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Testing the Transportation-induced Environmental Kuznets Curve Hypothesis: Evidence from Eight Developed and Developing Countries

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ABSTRACT

This paper focuses on the relationship between air transportation, economic growth, and carbon emissions in 8 developing and 8 developed countries during the period 1980-2013 by testing the Environmental Kuznets Curve (EKC) hypothesis. We use annual panel data from the World Bank in order to demonstrate environmental sensibility of both developed and developing countries. In this context, the research results demonstrate that environmental sensitivity is pretty low for both developed and developing countries in the period 1980-2000. Afterwards, the environmental issues of the two groups of countries are evaluated over the period from 2001 to 2013 and the research results indicate that their sensitiveness has increased remarkably, which supports the inverse-U shape of the EKC. These empirical results are also consistent with the Kyoto protocol's political aims and goals. In addition, based on the Johansen co-integration test results, there is a long-term stable relationship between as air transportation, CO_2 emissions, energy use, and gross domestic product for both developed and developing countries, with the exception of Colombia and Turkey.

Keywords: Transportation, Environmental Kuznets Curve Hypothesis, International Economics
JEL Classifications: L91, Q50, F10

1. INTRODUCTION

The transportation sector has generated atmospheric pollution and has damaged the environment. The vast majority of academic research reveals the connection between transportation, CO_2 emissions, and economic growth. In light of these facts, transportation- related CO_2 emissions have caused lots of concern among researchers globally due to their fast growth rates and the fact that carbon dioxide is the major greenhouse gas. Nowadays, the transportation sector contributes nearly 13% to total global greenhouse gas emissions, of which carbon dioxide emission is the biggest part. Since the beginning of the 1990s emissions from the air transportation sector have had the highest growth rates. They account for nearly 3.5% of all anthropogenic CO_2 emissions that contribute to global warming as a result of burning fossil fuel (approximately 0.3 giga-tons/year of carbon dioxide emissions).

Developing countries like Brazil have experienced increased amounts of carbon dioxide emissions driven by strong air transportation demand growth (Simões and Schaeffer, 2005).

A large number of researchers have made an effort to measure the relationship between energy consumption, environmental pollution, and economic growth. In this context, some authors (Lean and Smyth, 2010; Liu et al., 2011; Ong et al., 2012; Azlina et al., 2014) claim that transportation is one of the main contributors to energy consumption and carbon emissions through certain segments or sectors of the economy. Transportation facilities contribute to both economic growth (Pradhan and Bagchi, 2013) and total CO_2 emissions (Xu et al., 2016). Furthermore, expansion of the transportation network (railway, seaway, airway, and roadway) leads to increased levels of air pollution. A rise in the capacity of the transportation sector comes with increased demand for energy such as warehouse logistics, civil aviation, airway freight, cable transportation, human-powered transportation, animal-powered transportation, space transportation, ship transportation, rail, road, and off-road transportation (Chen and He, 2014; Chandran and Tang, 2013; Guo et al., 2010; Arvin et al., 2015).

Mirzaei and Bekri (2017) state that governments have responsibility and obligation to reduce carbon emissions from the air transportation sector. The constant growth in carbon emissions has brought up apprehension related to the sustainability of our world and how to attain a less polluted environment.

Global warming has caused concerns regarding sustainable development, which has economic implications and affects the overall environmental sensitivity in the world. Many countries, both developed and developing, have sought to promote the development of their air transportation sector to support economic recovery and sustainable economic development in the long-run (Chen 2015).

The empirical relationship between transportation, economic growth, and energy consumption has been comprehensively inspected in the academic literature of energy economics (Grossman and Krueger, 1995; Matus et al., 2008; Dargay et al., 2007; Ang, 2007; Zhang and Cheng, 2009; Menyah and Wolde-Rufael, 2010). However, the direction of causality among the variables is still not agreed upon, even though many academic researchers have verified the empirical link between air pollution and energy consumption.

In this context, the Environmental Kuznets Curve (EKC) hypothesis confirms the inverted-U relationship between environmental pollution and real income. Initially, both air pollution and gross domestic product (GDP) increase; however, the trend reverses beyond some level of income, so that at high income levels and GDP, environmental sensitivity is triggered. Such model was first proposed by Grossman and Krueger (1991) and the theory has been designated as the EKC by Panayotou (1993). In addition, the inverted-U hypothesis, founded by Kuznets (1955), states that income inequality rises in the early periods of evolution and decreases later on.

One of the most significant goals of this paper is to determine the existence of the EKC hypothesis- the relationship between real income growth and environmental pollution, which has been supported by a lot of academics (Hamit-Haggar, 2012; De Vita et al., 2015; Heidari et al., 2015; Zambrano-Monserrate et al., 2016; Al-Mulali et al., 2016; Keho, 2017). In fact, it would be expected that transportation development might have a positive effect on the increase in CO_2 emissions. The increasing volume of carbon emissions due to various types of transportation (car, ship, airplane, and train) has led to a significant increase in CO_2 emissions globally. There is a wide range of evidence regarding the correlation between CO_2 emissions and the volume of transportation in the academic literature (Al-Ghandoor et al., 2013; Lipscy and Schipper, 2013).

Air transportation is a very important sector given its large contribution to most countries' GDP, its consumption of goods and services, its role in environmental development, and the revenue it brings to national and international trade. It can also allow countries to improve their comparative economic advantage (Agbelie, 2014).

Our paper aims to contribute to the existing body of knowledge in the following ways. This research focuses on air transportation, economic growth, and environmental development and provides a literature review on the topic. The main questions of interest are whether air transportation activities enhance economic growth and if air transportation activities do increase energy use and CO_2 emissions. Although the causal relationship between economic growth and air transportation activity has been studied before, the core contribution of this study is to investigate this relationship combining it with the degree of energy use and CO_2 emissions. The remainder of the paper is organised as follows. Section 2 presents a brief literature review. Section 3 describes the data and the methodology of the paper. Section 4 discusses the empirical results, and concludes.

2. LITERATURE REVIEW

Economic growth has become imperative for all countries in order to promote transportation development. GDP is a general indicator used to measure economic growth. Transportation significantly contributes to economic growth necessary to achieve national and international socio-economic development goals. Transportation activities contributes to economic growth both directly and indirectly (Arvin et al., 2015).

A vast number of studies address environmental and economic development and provide empirical evidence. Academic researchers have increasingly focused on GDP and CO_2 emissions in many countries by using different types of empirical models. However, air transportation development has not been considered as a variable in econometrical models. Recent studies that examine the effects of economic growth on environmental and sea transportation development are discussed below.

Chen (2015) states that the international economic crisis brought to China the great opportunity to transform its resources-driven expansive model to an ecological development model. Economic growth may play a crucial role in explaining environmental development. Tamazian et al. (2009) find that economic development affects environmental quality in the BRIC economies. Economic development reduces environmental degradation at higher levels of economic growth.

Behera and Dash (2017) addresses the issues of the long-run relationship between CO_2 emissions, primary energy consumption, fossil fuel energy consumption, urbanisation, and foreign direct investment FDI by implementing the Pedroni and Westerlund co-integration tests in 17 high and middle-income countries over the period 1980-2013. The results show that primary energy and fossil fuel energy consumption, and FDI are essentially producing.

CO_2 emissions which destroy environmental quality and the atmosphere. Similarly, the study undertaken by Charfeddine and Khediri (2015) explores the relationship between CO_2 emissions, economic growth, electricity consumption, financial development, urbanisation, and trade openness.

Arvin et al. (2015) find that there is unidirectional causality from economic growth towards both CO_2 emissions and urbanisation. It propounded that passenger carriage intensity should be advanced in the developing countries within the G-20 in order to propel economic growth. Gaspara et al. (2017) compare a sustainable development approach with the traditional economic growth approach and their relationship with energy consumption. The paper concludes that GDP growth is not completely dependent on energy consumption, but an increase in GDP results in higher energy consumption. Amri (2017) examines the short and long-term relationship between renewable and non-renewable energy in terms of GDP and capital flow in Algeria in order to comprehend the Granger causality directions. There is a unidirectional long-term impact of renewable alternative energy sources on economic growth and there is no short-term causality between alternative energy sources and both capital flows and GDP. However, Ozturk and Acaravci (2013) demonstrate that carbon emissions and financial development have no remarkable effect on per capita CO_2 emissions in the long-term. There is a proof of a short-term unidirectional causal relationship from financial growth towards per capital energy usage, per capital real income, and the square root of per capita real income.

Iamsiraroj (2016) indicates that foreign direct investment is associated with higher rates of economic growth. Foreign direct investment improves economic growth and growth attracts FDI inflows, which in turn encourages growth further. Chen (2015) states that China has faced a rapid growth process before the 1990s; subsequently, it has tried to enhance its ecological development performance from 1999 to 2002. Besides, China turned its Electronic Data Interchange progress after 2003, reduced it to a lower level in 2007, and reinitiated ecological economic transition in recent years. The study uses panel data for 31 Chinese provinces covering the period 1985-2012, using variables such as labor force, energy consumption, intermediate inputs, actual total factor productivity, gross output value, waste water, waste gas, and capital stock.

Mazzarino (2000) investigates energy consumption and carbon emissions in Italy's transportation sector between 1980 and 1995, implementing a comparative static approach. His results point out that GDP growth is the main factor causing the variation in carbon dioxide emissions in Italy.

Ito (2016) analyses the linkage between CO2 emissions, renewable and non-renewable energy consumption, and economic growth. The results show that non-renewable energy has negative direct effect on economic growth in developing countries. However, there is positive relationship between renewable energy use and economic growth in the long-run.

Schandl et al. (2016) state that the achievement of national and international socio-economic development goals contribute significantly to economic growth and environmental development Therefore, to quantify the benefits of an air transportation infrastructure project, one needs to understand the direct costs in a socioeconomic and environmental context. Air transportation activities can contribute to economic growth both directly and indirectly. On the other hand, air transportation significantly increases energy use and carbon dioxide emissions in many countries globally. Air transportation's economic benefits are generally best evaluated in long-term planning.

Li et al. (2016) intend to address several important solutions for transportation. First of all, governments can regulate private vehicle ownership in order to reduce total CO_2 emissions. Secondly, stricter energy use standards can help develop energy efficiency in China's transportation sector.

Idrisov et al. (2016) point out that, in order to reduce the effects of Russia's terms of trade volatility on its economic growth, structural reforms are obligatory and diversification of international trade is required for sustainable economic development.

Mishalani et al. (2014) analysed CO_2 emissions variables in 146 urbanised areas in the United States. The results explain that population density has a considerable impact on transportation-related CO_2 emissions. Sghari and Hammami (2016) research how economic growth, energy use, and carbon emissions are related in the long-run and provide some proof of inefficient energy use in Tunisia since environmental pressure tends to increase faster than economic growth. Energy and environmental policies in developed and developing countries have increasingly focused on the air transportation sector. Nevertheless, the movement of goods between individual countries has increased at the rate of economic growth, leading to higher energy use and carbon emissions from sea transportation.

Jiang et al. (2017) conclude that transportation investment in China has had a positive effect on economic growth, which is clearly different at the national level and up-country level. Air transportation involves different types of facilities such as total fleet, oil tankers, bulk carriers, general cargo, container ships, and other types of ships. The fact that air transportation is vital to the smooth operation of international trade has been widely debated by both academic and policy perspectives. Lee et al. (2017) suggest that energy conservation and low-emission technology have an important role to catalyse the shift towards economic growth. Zhang (2011) emphasises that China's economic development contributes significantly to the increase in carbon emissions and China's FDI has the least effect on carbon emissions due to its relatively small volume compared to GDP. Some studies find a negative relationship between economic growth and environmental development, while on the contrary; other studies find evidence of environmental development's positive effect on GDP growth.

3. DATA AND METHODOLOGY

This study uses annual carbon dioxide emissions (kt), energy use (E) (kt of oil equivalent), GDP at market prices (current

US$), and road and rail transportation data for the period between 1980 and 2013 in Turkey. The data was collected from the official website of the World Bank (2017) and the OECD (2017). The empirical estimation (panel data analysis) includes 16 countries, 8 developing countries (Argentina, Brazil, Bulgaria, Colombia, Mexico, Turkey, Venezuela, and Greece) and 8 developed countries (Canada, Finland, France, Italy, Netherlands, Spain, UK, and the USA). The dataset is split into 2 periods- from 1980 to 2000, and from 2001 to 2013. The main reason of splitting the data into two periods is to demonstrate the EKC hypothesis and test the Kyoto Protocol's political results and its influence. In this study, economic growth, environmental factors such as CO_2 emissions, and energy use are considered as the independent variables, and air transportation development is the dependent variable.

Baltagi (2004) indicates that panel data analysis takes into account both fixed and random effects. In order to determine the type of effect, the Hausman statistical test has to be performed. Based on the test's results performed on the developed countries between 1980 and 2000, the fixed-effects test is chosen ($P < 0.05$, Table 1). Thus, there is a long-term relationship between GDP, energy use, CO_2 emissions, and air transportation. The test results also indicate that developed countries' environmental consciousness is too low during the 1980-2000 period (Table 1). However, developed countries have concentrated more on environmental awareness rather than production output and export capacity between 2001 and 2013 (Table 1).

These empirical findings are consistent with the EKC hypothesis which demonstrates an inverted-U shape. From 1980 to 2000, CO_2 emissions were rising and after the breakeven point, energy use and CO_2 emissions started decreasing. However, as a result, production capacity has been declining as well. The Kyoto Protocol was established to reduce greenhouse gas emissions and the results of the panel data analysis (Table 2) show that after signing the agreement, developed countries started taking into account environmental sensitivity much more seriously.

A panel data model was implemented by performing a pooled OLS. The Hausman test was performed to confirm whether fixed or random effects are present in the series. The test determines infringement of the random effects test that the illustrative parameters are orthogonal to the unit effects. Since the resulting $P < 0.05$ (Table 3), the null hypothesis H_0 is rejected and a fixed-effects model is utilised. The test results demonstrate that as long as air transportation is growing, the developed countries' sensitivity

Table 1: Developed countries cross section random-effects test results

Hausman test-developed countries for 1980-2000				
Test results	**Chi-square statistic**		**Chi-square d.f.**	**P**
Cross-section random	11.115.022		3	0.0111
Cross-section fixed effects test comparisons				
Variable	**Fixed**	**Random**	**Var. (Diff.)**	**P**
GDP?	5761.866	5199.9291	60034.1115	0.0218
ENRGY?	−58754.45	−43813.77	42395923.43	0.0218
CO_2?	11902279.6	14200666.5	758874674585.7	0.0083
Hausman test-developed countries for 2001-2013				
Test results	**Chi-square statistic**		**Chi-square d.f.**	**P**
Cross-section random	1.137077	3		0.7681
Cross-section random effects test comparisons				
Variable	**Fixed**	**Random**	**Var (Diff.)**	**P**
GDP?	7672.177492	10788.0676	51636227.96	0.6646
ENRGY?	−696475.359	−37005.1451	788498710788	0.4577
CO_2?	159722091.7	19231304.9	6908864517619	0.5930

Table 2: Pooled panel data regression results

Dependent variable: Air_trns, total pool observations: 168				
Variable	**Coefficient**	**SE**	**t-Statistic**	**P**
Constant	120902966	54668907	2.211549	0.0284
GDP	5761.866	729.5560	7.897771	0.0000
Energy_use	58754.45	15592.33	3.768164	0.0002
CO_2	11902280	4592203.0	2.591845	0.0104
Effects specifications				
Cross-section fixed (dummy variables)				
R^2		0.953018		
Adjusted R^2		0.950026	Mean dependent variable	76548264
S.E. of regression		33623245	S.D. dependent variable	150406596
Sum squared resid		1.77492	Akaike info criterion	37.56257
Log likelihood		3144256	Schwarz criterion	37.76711
F-statistic		318.4727	H/Q criteria	37.64558
P (F-statistic)		0	Durbin-Watson statistic	0.164655

Table 3: Developed countries cross-sectional random-effects test results

Hausman test-developing countries for 1980-2000				
Test results	**Chi-square statistic**		**Chi-square d.f.**	**P**
Cross-section random	14.281213		3	0.0025
Cross-section fixed effects test comparisons				
Variable	**Fixed**	**Random**	**Var (diff.)**	**P**
GDP?	340.706001	293.590562	459.380476	0.0279
ENRGY?	−0.000098	−0.000077	0.000000	0.0014
CO_2?	856137.6342	543657.633	8737008124.16	0.0008
Hausman test-developing countries for 2001-2013				
Test results	**Chi-square statistic**		**Chi-square d.f.**	**P**
Cross-section random	19.437480		3	0.0002
Cross-section fixed effects test comparisons				
Variable	**Fixed**	**Random**	**Var (Diff.)**	**P**
GDP?	911.205954	1312.23569	32746.649812	0.0267
ENRGY?	41305.19144	19270.7608	94828661.0751	0.0237
CO_2?	−2517805.87	−4247142.25	3409961533499	0.3490

towards the environment is extremely low due to the high CO_2 emissions and energy consumption in the period 1980-2000.

As already indicated, air transportation is the dependent variable and GDP, CO_2 emissions, and energy consumption are the independent variables. The pooled regression results are displayed in Table 2. The $R^2 = 0.95$, which implies that 95% of environmental sensitivity can be explained by these four variables. Besides, the coefficient forecasts both random and fixed effects and ensure more support. The probability demonstrates the rejection of the hypothesis. Therefore, the least square dummy variable for the provided series is conducted. F = 318.47 and the probability of F is 0. In this way, the H_0 is rejected and factors of sensibility towards environment are not owing to random chances, rather it can be clarified by the relevant test.

Developed countries' environmental sensitivity has increased significantly between 2000 and 2013 and the panel data model empirically supports this finding. The correlation between air transportation, GDP, CO_2 emissions, and energy consumption is very low. The P values for GDP, energy consumption, and CO_2 emissions are 0.6646, 0.4577, and 0.5990, respectively in Table 1. The research results confirm that developed countries' environmental consciousness increased considerably in the second estimation period 2000-2013.

Table 2 shows that the coefficient of the energy use variable is negative. Besides, the estimated coefficients for energy use and GDP are significant at the 1% level. The result of the pooled panel data regression demonstrates that GDP, CO_2, and energy consumption influence air transportation.

$$ln\,(CO_2)_t = \alpha_0 + \alpha_1\, ln\,(GDP)_t + \alpha_2\, ln\,(EC)_t + e_t \quad (1)$$

α_0, α_1, α_2 are the estimated parameters, t is the time index, and e is the error term.

$$ln\,(CO_2)_t = \alpha_0 + \alpha_1\, ln\,(GDP)_t + \alpha_2\, ln\,(Air\_trns)_t + \alpha_3\, ln\,(EC)_t + e_t \quad (2)$$

α_0, α_1, α_2, α_3 are the estimated parameters, t is the time index, and e is the error term.

Two separate models are estimated in the study. The first one contains the CO_2 emissions, GDP, and energy consumption variables, and the second model- the CO_2 emissions, GDP, air transportation, and the energy consumption variables. The two models are used to determine the co-integration and causal relationships between the variables.

The ADF unit root test (which has accounted for the Akaike Information Criterion [AIC]) is applied to the air transportation, CO_2 emissions, energy use, and GDP variables to test for stability. The maximum lag length is determined to be 2 as per Serena and Perron's (2001) recommendation.

The developed countries ADF unit root test shows that the series are not stationary. A standard process to convert non- stationary to stationary series is taking the first difference of the series (Tables 4 and 5). The Johansen cointegration test is used to test the long-term stable relationship between air transportation, CO_2 emissions, energy use, and GDP.

The ADF unit root test (which has accounted for the AIC) is applied to the air transportation, CO_2 emissions, energy use, and GDP variables to test for stability. The maximum lag length is determined to be 2 as per Serena and Perron's (2001) recommendation.

The developing countries ADF unit root test also shows that the series are not stationary. Similar to the developed countries, taking first difference of the series converts them to stationary series (Tables 4 and 5). Based on the Johansen co-integration test results, both developed and developing countries exhibit a long-term stable relationship between the variables, with the exception of Colombia and Turkey (Tables 6 and 7).

The UK and Bulgaria are selected for both variance decomposition and impulse response analysis to reveal the impact of GDP, CO2 emissions, and energy use on air transportation. We use the VAR model to capture the linear interdependence between the four variables GDP, CO2 emissions, air transportation, and energy use for both countries. The lag order is 2. After using the inverse roots of

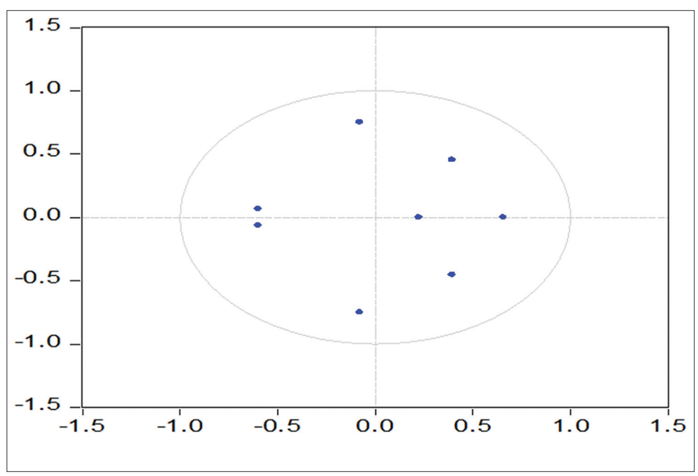
Table 4: Developed countries ADF unit root test results, 1980-2013

Countries	Variables	Series at I (0)	After converting from I (0) to I (1)
		t-stat/crit-val %5/P val	t-stat/crit-val %5/P val
	GDP	0.91/−2.95/0.9945	−5.86/−2.96/0.0000
Canada	*Air_trns*	2.10/−2.96/0.9998	−5.86/−2.96/0.0000
	CO_2	−0.95/−2.95/0.7572	−4.42/−2.95/0.0014
	Energy_Use	−1.30/−2.95/0.6162	−4.22/−2.95/0.0023
Finland	*GDP*	−0.33/−2.95/0.9094	−4.59/−2.95/0.0009
	Air_trns	0.48/−2.95/0.9836	−5.38/−2.95/0.0001
	CO_2	−2.82/−2.95/0.0656	−6.03/−2.95/0.0000
	Energy_Use	−1.61/−2.95/0.4633	−6.71/−2.95/0.0000
France	*GDP*	−0.18/−2.95/0.9308	−4.86/−2.95/0.0004
	Air_trns	−0.62/−2.95/0.8525	−4.95/−2.95/0.0003
	CO_2	−2.74/−2.95/0.0777	−7.23/−2.95/0.0000
	Energy_Use	−1.58/−2.95/0.4810	−6.67/−2.95/0.0000
Italy	*GDP*	−0.75/−2.95/0.8199	−4.70/−2.95/0.0006
	Air_trns	−1.65/−2.95/0.4419	−7.11/−2.95/0.0000
	CO_2	−0.62/−2.95/0.8523	−3.39/−2.95/0.0187
	Energy_Use	−1.24/−2.95/0.6441	−4.15/−2.95/0.0028
Netherlands	*GDP*	0.01/−2.95/0.9531	−4.77/−2.95/0.0005
	Air_trns	−0.78/−2.95/0.9922	−5.69/−2.95/0.0000
	CO_2	1.19/−2.95/0.9974	−6.19/−2.95/0.0000
	Energy_Use	−1.65/−2.95/0.4434	−6.39/−2.95/0.0000
Spain	*GDP*	−0.42/−2.95/0.8938	−4.06/−2.95/0.0036
	Air_trns	−0.62/−2.95/0.8508	−4.80/−2.95/0.0005
	CO_2	−1.17/−2.95/0.6720	−3.77/−2.95/0.0074
	Energy_Use	−1.51/−2.95/0.5115	−3.00/−2.95/0.0452
UK	*GDP*	−0.39/−2.95/0.8995	−4.62/−2.96/0.0008
	Air_trns	1.06/−2.95/0.9963	−4.59/−2.96/0.0009
	CO_2	1.19/−2.95/0.9974	−8.41/−2.95/0.0000
	Energy_Use	−1.38/−2.96/0.5742	−6.60/−2.96/0.0000
USA	*GDP*	0.32/−2.95/0.9759	−3.74/−2.95/0.0080
	Air_trns	−1.09/−2.95/0.7077	−4.64/−2.95/0.0008
	CO_2	−0.65/−2.95/0.8450	−4.65/−2.95/0.0008
	Energy_Use	−0.94/−2.95/0.7600	−4.72/−2.95/0.0006

the characteristic AR polynomial, all the roots lie inside the unit circle. Thus, the VAR model is stationary (Figure 1). We also perform variance decomposition and impulse response analysis on the data. The impulse response model is used to test the tenor of the relationships between the relevant variables. The results demonstrate that GDP has the strongest impact on air transportation compared to energy consumption and CO2 emissions in the UK (Table 8). The variance decomposition results confirm the impulse response analysis (Table 8 and Figure 2). The empirical findings indicate that the UK government's sensitivity towards the environment is too high. The GDP variable is more significant compared to the other parameters such as CO2 emissions and energy consumption.

We use the VAR model for Bulgaria, similar to the case for the UK. After using the inverse roots of the characteristic AR polynomial, all the roots lie inside the unit circle. Thus the VAR model is stationary (Figure 3). The empirical findings indicate that energy use has the strongest impact on air transportation compared to CO_2 emissions and GDP (Table 9). Variance decomposition also confirms the results of the impulse response analysis (Table 9 and Figure 3). The empirical findings indicate that the Bulgarian government should concentrate more on alternative energy resources, such as solar and wind power, to decrease the level of CO_2 emissions while increasing GDP (Figure 4).

Figure 1: Inverse roots of AR characteristic polynomial (VAR) analysis for the UK



4. CONCLUSION

While most empirical studies have concentrated on the connection between economic growth and environmental development, the relationship between energy use, carbon emissions, and economic development is a relatively new research area and there is a lack of empirical analysis on this subject. This research paper addresses

Table 5: Developing countries ADF unit root test results, 1980 to 2013

Countries	Variables	Series at I (0)	After converting from I (0) to I (1)
		t-stat/crit-val %5/P val	t-stat/crit-val %5/P val
Argentina	*GDP*	0.03/−2.95/0.9551	−4.83/−2.95/0.0005
	Air_trns	−0.37/−2.95/0.9029	−5.25/−2.95/0.0001
	CO_2	−0.95/−2.95/0.7574	−4.77/−2.95/0.0005
	Energy_Use	−0.27/−2.95/0.9181	−5.84/−2.95/0.0000
Brazil	*GDP*	0.76/−2.95/0.9919	−4.37/−2.95/0.0016
	Air_trns	3.84/−2.98/1.0000	−3.73/−2.98/0.0095
	CO_2	1.49/−2.95/0.9990	−5.17/−2.95/0.0002
	Energy_Use	3.95/−2.98/1.0000	−6.31/−2.95/0.0000
Bulgaria	*GDP*	0.85/−2.95/0.9935	−4.46/−2.95/0.0012
	Air_trns	−1.47/−2.95/0.5318	−5.44/−2.95/0.0001
	CO_2	−1.03/−2.95/0.7291	−5.79/−2.95/0.0000
	Energy_Use	−1.15/−2.95/0.6811	−4.40/−2.95/0.0014
Colombia	*GDP*	2.90/−2.95/1.0000	−3.73/−2.95/0.0082
	Air_trns	5.10/−2.95/1.0000	−7.41/−2.97/0.0000
	CO_2	−7.10/−2.96/0.0000	−7.68/−2.97/0.0000
	Energy_Use	−1.63/−2.95/0.4553	−6.10/−2.95/0.0000
Mexico	*GDP*	−0.12/−2.95/0.9384	−5.54/−2.96/0.0001
	Air_trns	−0.20/−2.95/0.9284	−7.04/−2.95/0.0000
	CO_2	−3.75/−2.95/0.0076	−8.48/−2.95/0.0000
	Energy_Use	−1.69/−2.95/0.4258	−6.95/−2.95/0.0000
Turkey	*GDP*	0.67/−2.95/0.9896	−5.94/−2.95/0.0000
	Air_trns	9.35/−2.95/1.0000	−8.26/−2.96/0.0000
	CO_2	−0.82/−2.95/0.7997	−−5.99/−2.95/0.0000
	Energy_Use	−0.04/−2.95/0.9470	−5.98/−2.95/0.0000
Venezuela	*GDP*	0.27/−2.95/0.9733	−2.48/−2.96/0.1279
	Air_trns	−3.07/−2.95/0.0386	−5.31/−2.96/0.0001
	CO_2	−3.04/−2.95/0.0411	−6.46/−2.96/0.0000
	Energy_Use	−0.98/−2.95/0.7454	−13.66/−2.95/0.0000
Greece	*GDP*	−2.18/−2.95/0.2141	−4.15/−2.95/0.0028
	Air_trns	−1.56/−2.95/0.4895	−5.89/−2.96/0.0000
	CO_2	−1.83/−2.95/0.3564	−5.42/−2.95/0.0001
	Energy_Use	−0.63/−2.95/0.8499	−5.60/−2.95/0.0001

Figure 2: Impulse response analysis for the UK, 1980-2013

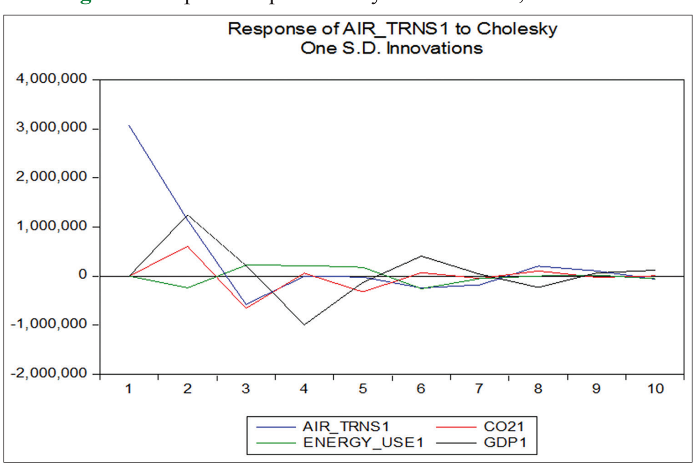
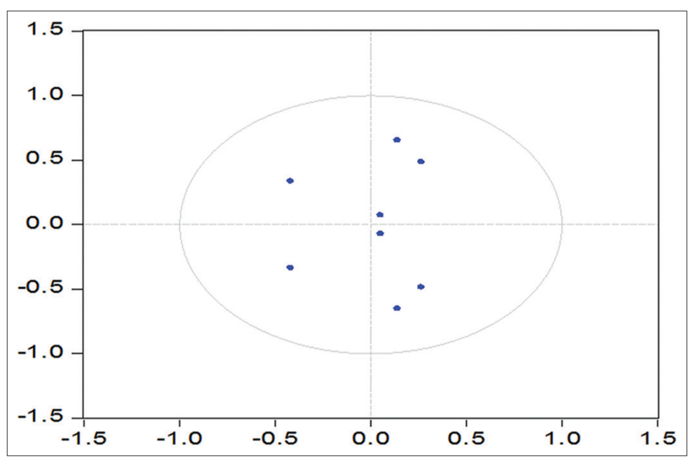


Figure 3: Inverse roots of AR characteristic polynomial (VAR) analysis for Bulgaria



the impact of economic growth, environmental development, CO_2 emissions, and energy use on air transportation.

We apply panel data analysis to 16 countries, covering 2 time periods- from 1980 to 2000 and from 2001 to 2013. The main reason to divide the data into two periods is to demonstrate the EKC hypothesis and to test the Kyoto Protocol's political results and its influence. According to the empirical results, between 1980 and 2000, CO_2 emissions, energy use, GDP, and air transportation were correlated considerably. However, between 2000 and 2013, the coefficient of correlation decreased dramatically which implies the objective of the Kyoto Protocol was achieved. The empirical results confirm that there is co-integration among the variables considered in this study. Existing studies have mainly examined the effects of energy use, carbon emissions, and economic growth on air transportation. Air transportation energy use and the associated carbon emissions have increased faster in developing

Table 6: Developed countries Johansen co-integration test results, 1980 to 2013

Countries	Hypothesis	Eigenvalue	Trace statistics	0.05 critical value	P value
Canada	r=0	0.734595	85.55693	47.85613	0.0000
	r=1, r≥1	0.502648	44.43551	29.79707	0.0005
	r=2, r≥2	0.383431	22.78332	15.49471	0.0033
	r=3, r≥3	0.222259	7.792204	3.841466	0.0052
Finland	r=0	0.629691	70.30381	47.85613	0.0001
	r=1, r≥1	0.459045	39.50789	29.79707	0.0028
	r=2, r≥2	0.312913	20.46092	15.49471	0.0082
	r=3, r≥3	0.247787	8.826793	3.841466	0.0030
France	r = 0	0.624182	61.95192	47.85613	0.0014
	r=1, r≥1	0.398491	31.61377	29.79707	0.0305
	r=2, r≥2	0.304642	15.85605	15.49471	0.0441
	r=3, r≥3	0.137704	4.592867	3.841466	0.0321
Italy	r=0	0.697204	76.91772	47.85613	0.0000
	r=1, r≥1	0.553029	39.88218	29.79707	0.0025
	r=2, r≥2	0.286900	14.91911	15.49471	0.0609
	r=3, r≥3	0.133356	4.436947	3.841466	0.0352
Nether Lands	r=1, r≥1	0.551625	42.10276	29.79707	0.0012
	r=2, r≥2	0.363208	17.23689	15.49471	0.0271
	r=3, r≥3	0.099421	3.246238	3.841466	0.0716
Spain	r=0	0.634209	59.40495	47.85613	0.0029
	r=1, r≥1	0.366831	28.22843	29.79707	0.0750
	r=2, r≥2	0.259179	14.06087	15.49471	0.0813
	r=3, r≥3	0.142368	4.760987	3.841466	0.0291
UK	r=0	0.620921	64.76391	47.85613	0.0006
	r=1, r≥1	0.436541	34.69359	29.79707	0.0126
	r=2, r≥2	0.314333	16.91009	15.49471	0.0304
	r=3, r≥3	0.154751	5.211827	3.841466	0.0224
USA	r=0	0.670231	75.10989	47.85613	0.0000
	r=1, r≥1	0.468280	40.71965	29.79707	0.0019
	r=2, r≥2	0.351236	21.13885	15.49471	0.0063
	r=3, r≥3	0.220586	7.725596	3.841466	0.0054

Table 7: Developing countries Johansen co-integration test results, 1980-2013

Countries	Hypothesis	Eigenvalue	Trace statistics	0.05 critical value	P value
Argentina	r=0	0.573162	57.62989	47.85613	0.0046
	r=1, r≥1	0.429077	31.23798	29.79707	0.0339
	r=2, r≥2	0.287078	13.86247	15.49471	0.0868
	r=3, r≥3	0.103084	3.372593	3.841466	0.0663
Brazil	r=0	0.461357	47.49711	47.85613	0.054
	r=1, r≥1	0.347979	28.31732	29.79707	0.0733
	r=2, r≥2	0.292646	15.05929	15.49471	0.0581
	r=3, r≥3	0.130259	4.326361	3.841466	0.0375
Bulgaria	r=0	0.787007	93.16948	47.85613	0.0000
	r=1, r≥1	0.482559	45.22815	29.79707	0.0004
	r=2, r≥2	0.377704	24.80349	15.49471	0.0015
	r=3, r≥3	0.278031	10.09898	3.841466	0.0015
Colombia	r=0	0.611943	56.01625	47.85613	0.0071
	r=1, r≥1	0.431406	26.67155	29.79707	0.1099
	r=2, r≥2	0.220532	9.169288	15.49471	0.35
	r=3, r≥3	0.045569	1.445845	3.841466	0.2292
Mexico	r=1, r≥1	0.526981	55.39916	29.79707	0.0000
	r=2, r≥2	0.462266	32.19197	15.49471	0.0001
	r=3, r≥3	0.341677	12.95982	3.841466	0.0003
Turkey	r=0	0.669353	67.23879	47.85613	0.0003
	r=1, r≥1	0.490537	32.93102	29.79707	0.0211
	r=2, r≥2	0.320692	12.02466	15.49471	0.1557
	r=3, r≥3	0.001211	0.037573	3.841466	0.8463
Venezuela	r=0	0.748174	93.43166	47.85613	0.0000
	r=1, r≥1	0.665213	50.68209	29.79707	0.0001
	r=2, r≥2	0.297912	16.75999	15.49471	0.0321
	r=3, r≥3	0.170514	5.79542	3.841466	0.0161
Greece	r=0	0.659201	63.58185	47.85613	0.0009
	r=1, r≥1	0.371715	30.21153	29.79707	0.0448
	r=2, r≥2	0.293573	15.80394	15.49471	0.0449
	r=3, r≥3	0.149787	5.030316	3.841466	0.0249

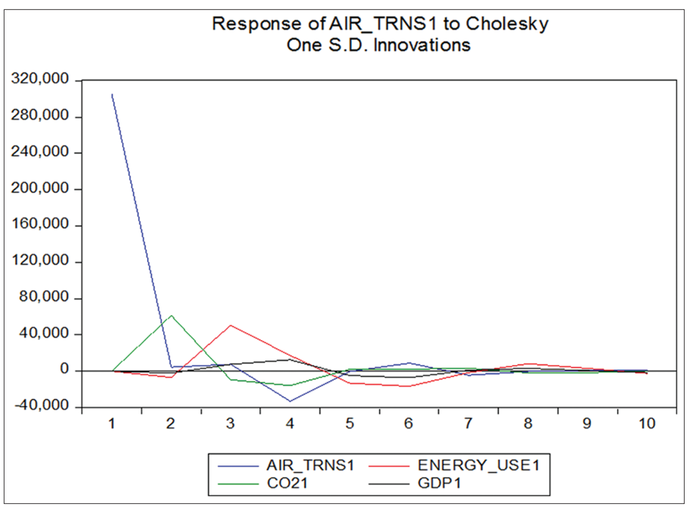
Table 8: Variance decomposition for the UK, 1980-2013

Prd	S.E.	AIR_TRNS	CO_2	ENERGY USE	GDP
1	3067510	100.0000	0.000000	0.000000	0.000000
2	3564627	84.36315	2.915320	0.446183	12.27535
3	3682277	81.48324	5.892704	0.782367	11.84169
4	3819511	75.73314	5.502024	1.055402	17.70943
5	3839207	74.95996	6.137760	1.262632	17.63964
6	3877567	73.86524	6.050282	1.669402	18.41507
7	3882320	73.89010	6.048687	1.680742	18.38047
8	3895839	73.65164	6.082924	1.669223	18.59621
9	3897924	73.64558	6.079360	1.670351	18.60471
10	3900616	73.56664	6.071300	1.685534	18.67652

Table 9: Variance decomposition for Bulgaria, 1980-2013

Prd	S.E.	AIR_TRNS	CO_2	ENERGY USE	GDP
1	305354.5	100.0000	0.000000	0.000000	0.000000
2	311590.0	96.05862	0.048013	3.889572	0.003800
3	316010.4	93.44845	2.618321	3.870755	0.062473
4	318847.7	92.86551	2.870260	4.047142	0.217086
5	319162.9	92.68223	3.035064	4.043616	0.239092
6	319809.6	92.38616	3.292845	4.032562	0.288432
7	319862.6	92.37460	3.293792	4.041853	0.289754
8	319988.3	92.30215	3.357193	4.041702	0.298957
9	320010.2	92.29041	3.366249	4.043847	0.299490
10	320023.9	92.28390	3.371087	4.043821	0.301193

Figure 4: Impulse response analysis for Bulgaria, 1980-2013



countries. Given the latest trends, the ability to decrease carbon emissions from air transportation does not seem encouraging. By developing air transportation sector, these countries will reduce their CO_2 emissions and ensure better environmental quality and sustainable development. They should move more towards green and intelligent urbanisation such as clean and intelligent air transportation systems.

The findings indicate that there exists a unidirectional causality from economic growth towards energy use and CO_2 emissions in the studied countries. These results concur with the findings of two previous studies on the relationship between air transportation and GDP. This research also confirms the causal relationships between CO_2 emissions and economic growth. Economic growth acts as an important driver leading to air transportation increase, which should be taken into account when environmental application is projected. Governments could also encourage research and development in air transportation eco-friendly technologies.

The study is applicable not only to the 16 countries studied here, but can be used to test the relationship between economic growth and environmental development for all countries globally. Due to limited data availability, the results in this paper can be expanded further in the future.

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