JEL Classification: Q50, Q53, Q56
Keywords: Environmental Kuznets Curve, pollution, education, European Union countries

Does Education Affect Environmental Pollution? An Empirical Analysis of the Environmental Kuznets Curve

Çiğdem Börke TUNALI - Department of Economics, Faculty of Economics, Istanbul University, Turkey (cbtunali@istanbul.edu.tr)

Abstract

Environmental Kuznets Curve hypothesizes that there is an inverted U-shaped relationship between environmental degradation and economic development. Since 1990s, many researchers have empirically analysed the Environmental Kuznets Curve hypothesis. In recent years, although researchers consider additional variables while investigating the validity of this hypothesis the number of studies which take into account education is limited. This study aims to empirically analyse the Environmental Kuznets Curve hypothesis augmented with education in 21 European Union countries over the period 1991-2018. According to the results of the empirical estimations, the Environmental Kuznets Curve hypothesis augmented with tertiary school enrolment holds for the 21 European Union countries under investigation in the long-run.

1. Introduction

Climate change has devastating effects on humanity. According to the recent estimates of World Health Organization, climate change is expected to lead to almost 250000 additional deaths per year between the period 2030-2050 and the direct damage costs to health will be between USD 2-4 billion/year by 2030 (World Health Organization, 2021). On 17th of September 2020, the European Commission proposed to cut greenhouse gas emissions by at least 55% by 2030 (European Commission, 2020, 2021). The main objectives of this proposal are to set a more cost-effective and ambitious path to achieve climate neutrality by 2050, to encourage the creation of green jobs and to maintain the European Union's track record of decreasing greenhouse gas emissions while growing its economy and to encourage international partners to increase their ambition to restrict the rise in global temperature to 1.5 ^{0}C and to prevent the most acute results of climate change (European Commission, 2020, 2021). As it is clearly seen, climate change has become a significant issue that is intensively debated recently. Hence, determining which factors affect the greenhouse gas emissions and measuring the magnitude of the effects are crucial in order to design and implement appropriate policies which aim to achieve the climate targets of the European Union.

In the existing literature, the effect of economic growth on environment has been intensively discussed both by researchers and policy makers since the beginning of 1990s. The main argument of all studies is that in the early stages of development

https://doi.org/10.32065/CJEF.2022.01.02

The author would like to thank the editor and two anonymous referees for their valuable comments and suggestions.

economic growth leads to environmental degradation however, after a certain point economic growth results in environmental improvement (Dinda, 2004). This relationship between economic growth and environmental quality is called the Environmental Kuznets Curve (EKC) since a similar relationship between economic development and income inequality was put forward by Kuznets (1955).

Since the seminal work of Grossman and Krueger (1991) a great number of studies have investigated the relationship between economic growth and environmental deterioration empirically. However, existing evidence with regard to the validity of the EKC hypothesis is mixed and inconclusive (Williamson, 2017). According to Hill and Magnani (2002), the results of the empirical studies are susceptible to a number of factors such as the choice of the variables, countries and the time period and they suggest that one of the important omitted variables in the existing literature is education. Although a small number of studies have taken into account education in the last two decades these studies do not provide coherent evidence with regard to the effect of education on environmental quality (Balaguer and Cantavella, 2018). The aim of this study is to empirically investigate the validity of the EKC hypothesis augmented with education in 21 European Union countries over the period 1991-2018. In the empirical analysis, both secondary school enrolment ratio and tertiary school enrolment ratio are used as education variables and carbon dioxide emission is employed as an environmental pollution indicator in the baseline model. In addition to this, as a robustness check, the models are also estimated by representing environmental pollution with nitrous oxide emission. In the European Union, carbon dioxide emissions from the burning of fossil fuels are the biggest source of greenhouse gas emissions and nitrous oxide emissions together with methane and the so-called F gases stand for almost 20% of the European Union's greenhouse gas emissions (European Commission, 2020). Hence, by taking into account two different environmental pollution and education variables this study fills a significant gap in the existing literature with regard to the effect of economic growth and education on environment. The results of this study help policy makers to design appropriate policies in order to achieve the climate targets of the European Union.

The structure of the paper is as follows: section 2 presents the literature review; section 3 explains the methodology and the data; section 4 discusses the results of the main empirical analysis, section 5 explains the results of robustness checks analysis and finally, section 6 concludes.

2. Literature Review

Simon Kuznets (1955) hypothesized that as income per capita rises income inequality increases at first and then, it starts to decrease after a turning point. Hence, the original Kuznets curve indicates an inverted-U shaped relationship between income per capita and income inequality (Kuznets, 1955). The term Environmental Kuznets Curve (EKC) was first used by Panayotou (1993). In his study, Panayotou (1993) puts forward that there is a Kuznets type inverted U-shaped relationship between environmental deterioration and economic development. According to the EKC hypothesis, at early stages of development an increase in income leads to a rise in environmental degradation; however, as income level passes a certain threshold environmental degradation starts to decline (Panayotou, 1993; Ketenci, 2018).

Since the beginning of 1990s the studies that empirically examine the EKC hypothesis by using various pollutants has exploded (Panayotou, 2003). Earlier studies generally find evidence supporting the EKC hypothesis (Grossman and Krueger, 1991, 1995; Shafik and Bandyopadhyay,1992; World Bank, 1992; Panayotou, 1993). However, there is still no consensus with regard to the existence or shape of the EKC and depending on the choice of the explanatory variables, methodologies, countries and the time frame researchers find mixed results (Shahbaz and Sinha, 2019). Here, a summary of the recent studies that empirically examine the EKC hypothesis is presented.[2]

He and Richard (2010) assess the existence of the EKC hypothesis in Canada by using time-series data between 1948 and 2004. In the empirical analysis, the authors draw on semiparametric and flexible nonlinear parametric modelling in order to obtain more robust results (He and Richard, 2010). The empirical findings provide little evidence in support of the EKC hypothesis (He and Richard, 2010). Iwata, Okada and Samreth (2010) analyse the EKC hypothesis in France by considering nuclear energy in electricity production over the period 1960-2003. Iwata, Okada and Samreth (2010) draw on Autoregressive Distributed Lag (ARDL) approach to cointegration and find evidence in favour of the EKC hypothesis. Fodha and Zaghdoud (2010) examine the validity of the EKC hypothesis in Tunisia over the period 1961-2004. By using cointegration analysis, Fodha and Zaghoud (2010) find that while there is an inverted-U shaped relationship between sulphur dioxide emissions and GDP the relationship between carbon dioxide emissions and GDP is monotonically increasing.

Park and Lee (2011) investigate the relationship between economic development and air pollution in the Republic of Korea. In their study, Park and Lee (2011) use annual panel data for 16 metropolitan regions over the period 1990-2005. According to the empirical results, Park and Lee (2011) suggest that each region has different EKC and coefficients are heterogenous along with the regions. Nasir and Rehman (2011) examine the relationship between carbon emissions and income in Pakistan by taking into account energy consumption and foreign trade during the period 1972-2008. In the empirical analysis, Nasir and Rehman (2011) use Johansen cointegration (vector error correction) model and find the existence of the EKC between carbon emissions and income in the long-run. Saboori, Sulaiman and Mohd (2012) analyse the EKC hypothesis for Malaysia over the period 1980-2009. The authors use ARDL cointegration model and find an inverted-U shaped relationship between carbon dioxide emissions and GDP in both the short-run and the long-run (Saboori, Sulaiman and Mohd, 2012).

Onafowora and Owoye (2014) investigate the relationship between economic growth, energy consumption, population density, trade openness and carbon dioxide emissions in Brazil, China, Egypt, Japan, Mexico, Nigeria, South Korea and South Africa depending on the EKC hypothesis. In the empirical analysis, ARDL cointegration model is employed and it is found that while there is an inverted-U shaped EKC in Japan and South Korea the relationship between economic growth and carbon dioxide emissions is N-shaped in the other six countries (Onafowora and

[2] For an extensive literature review see Dinda (2004), Kijima, Nishide and Ohyama (2010) and Shahbaz and Sinha (2019).

Owoye, 2014). Apergis and Ozturk (2015) test whether the EKC hypothesis holds for 14 Asian countries over the period 1990-2011. Apergis and Ozturk (2015) employ Generalized Method of Moments (GMM) methodology and take into account population density, land, industry shares in GDP and four indicators that measure the quality of institutions together with carbon dioxide emissions and GDP per capita. According to the results of the empirical analysis, Apergis and Ozturk (2015) suggest that the EKC hypothesis holds in countries under investigation. Al-Mulali, Saboori and Ozturk (2015) examine the EKC hypothesis in Vietnam between 1981 and 2011. In the empirical analysis, Al-Mulali, Saboori and Ozturk (2015) apply ARDL approach to cointegration and find that the EKC hypothesis does not hold since there is a positive relationship between GDP and pollution in both the short-run and the long-run.

Li, Wang and Zhao (2016) investigate the effect of economic development, energy consumption, trade openness and urbanization on carbon dioxide, waste water and waste solid emissions by using GMM estimator and ARDL methodology to cointegration in China. In the empirical analysis, Li, Wang and Zhao (2016) employ a dataset which covers 28 provinces of China during the period 1996-2012. According to the empirical results, Li, Wang and Zhao (2016) argue that the EKC hypothesis holds for all three major pollutant emissions in China. Al-Mulali and Ozturk (2016) examine the impact of energy prices on pollution and the validity of the EKC hypothesis in 27 advanced economies over the period 1990-2012. Al-Mulali and Ozturk (2016) use panel cointegration, fully modified ordinary least squares and vector error correction Granger causality techniques in the empirical analysis and find that the relationship between GDP and carbon dioxide emissions is inverted-U shaped. Hence, the results of the empirical analysis provide evidence in favour of the EKC hypothesis (Al-Mulali and Ozturk, 2016). Lin et al. (2016) analyse the EKC hypothesis and the determinants of carbon dioxide emissions in five African countries during the period 1980-2011. In the empirical analysis, Lin et al. (2016) apply panel cointegration and fully modified ordinary least squares techniques. According to the results of the empirical analysis, the determinants of carbon dioxide emissions are energy structure and energy intensity and the EKC hypothesis does not hold for the five African countries under investigation (Lin et al., 2016).

Atasoy (2017) examines the existence of the EKC hypothesis in 50 US States by using Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG) estimators over the period 1960-2010. The results of the empirical analysis are mixed and while AMG estimator confirms the validity of the EKC hypothesis CCEMG estimator gives weak evidence in support of the EKC hypothesis (Atasoy, 2017). Apergis, Christou and Gupta (2017) investigate whether the EKC hypothesis holds in 48 US States during the period 1960-2010. Similar to Atasoy's (2017) study, Apergis, Christou and Gupta (2017) employ CCEMG estimator and find that the EKC hypothesis is valid in only 10 US States. Shahbaz et al. (2017) analyse the EKC hypothesis for G-7 countries over the period 1820-2015. In the empirical analysis, Shahbaz et al. (2017) use nonparametric econometric techniques and suggest that the EKC hypothesis holds in Canada, France, Germany, Italy, the UK and the US but not in Japan. Pablo-Romero, Cruz and Barata (2017) tests the EKC hypothesis for 27 European Union countries during the period 1995-2009. Pablo-Romero, Cruz and Barata (2017) draw on total transport energy use, household transport energy use, productive transport energy use and estimate transport energy-EKC in the empirical analysis. According to the empirical results, Pablo-Romero, Cruz and Barata (2017) put forward that the EKC hypothesis holds in 27 European Union countries over the period under investigation. However, the results indicate that the turning point is not reached in any case (Pablo-Romero, Cruz and Barata, 2017). Williamson (2017) analyses the validity of the EKC hypothesis in 181 countries in 2012. In the empirical analysis, Williamson (2017) uses a number of control variables and estimate the regressions both for emissions of carbon dioxide and methane. According to the empirical results, Williamson (2017) suggests that mean years of education and government regime are the most significant variables together with the GDP per capita.

Sarkodie and Strezov (2018) investigate the EKC and Environmental Sustainability curve hypotheses in Australia, China, Ghana and the USA by using a dataset covering the period between 1971-2013. Sarkodie and Strezov (2018) apply Pooled Mean Group (PMG)/ARDL panel regression estimator, U-test regression, a bivariate model and panel non-causality test and find that while the EKC hypothesis holds in Australia and China there is a monotone and inverted-N relationship between carbon dioxide emissions and income levels in Ghana and the USA respectively. Churchill et al. (2018) examine the EKC hypothesis in a panel of OECD countries over the period 1870-2014. In the empirical analysis, Churchill et al. (2018) use panel data estimators that take into account cross-sectional dependence and parameter heterogeneity and suggest that the EKC hypothesis is valid for the panel as a whole. However, according to country specific results, the EKC hypothesis holds for 9 of the 20 countries (Churchill et al., 2018). Balaguer and Cantavella (2018) analyse an extension of the EKC hypothesis by taking into account education in Australia. Balaguer and Cantavella (2018) argue that education has two opposing effects on environment. Whilst the first effect emerges when education expands and hence, this increases the use of non-renewable energy sources and polluting emissions the second effect arises when education leads to social awareness with regard to environment and this improves environmental quality (Balaguer and Cantavella, 2018). In the empirical analysis, Balaguer and Cantavella (2018) apply ARDL cointegration model for the period between 1950-2014 and find that there is an inverted-U shaped relationship between education and carbon dioxide emission. These results indicate that education plays a significant role with regard to the EKC hypothesis (Balaguer and Cantavella, 2018). Similar to Balaguer and Cantavella's (2018) study, Umaroh (2019) investigate the effect of education on energy use in Indonesia by employing the EKC hypothesis over the period 1972-2016. In the empirical analysis, Umaroh (2019) use ARDL methodology to cointegration and put forward that the EKC hypothesis holds and there is an inverted-U shaped relationship between education and carbon dioxide emission in Indonesia.

Boubellouta and Kusch-Brandt (2020) examine the EKC hypothesis for a panel of 30 European countries (28 European Union countries+2) by using e-waste between the period 2000 and 2016. In the empirical analysis, Boubellouta and Kusch-Brandt (2020) use the GMM estimator as the main method and employ 2SLS estimator and cross-section method for robustness checks. The results of the empirical analysis show that the EKC hypothesis holds for e-waste in the 28 European Union countries and two areas (Boubellouta and Kusch-Brandt, 2020).

Kacprzyk and Kuchta (2020) investigate the EKC hypothesis for a panel of 161 countries over the period 1992-2012. In the empirical analysis, Kacprzyk and Kuchta (2020) employs fixed effect estimator and find that EKC exists for the countries under investigation. In addition to this, the results indicate that the turning point above which carbon dioxide emissions start to decrease is lower than previous studies presents (Kacprzyk and Kuchta, 2020). Ma, Ahmad and Oei (2021) analyse the relationship between real GDP, carbon dioxide emissions, renewable and non-renewable energy consumption, tourism development and labour force in France and Germany over the period 1995-2015 according to data availability. According to the results of the empirical analysis, Ma, Ahmad and Oei (2021) argue that EKC is valid and there is an inverted U-shaped relationship between carbon dioxide emission and real GDP in the long run. Shafiullah, Papavassiliou and Shahbaz (2021) examine the effect of education on carbon dioxide emission and energy consumption in the US by using state level data between the period 1976 and 2015. In the empirical analysis, Shafiullah, Papavassiliou and Shahbaz (2021) apply recent econometric methodologies that take into account the bias which stems from cross-section dependence in panel data. The results of this analysis show that education has a hump-shaped relationship with energy consumption and carbon dioxide emission (Shafiullah, Papavassiliou and Shahbaz, 2021). Boubellouta and Kusch-Brandt (2021) assess the EKC hypothesis in 174 countries for 2016 by using Ordinary Least Squares (OLS) estimator. Boubellouta and Kusch-Brandt (2021) use e-waste as the environmental pollution indicator and find that the EKC hypothesis holds at the world level. Moreover, according to the estimation results, Boubellouta and Kusch-Brandt (2021) put forward that the EKC hypothesis is valid in the sub-samples per continent except Asia.

A number of empirical studies investigate the EKC hypothesis by using meta-analysis. Li, Grijalva and Berrens (2007) examine systematic variation among EKC analyses by employing meta-analysis. In their study, Li, Grijalva and Berrens (2007) use 588 observations and come to the conclusion that the features of the data, methodology, estimation techniques and the selected environmental quality degradation indicator have significant effects on the validity of the EKC hypothesis and on the estimated income turning points. Sarkodie and Strezov (2019) investigate the historical trends on the EKC hypothesis by employing bibliometric and meta-analysis. According to the results of the meta-analysis, Sarkodie and Strezov (2019) put forward that the EKC hypothesis holds and the average turning point of annual income level is USD 8910. Furthermore, Sarkodie and Strezov (2019) suggest that because of the differences in the time period of the analysis and econometric methodologies there is heterogeneity across turning points of income levels. Saqib and Benhmad (2021) analyse the EKC hypothesis by developing an updated meta-analysis framework which is called as Preferred Reporting Items for Meta Regression Analysis (PRIMRA). In this study, Saqib and Benhmad (2021) review 101 papers published between 2006 and 2019 and find that there is a strong evidence that supports the EKC hypothesis in the long-run. Saqib and Benhmad (2021) also state that the choice of econometric techniques or the type of data used do not have any effects on the validity of the EKC hypothesis.

As it is seen from the above explanations, although there is a huge literature with regard to the EKC hypothesis the number of studies which take into account education is very low. Hill and Magnani (2002) state that education is one of the significant omitted variables in the EKC literature. Moreover, while some studies provide evidence that shows the validity of the EKC hypothesis other studies find that the EKC hypothesis does not hold in some countries. Hence, more empirical analyses are needed in order to reach more reliable and robust results. This study fills a significant gap in the existing literature by providing new evidence with regard to the validity of the EKC hypothesis augmented with education in 21 European Union countries.

3. Methodology and Data

In this study, a standard EKC equation augmented with education is estimated for a panel of 21 European Union countries[3] over the period 1991-2018. Similar to Balaguer and Cantavella's (2018) study, it is assumed that there is an inverted U-shaped relationship between education and environmental pollution. The baseline model is stated as follows:

$$lnemission_{it} = \alpha_{1i} lnyp_{it} + \alpha_{2i}(lnyp_{it})^2 + \alpha_{3i} lneducation_{it} + \alpha_{4i}(lneducation_{it})^2 + \phi_i + \varepsilon_{it} \tag{1}$$

$$i = 1, 2, \ldots, N, \qquad t = 1, 2, \ldots, T$$

In the above model, emission is the carbon dioxide emissions in metric tons per capita and yp is the GDP per capita in constant 2010 US Dollars. In order to represent education in the model, secondary school enrolment ratio and tertiary school enrolment ratio are used. Secondary school enrolment ratio is defined as the ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the secondary education (World Bank, 2021) for country i in time t. Similarly, tertiary school enrolment ratio is the ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the tertiary education (World Bank, 2021) for country i in time t. Furthermore, in the above model, ϕ are the country fixed effects and ε is the error term that is supposed to be independent and normally distributed. According to the conventional EKC hypothesis, it is expected that $\alpha_{1i} > 0$ and $\alpha_{2i} < 0$ and the coefficients of the education variables are zero (Balaguer and Cantavella, 2018). If both income and education affect carbon dioxide emissions exclusion of education variables leads to omitted variable bias (Balaguer and Cantavella, 2018). By assuming a positive correlation between income and education it is expected that $\alpha_{3i} > 0$ and $\alpha_{4i} < 0$ (Balaguer and Cantavella, 2018).[4]

For robustness checks, the above model is also estimated by using nitrous oxide emissions in metric tons per capita as an environmental pollution indicator.

Since the dataset does not cover a long period of time, it is imposed that the maximum lag equals to one and the following ARDL (1, 1, 1, 1, 1) equation is estimated (Pesaran, Shin and Smith, 1999):

---

[3] Croatia, Estonia, Luxembourg, Slovakia, Latvia, Lithuania and Slovenia are not included in the model due to missing data over the period under investigation.

[4] Carbon dioxide emission reaches its maximum value on (yp*, se*) where $yp^* = -\alpha_{1i}/2\alpha_{2i}$ and $se^* = -\alpha_{3i}/2\alpha_{4i}$ (Balaguer and Cantavella, 2018).

$$
\begin{aligned}
lnemission_{it} = {} & \beta_i + \gamma_{10i} lnyp_{it} + \gamma_{11i} lnyp_{it-1} + \gamma_{20i}(lnyp_{it})^2 \\
& + \gamma_{21i}(lnyp_{it-1})^2 + \gamma_{30i} lneducation_{it} \\
& + \gamma_{31i} lneducation_{it-1} + \gamma_{40i}(lneducation_{it})^2 \\
& + \gamma_{41i}(lneducation_{it-1})^2 + \sigma_i lnemission_{i,t-1} + \mu_{it}
\end{aligned} \tag{2}
$$

The error correction representation of this model is (Pesaran, Shin and Smith, 1999):

$$
\begin{aligned}
\Delta lnemission_{it} = {} & \varphi_i \big[emission_{i,t-1} - \alpha_{0i} - \alpha_{1i} lnyp_{it} - \alpha_{2i}(lnyp_{it})^2 \\
& - \alpha_{3i} lneducation_{it} - \alpha_{4i}(lneducation_{it})^2 \big] - \gamma_{11i} \Delta lnyp_{it-1} \\
& - \gamma_{21i} \Delta (lnyp_{it-1})^2 - \gamma_{31i} \Delta lneducation_{it-1} \\
& - \gamma_{41i} \Delta (lneducation_{it-1})^2 - \sigma_i lnemission_{i,t-1} + \mu_{it}
\end{aligned} \tag{3}
$$

where:

$$
\alpha_{0i} = \frac{\beta_i}{1-\sigma_i}, \alpha_{1i} = \frac{\gamma_{10i} + \gamma_{11i}}{1-\sigma_i}, \alpha_{2i} = \frac{\gamma_{20i} + \gamma_{21i}}{1-\sigma_i}, \alpha_{3i} = \frac{\gamma_{30i} + \gamma_{31i}}{1-\sigma_i}, \alpha_{4i} = \frac{\gamma_{40i} + \gamma_{41i}}{1-\sigma_i},
$$

$$
\varphi_i = -(1-\sigma_i)
$$

The EKC model stated above can be empirically analysed in a number of ways (Martinez-Zarzoso and Bengochea-Morancho, 2004). The main methods used to estimate this kind of model are static fixed effect (SFE) or dynamic fixed effect (DFE) approaches which impose homogeneity on all slope coefficients and allows only the intercepts to vary across groups (Martinez-Zarzoso and Bengochea-Morancho, 2004; Blackburne and Frank, 2007). However, if the slope coefficients are not identical across countries then, the results obtained from these approaches are inconsistent and possibly delusive (Blackburne and Frank, 2007). Since the trajectory of carbon dioxide emissions and income levels vary country by country it is difficult to hold the assumptions of SFE and DFE approaches (Martinez-Zarzoso and Bengochea-Morancho, 2004). Pesaran and Smith (1995) and Pesaran, Shin and Smith (1997, 1999) develop the Mean Group (MG) and the Pooled Mean Group (PMG) estimators to estimate dynamic heterogenous panels. While the MG estimator allows the intercepts, slope coefficients and error variances to vary across groups (Pesaran and Smith, 1995), PMG estimator restricts the long-run coefficients to be the same and it allows the intercepts, short-run coefficients and error variances to vary across groups (Pesaran, Shin and Smith, 1997, 1999). Hence, it is stated that the PMG estimator is an intermediate estimator between the MG estimator and the DFE estimator (Martinez-Zarzoso and Bengochea-Morancho, 2004). In this study, MG, PMG and DFE estimators are employed and Hausman test (Hausman, 1978) is calculated in order to choose the efficient estimator.

As stated earlier, the dataset used to estimate the EKC model augmented with education covers 21 European Union countries over the period 1991 and 2018. This time period is chosen according to the data availability. The list of the countries under investigation can be seen in the appendix. Since there are some missing values in the secondary school enrolment data of Belgium, Cyprus, Denmark, Greece, Hungary, Ireland, Malta, the Netherlands, Portugal and the United Kingdom and there are some missing values in the tertiary school enrolment data of Austria, Belgium, Cyprus, Denmark, Germany, Greece, the Netherlands and Portugal linear interpolation is used in order to fill in these values. All the variables are used in natural logarithms in the estimations and the whole dataset is obtained from the World Bank-World Development Indicators database (World Bank, 2021). Since nitrous oxide emission per capita data is not directly available this data is calculated by dividing nitrous oxide emission with population. Population data is also obtained from the World Bank-World Development Indicators database (World Bank, 2021). Table 1 shows the descriptive statistics for all variables used in the estimations.

Table 1 Descriptive Statistics

Variables		*Mean*	*Standard Deviation*	*Minimum Value*	*Maximum Value*	*Observations*
Emission (Carbon dioxide)	Overall	7.695764	2.280649	2.964713	13.92722	N = 588
	Between		2.080373	4.435461	11.31989	n = 21
	Within		1.035607	3.993166	12.15899	T = 28
Emission (Nitrous oxide)	Overall	0.6642044	0.4647036	0.0825372	2.984354	N = 588
	Between		0.4537192	0.1321627	2.42348	n = 21
	Within		0.1398472	0.1773697	1.225078	T = 28
GDP per capita	Overall	30736.76	15406.26	3784.078	76415.36	N = 588
	Between		14898.77	5711.55	55924.82	n = 21
	Within		16.09138	9.236692	118.5407	T = 28
Education (Secondary)	Overall	106.8934	17.76763	65.56736	163.9347	N = 588
	Within		15.43416	85.80352	150.3456	n = 21
	Between		9.40385	58.22492	149.3094	T = 28
Education (Tertiary)	Overall	55.38045	20.33787	9.24712	142.852	N = 588
	Between		12.73401	31.81019	82.27251	n = 21
	Within		16.09138	9.236692	118.5407	T = 28

Source: Author's estimations.

4. Results and Discussion

Before estimating the EKC model, Im-Pesaran-Shin (IPS) (Im, Pesaran and Shin, 2003) and Fisher Augmented Dickey Fuller (ADF) (Choi, 2001) unit root tests are employed in order to determine the order of integration of the variables. Although ARDL model can be estimated as long as the variables are I(0) or I(1) (Pesaran and Smith, 1995; Pesaran, Shin and Smith, 1997, 1999) we estimate the unit root tests to ensure that either the variables are stationary at their levels or they are first difference stationary. Table 2 shows the results of IPS and Fisher ADF unit root tests. According to the results of the IPS unit root test, all variables except carbon dioxide emissions, GDP per capita and the square of GDP per capita are stationary at their levels. The results of this test also indicate that carbon dioxide emissions, GDP per capita and the square of GDP per capita become stationary when their first differences are taken. According to the results of the Fisher ADF unit root test, while secondary school enrolment ratio and the square of secondary school enrolment ratio are stationary at their levels carbon dioxide emissions, nitrous oxide emissions, GDP per capita, the square of GDP per capita, tertiary school enrolment ratio and the square of tertiary school enrolment ratio become stationary when their first differences are taken.

Table 2 Unit Root Test Results

	Level		First Difference	
Variables	*Im-Pesaran-Shin (W-t-bar Statistic)*	*Fisher ADF (Inverse Normal Z Statistic)*	*Im-Pesaran-Shin (W-t-bar Statistic)*	*Fisher ADF (Inverse Normal Z Statistic)*
lnemission (carbon dioxide)	0.5033	2.1972	-15.0592***	-11.1474***
lnemission (nitrous oxide)	-3.6127***	-0.1845	---	-13.0330***
lnyp	-0.6693	0.4735	-10.0649***	-9.0195***
(lnyp)^2	-0.7427	0.4928	-10.1457***	-9.0988***
lneducation (secondary)	-4.3301***	-4.5601***	---	---
(lneducation)^2 (secondary)	-4.2383***	-4.4017***	---	---
lneducation (tertiary)	-3.3001***	-1.1619	---	-7.0175***
(lneducation)^2 (tertiary)	-2.0983**	-0.1722	---	-6.4892***

Notes: ** and *** represent 5% and 1% significance levels respectively. H_0 hypothesis of the Im-Pesaran-Shin (Im, Pesaran and Shin, 2003) and Fisher ADF (Choi, 2001) unit root tests states that all panels contain unit roots. A time trend is included to the tests for the levels. Lag length is chosen according to the Akaike Information Criteria.

Source: Author's estimations.

Since all of the variables are stationary either at their levels or when their first differences are taken PMG, MG and DFE estimators can be used in order to estimate the EKC model. Table 3 shows the results of the PMG, MG and DFE estimations together with the Hausman test statistic.

In table 3, whilst model 1 shows the estimation results of the EKC model in which secondary school enrolment ratio is used as the education variable model 2 displays the estimation results of the EKC model in which tertiary school enrolment ratio is employed as the education variable. Since Hausman test statistic points out that PMG estimator is consistent and efficient for both models the results of this estimator is evaluated.

According to the estimation results in column 2 and column 3, error correction coefficients are statistically significant and negative. So, it is put forward that there is a long-run equilibrium relationship between the variables (Blackburne and Frank, 2007). Although the short-run coefficient estimates of the EKC model augmented with secondary school enrolment ratio and the EKC model augmented with tertiary school enrolment ratio are not statistically significant long-run coefficient estimates are statistically significant for both models. The estimation results of the EKC model augmented with secondary school enrolment ratio (column 2) indicate that both GDP per capita and secondary school enrolment have inverted-U shaped relationships with carbon dioxide emission in the long-run. However, only the coefficient estimates of GDP per capita are statistically significant. Hence, it is argued that although the conventional EKC hypothesis holds education represented by secondary school enrolment ratio does not have any effects on environmental pollution. These results also show that carbon dioxide emission reaches its maximum value when GDP per capita is USD 4409. The estimation results of the EKC model augmented with tertiary school enrolment ratio (column 3) show that both GDP per capita and tertiary school enrolment have statistically significant and hump-shaped relationships with carbon dioxide emission in the long-run. According to the long-run coefficient estimates of this model, carbon dioxide emission takes its maximum value when GDP per capita is USD 19905 and tertiary school enrolment ratio is %17.54.

Table 3 Pooled Mean Group, Mean Group and Dynamic Fixed Effect Estimations Results (Dependent Variable: Carbon Dioxide Emission)

	Pooled Mean Group (PMG)		***Mean Group (MG)***		***Dynamic Fixed Effect (DFE)***	
Variables	***Model 1***	***Model 2***	***Model 1***	***Model 2***	***Model 1***	***Model 2***
Long Run Coefficients						
lnyp	3.008105*** (0.6631645)	1.999698*** (0.5308827)	-76.90914 (129.1967)	-123.351 (83.39309)	6.307113*** (2.231035)	5.341905** (2.253287)
(lnyp)^2	-0.1792299*** (0.0342324)	-0.1009998*** (0.0286729)	3.645977 (6.184163)	5.708814 (3.924166)	-0.3531075*** (0.1180636)	-0.2835535** (0.1181754)
lneducation (secondary)	-2.220997 (5.686849)		71.42356 (54.0669)		-4.797553 (7.322504)	
(lneducation)^2 (secondary)	0.2206511 (0.6074249)		-7.791465 (5.819387)		0.4499703 (0.7535345)	
lneducation (tertiary)		0.8976039*** (0.2895028)		9.848577* (5.828757)		1.198301** (0.5379968)
(lneducation)^2 (tertiary)		-0.1566798*** (0.0386829)		-1.092324 (0.6962326)		-0.1902989** (0.0756623)
Error Correction Coefficient	-0.165064*** (0.0380067)	-0.2120707*** (0.0541737)	-0.455572*** (0.0658372)	-0.5108696*** (0.069428)	-0.076562*** (0.0203822)	-0.0807169*** (0.0189262)
Δlnyp	-1.467129 (8.679264)	1.908994 (6.116714)	-32.64205 (13.92098)	-33.35905** (14.28984)	0.4214555 (0.7127559)	0.428479 (0.7028198)
Δ(lnyp)^2	0.1064363 (0.4106304)	-0.0555519 (0.2909776)	1.61409 (0.6526352)	1.612376** (0.6690796)	0.006968 (0.0356689)	0.0053491 (0.034655)
Δlneducation (secondary)	34.65628 (25.01674)		-18.92302 (19.13889)		-0.3228321 (0.7235057)	
Δ(lneducation)^2 (secondary)	-3.748259 (2.71086)		1.993738 (2.035589)		0.03683774 (0.0769456)	
Δlneducation (tertiary)		-1.161875 (1.230064)		-0.8248748 (2.447207)		0.4096588 (0.4138335)
Δ(lneducation)^2 (tertiary)		0.1486317 (0.1518777)		0.0865712 (0.2936614)		-0.0454349 (0.0540989)
Intercept	-0.7593085*** (0.1701029)	-1.896679*** (0.4748477)	-159.4085*** (48.87157)	-10.95501 (44.7623)	-1.00833 (1.227693)	-2.009406*** (0.7320925)
Hausman Test (p value)			2.45[a] 0.6540	5.15[a] 0.2720	1.58[b] 0.8130	4.12[b] 0.3902

Notes: Standard errors are reported in parentheses. *, ** and *** represent 10%, 5% and 1% significance levels respectively. xtpmg routine developed by Blackburne and Frank (2007) is employed in Stata for estimations. The lag structure of the models is ARDL (1, 1, 1, 1, 1).
[a] PMG estimator is more efficient than MG estimator under the null hypothesis.
[b] PMG estimator is more efficient than DFE estimator under the null hypothesis.

Source: Author's estimations.

As of 2018, tertiary school enrolment ratio of all countries is higher than %17.54 level. Hence, it is suggested that an increase in tertiary school enrolment ratio leads to lower carbon dioxide emission in all countries under investigation. In addition to this, GDP per capita levels of all countries except Bulgaria, Hungary, Poland and Romania are higher than USD 19905 in 2018. Thus, it is argued that economic growth decreases carbon dioxide emission in all countries besides Bulgaria, Hungary, Poland and Romania. These results indicate significant policy implications with regard to environment. Since the increase in tertiary school enrolment ratio results in a decrease in carbon dioxide emission in all countries policies aiming to increase tertiary school enrolment have positive effects on the environment. In a similar vein, besides Bulgaria, Hungary, Poland and Romania rising GDP per capita levels decreases carbon dioxide emission. Hence, it is put forward that apart from Bulgaria, Hungary, Poland and Romania economic growth policies lower environmental degradation which stems from carbon dioxide emission. In addition to this, in Bulgaria, Hungary, Poland and Romania although rising GDP per capita levels has a negative effect on environment this negative effect is partially compensated by increasing tertiary school enrolment ratio. Therefore, policy makers in these countries should design and implement education policies which lead to increasing enrolment to the tertiary school in order to alleviate the negative effects of economic growth on environment.

In summary, the estimation results of the EKC model augmented with tertiary school enrolment ratio show that both GDP per capita level and tertiary school enrolment ratio have inverted-U shaped relationships with carbon dioxide emission in 21 European Union countries over the period 1991-2018. So, these results indicate the validity of the EKC hypothesis. According to the long-run coefficient estimates, carbon dioxide emission takes its maximum value when GDP per capita is USD 19905 and tertiary school enrolment ratio is 17.54%. As of 2018, tertiary school enrolment ratio passes 17.54% threshold in all countries under investigation and GDP per capita level passes USD 19905 threshold in countries besides Bulgaria, Hungary, Poland and Romania. Thus, it is suggested that whilst education policies aiming to increase the enrolment to tertiary school has a positive effect on environment in all countries under investigation economic policies leading to higher GDP per capita levels alleviating environmental degradation in countries except Bulgaria, Hungary, Poland and Romania.

5. Robustness Checks

As a robustness check, the EKC model augmented with secondary and tertiary school enrolment ratio is estimated once again by using the nitrous oxide emission as an environmental pollution indicator. Table 4 shows the results of these estimations.

In table 4, model 1 shows the estimation results of the EKC model in which secondary school enrolment ratio is used as the education variable and model 2 displays the estimation results of the EKC model in which tertiary school enrolment ratio is employed as the education variable. According to the Hausman test statistic, while PMG estimator is consistent and efficient for the EKC model augmented with secondary school enrolment ratio the consistent and efficient estimator for the EKC model augmented with tertiary school enrolment ratio is DFE. However, when PMG and DFE estimators are compared for the EKC model augmented with tertiary school enrolment ratio the Hausman test statistic is not positive definite. This means that Hausman test statistic may not have resulted in the best possible value and the result of the test may not be reliable (Rockefeller College University at Albany, 2006). Since DFE estimator is more restrictive in comparison to PMG estimator (Blackburne and Frank, 2007) similar to the EKC model augmented with secondary school enrolment ratio, the results of PMG estimator are evaluated for the EKC model augmented with tertiary school enrolment ratio.

Table 4 Pooled Mean Group, Mean Group and Dynamic Fixed Effect Estimations Results (Dependent Variable: Nitrous Oxide Emission)

	Pooled Mean Group (PMG)		***Mean Group (MG)***		***Dynamic Fixed Effect (DFE)***	
Variables	***Model 1***	***Model 2***	***Model 1***	***Model 2***	***Model 1***	***Model 2***
Long Run Coefficients						
lnyp	4.053465*** (0.5597765)	3.892612*** (0.9319267)	39.28583 (47.98651)	-121.6359 (121.3802)	5.758237*** (1.598526)	5.743109*** (1.478515)
(lnyp)^2	-0.2294199*** (0.0285)	-0.1962166*** (0.046933)	-1.938711 (2.289416)	5.684393 (5.712867)	-0.3236261*** (0.0856632)	-0.3113106*** (0.0832832)
lneducation (secondary)	3.722363*** (3.093923)		41.63492 (77.4769)		0.0980943 (9.279756)	
(lneducation)^2 (secondary)	-0.3839922 (0.3228664)		-4.563039 (8.335221)		-0.0165585 (0.9784887)	
lneducation (tertiary)		1.123692*** (0.2423863)		74.57806 (70.12194)		0.2605758 (0.4602487)
(lneducation)^2 (tertiary)		-0.178379*** (0.0294023)		-8.681781 (8.113958)		-0.0521144 (0.0568356)
Error Correction Coefficient	-0.2396232*** (0.0401959)	-0.3016107*** (0.0555644)	-0.4165644*** (0.047764)	-0.5033823*** (0.0710358)	-0.1405217*** (0.0355758)	-0.1542821*** (0.0371185)
Δlnyp	17.6062 (12.78024)	23.12868** (11.46249)	-37.97215** (18.80063)	-20.5591** (9.712188)	0.7990041 (1.071586)	0.7111768 (0.9535803)
Δ(lnyp)^2	-0.814637 (0.6019191)	-1.085549** (0.5407007)	1.837679** (0.8886084)	1.000345** (0.4643342)	-0.0179167 (0.0526881)	-0.0138384 (0.0477649)
Δlneducation (secondary)	51.39935 (37.09499)	1.595352 (0.9983959)	43.49801 (33.761)	-0.8179455 (2.16576)	-0.5631297 (1.202937)	0.3771257 (0.3224147)
Δ(lneducation)^2 (secondary)	-5.611803 (4.000066)	-0.2016601 (0.1365514)	-4.753251 (3.648235)	0.0815355 (0.290144)	0.0667249 (0.1282435)	-0.0496287 (0.0478027)
Δlneducation (tertiary)						
Δ(lneducation)^2 (tertiary)						
Intercept	-6.547141*** (1.110865)	-6.531882*** (1.208912)	-102.5945 (63.51688)	-24.92248 (52.40008)	-3.623486 (3.317828)	-4.165817*** (1.203504)
Hausman Test (p value)			3.38[a] 0.4959	2.24[a] 0.6922	2.55[b] 0.6365	10.04[b] 0.0397

Notes: Standard errors are reported in parentheses. ** and *** represent 5% and 1% significance levels respectively. xtpmg routine developed by Blackburne and Frank (2007) is employed in Stata for estimations. The lag structure of the models is ARDL (1, 1, 1, 1, 1).
[a] PMG estimator is more efficient than MG estimator under the null hypothesis.
[b] PMG estimator is more efficient than DFE estimator under the null hypothesis.

Source: Author's estimations.

The results of the EKC model in which nitrous oxide emission is used as an environmental pollution indicator are very similar to the results of the EKC model in which environmental pollution is represented by carbon dioxide emission. According to the estimation results in column 2 and column 3 of table 4, error correction coefficients are statistically significant and negative. So, it is argued that there is a long-run equilibrium relationship between the variables (Blackburne and Frank, 2007). Although the short-run coefficient estimates of the EKC model augmented with secondary school enrolment ratio are not statistically significant and only the short-run coefficient estimates of GDP per capita are statistically significant in the EKC model augmented with tertiary school enrolment ratio long-run coefficient estimates are statistically significant for both models. The estimation results of the EKC model augmented with secondary school enrolment ratio (column 2) indicate that both GDP per capita and secondary school enrolment ratio have hump-shaped relationships with nitrous oxide emission in the long-run. However, only the coefficient estimates of GDP per capita are statistically significant. Hence, these results show that although the conventional EKC hypothesis holds education represented by secondary school enrolment ratio does not have any effects on environmental pollution. According to the coefficient estimates of GDP per capita and the square of GDP per capita, nitrous oxide emission reaches its maximum value when GDP per capita is USD 6863. The estimation results of the EKC model augmented with tertiary school enrolment ratio (column 3) displays that while both GDP per capita and tertiary school enrolment have statistically significant and reverse U-shaped relationships with nitrous oxide emission in the long-run only GDP per capita has a statistically significant and hump-shaped relationship with nitrous oxide emission in the short-run. According to the long-run coefficient estimates of this model, nitrous oxide emission takes its maximum value when GDP per capita is USD 20310 Dollars and tertiary school enrolment ratio is %8.56.

In 2018, tertiary school enrolment ratio of all countries is higher than %8.56 level. Hence, it is suggested that an increase in tertiary school enrolment ratio results in lower nitrous oxide emissions in all countries under investigation. Moreover, GDP per capita levels of all countries except Bulgaria, Hungary, Poland and Romania are higher than USD 20310 in 2018. Thus, it is suggested that economic growth decreases nitrous oxide emissions in all countries excluding Bulgaria, Hungary, Poland and Romania.

As it is clearly seen, the results obtained from the EKC model in which nitrous oxide emission is used as an environmental pollution indicator are in line with the results of the EKC model in which environmental pollution is represented by carbon dioxide emission. The estimation results of both of these models indicate that conventional EKC hypothesis holds in 21 European Union countries under investigation over the period 1991-2018. In addition to this, the results show that whilst secondary school enrolment ratio does not have a statistically significant effect on environmental pollution tertiary school enrolment ratio has a statistically significant and hump-shaped relationship with both carbon dioxide and nitrous oxide emissions. According to the results of both of these models, tertiary school enrolment ratio is higher than the threshold value in all countries under investigation. So, it is argued that increasing the enrolment to tertiary school leads to lower carbon dioxide and nitrous oxide emissions. Similarly, GDP per capita levels are higher than the threshold value in all of the countries besides Bulgaria, Hungary, Poland and Romania. Hence, it is put forward that rising GDP per capita levels decreases environmental pollution which stems from carbon dioxide and nitrous oxide emissions in all countries apart from Bulgaria, Hungary, Poland and Romania. Consequently, it is put forward that while education policies aiming to increase the enrolment to tertiary school decreases both carbon dioxide and nitrous oxide emissions economic policies leading to higher GDP per capita levels lead to lower carbon dioxide and nitrous oxide emissions in countries except Bulgaria, Hungary, Poland and Romania. Since these results have significant policy implications with regard to environment policy makers should necessarily take into account environmental effects of economic growth and education policies in order to design environment-friendly policies.

6. Conclusion

This paper empirically analyses the EKC hypothesis augmented with education in 21 European Union countries over the period 1991-2018. Since there is limited number of studies that take into account education within the EKC framework the aim of this study is to fill in this gap in the existing literature by providing new evidence for the European Union countries under investigation.

In the baseline empirical analysis, carbon dioxide emission is used as the environmental pollution indicator and education is represented by secondary and tertiary school enrolment ratios. As a robustness check, the EKC model augmented with secondary and tertiary school enrolment ratios is estimated once again by employing nitrous oxide emission as an indicator of environmental pollution.

According to the results of the baseline empirical analysis, while secondary school enrolment ratio does not have a statistically significant effect on environmental pollution GDP per capita and tertiary school enrolment ratio have statistically significant and hump-shaped relationships with carbon dioxide emission in the long-run. The coefficient estimates of the EKC model augmented with tertiary school enrolment ratio indicate that carbon dioxide emission takes its maximum value when GDP per capita is USD 19905 and tertiary school enrolment ratio is %17.54. As of 2018, tertiary school enrolment ratio of all countries is higher than %17.54 level and GDP per capita levels are higher than USD 19905 in countries except Bulgaria, Hungary, Poland and Romania. These results indicate significant policy implications with regard to environment. Since the increase in tertiary school enrolment ratio results in a decrease in carbon dioxide emission in all countries education policies aiming to increase tertiary school enrolment ratio have positive effects on environment. Similarly, besides Bulgaria, Hungary, Poland and Romania economic policies which aim to increase GDP per capita levels lead to lower carbon dioxide emission. In Bulgaria, Hungary, Poland and Romania although rising GDP per capita levels has a negative effect on environment this negative effect is partially compensated by increasing tertiary school enrolment ratio. Therefore, policy makers in these countries should implement education policies which lead to increasing enrolment to the tertiary school in order to alleviate the negative effects of economic growth on environment.

The results obtained from the EKC model in which nitrous oxide emission is used as an environmental pollution indicator are in line with the results of the EKC model in which environmental pollution is represented by carbon dioxide emission. According to the estimation results of the EKC model in which environmental pollution is represented by nitrous oxide emission, whilst secondary school enrolment ratio does not have a statistically significant effect on nitrous oxide emission both GDP per capita and tertiary school enrolment ratio have statistically significant and reverse U-shaped relationships with nitrous oxide emission in the long-run. The long-run coefficient estimates of this model indicate that nitrous oxide emission takes its maximum value when GDP per capita is USD 20310 and tertiary school enrolment ratio is %8.56. In 2018, tertiary school enrolment ratio of all countries is higher than %8.56 level and GDP per capita levels of all countries except Bulgaria, Hungary, Poland and Romania are higher than USD 20310. By taking into account these results, it is suggested that while education policies aiming to increase the enrolment to tertiary school decreases nitrous oxide emission in all countries under investigation economic policies leading to higher GDP per capita levels result in lower nitrous oxide emission in countries except Bulgaria, Hungary, Poland and Romania.

In conclusion, the results of this empirical analysis suggest that tertiary education is a significant determinant of environmental degradation and both GDP per capita and tertiary school enrolment ratio have hump-shaped relationships with carbon dioxide and nitrous oxide emissions in 21 European Union countries over the period under investigation. Hence, policy makers should consider the relationship between these variables in order to design appropriate economic growth and education policies without inducing environmental deterioration.

APPENDIX

1. List of the Countries

1. Austria
2. Belgium
3. Bulgaria
4. Cyprus
5. Czechia
6. Denmark
7. Finland
8. France
9. Germany
10. Greece
11. Hungary
12. Ireland
13. Italy
14. Malta
15. The Netherlands
16. Poland
17. Portugal
18. Romania
19. Spain
20. Sweden
21. The United Kingdom

REFERENCES

Al-Mulali U, Saboori B, Ozturk I (2015): Investigating the Environmental Kuznets Curve Hypothesis in Vietnam. *Energy Policy*, 76:123-131.

Al-Mulali U, Ozturk, I (2016): The Investigation of the Environmental Kuznets Curve Hypothesis in the Advanced Economies: The Role of Energy Prices. *Renewable and Sustainable Energy Reviews*, 54:1622-1631.

Apergis N, Christou C, Gupta R (2017): Are There Environmental Kuznets Curves for US State-Level CO_2 Emissions? *Renewable and Sustainable Energy Reviews*, 69:551-558.

Apergis N, Ozturk I (2015): Testing Environmental Kuznets Curve Hypothesis in Asian Countries. *Ecological Indicators*, 52:16-22.

Atasoy BS (2017): Testing the Environmental Kuznets Curve Hypothesis across the US: Evidence from Panel Mean Group Estimators, *Renewable and Sustainable Energy Reviews*, 77:731-747.

Balaguer J, Cantavella M (2018): The Role of Education in the Environmental Kuznets Curve. Evidence from Australian Data. *Energy Economics*, 70:289-296.

Blackburne EF, Frank MW (2007): Estimation of Nonstationary Heterogenous Panels. *The Stata Journal*, 7(2):197-208.

Boubellouta B, Kusch-Brandt S (2020): Testing the Environmental Kuznets Curve Hypothesis for E-waste in the EU28+2 Countries. *Journal of Cleaner Production*, 277:1-11.

Boubellouta B, Kusch-Brandt S (2021): Cross-Country Evidence on Environmental Kuznets Curve in Waste Electrical and Electronic Equipment for 174 Countries. *Sustainable Production and Consumption*, 25:136-151.

Choi I (2001): Unit Root Tests for Panel Data. *Journal of International Money and Finance*, 20(2):249-272.

Churchill SA, Inekwe J, Ivanoski K, Symth R (2018): The Environmental Kuznets Curve in the OECD: 1870-2014. *Energy Economics*, 75:389-399.

Dinda S (2004): Environmental Kuznets Curve Hypothesis: A Survey. *Ecological Economics*, 49(4):431-455.

European Commission (2020): Communication from the Commission to the European Parliament, The Council, the European Economic and Social Committee of the Region, Stepping up Europe's 2030 Climate Ambition Investing in a Climate-Neutral Future for the Benefit of Our People, The 2030 Climate Target Plan. COM(2020) 562, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0562&from=EN.

European Commission (2021): 2030 Climate Target Plan, https://ec.europa.eu/clima/eu-action/european-green-deal/2030-climate-target-plan_en.

Fodha M, Zaghdoud O (2010): Economic Growth and Pollutant Emissions in Tunisia: An Empirical Analysis of the Environmental Kuznets Curve. *Energy Policy*, 38(2):1150-1156.

Grossman GM, Krueger AB (1991): Environmental Impacts of a North American Free Trade Agreement. *NBER Working Paper* 3914, https://www.nber.org/papers/w3914.pdf.

Grossman GM, Krueger AB (1995): Economic Growth and the Environment. *The Quarterly Journal of Economics*, 110(2):353-377.

Hausman JA (1978): Specification Tests in Econometrics. *Econometrica*, 46(6):1251-1271.

He J, Richard P (2010): Environmental Kuznets Curve for CO_2 in Canada. *Ecological Economics*, 69(5):1083-1093.

Hill RJ, Magnani E (2002): An Exploration of the Conceptual and Empirical Basis of the Environmental Kuznets Curve. *Australian Economic Papers*, 41(2):239-254.

Im KS, Pesaran MH, Shin Y (2003): Testing for Unit Roots in Heterogenous Panels. *Journal of Econometrics*, 115(1):53-74.

Iwata H, Okada K, Samreth S (2010): Empirical Study on the Environmental Kuznets Curve for CO_2 in France: The Role of Nuclear Energy. *Energy Policy*, 38(8):4057-4063.

Kacprzyk A, Kuchta Z (2020): Shining a New Light on the Environmental Kuznets Curve for CO_2 Emissions. *Energy Economics*, 87:1-10.

Ketenci N (2018): The Environmental Kuznets Curve in the Case of Russia. *Russian Journal of Economics*, 4:249-265.

Kuznets S (1955): Economic Growth and Income Inequality. *American Economic Review*, 45(1):1-28.

Kijima M, Nishide K, Ohyama A (2010): Economic Models for the Environmental Kuznets Curve: A Survey. *Journal of Economic Dynamics and Control*, 34(7):1187-1201.

Li H, Grijalva T, Berrens RP (2007): Economic Growth and Environmental Quality: A Meta-Analysis of Environmental Kuznets Curve Studies. *Economics Bulletin*, 17(5):1-11.

Li T, Wang Y, Zhao D (2016): Environmental Kuznets Curve in China: New Evidence from Dynamic Panel Analysis. *Energy Policy*, 91:138-147.

Lin B, Omoju OE, Nwakeze NM, Okonkwo JU, Megbowon T (2016): Is Environmental Kuznets Curve Hypothesis a Sound Basis for Environmental Policy in Africa? *Journal of Cleaner Production*, 133:712-724.

Ma X, Ahmad N, Oei PY (2021): Environmental Kuznets Curve in France and Germany: Role of Renewable and Nonrenewable Energy. *Renewable Energy*, 172:88-99.

Martinez-Zarzoso I, Bengochea-Morancho A (2004): Pooled Mean Group Estimation of an Environmental Kuznets Curve for CO_2. *Economics Letters*, 82(1):121-126.

Nasir M, Rehman FU (2011): Environmental Kuznets Curve for Carbon Emissions in Pakistan: An Empirical Investigation. *Energy Policy*, 39(3):1857-1864.

Onafowora OA, Owoye O (2014): Bounds Testing Approach to Analysis of the Environment Kuznets Curve Hypothesis. *Energy Economics*, 44:47-62.

Pablo-Romero MP, Cruz L, Barata E (2017): Testing the Transport Energy-Environmental Kuznets Curve Hypothesis in the EU27 Countries. *Energy Economics*, 62:257-269.

Panayotou T (1993): Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development. *World Employment Programme Research Working Paper*, 238, International Labour Organization,
https://www.ilo.org/public/libdoc/ilo/1993/93B09_31_engl.pdf.

Panayotou T (2003): Economic Growth and the Environment. *Economic Survey of Europe*, 2:45-72, https://www.unece.org/fileadmin/DAM/ead/pub/032/032_c2.pdf.

Park S, Lee Y (2011): Regional Model of EKC for Air Pollution: Evidence from the Republic of Korea. *Energy Policy*, 39(10):5840-5849.

Pesaran MH, Smith RP (1995): Estimating Long-run Relationships from Dynamic Heterogenous Panels. *Journal of Econometrics*, 68(1):79-113.

Pesaran MH, Shin Y, Smith RP (1997): Pooled Estimation of Long-run Relationships in Dynamic Heterogenous Panels. *Department of Applied Economics University of Cambridge*, http://www.econ.cam.ac.uk/people-files/emeritus/mhp1/jasaold.pdf.

Pesaran MH, Shin Y, Smith RP (1999): Pooled Mean Group Estimation of Dynamic Heterogenous Panels. *Journal of the American Statistical Association*, 94:621-634.

Rockefeller College University at Albany (2006): PAD 705 Handout Panel Data, https://www.albany.edu/faculty/kretheme/PAD705/SupportMat/PanelData.pdf.

Saboori B, Sulaiman J, Mohd S (2012): Economic Growth and CO_2 Emissions in Malaysia: A Cointegration Analysis of the Environmental Kuznets Curve. *Energy Policy*, 51:184-191.

Saqib M, Benhmad F (2021): Updated Meta-Analysis of Environmental Kuznets Curve: Where do We Stand? *Environmental Impact Assessment Review*, 86, Article 106503.

Sarkodie SA, Strezov V (2018): Empirical Study of the Environmental Kuznets Curve and Environmental Sustainability Curve Hypothesis for Australia, China, Ghana and USA. *Journal of Cleaner Production*, 201:98-110.

Sarkodie SA, Strezov V (2019): A Review on Environmental Kuznets Curve Hypothesis using Bibliometric and Meta-Analysis. *Science of the Total Environment*, 649:128-145.

Shafik N, Bandyopadhyay S (1992): Economic growth and Environmental Quality: Time Series and Cross-Country Evidence. Policy, Research Working Papers, No. WPS 904, World Development Report, Washington, D.C.: World Bank Group, http://documents1.worldbank.org/curated/en/833431468739515725/pdf/multi-page.pdf.

Shafiullah M, Papavassiliou VG, Shahbaz M (2021): Is There an Extended Education-Based Environmental Kuznets Curve? An Analysis of US States. *Environmental and Resource Economics*, 80(4):795-819.

Shahbaz M, Shafiullah M, Papavassiliou VG, Hammoudeh S (2017): The CO_2-Growth Nexus Revisited: A Nonparametric Analysis for the G7 Economies over Nearly Two Centuries. *Energy Economics*, 65:183-193.

Shahbaz M, Sinha A (2019): Environmental Kuznets Curve for CO_2 Emissions: A Literature Survey. *Journal of Economic Studies*, 46(1):106-168.

Umaroh R (2019): Does Education Reduce CO2 Emissions? Empirical Evidence of the Environmental Kuznets Curve in Indonesia. *Journal of Reviews on Global Economics*, 8:662-671.

Williamson C (2017): Emission, Education, and Politics: An Empirical Study of the Carbon Dioxide and Methane Environmental Kuznets Curve. *The Park Place Economist*, 25(1):21-33, https://digitalcommons.iwu.edu/parkplace/vol25/iss1/9/.

World Bank (1992): World Development Report 1992: Development and the Environment, World Development Report; World Development Indicators, Washington D.C.: World Bank Group, http://documents1.worldbank.org/curated/en/995041468323374213/pdf/105170REPLACEMENT0WDR01992.pdf.

World Bank (2021): World Development Indicators, https://databank.worldbank.org/source/world-development-indicators.

World Health Organization (2021): Climate Change and Health. *World Health Organization Fact Sheets*, https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health.