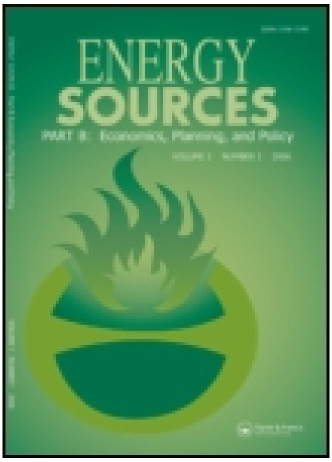

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A Dynamic Analysis of CO_2 Emissions and the GDP Relationship: Empirical Evidence from High-income OECD Countries

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A Dynamic Analysis of CO_2 Emissions and the GDP Relationship: Empirical Evidence from High-income OECD Countries

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A positive relationship between carbon dioxide (CO_2) emissions and gross domestic product (GDP) is shown in this article; examining the per capita income and CO_2 emissions of 20 high-income countries for 1961–2004. It also appears that there is a positive relation from GDP to CO_2 except for Norway. While we found the coefficients for individual countries to be from 0.27–1.73, the panel varies from 0.70–1.03 in terms of time dummies effect. On the other hand, when we examine dynamic ordinary least squares (DOLS) estimates, the results are in the line with fully modified ordinary least squares (FMOLS) estimates. The panel FMOLS test results in average illustrate that a 1% increases in GDP causes a 0.86% rise in CO_2 emission whereas a 1.07% increase is found from DOLS.

1. INTRODUCTION

In recent years, global warming and environmental pollution have been the subjects of a great deal of political controversy. Another debate has been about the income differences between developed countries and others. In this context, the studies on the relationship between various indicators of environmental degradation and income per capita have been increased. Kuznets (1955) investigated the distribution of income increase or decrease in the course of a country's economic growth. Kuznetz (1955*)* illustrated that the shape of the relationship between income per capita and income inequality is an inverted-U. In the beginning of the 1990s, the Kuznetz Curve began to be used in order to analyze the relationship between various indicators of environmental degradation and income per capita (Stern, 2004). Grosman and Krueger (1991) found an inverse U-shaped relationship between per capita income and pollution, while some pollutants rise with income at low income levels, reach a turning point at a higher level and, following income growth, subsequently leads to lower pollution. This new evidence has been called the Environmental Kuznets Curve (EKC) by Panayotou (1993). Many further studies have been attempted to estimate the EKC in the early 1990s by Grossman and Krueger (1991), Panayotou (1993), Selden and Song (1994), and Shafik (1994).

EKC measures a number of different impacts as related to environmental quality. In the literature, it has been argued that economic growth affects the environment in three different channels:

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scale effect, composition effect, and technique effect. The scale effect means an increase in income level will result an increase in pollution and environmental degradation, without the structure and technology of economy change. The traditional view that economic development and environmental quality are conflicting goals reflects the scale effect alone (Stern, 2004). The composition effect isolates the outcomes of sectorial transformations along the development path (Meunie and Pouyanne, 2009). The different sectors in the economy have different pollution and resource use intensities. It is expected that manufacturing in industry tends to be more pollution intensive than agriculture or service sectors. Finally, the technical effect describes the decrease of sector emission intensities environmental degradation as resulting from the use of more efficient productions. Households also demand more environmentally quality products depending on an increase in their income, while the low-income level group of households are less concerned with the environmentality of product.

2. LITERATURE REVIEW

Numerous theoretical and empirical studies have investigated the broad relationship between economic development and environmental quality. This suggestion was tested by Grossman and Krueger (1994), Shafik and Bandyopadahyay (1992), Panayotou (1993), and Selden and Song (1994). They found that pollution levels increase as a country develops, but start to decrease as rising income passes beyond a threshold level. In contradiction of these findings, Hettige et al. (2000) performed a variety of econometric estimations with a parametric functional form for 12 countries' data sets over the period 1989–1995 which were collected from direct observations of industrial water pollution measured by biological oxygen demand at the plant level. Their consequences reject the EKC hypothesis and show that industrial water pollution rises rapidly for middle income and remains unchanged thereafter. Furthermore, on the basis of cross-sectional data for CO_2 emissions by a nonparametric approach to test the environmental efficiency, Taskin and Zaim (2000) calculated environmental efficiency indices for low- and high-income countries between 1975–1990. The connection between the environmental efficiency index and gross domestic product (GDP) per capita exhibited a U shape followed by an inverted U, i.e., the EKC hypothesis holds only for countries with sufficiently high GDP per capita (more than US$5,000). Focacci (2005) examined the EKC hypothesis for three developing countries, namely, Brazil, China, and India, and found that it did not hold for such countries. Paudel et al. (2005) utilized semi-parametric and parametric models to investigate the EKC for three types of water pollution, namely, nitrogen, phosphorus, and dissolved oxygen (DO) and indicated that the EKC for nitrogen was significant, but not for phosphorus or DO. Azomahou et al., (2006) examined the empirical relation between CO_2 emissions per capita and GDP per capita during the period 1960–1996, using a panel of 100 countries. Relying on the nonparametric poolability test of Baltagi et al. (1996), they found the evidence of structural stability of the relationship. They then specified a nonparametric panel data model with country-specific effects. Estimation results demonstrated that this relationship is upward sloping. Using a panel data set for 20 years (1981–2001), Barua and Hubacek (2009) applied both the generalized least square (GLS) and Arellano-Bond generalized method of moments econometric methods. They did not find evidence in support of the EKC hypothesis. Overall, they found that the decline in pollution during the process of economic growth was only temporary, as it tended to rise with further income growth. Population density, livestock population and literacy were found to have strong effects on the water quality of the rivers of India. Aslan and Kula (2009) examined the existence of the Kuznet curve by dynamic panel data analysis for high and middle-low income Organisation for Economic Co-operation and Development (OECD) countries in Europe and Central Asia from 1993–2004. They found that EKC is valid for only those of the OECD countries with high income.

Hence, the present study may be considered as a complementary study to the previous studies about the CO_2-GDP relationship. Different from previous studies, this study not only examines relationships but also examines the power of the relationship between CO_2 and GDP by dynamic ordinary least squares and fully modified ordinary least squares. In addition to relation, a panel causality test is applied to examine the relations between CO_2 and GDP. The causality relationship between CO_2 and GDP has important policy implications. Hence, several studies have attempted to establish the relationship between CO_2 and GDP (See Table 1). A general observation from these studies is that the results have been mixed.

3. PRELIMINARY OVERVIEW OF THE DATA AND RESULTS

Before undertaking the econometric analysis of EKC and the pollution haven hypothesis, the data employed in the applied work is introduced and the main features and preliminary statistical analysis are provided in this section.

The data is obtained from World Development Indicators online database published by World Bank which includes CO_2 emissions (metric tons per capita) GDP per capita (constant 2000 US$). In our data set of high-income OECD countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

4. EMPIRICAL RESULTS

Cointegration analysis developed in the mid-'80s and introduced the idea that even if underlying time series are non-stationary, linear combinations of these series might be stationary. Therefore, before employing panel cointegration techniques, it is essential to verify that all variables are integrated of order one in levels. It is well known that the traditional unit root tests or cointegration tests method (e.g., augmented Dickey-Fuller test (ADF) or residual-based cointegration tests) involves the low power problem for non-stationary data. The primary motivation for panel data unit root tests as proposed to traditional unit root tests is to take advantage of the additional information provided by pooled cross-section time series to increase test power. Thus, one of the most widely used unit root tests, which is called Im, Pesaran, and Shin (IPS) (Im at al., 2003) and Levin, Lin, and Chu test (Levin et al., 2002), is used in this study. In the first step, panel unit root tests are applied. The panel unit root tests of all variables for three groups are tested both in levels and in first differences in Table 2. It can be inferred from the Table 2 that the unit root hypothesis cannot be rejected when the variables are taken in levels. However, when the first differences are used, the hypothesis of unit root non-stationary is rejected at the 1% level of significance. These results enable us to test the cointegration among variables in I(1) level.

A relationship between energy consumption and economic growth (GDP) is researched by employing the cointegration framework introduced by Pedroni (1999) in the second step of estimation. It allows the investigation of heterogeneous panels, in which heterogeneous slope coefficients, fixed effects and individual specific deterministic trends are permitted. This framework provides cointegration tests for both heterogeneous and homogenous panels with seven regressors based on seven residual-based statistics.

Of the seven tests, the panel v-statistic is a one-sided test where large positive values reject the null hypothesis of no cointegration, whereas large negative values for the remaining test statistics reject the null hypothesis of no cointegration. Table 3 reports both the within- and between-dimension panel cointegration test statistics. With the exception of the panel v-test, the other six test statistics reject the null hypothesis of no cointegration at the 1% significance level. Having established cointegration in the long run by Pedroni (1999) in Table 3, we examine the direction of causality between GDP and CO_2.

TABLE 1
Summary of Empirical Studies of the CO_2-GDP Nexus

Author(s)	*Data/Period/Sample/ Source/Variable*	*Methodology*	*Results*
Grossman and Krueger (1991)	1977, 1982, and 1988, annual frequency, SO_2, suspended particles matters (SPM), dark matter (smoke), 42 countries for SO_2, 19 countries for dark matter, 29 countries for suspended particles. Site dummy, population density, time trend, trade intensity, communist country dummy. Source, Global Environment Monitoring System (GEMS).	Panel data analysis, random effects, level, cubic specification.	EKC hypothesis confirmed only for SPM. SO_2 and dark matter follow an N-shaped pattern. Turning points for SO_2 \$4,500 and \$15,000 approximately, for dark matter \$5,000 and \$10,000 approximately and for SPM around \$9,000 (1985 USD).
Panayotou (1993)	30 countries, 1982–1994. Inverted U. \$3,137 (1990 USD, nominal exchange rate) Population density. Source, GEMS.	Ordinary Least Squares (OLS)	First paper coined the pollution-income relationship by EKC.
Selden and Song (1994)	1973–1975, 1979–1981, 1982–1984, sample of developed and developing countries, annual frequency, SO_2, NOx (oxides of nitrogen), SPM, CO_2, GDP, population density.	Panel data analysis, cross section, fixed and random effects, quadratic specification.	EKC hypothesis is confirmed. Turning points for SPM and SO_2 range between \$8,000–\$10,300, for NOx between \$11,200–\$21,800 and for CO_2, between \$5,900–\$19,100.
Selden and Song (1995)	1951–1986, 130 countries, annual frequency, CO_2, GDP, population density and period fixed effect. Inverted U curve.	Panel data analysis, pooling, fixed and country-specific effects, quadratic and cubic specifications in levels and logs.	EKC hypothesis confirmed for level with turning point at \$35,428. For logs EKC not confirmed, the turning point is very high (approximately at \$8,000,000). Although find EKC, the authors believe the total emission will not decrease in very long term, as most of the population are living in the relatively poor countries
Shafik (1994)	1961–1986, 149 countries, annual frequency. Concentration: \$8,000 (1990 USD Purchasing Power Parity (PPP)) Inverted U. Emission: increasing SPM, SO_2, relationship lack of clean water, lack of urban sanitation, dissolved oxygen, carbon emissions, municipal waste, deforestation, GDP. Time trend, site dummy. Source, World Bank.	Panel data analysis based on OLS estimates, linear, quadratic and cubic specifications in logs.	Concentration indicators more easily show inverted U curve with income growth. EKC hypothesis confirmed only for SO_2 and SPM. Turning points for SPM and SO_2 are \$3,280 and \$ 3,670 respectively.

(*continued*)

TABLE 1
(*Continued*)

Author(s)	*Data/Period/Sample/ Source/Variable*	*Methodology*	*Results*
Grossman and Krueger (1994)	Numerous cities in 30 countries in 1977, 1982, 1988, 1979–1990, annual frequency, urban pollution, state of the SO_2, SPM, oxygen regime in river basins, fecal contamination of river basins and contamination of river basins by heavy metals, population density, site dummy, time trend. Turning point, peak: $4,053, trough: $14,000.Source, GEMS.	Panel data analysis, random effects, cubic specification.	EKC hypothesis is confirmed for the majority of indicators. The turning points vary but in most cases they come before a country reaches a per capita income of $8,000.
Tucker (1995)	1971–1991, 137 countries, annual frequency, CO_2, GDP.	Panel data analysis.	EKC is confirmed for the majority of countries.
Shukla and Parikh (1996)	City-level cross-country data. Monotonically negative relationship. City population, squared city population. Source, World Resources Institute.	Level, square.	The inverted U relationship is found between city population and pollution.
Moomaw and Unruh (1997)	1950–1992, 16 OECD countries, annual frequency, GDP, CO_2.	Panel data analysis, fixed effects, cross section effects and country specific regression model, structural transition model.	EKC hypothesis confirmed but with inverted -V shape. Turning points for each country vary between $8,884–$15,425.
Panayotou (1997)	30 developing and developed countries, 1982–1994. Growth rate, population density, quality of institution, scale effect, composition effect, time trend. Inverted U before and U curve after structural determinants included. Source, GEMS.	Unbalanced panel of cross-section panel data (fixed and random effect).	Inclusion of the structural determinants can change the form of EKC. Article offers more policy implication to EKC hypothesis.
Carson et al. (1997)	US, 1990. Population density, percentage of urban population. Monotonically decreasing relationship.	OLS for cross-country data.	It is more interesting to see percentage change instead of absolute change of emission in EKC studies as different initial pollution situations induce difficulties of different levels in pollution reduction.

Cole et al. (1997)	11 OECD countries in 1970–1992. Annual frequency, NO_2, SPM, CO, SO_2, CO_2 methane, municipal waste, CFCs and GDP, total energy use, trade intensity, time trend. Inverted U curve. Source, OECD.	generalized least square, random effect Cross-country panel data analysis, quadratic specification in levels and logs.	EKC exist only for local air pollutants whilst indicators with a more global or indirect impact either increase monotonically with income or else have predicted turning points at high per capita income levels. Including other factors has little impact on EKC form.
de Bruyn et al. (1998)	1961–1993, Netherlands, UK, USA, Western Germany, annual frequency, SO_2, CO_2,NOx, GDP, energy price index.	Estimation of a dynamic OLS model.	Economic growth has a direct positive effect on the levels of emissions.
Torras and Boyce (1998)	1977–1991, annual frequency, SO_2, smoke, heavy particles, dissolved O_2, fecal coliform access to sanitation, GDP, population density, etc.	Panel data analysis.	Mixed.
Dijkgraaf and Vollebergh (2001)	24 OECD countries between 1960–1997. CO_2, per capita GDP, population energy consumption.	Panel Data: fixed effect.	The findings suggest that panel-based estimations of the inverted-U hypothesis for CO_2 are inconsistent. The results challenge the existence of an overall EKC for carbon dioxide emissions.
Roca et al. (2001)	1972–1996 for CO_2 and 1980–1996 for SO_2, CH_4, N_2O, NOx, NMVOC (non-methanic volatile organic compounds) Spain, annual frequency.	Time series model, OLS estimation, cubic specification.	EKC hypothesis confirmed only for SO_2.
Friedl and Getzner (2003)	1960–1999, Austria, annual frequency, CO_2, GDP, imports, share of the tertiary (service) sector.	Time series model, cointegration test, structural model, linear, quadratic and cubic specifications.	EKC hypothesis not confirmed. N-shaped relationship between GDP and CO_2 is found to fit the data most appropriately.
Martinez-Zarzoso and Bengochea-Morancho (2004)	1975–1998, annual frequency, 22 OECD countries, CO_2, GDP from International Energy Agency.	Panel data analysis, pooled mean group estimation, Autoregressive Distributed Lag cointegration approach, cubic specification	EKC hypothesis is not confirmed. For the majorityof countries N-shaped curve is found.
Lantz and Feng (2006)	1970–2000, Canada (five regions), annual frequency, CO_2, GDP, population, technological change.	Panel data analysis, pooled and fixed effects, quadratic specification.	Inverted-U shaped relationship exists with population and technology as explanatory variables. EKC not confirmed when only GDP and CO_2 as explanatory variable.

(*continued*)

TABLE 1
(*Continued*)

Author(s)	*Data/Period/Sample/ Source/Variable*	*Methodology*	*Results*
Galeotti et al. (2006)	1960–1997 for OECD countries and 1971–1997 for non-OECD countries. Variables are populations, CO_2, and GDP.	Robustness, reduced-form regressions. Second-order or at most third-order polynomial functions for the linear or log-linear models.	The econometric results lead to two conclusions. Firstly, published evidence on the EKC does not appear to depend upon the source of the data, at least as far as carbon dioxide is concerned. Secondly, when an alternative functional form is employed, there is evidence of an inverted-U pattern for the group of OECD countries, with reasonable turning point, regardless of the data set employed. Not so for non-OECD countries as the EKC is basically increasing (slowly concave) according to the IEA data and more bell-shaped in the case of Carbon Dioxide Information Analysis Center data.
Aslanidis and Xepapadeas (2006)	1929–1994, USA (48 states), SO_2, NOx, GDP.	Panel data analysis, static smooth transition regression model (STR).	EKC hypothesis is confirmed for SO_2 only. There is a robust smooth inverse-V shaped pollution income path for SO_2.
Barquín (2006)	OECD and non-OECD countries in 1973 and 2000. Electricity, petroleum, SO_2, CO_2, per GDP.	Time series model and “Income Turning Point” (ITP) calculation.	The conclusion is that, if it is possible to prove the existence of environmental Kuznets curve models, their utility as instruments of economic policy is debatable.
Soytas et al. (2007)	1960–2004, USA, annual frequency, energy, labor, gross fixed capital formation	Time series model, Granger causality (Toda and Yamamoto procedure).	Income does not cause CO_2. Economic growth may not become a solution to problem as suggested by the EKC hypothesis.
Cialani (2007)	1861–2002, Italy, annual frequency, CO_2, GDP.	Time series model, OLS estimation and index decomposition analysis, linear, quadratic and cubic specifications in logs.	Results do not support the EKC hypothesis. The development pathway has not yet reached the turning point.
Ang (2008)	1960–2000, France, annual frequency, CO_2, GDP, commercial energy use.	Time series model, ARDL cointegration approach, Granger causality, quadratic specification.	There is support in favor of the EKC hypothesis. Unidirectional causality running from GDP growth to growth of pollutant emissions in the long run.

Halicioglu (2008)	1960–2005, Turkey, annual frequency, CO–, GDP, trade openness, energy consumption.	Time series model, ARDL cointegration approach, stability tests, Granger causality, quadratic specification.	The empirical results suggest that income is the most significant variable in explaining the carbon emissions in Turkey, which is followed by energy consumption and foreign trade. Moreover, there exists a stable carbon emissions function. The results also provide important policy recommendations. There is some support of the EKC hypothesis. Bidirectional short and long-run causality between CO_2 and GDP.
Annicchiarico et al. (2009)	1861–2003, Italy, annual frequency, CO_2, GDP.	Time series model, Engel-Granger cointegration test, rolling regression and error correction modeling technique, GLS, log quadratic specification.	EKC hypothesis confirmed for total sample with turning points at approximately $39,000. EKC for sub-period 1861–1959 is rejected and for the subsample 1960–2003 is accepted with turning points at approximately, $20,000.
Akbostanci et al. (2009)	1968–2003 and 1992–2001, Turkey, 58 provinces, annual frequency, SO_2, CO_2, PM10, GDP, population density.	Time series model and panel data analysis, Johansen cointegration test, cubic specification.	EKC hypothesis is not confirmed neither for time series model nor panel data model.
Atıcı (2009)	Central and Eastern European countries (Bulgaria, Hungary, Romania, and Turkey) in 1980–2002. per capita GDP, per capita energy use and trade openness index (ratio of goods traded/GDP), per capita CO_2 emission.	Panel data: fixed effect model and random effect model .	The results show that the per capita emissions are consistent with EKC in the region. However, energy use per capita has a significant deteriorating impact on the emission levels, indicating that the increasing energy demand is met by polluting technologies rather than cleaner ones. Therefore, environmentally friendly technologies should be used to meet the increasing energy demand in the region. Another implication is that an awareness of the environment and a willingness to protect the quality of the environment begins at the turning point of real GDP per capita of $2,077–$3,156.

(*continued*)

TABLE 1
(*Continued*)

Author(s)	*Data/Period/Sample/ Source/Variable*	*Methodology*	*Results*
Galeotti et. al. (2009)	24 OECD countries over the period 1960–2002. Per capita emissions or concentrations CO_2 and per capita GDP (in billions of PPP 1995 US dollars).	Fractional integration and System cointegration tests.	The results show that the existence of a unit root in the log of per capita CO_2 and GDP series, in addition to the absence of a unit root in the linear combination among these variables, are prerequisites in order for the notion of EKC to be statistically and economically meaningful. However, tests of these hypotheses need not be confined to the limiting set of integer numbers for the order of integration of the series involved. Nonetheless, our empirical analysis has pointed out that the EKC still remains a very fragile concept.

TABLE 2
IPS Panel Unit Root Test Results

	Variables	*Without trend* (Level)	*With trend* (Level)	*Without trend* (First Difference)	*With trend* (First Difference)
Levin, Lin, and Chu*	GDP	−8.55555*	−3.61827*	−14.0606*	−12.3945*
	CO2	−7.67144*	−3.89385*	−13.0780*	−11.2699*
Im, Pesaran, and Shin	GDP	−1.68510	0.44044	−11.5013*	−11.5188*
	CO2	−4.81452*	−1.51651	−12.6068*	−11.3412*

Note: *denotes a 99% confidence level. Optimal lag determination is based on Modified Schwarz Information Criterion.

TABLE 3
The Results of Panel Cointegration Tests

	With trend		*Without trend*	
	Statistics	*Prob*	*Statistics*	*Prob*
Within dimension Test statistics				
Panel v-Statistic	−2.143972	0.9840	2.018093	0.0218
Panel rho-Statistic	−16.79352	0.0000	−22.48522	0.0000
Panel PP-Statistic	−17.76052	0.0000	−16.87681	0.0000
Panel ADF-Statistic	−18.12881	0.0000	−17.03854	0.0000
Between dimension Test statistics				
Group rho-Statistic	−13.81788	0.0000	−19.27522	0.0000
Group PP-Statistic	−19.42773	0.0000	−19.05922	0.0000
Group ADF-Statistic	−19.50496	0.0000	−18.90442	0.0000

Engle and Granger (1987) illustrate that if two non-stationary variables are cointegrated, a vector autoregression in first differences will be misspecified. Having a long-run equilibrium relationship between GDP and CO_2, when testing for Granger causality we specify a model with a dynamic error correction representation. This implies that the traditiona model is augmented with a one-period lagged error correction term that is achieved from the cointegrated model based on OLS. The Granger causality test is derived from the following regressions:

$$\Delta \ln GDP_{it} = \varphi_{1i} + \sum_{p} \varphi_{11ip} \Delta \ln GDP_{it-p} + \sum_{p} \varphi_{12ip} \Delta \ln CO2_{it-p} + \Psi_{1i} ECT_{t-1} \tag{1}$$

$$\Delta \ln CO2_{it} = \varphi_{2i} + \sum_{p} \varphi_{21ip} \Delta \ln CO2_{it-p} + \sum_{p} \varphi_{22ip} \Delta \ln GDP_{it-p} + \Psi_{2i} ECT_{t-1} \tag{2}$$

Eqs. (1) and (2) are estimated using the pooled mean group estimator proposed by Pesaran et al. (1999). Short-run causality is tested based on $H_0 = \varphi_{12ip} = 0$ and $H_0 = \varphi_{22ip} = 0$ for all i and k and the null hypothesis for long-run causality is $\psi_{ji} = 0$, where $j = 1{,}2$.

The panel Granger causality test results are reported in Table 4. According to causality test results, although there is a long- and short-run relation from GDP to CO_2, there is no relation from CO_2 to GDP. Our models are based on the regression such as suggested in Pedroni (2001):

$$y_{it} = \alpha_i + \beta_i C02_{it} + \mu_{it} \qquad i = 1, 2, ., N \quad t = 1, 2, ., T \tag{3}$$

TABLE 4
Panel Granger Test Results

Source of Causation	*Δln GDP*	*Δln CO2*	*ECM_{t-1}*
Δln GDP	—	0.094* (0.042)	0.061* (0.027)
Δln CO2	0.19 (0.263)	—	0.042 (0.409)

Note: Standard errors are in parentheses and * denotes statistical significance at 5% level.

where y_{it} is the log GDP per capita, $CO2_{it}$ is the log CO_2 emissions and y_{it} and $CO2_{it}$ are cointegrated with slopes βi, which may or may not be homogeneous across i.

$$y_{it} = \alpha_i + \beta_i CO2_{it} + \sum_{k=-Ki}^{Ki} \gamma_{ik} \Delta CO2_{it-k} + u_{it} \qquad i = 1, 2, ., N \quad t = 1, 2, ., T \tag{4}$$

The individual and panel test results are presented in Table 5. According to FMOLS test results, there is a positive relation from GDP to CO_2 except for Norway. While we found the coefficients for individual countries from 0.27 to 1.73, the panel varies from 0.70 to 1.03 in terms of time dummies effect. The most powerful relation between GDP and CO_2 is found for Italy which is 1.73.

TABLE 5
FMOLS and DOLS Estimates

Country	*FMOLS*	*t-stat*	*DOLS*	*t-stat*
Australia	0.27	1.02	0.29	0.64
Austria	1.29	3.53**	1.63	3.30**
Belgium	1.30	3.22**	1.35	2.26*
Canada	0.74	2.62**	1.02	2.22*
Denmark	1.57	2.74**	2.59	2.43*
Finland	0.44	0.89	0.32	0.44
France	1.68	4.57**	1.80	3.65**
Greece	1.11	5.49**	1.17	4.40**
Iceland	0.68	2.81**	1.05	2.52*
Ireland	0.34	1.33	0.64	1.85*
Italy	1.73	6.59**	1.69	4.87**
Japan	1.22	9.15**	1.31	8.36**
Korean Rep.	0.93	3.77**	1.16	2.87**
Luxembourg	1.42	4.32**	1.81	3.49**
Netherlands	1.68	3.71**	1.89	2.89**
Norway	−0.12	−0.14	0.50	0.35
Portugal	0.78	4.12**	0.99	3.77**
Spain	1.12	3.65**	1.30	3.56**
Sweden	1.40	2.60**	1.86	2.36*
Switzerland	1.28	3.47**	1.60	3.45**
United Kingdom	0.77	2.95**	0.85	1.69*
United States	1.07	6.03**	1.16	3.11**
PANEL RESULTS				
Without time dummies	1.03	16.73**	1.27	13.75**
With time dummies	0.70	9.70**	0.87	7.70**

Note: * and ** indicate 10% and 1% statistical significance levels, respectively.

In addition, the weakest significant relation is found for Australia, which is 0.27. On the other hand, when we examine DOLS estimates, the results are in the line with FMOLS estimates. However, the most powerful relation between GDP and CO_2 is found for the Netherlands (1.68) and the weakest significant relation is found for Ireland (0.64). The panel FMOLS test results in average illustrate that 1% increases in GDP causes a 0.86% rise in CO_2 emission whereas a 1.07% increase is found from DOLS.

5. CONCLUSION

EKC examines the links changes in environmental quality have to national economic growth. We compare EKC models to high-income OECD countries of per capita CO_2 emissions and per capita GDP, and find that while there is a long- and short-run relation from GDP to CO_2, there is no relation from CO_2 to GDP. According to FMOLS test results, there is a positive relation from GDP to CO_2 except for Norway. While we found the coefficients for individual countries to be from 0.27–1.73, the panel varies from 0.70–1.03 in terms of time dummies effect. On the other hand, when we examine DOLS estimates, the results are in the line with FMOLS estimates.

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