CO_2 emission in Chile, Greece, Korea, Mexico, Slovenia and Turkey. On the other hand both long and short run income elasticity have found statistically non significant for Israel and Poland in upper middle income OECD countries panel. Additionally all of the other countries error correction term have found statistically significant except Korea, New Zealand, Poland, Portugal and Spain. From this view, the long run relationship between per capita income and per capita CO_2 emission has being supported at countries which have a statistically significant error correction term. Consequently the results that support the EKC hypothesis have found only for Czech Republic, Greece, Slovak Republic and Slovenia in upper middle income OECD countries panel.

According to the results of higher income OECD countries panel in Table 4, error correction term have found statistically significant expect for Canada, Ireland, Italy and Luxemburg. Therefore the long run relationship between per capita income and per capita CO_2 emission for higher income OECD countries has asserted by ECM. On the other hand short run income elasticity of higher income OECD countries have found statistically significant except for Australia, Belgium, Canada, Estonia, France, Luxemburg and Netherland. Additionally, in the long run, 1 per cent increase in per capita income reduces per capita CO_2 emission by around 0,55 per cent in Belgium, 0,95 per cent in Denmark, 0,69 per cent in France, 0,72 per cent in Germany, 0,18 per cent in Iceland, 0,38 per cent in Sweeden, 0,65 per cent in Switzerland, 0,46 per cent in UK at 1 per cent level of significance and 0,26 per cent in USA at 5 per cent level of significance. Although it is found for Norway that income increase has a positive impact on CO_2 emission in the long run. In the sense of EKC hypothesis, if a country's long run income elasticity smaller than the short run income elasticity, then this indicated that income increases leads to less CO_2 emission. In this context the results of Denmark, Germany, Iceland, Norway, Sweeden, Switzerland, UK and USA seem to be consistent with EKC hypothesis.

According to the results of BRICS countries panel in Table 4, in the short run, 1 per cent increase in per capita income causes an increase at per capita CO_2 emission in Brazil and China at 5 per cent level of significance and Russian Federation at 10 per cent level of significance while short run income elasticity have found statistically insignificant in India and South Africa. However in the long run, a positive and statistically significant relationship between per capita income and per capita CO_2 emission have found for each countries in BRICS countries panel. According to EKC hypothesis, as can be shown in Table 4, the long run income elasticity have found smaller than the short run income elasticity in China and Russian Federation.

5. Conclusion

The long term relationship between economic growth and CO_2 emission is frequently discussed in environmental economics literature. In this regard the EKC hypothesis asserts that countries will reduce their CO_2 emissions as their income increases. In this study, the EKC hypothesis has tested by the help of panel data estimation techniques for 34 OECD and 5 BRICS countries. Additionally to avoid the problem of multi-collinearity between the level of income, income squared and income cubed in estimation, with reference to Narayan and Narayan (2010) short and long run income elasticity have used as an alternative way to investigate the EKC hypothesis. Consequently if the long run income elasticity smaller than income elasticity of short run, then this result implies CO_2 emissions will decrease due to the increase in per capita income over time. In other respects OECD countries are not homogeneous when the structural, technological and economic development differences among OECD countries has considered. Concordantly OECD countries have classified as two panel groups due to an average per capita income of OECD general. In this context four panel groups

(OECD, upper middle income OECD, higher income OECD and BRICS) have used to test the EKC hypothesis in this study. On the other hand individual countries estimations were also included to study. According to the individual country findings, the estimated long run income elasticity have found smaller than the short run income eleasticity in Czech Republic, Greece, Slovak Republic, Slovenia, Denmark, Germany, Iceland, Norway, Sweeden, Switzerland, United Kingdom (UK), Unites States of America (USA), China and Russian Federation which are the 36 % of the sample. Additionally inverse relationship between per capita income and per capita CO_2 emission in the long run has found due to the short and long run income elasticities in OECD countries, upper middle income OECD countries and higher income OECD countries panels .

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