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Testing the transport-induced Environmental Kuznets Curve Hypothesis: The Role of Air and Railway Transport

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Corresponding Author:	Samuel Asumadu Sarkodie Nord University Bodo, Nordland Norway
First Author:	Sinan ERDOGAN
Order of Authors:	Sinan ERDOGAN
	Festus Adedoyin
	Festus Bekun
	Samuel Asumadu Sarkodie
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Response to Reviewers:	Dear Editor and Anonymous Reviewers, Thank you for the privilege and the time spent in improving the quality of our manuscript under your consideration. We have critically reviewed the manuscript based on your valuable comments and recommendations. Our response to the Reviewers is written in red for easy reference. We have attached both the marked version and the clean version. Comments from the editors and reviewers: Reviewer #1: The paper is interesting and well prepared. The methodology employed is appropriate and results are presented well. RESPONSE: Thanks for your useful comments. We appreciate your time and efforts in improving our manuscript. I have only following suggestions to improve the paper: - section 3 "3. Model, Data, Methodology and Empirical Results" should be corrected as "3. Model, Data and Methodology" RESPONSE: Thanks for your useful comments. We have incorporated the changes in Page 12.

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Dear Editor and Anonymous Reviewers,

Thank you for the privilege and the time spent in improving the quality of our manuscript under your consideration. We have critically reviewed the manuscript based on your valuable comments and recommendations.

Our response to the Reviewers is written in ***red*** for easy reference. We have attached both the marked version and the clean version.

Comments from the editors and reviewers:

Reviewer #1: The paper is interesting and well prepared. The methodology employed is appropriate and results are presented well.

RESPONSE: Thanks for your useful comments. We appreciate your time and efforts in improving our manuscript.

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Highlights

- Effect of airline and railway industry on CO_2 emissions is assessed in the context of the EKC hypothesis
- We find a positive significant relationship between emissions and economic growth
- Air transportation drives pollution while railway transportation and urbanization decline emission
- The study confirms fossil fuel energy consumption induced pollutant emissions
- Intensifying R&D into more fuel-efficient airlines is essential to improve environmental quality

Title page

Testing the transport-induced Environmental Kuznets Curve Hypothesis: The Role of Air and Railway Transport

Sinan ERDOGAN

Department of Economics, Faculty of Economics and Administrative Sciences,

Hatay Mustafa Kemal University, Hatay, Turkey,

E-mail: phderdogan@gmail.com

Festus Fatai ADEDOYIN

Department of Accounting, Economics and Finance, Bournemouth University, United Kingdom

Email: fadedoyin@bournemouth.ac.uk

Festus Victor BEKUN

Faculty of Economics Administrative and Social sciences, Istanbul Gelisim University, Istanbul, Turkey

&

Department of Accounting, Analysis and Audit, School of Economics and Management, South Ural State University, 76, Lenin Aven., Chelyabinsk, Russia 454080.

E-mail: fbekun@gelisim.edu.tr

Samuel Asumadu SARKODIE

Nord University Business School (HHN). Post Box 1490, 8049 Bodø, Norway

Email: asumadusarkodiesamuel@yahoo.com

Testing the transport-induced Environmental Kuznets Curve Hypothesis: The Role of Air and Railway Transport

Abstract

The airline and railway industry contribute immensely to economic development, however, its role in environmental pollution requires attention. Here, this study builds on the theoretical pedigree of the environmental Kuznets curve (EKC) hypothesis to explore the contribution of the air and railway transportation sector and urbanization to the emission-growth argument. We utilized annual time-frequency data from 1995-2014 for a panel of top 10 air passenger carrier countries using robust panel estimators that ameliorate for cross-sectional dependency. The empirical analysis shows a positive significant relationship between emissions and economic growth, thus, economic growth is emission-embedded with limited green growth. The existence of the EKC phenomenon is affirmed for the investigated blocs — where economic growth is prioritized over environmental quality. Additional, while air transportation drives pollution, railway transportation and urbanization decline emission over the sampled period. The results underscore the need for clean and environmentally friendly energy sources for air sector operations.

Keywords: Energy consumption; Transport emissions; Airline emissions; railway emissions; pollutant emission; Urbanization

1. Introduction

Transportation is an important sector of any economy either the road, rail, air transport etc. however, transport contributes to the emission of greenhouse gases such as carbon dioxide. It is reported that transport activities are responsible for 14% of total greenhouse gas emissions. The major contributor to the emissions from transport activities is attributed to road transportation activities. The aviation sector is the second largest contributor to greenhouse gas emissions, and nearly responsible for 2-4% of total anthropogenic emissions (Air Transport Action Group, 2019). However, the carbon emissions from the airline industry are more dangerous than other transport activities — because of both distorting the composition of the atmosphere at high altitudes and exacerbating greenhouse gas concentration at the surface environment. Moreover, half of the greenhouse gas emissions are emitted near-surface environment while the other half occurs above an altitude of 6000 meters (Balkanski et al., 2010). If a round-trip flight from London to New York produces about 986 kg of carbon dioxide emissions per passenger, then this value is higher than the annual average CO_2 emissions per capita of 56 countries (Kommenda, 2019). It may be said that the airline industry increases both the concentration of greenhouse gas emissions on the surface and atmosphere, which in turn increases environmental pollution. In addition, the transport industry was one of the strategic sectors emphasized in the 1997 Kyoto protocol that required attention. The purpose was to diminish worldwide greenhouse gas emissions by 5.2% of 1990 levels by 2012 (Chapman, 2007).

Emissions from transportation pose other risks to the environment as well as the economy. The transport-carbon dioxide emission relationship cannot be overemphasized, this is because it is an important aspect of economic development. Hence, there is a need for more stringent regulations and policies on environmental protection to control the transport-carbon dioxide emission relationship (Ouyang et al., 2019). This is why the environmental Kuznets curve (EKC) hypothesis highlights that environmental pressure increases up to a certain level of income growth and diminishes thereafter. The validation of the EKC phenomenon i.e there is an inverted U-shape nexus between carbon dioxide emission and per capita income has been confirmed by a number of studies (Sugiawan and Managi, 2016; Al-mulali et al., 2015; Zaman et al., 2016). The EKC hypothesis is a useful conceptual tool to tackle environmental issues caused by greenhouse gas emissions (Sarkodie and Strezov, 2019). Curtailing environmental issues caused by transport emissions will lead to an increase in income level to a point where environmental pressure begins to decline.

Energy consumption may lead to an increase in the emission of carbon dioxide while the air and rail transport system contributes immensely to the energy-emission nexus. Meaning that air transport contributes more to greenhouse gas emission than road transport — as air transport emissions directly affect the environment. The extending use of the electric-powered railway is historically considered as an eco-friendlier form of transportation for ensuring the sustainability of transportation activities. A two-way causal relationship between CO_2 emissions and transport has been reported, thus, CO_2 emissions affect transport and vice versa (Abdallah et.al, 2013). However, findings from other studies conducted on the transport-emission relationship remain inconclusive.

There are many opposing views which emphasizes the economic benefits of the airline industry. However, the main environmental concern of the transport industry is reducing road and airline transport pollution and its distorting effects, of which there are limited studies. The aim of this study is to test the role of the airline and railway industry on environmental pollution among related countries. Few studies have examined the transport-emission nexus and the validity of the EKC hypothesis distinctively. Yet, to the best of our knowledge, no study has investigated the effect of airline and railway industry on environmental pollution in the context of the EKC hypothesis. The findings of this study may be key to ensuring the environmental sustainability of eco-friendly transportation technologies.

2. Literature Review

The environmental pollution-economic development nexus has extensively been examined by researchers since the study of Grossman and Krueger (1991) was proposed. The main concern of Grossman and Krueger (1991) was to unearth how environmental degradation changes in the dynamic growth path of 42 countries. Therefore, a cubic model was used to empirically assess the linkage and reported an N-shaped nexus between environmental pollution and economic development. The environment-economic growth nexus has been tested with several estimation methods and energy-related or macroeconomic variables in various samples reported in Table 1.

Table 1. Interactions between Environmental Degradation, Energy Consumption, and Macroeconomic Variables

Author(s)	**Sample-Period**	**Method**	**Energy-Macroeconomic Variables**	**EKC**
Shafik & Bandyopadhyay (1992)	149 Countries, 1960-1990	PRE	-	Invalid
Selden & Song (1994)	30 Countries	POLS, FE, RE	Population Density (-)	Valid
Panayotou (1997)	30 Developed and Developing Countries, 1982-1994	FE, RE	Population Density (+) Policy Variable (-)	Valid
Dinda et al. (2000)	33 Countries, 1979-1990	PRE	-	Invalid

Dijkgraaf & Vollebergh (2001)	24 OECD Countries, 1960-1997	FE	-	Invalid
Narayan & Narayan (2010)	43 Developing Countries, 1980-2004	PDA	-	M
Ozturk & Acaravci (2013)	Turkey, 1960-2007	ARDL	EC (+) TR (+) FD (*)	Valid
Tiwari et al. (2013)	India, 1966-2009	ARDL	CC (+) TR (+)	Valid
Apergis & Ozturk (2015)	14 Asian Countries, 1990-2011	GMM, FMOLS, DOLS	Population Density (-) Land (+) Industry Shares in GDP (+) Institutions (M)	Valid
Shahbaz et al. (2015)	12 Africa Countries, 1980-2012	PDA	Energy Intensity (+)	Valid
Jebli et al. (2016)	25 OECD Countries, 1980-2010	FMOLS, DOLS	REC (-) NREC (+) TR (-)	Valid
Al-Mulali et al. (2016)	7 Regions, 1980, 2010	DOLS	REC (M) TR (M) UR (M)	M
Shahbaz et al. (2016)	19 African Countries, 1971-2012	ARDL	Energy Intensity (M) Globalization (M)	M

Ertugrul et al. (2016)	Developing Countries, 1971-2011	ARDL	TR (M) EC (M)	M
Dogan & Turkekul (2016)	USA, 1960-2010	ARDL	EC (+) TR (-) UR (+) FD (*)	Invalid
Acaravci & Akalin (2017)	Developed and Developing Countries, 1980-2010	CCE	TR (M)	M
Sarkodie & Adams (2018)	South Africa, 1971-2017	ARDL	UR (*) REC (-) NREC (+) Political Institutions (-) Nuclear Energy (*)	Valid
Destek et al. (2018)	EU Countries, 1980-2013	CCE-Mean Group	EC (+) NREC (+) REC (-) TR (-) FD (+)	Invalid
Pata (2018)	Turkey, 1971-2014	ARDL	UR (+) Import (+) Export (-) Industrialization (+) CC (+)	Valid

			Noncarbohydrate Energy (-)	
Aslan et al. (2018)	USA, 1966-2013	Bootstrap Rolling Window Approach	-	Valid
Ulucak & Bilgili (2018)	Low-, Middle-, and High-Income Countries, 1961-2013	CUP-FM, CUP-BC	TR (M) Human Capital (M) Biocapacity (M)	Valid
Sarkodie & Strezov (2019)	5 Countries, 1982-2016	Driscoll-Kraay Method	Foreign Direct Investment (+) Energy Consumption (+)	M
Danish et al. (2020)	BRICS, 1992-2016	FMOLS, DOLS	RNEC (-) Natural Resources Rent (-) URB (-)	Valid

M: Mixed Results, REC: Renewable Energy Consumption, NREC: Non-Renewable Energy Consumption, TR: Trade Openness, UR: Urbanization, FD: Financial Development, EC: Energy Consumption: *: No Statistically Significant Effect, CC: Coal Consumption, POLS: Pooled OLS, FE: Fixed Effects, RE: Random Effects, GMM: Generalized Method of Moment, FMOLS: Fully

Modified Ordinary Least Squares, DOLS: Dynamic OLS, PRE: Panel Regression Analysis, PDA: Panel Data Analysis, CCE: Common Correlated Effect Estimator.

2.1 Related Studies on the Energy-Economic Growth Nexus

Economic development is a point of focus for many countries, that is why activities and actions of countries are directed towards ensuring sustained economic growth. There are several studies on the nexus between energy utilization and economic development (Adedoyin et al., 2020a, 2020b; Udi et al., 2020). Three conclusions, namely bidirectional, unidirectional and no-causality, are often made on the nexus between energy, emissions and growth. The extant literature found a bidirectional causality relationship between CO_2 emissions and income level (Pao and Tsai, 2011). Other studies found a one-way causal relationship from income level to CO_2 emissions (Solarin, 2014). Using disaggregate energy consumption, a one-way causal nexus from economic growth to renewables was confirmed in the short run while feedback causality was affirmed in the long-run. A two-way relationship between fossil fuels energy and economic growth was confirmed both in short- and long- run, (Apergis and Payne, 2012). Increasing the penetration of renewables had a mitigating effect on environmental degradation while conventional energy sources spur CO_2 emissions (Ozcan et al., 2019). In addition, the diversification of the energy mix with renewable energy is found to increase economic development (Cowan et al., 2014). In contrast, strong evidence of feedback effect is reported between CO_2 emissions, fossil fuels and economic development (Wooldridge, 2008).

2.2 Transport-Emissions nexus

The environmental impact of transport cannot be overemphasized, because the transport sector is one of the major global consumers of energy that burns a large percentage of petroleum. This leads to the creation and emission of carbon dioxide and other greenhouse gases that may degrade the environment, leading to climate change. However, air-railway transportation has a positive and significant relationship with energy demand, (Rashid Khan et al., 2018). Energy consumption underpins the proper functioning of air-railway transportation systems, hence, resulting in the emission of anthropogenic greenhouse gases that affect the environment. A study found a two-way causal relationship between CO_2 emissions and transport (Abdallah et.al, 2013). This means that CO_2 emissions affect the transport sector whereas transportation leads to CO_2 emissions. The accumulation of the atmospheric emissions results in air pollution and degradation of the environment, with a long-term economic effect. Several studies found a strong relationship between transport energy consumption and transport infrastructure and economic development. Energy consumed by the transport sector and others namely waterways, airways, railways, roads and terminals, seaports, refuelling depots, trucking terminals, warehouses, and airports were found to affect economic development (Beyzatler et.al, 2014; Saidi et al., 2018).

Other factors that may affect the role in the transport sector-led emissions include economic growth, tourism, employment (Küçükönal and Sedefoğlu, 2017). These factors are interwoven and depend on each other, thus, urbanization and transport affect tourism. Meaning that tourism, the influence of urbanization, and passenger carriage intensity affects economic growth (Arvin et al., 2015). Hence, proper regulations of tourism and tourists' activities and energy consumption have a positive impact on economic growth. There is a long term linkage existing between airline service levels and the variation in interest rates and market concentration, (Stamolampros and Korfiatis, 2019). There is a significant relationship between the degree of market based environmental regulation stringency and population exposure. With stricter environmental regulations, the positive correlations of population exposure to pollution gradually decline.

There is an increase in departure frequency in routes that have experienced liberalization compared to those governed by restrictive bilateral air service agreements. Partially liberalized routes experience larger departure frequency compared to fully liberalized routes, (Abate, 2016). Meanwhile, there is a long-run equilibrium relationship existing between economic growth and domestic air passenger traffic. There is a short-run one-way causal relationship from domestic air passenger traffic to economic growth, (Hu et al., 2015). Economic growth and air transport demand are co-integrated, leading to an increase in air transport demand due to expansive economic activities (Marazzo et al., 2010). Economic development has a long term effect on the number of people scheduled to book a flight and Air passenger traffic, exerting the same influence on the number of goods (Air freight volumes) transported by air (Hakim and Merkert, 2016). However, Air funding mechanisms significantly increase passenger flows and travel conditions or leisure and business passengers and increases the gross value-added to the economy (Smyth et al., 2012).

2.3 Gap in the literature

The following features can be observed in existing studies. First, the early studies were mainly focused on the interaction between economic growth and environment, thus, testing the existence of the EKC. Second, other studies included the other energy and macroeconomic indicators, which are associated with environmental degradation, alongside economic growth. The extant literature confirms the deteriorating effects of fossil fuels and the mitigating effects of renewables on the environment. However, there is no consensus on the effects of trade and urbanization on the environment. Third, there is limited literature investigating the role of transport industries on environmental degradation. Fourth, due to the varying methodology, sample design or explanatory variables used, there is no consensus on the existence of EKC. This paper aims to unveil the role of the airline and rail transport industry on environmental pollution, alongside traditional energy consumption and macroeconomic variables and tend to fill the existing gaps in the literature.

3. Model, Data, Methodology and Empirical Results

3.1 Model and Data

In order to analyze the effect of transport industry on environmental degradation, we employed a linear logarithmic model based on data from 1995-2014 in selected top airways passenger-carrier countries[1] expressed as:

$$\ln CO_{2it} = \beta_{0i} + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{it}^2 + \beta_3 \ln A_{it} + \beta_4 \ln R_{it} + \beta_5 \ln FC_{it} + \beta_6 \ln U_{it} + \varepsilon_{it} \qquad \textbf{(1)}$$

where the CO_2 is represents carbon dioxide emissions per capita, Y and Y^2 are real GDP per capita (constant, 2010 US$) and the square of real GDP, respectively. The *A* is airways transport (passenger carried), the *R* is the railway transport (passenger carried), and both *A* and *R* were used as a proxy for the size of airline and railways industries. *F* is the fossil fuel energy consumption (% of total), and *U* is the urban population (% of the total population). All data were retrieved from World Bank online database (World Bank, 2019).

3.2 Methodology

In this study, we employed standard LM test and Delta tests suggested by Breusch-Pagan (1980) and Pesaran and Yamagata (2008), respectively, to test the existence of cross-section dependence and slope homogeneity[2]. After preliminary analyses, we unearthed the stationarity properties of variables by using a bootstrap-based unit root test, proposed by Smith et al. (2004). They adopt the methodology of Im et al. (2003) to estimate $\bar{t}$ statistics and consider cross-section dependence by using the bootstrap specification. The $\bar{t}$ statics can be obtained by using the following specification:

$$\bar{t}_s = \sqrt{N}\left\{\bar{t} - E(t_i)\right\} \Big/ \sqrt{Var(t_i)} \qquad \textbf{(2)}$$

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[1] The data used in this study cover the countries, which are in top 10 air passenger-carrier countries (China, Germany, India, Ireland, Japan, Turkey, United Kingdom and United States). Brazil and Indonesia were not included because of data constraints

[2] The LM and Delta tests are widely known estimation techniques, hence, were not specified in the study.

where $\bar{t} = N^{-1}\sum_{i=1}^{N} t_i$. Moreover, this method tests the null of the non-stationarity hypothesis against the alternative of stationarity.

In order to test whether long-run relationships exist among variables, we utilized the variance ratio-based cointegration method, suggested by Westerlund (2005). Westerlund proposes two statistics which are group-mean and panel variance ratio statistics. Because of slope heterogeneity, we used group-mean variance ratio statistics estimated by the following specification expressed as:

$$VR_G = \sum_{i=1}^{N}\sum_{t=1}^{T} E_{it}^{2} R_i^{-1} \qquad \textbf{(3)}$$

where $E_{it} \equiv \sum_{j=1}^{t} \hat{e}_{ij}$, $R_{it} \equiv \sum_{t=1}^{T} \hat{e}_{it}^{2}$ and $\hat{e}_{it}$ is the residual term, obtained by the data generating process of Westerlund, and the null of "*no cointegration*" is tested against the alternative of "*some panels are cointegrated*" through the outlined specification. In terms of robustness, the variance ratio-based cointegration test has a satisfactory small sample performance. Finally, we implemented the and Mean-Group and FMOLS estimation procedures proposed by and Pesaran and Smith (1995) and Pedroni (2000), respectively, to estimate the long-run parameters. The Mean-Group (MG) estimator allows to include country-specific heterogeneity, and estimates panel coefficients by taking the arithmetic average of the heterogeneous coefficients. The panel FMOLS strategy can be applied as $\beta_{GFMOLS} = N^{-1}\sum_{i=1}^{N} \beta_{FMOLSi}$, where β_{FMOLSi} is obtained by using individual FMOLS estimation of Eq.(1), and related t-ratio could be estimated as $t_{\beta_{GFMOLS}} = N^{-1/2}\sum_{i=1}^{N} t_{\beta_{FMOLSi}}$.

4. Empirical Results and Discussions

We began our analysis by conducting cross-sectional dependence and delta tests. According to the test results (Table 2), the null hypothesis of no cross-sectional dependence is strongly accepted for the model, whereas rejected for variables with different significance levels. Thus, there is no existence of cross-sectional dependence in the model, while existing in the sampled variables.

In addition, the null hypothesis of slope homogeneity by the delta test is rejected at 1% significance level, confirming the presence of slope heterogeneity.

Table 2. Cross-sectional dependence and delta tests

Variable	LM	$\tilde{\Delta}$	$\tilde{\Delta}_{adj}$
Model	25.888 (0.579)	7.146 (0.000)	7.719 (0.000)
CO_2	56.417 (0.000)		
Y	42.550 (0.038)		
Y^2	42.064 (0.043)		
A	56.228 (0.001)		
R	43.926 (0.028)		
FC	50.195 (0.006)		
U	69.851 (0.000)		

Note: The estimation is based on the null hypothesis of "no cross-section dependence" for the LM test, while "slope homogeneity" for Delta Tests.

After determining the existence of cross-sectional dependence for the sampled variables, we utilized the bootstrap-based unit root test by Smith et al., which controls for cross-sectional dependence. According to the unit root test results (Table 3), the null hypothesis of a unit root is accepted in the model with constant, and constant and trend with different significance levels. However, all the variables were stationary at first difference, therefore, it can be inferred that all variables exhibit *I(1)* process. The confirmation of *I(1)* integrational level requires the investigation of the existence of possible cointegration among variables.

Table 3. Smith et al. Bootstrap Unit Root Test Results

	Level		1st Difference	
	Constant	Trend +Constant	Constant	Trend + Constant
Variables	$\bar{t}$-Stat	$\bar{t}$-Stat	$\bar{t}$-Stat	$\bar{t}$-Stat
CO_2	-0.224 (0.998)	-2.086 (0.534)	-4.351 (0.000)	-4.616 (0.000)
Y	-1.366 (0.549)	-2.180 (0.418)	-3.183 (0.006)	-3.223 (0.000)
Y^2	-1.206 (0.651)	-2.146 (0.449)	-3.156 (0.008)	-3.223 (0.031)
A	-0.911 (0.901)	-1.853 (0.757)	-3.738 (0.000)	-3.857 (0.000)
R	-1.493 (0.506)	-2.486 (0.186)	-4.408 (0.000)	-4.376 (0.001)
FC	-0.485 (0.994)	-1.516 (0.956)	-3.798 (0.000)	-4.401 (0.000)
U	-1,182 (0.089)	-2.625 (0.153)	-2.459 (0.026)	-14.914 (0.023)

Note: The maximum lag-length was determined as k=2. Probability values were obtained based on 5,000 bootstrap replications shown in parenthesis (.).

The non-existence of cross-sectional dependence in the model makes first-generational panel data estimation methods feasible. Therefore, we investigated the possible cointegration relationship among variables by using the variance ratio-based cointegration method. According to the results presented in Table 4, the null hypothesis of "*no cointegration*" is rejected, therefore, it can be concluded that there exists a long-run cointegration relationship among variables.

Table 4: Variance Ratio-Based cointegration test Result

	Statistics
VR_g	-1.745 (0.040)

Note: The value in parenthesis (.) is the *p-value* for variance ratio-based cointegration test

After confirming the long-run relationship among the variables, we utilized FMOLS and MG estimators to estimate the long-run parameters and report the results in Table 5. According to both FMOLS and MG results, GDP per capita has a positive and statistically significant coefficient, while GDP per capita square has a negative and statistically significant coefficient. Thus, these findings confirm an inverted-U shaped relationship between economic growth and environmental degradation, thus, validating the EKC hypothesis. The existence of EKC confirms the results of Selden and Song (1994), Panayotou (1997), Ozturk and Acaravci (2010), Ozturk and Acaravci (2013), Tiwari et al. (2013), Apergis and Ozturk (2015), Shahbaz et al. (2015), Jebli et al. (2016), Sarkodie and Adams (2018), Pata (2018), Aslan et al. (2018), Danish et al. (2020). Based on the FMOLS and MG results, the turning point of the EKC is approximately US$ 62,692 and US$ 74,458, respectively. There are policy implications for the turning point of the EKC between US$ 62,692 and US$ 74,458. First, it can be said that the EKC mechanism works properly, and economic development may deteriorate environmental conditions at the early stage of development. After passing over the turning point of income level (US$ 62,692 and US$ 74,458), environmental pollution begins to decline with sustained economic development. Second, the turning point of income level is higher than the income level of eight countries in 2014, however, the income level of Ireland achieved the turning point in 2015 and outgrown in 2017.

Table 5: FMOLS Estimations for Transport-Induced EKC

Variables	FMOLS Results	MG Results
Y	32.564	22.302
	(0.001)	(0.044)
Y^2	-1.474	-0.994
	(0.001)	(0.058)
A	0.070	0.0642
	(0.000)	(0.111)
R	-0.041	-0.033
	(0.008)	(0.582)
FC	2.445	2.438
	(0.000)	(0.001)
U	-3.303	-3.312
	(0.000)	(0.002)

Note: Values in parenthesis (.) are the *p-values*

On one hand, the findings of the FMOLS estimator indicate that the airline industry has a positive and statistically significant effect, whereas the railway industry has a negative and statistically significant effect on environmental degradation. Consequently, a 1% increase in the number of airway passengers increases carbon dioxide emissions by 0.07%, while a 1% increase in the number of railway passengers decreases carbon emissions by 0.04%. In contrast, the MG estimation results reveal that the airline and railway industry have positive and negative coefficients, respectively, however, these findings are statistically insignificant. Schafer and Waitz (2014) emphasized that unintended consequences of the airline industry such as environmental degradation, noise are inevitable because is one of the fastest-growing industries. Chapman (Chapman) emphasized that the environmental effect of the airline industry is much more than only emitting CO_2, due to its effect at the upper atmosphere, which exacerbates the composition of the atmosphere. Shaw et al. emphasized that extending the use of the railway is an alternative option for reducing the pollutant effects of the airline industry. The Department for Transport of the UK (2004) reported that the empirical findings of airline and railway industries are in parallel with expectations.

The FMOLS and MG result further indicate that fossil fuel energy consumption has a statistically significant positive effect on environmental degradation. This empirically means that a 1% increase in fossil fuel energy consumption escalates CO_2 emissions by 2.44%. This confirms the existing results in the literature reported by Jebli et al. (2016), Sarkodie and Adams (2018), and Destek et al. (2018). The fossil fuel-led emissions can be attributed to the spread and dependence on fossil energy sources across the sampled countries. According to the 2014 World Bank data (World Bank, 2019), the average share of fossil fuels in the energy portfolio of the sampled countries was ~84.39%, while the share of renewable energy consumption was averaged at ~13.01% in the total energy consumption. Hence, the domination of fossil fuel consumption with little or no green input is one of the major inhibitors of environmental sustainability. Therefore, one of the main policy implications and concern is how to sustainably reduce fossil fuel energy consumption without hampering economic development in the sampled countries.

Urbanization has a statistically significant negative effect on CO_2 emissions, corroborating the results by Danish et al. (2020). It may be expected that a 1% increase in urbanization could approximately decrease CO_2 emissions by 3.3%. The reducing effect of urbanization may be related to the more effective implementation of emission mitigation and taxation policies in urbanized areas compared to the rural setting. It is reported that city-dwellers have more advantages to higher education which contributes to raising awareness on environmental issues and demand for a clean environment (Danish et al. 2020). The rising number of well-educated individuals may push the policymakers to take measures for extending cleaner activities, thus, structural change of the economy will step-up, and the composition effect of EKC will occur. In addition, cities are a source of R&D activities, innovation and technological advancement. It can, therefore, be expected that an increasing number of R&D activities on eco-friendly production technologies in cities may accelerate the structural change of economies, and it may help in the occurrence of the technique effect of EKC.

5. Conclusion

This present study stems from the need of most economies and government officials to decarbonize the economic growth trajectory from pollution emissions. This is consistent with the sustainable development goal (SDG) 7 and 11 of access to clean energy sources and mitigating greenhouse gas — climate change effect respectively. We focused on exploring the theme for top 10 air passenger carrier countries from 1995-2014. We applied a novel and robust panel estimation tools to achieve the aim of examining the framework of the EKC hypothesis. Contrary to previous attempts in previous studies, we augmented the theme by distinctively accounting for the role of both air and rail transportation.

The empirical results affirm the existence of the EKC phenomenon and confirmed fossil fuel energy consumption induced pollutant emissions for the examined period. Evidence from the study shows that air transportation engenders CO_2 emissions. The plausible explanation is connected to the prevalence and intense adoption of fossil fuel energy across the examined countries. The study demonstrated that economic growth is pollution-embedded. On the contrary, rail transportation and urbanization show potential to dampen the effect of CO_2 emissions. This suggests the consciousness of the urban population of the implication(s) of clean energy exploration as an alternative to a friendlier ecosystem. The mitigating effect of rail transportation could be credited to the electric-powered fuel source and less popularity compared to other forms of transportation.

Given the highlights of this study, the following policies are recommended:

(i) The positive significant nexus between emissions, fossil fuel consumption and growth implies a pollution-led economic development. Because a great part of the energy consumed is from traditional energy-intensive industries, optimization of energy consumption structures requires the adoption of renewable energy sources. From a policy standpoint, there is an urgent need to decentralize the use of fossil fuel energy to cleaner energy sources. This position has been promoted by Bekun et al. (2019a) for South Africa and a panel of European member countries (Bekun et al., 2019b). The crusade for cleaner energy stems from its friendliness to the ecosystem.

(ii) The transportation induced environmental degradation is a call to move to low-carbon fuel planes and carriers in the blocs investigated. There is also a need for administrators is intensify efforts into Research and development in more fuel-efficient airlines that are environmentally friendly.

Though there is a global interest to tighten environmental regulations and to reinforce the commitment of the transportation sector like aviation and the utilization of fossil fuel energy sources. The need to maintain the momentum of the conscious population of the inherent benefits and adverse effect of environmental issues is pertinent.

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Author Contribution

S.E: Conceptualization, Data curation, Formal analysis, Methodology, Software, Validation; Visualization; **F.F.A.:** Writing – original draft, **F.V.B:** Writing – original draft; and **S.A.S:** Funding Acquisition, Writing – original draft, Writing – review & editing.