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Research paper

Generation of energy and environmental-economic growth consequences: Is there any difference across transition economies?

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ABSTRACT

One of the European Union's (EU) membership conditions includes an ambitious energy policy objective such as energy security, environmental protection and diversification using renewables. However, the impact of the energy policy on environmental sustainability is yet to be assessed. In line with EU energy policy, we investigate the nexus between energy generation and CO_2 emissions in three blocs of countries namely Central and Eastern Europe (CEE), Commonwealth of Independent States (CIS) and New Member States (NMS) from 1992–2014. The experimental exercise was conducted using the Generalized Method of Moment. The empirical results show that a 1% increase in renewable energy generation increases CO_2 emissions in CIS countries by 0.04% and CEE countries by 0.02% respectively, but decreases CO_2 emissions by 0.02% in NMS countries. Both subsamples of NMS and CIS countries conform to the inverted U-shape of the EKC hypothesis. However, the results of the subsample of CEE countries do not uphold the EKC hypothesis. This, suggests that environmental consequences of sustained economic growth in CEE countries does not increase pollutant emissions. Thus, we conclude that there exists a difference in the level of environmental degradation across the blocs. This study highlights the need to embark on decarbonized economic agenda that prioritizes clean environment.

1. Introduction

The rise in the demand for energy worldwide is an affirmation to the supposition that, energy is the engine of growth in this 21st century (Ozcan and Ozturk, 2019). In addition to urbanization, population explosion is another reason that underpins the high demand for energy and its related services (Feng et al., 2018; Chu et al., 2017). Albeit the positive effects of growth in the form of employment, poverty reduction and rising standards of living, economic growth is adjudged as a driver of CO_2 emissions and natural resource depletion (Mardani et al., 2019). Fossil fuels are largely the energy source used in powering economic development that negates environmental sustainability through CO_2 emissions (Owusu and Asumadu, 2016; Nathaniel and Nathaniel, 2019).

Pata (2018) and Hanif et al. (2019) opine that by using fossil fuels to power the world economies, a wide range of negative externalities abounds. These externalities include toxic gas emissions, natural resource depletion, air pollution, wildlife endangerment, and global warming. This has put humanity in a tripartite problem of Energy, Environment and Economy (3Es). Thus, in energy-intensive based economy, the fundamental question is whether trade-off exists between achieving growth and environmental sustainability. Conserving the environment is a vital natural capital to humanity, therefore, requires environmentally friendly and sustainable productivity. Protecting the environment against the negative externalities of CO_2 emissions is paramount and underscores the UN's SDGs of food security, poverty eradication, among others are hinged on the natural capital of the earth (Sarkodie and Strezov, 2018).

An aspect of the current dialog on sustainability involves the use of alternative energy sources as a means to mitigate the environmental impact of CO_2 emissions while satisfying the energy needs for economic growth (Apergis and Payne, 2010a). Notwithstanding, the positive contribution of energy in deriving growth of global economies has negative effects of natural resource depletion and environmental degradation that are

Abbreviations: NMS, New Member States; CEE, Central and Eastern Europe; CIS, Commonwealth of Independent States; EKC, Environmental Kuznets Curve

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costly to ignore. To solve this trilemma calls for an economic blueprint that guarantees a healthy and wealthy world (Zaman and Moemen, 2017).

The economically and technologically developed countries have over the years exerted effort to shift from fossil fuel consumption to green energy. This decision has motivated developing economies to join the crusade of a green environment following the Kyoto Protocol of 1997. This is a UN treaty legally binding 192 advanced, emerging markets and developing economies, with the sole objective of reducing the global level of CO_2 emissions (Kivyiro and Arminen, 2014).

The emerging markets, sometimes called transition economies refer to countries that are undergoing a fundamental structural change from socialism to capitalist economies. According to Zugravu and Millock (2008), two factors have contributed to improving the environmental quality of the transition economies. First, the expansion of productive activities of the economies geared by changes in industrial production. This is plausible because the transition to full-blown market economies must ensure a sustainable growth model such as energy security. This means that apart from renewables, conventional forms of energy cannot guarantee energy security hinged on sustainable growth effect.

Second, improvements in environmental quality require reforms in environmental policies and regulation because of the democratization of the economies. Thus, democratic societies allow activists, civil societies and other non-governmental organizations to express their preferences to policy and concerned polluting firms in pursuit of reducing CO_2 emissions and enforcing environmental legislation (Zugravu and Millock, 2008). CO_2 is at the core of the transition policies of these transition countries. Although the transiting economies are pursuing the same goal of greener economies by reducing greenhouse gas emissions, the countries inherently have certain individual peculiarities that are worthy of note. While some countries such as Czech Republic, Estonia, Latvia, Lithuania, and Russia pursued a radical transition to abolish all socialist-oriented policies overnight, countries such as Hungary, Romania, Bulgaria, Slovenia, and Croatia approached transition in a slower manner (Gurkov, 2018). Russia began a transition in 1990, while countries such as Czech Republic, Poland, Estonia, Latvia, Lithuania kick-start their transition in the early 90s, however, Georgia lagged until the 2000s (Gurkov, 2018).

These countries have varying levels of pollution in the path towards economic development. For example, while the economy of the old Soviet Union created several ecological problems largely due to improper management of nuclear and waste issues (Zugravu and Millock, 2008), environmental issues are not so pronounced in other blocs of transition economies like the Central European Economies (CEE). This means that CEE countries may have the same policy of reducing emissions, but the pace with which they approach their ecological issues will differ depending on the intensity of CO_2 emissions.

In the early 2000s, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia joined the EU whereas Russia and the other nine members of the Commonwealth of Independent States (CIS) differ on that. To join the EU, the precondition to qualify for membership is to ratify the Kyoto Protocol and Paris agreement. By doing this the chances are that these countries will cut substantial CO_2 emissions during their transition journey.

Therefore, these countries have peculiarities in economic structure, mode of transition, and CO_2 emission intensity that have posed several structural, institutional and political obstacles which in effect have created setbacks in the actualization of the green agenda of these economies. For example, Gurkov (2018) documented that countries earlier identified as radical transitionists have had transition crisis such as price instability, decrease in growth and unemployment. Hence, studies of this sort are timely and worthwhile given the pressure across the globe for cleaner and affordable energy. This proposition is per the seventh goal of the United Nations' Sustainable Development Goals (SDG's).

The contribution of this study is in three-fold: first, this study investigates the differences in the environmental-growth consequence across various blocs of transition economies differing from other related studies (Bercu et al., 2019) carried out on transition economies. Second, this study contributes to the literature on energy-emissions-growth nexus for transition countries. Third, we contribute to the literature by providing evidence against the presence of the Environmental Kuznets Curve (EKC) in the CEE countries.

Besides, this study is related to that of Apergis and Payne (2010a,b) whose focus was on the CIS countries, but our study has a broader study population covering transition economies in CIS countries, New Member States (NMS) and Central European Economies. We also use a wider range of data (1992–2018) capturing a good number of years after the transition of these economies. Our study differ from Morales-Lage et al. (2019) in terms of methodological application — we use the system-GMM estimator for the model estimation. In estimating the model on growth-energy-emissions for the selected transition economies, we establish a relationship among the variables using a unique process. Contrary to Bercu et al. (2019), we include CO_2 emissions as the explained variable and make use of the sys-GMM estimator while including estimations for country groups.

The next section presents a review of literature, while section three discusses the data, variables, model and method. Section four discusses the results and implication for energy policy in the transition economies, while section five concludes the research with vital policy recommendations.

2. Review of literature

2.1. Transition economies

A transition economy is otherwise termed a post-communist economy. It is termed so because it is an economy in the process of transformation from a centrally planned economy to a market economy (Gurkov, 2018). According to Gurkov (2018), transition economies can be categorized into three categories reported as:

- 13 countries in CEE (Albania, Bulgaria, Bosnia and Herzegovina, Croatia, Czech Republic, Hungary, Kosovo, Poland, Republic of Macedonia, Romania, Serbia and Montenegro, Slovak Republic, and Slovenia).
- 15 countries of the former Soviet Union (Armenia, Azerbaijan, Belarus, Estonia, Latvia, Lithuania, Kazakhstan, Kyrgyz Republic, Georgia, Ukraine Moldova, Russia, Tajikistan, Turkmenistan, and Uzbekistan). Apergis and Payne (2010a,b) termed them Eurasia. These countries formed an economic integration that is today known as the CIS. However, the countries of northern Europe also called the east Baltic states or Balkans because of their proximity to the coast of the Baltic sea. Estonia, Latvia and Lithuania did not join the CIS for political reasons. But they are still members of the EU since 2004. Also, Georgia and Ukraine pulled out in 2008 and 2018 respectively. This leaves the present tally of the CIS to 10 member states.
- 5 countries in East Asia (Cambodia, China, Laos, Mongolia, and Vietnam); and 1 country in Latin America (Cuba).

It is pertinent to note that, five of the CEE countries, also known as the west Balkans; Albania, Bosnia Herzegovina, Serbia Montenegro, Kosovo and Macedonia have initiated and are at different levels of Pre-EU accession protocol. It was the EU that coined the term western Balkans in the 2000s referring to the countries in south-eastern Europe that were not in the EU but could aspire to join the bloc (Dabrowski et al., 2018)

In this study, we are interested in the transition countries in the EU and also the mentioned six Balkans states. The reason is not far-fetched as it a fact that the EU is the champion of the fight against CO_2 emission and a champion of green and renewable energy. Relatively, the EU has held itself in very high standards in the areas of reducing CO_2 emissions. Within the EU, members are obliged to tailor their national environmental policies to that of the EU (Raszkowski, 2019). For the simple reason that most of these transition countries share the same economic bloc, meaning that they have certain similarities and mutual understanding regarding green energy policy.

Russia is a country of interest in this work because it is the transition economy with the highest level of CO_2 emissions and ranks 4th globally tailing China, the US and India (Ketenci, 2018). Russia has tremendous strategic influence regarding the energy security of the CIS countries and the Balkans states. This is because, all CIS countries depend on Russia's oil and gas to meet their energy needs and also serve as distribution routes and centers for the sale of Russia's carbon resources to the world energy markets (Apergis and Payne, 2010b). This justifies the inclusion of the CIS economies in this study.

2.2. Energy consumption and CO_2 emissions in Russia

Following Russia's transition to a market economy, the energy sector has seen the development of the power sector undergo certain changes to curb environmental pollution (Busarov et al., 2001). The target was to cut emissions to 25%–30% from the inception of the transition in 1990 by the year 2030 (Ketenci, 2018). However, (Korppoo and Alexey, 2017) expressed doubt on the achievement, because until 2012, CO_2 emissions in Russia are still at 68% from 1990. Karghiev (2006) is perhaps not wrong to have declared Russia pollution and resource-intensive nation. Because approximately 90% of its energy is from fossil fuels (Apergis and Payne, 2010a).

OECD (2013) expressed fears on the devastating consequences the gigantic energy sector of the Russian economy has on the biosphere. OECD (2013) documented that, at the beginning of its transition to a market-oriented economy in the 90s, Russia had implemented several environmental reform policies (The Federal Law on Environmental Protection of 191). By this, it was constitutionally declared that "*every Russian shall as a matter of constitutional right shall enjoy a safe environment and will be compensated for damage to health or property arising from any environmental law violations*". In 1996, a full-blown transition concept anchored on greener Russia was brought on board, followed by a National Environmental Action Plan and other complementing policies at the regional level. This is in addition to the efforts of the environmental agencies were geared to support environmental civil societies, planning and coordination of the regional policies and implementation of these policies.

Albeit these environmental policies, Russia has no comprehensive policy plan for renewable energy as a substitute for fossil fuel for almost two decades after kick-starting the transition journey (Karghiev, 2006). This is perhaps one of the major reasons Russia is still termed as a carbon-intensive economy. In addition to the ever-increasing productive performance of the economy due to several economic reforms of market economy implemented by the government, the transition has led to increasing pollution intensity-based economy. The mismatch between economic expansion and renewable energy penetration is perhaps a contributory factor.

This is evident in the empirical work of Ketenci (2018) indicating a positive and direct relationship between an increase in CO_2 emissions with economic growth in Russia. Although at a certain point of growth level, CO_2 was observed to have declined at an unsatisfactory level.

According to OECD (2013), notable among the reasons for the unsatisfactory level of emissions during the earlier days of the transition include downplaying of environmental institutions at the federal level making environmental policy coordination, integration and implementation difficult. Second, environmental protection budgets were cut and expenditures had to be delayed. These amongst other issues have culminated the policy space which led to continual use of a substantial amount of natural resource capital and fossil fuels for advancing the economic agenda. The objective of the earlier conceived green policy of cutting emissions from the 1990 levels to only 25% to 30% band is therefore defeated.

2.3. Energy consumption and CO_2 emissions in CEE countries

Within a decade and a half of their transition, the CEE economies were able to cut down the level of CO_2 emissions significantly. Zugravu and Millock (2008) reported that, without stringent environmental policies, the economic growth experienced in these economies would have increase CO_2 emissions by 31% from 1995–2003. But, this was mitigated by the environmental policy reforms undertaken by the CEE economies resulting in a decline of emissions by 58% from the 1990 levels. This study underscores the importance of strong institutions in their quest for a greener environment.

Similarly, Bercu et al. (2019) opined that good governance has a direct and indirect effect on economic growth and energy consumption in the CEE countries. Having studied a panel of 14 countries of the CEE countries, they confirmed the validity of the energy-led growth hypothesis from a regression of electricity consumption, economic growth, and good governance. Implicit in the study is that good governance and strong institutions (strict adherence to energy policies and international environmental treaties such as the Paris agreement) could lead to energy efficiency in the CEE countries.

Çetintaş (2016) studied the relationship between energy demand and economic growth in 17 transition economies of which 7 are from the CEE. In the long run, evidence of unidirectional causality running from economic growth to energy demand was established. In other words, as the economic activities of the transition economies increase, energy demand needed to sustain growth increases. Deducing that both policies of growth and clean energy can be pursued simultaneously — as energy conservation policies have a neutral effect on economic growth (Çetintaş, 2016).

Similarly, because of the primacy of fossil fuels in the production process of the CEE countries, Georgantopoulos et al. (2011) examined the causation between energy consumption the economic performance of three CEE states of Albania Bulgaria and Romania to ascertain the possibility of implementing environmental sustainability policies without harming economic development. For Albania, energy and GDP were found to have a neutral effect on each other. But for Bulgaria and Romania, growth was seen to be uni-directionally causing CO_2 emissions, hence, in contrast to Bulgaria and Romania, conservation policies have no growth consequences in Albania.

2.4. Energy consumption and CO_2 emissions in the Baltic region (NMS countries)

There are two categories of Balkans: East and West. While the east consists of Estonia, Latvia and Lithuania, the West Balkans are five, namely, Albania, Bosnia Herzegovina, Serbia Montenegro, Kosovo and Macedonia. Since the west Balkans have formed part of the CEE countries as shown by Gurkov (2018) they are treated in the CEE bloc. This is justifiable, in the sense that, in their quest to become part of the EU, the West Balkans have since activated Pre-EU accession protocol sharing similar environmental policy regulations during their transition. On the other hand, the east Baltic states of Estonia, Latvia and Lithuania are neither in the CEE category nor in the CIS, but the newest members of the EU with their admittance in the 2000s. Therefore, they are categorized under the NMS bloc in this work.

Furuoka (2017) studied the east Balkans states of Estonia, Latvia and Lithuania from 1992–2011 within the framework of conservation hypothesis. Findings reveal that the economic growth levels of the east Balkans cause an expansion in the demand for renewable energy. Whereas an increase in renewable energy consumption means a reduction in fossil fuels, it then means that growth in these countries is associated with a decreasing level of CO_2 emissions. Thus, there was a unidirectional causality from growth to renewables. Meaning that conservation policies taken by the government cannot inhibit growth.

This work will contribute to the knowledge of limited literature in this bloc, by presenting the findings of the east Baltic States in the NMS bloc to take care of their isolative peculiarity.

2.5. Energy consumption and CO_2 emissions in the CIS countries

On the environmental front, Apergis and Payne (2009) opined that the CIS countries failed on issues of reducing CO_2 emissions due to some challenges. Empirical evidence that lends credence to this assertion can be found in Çetintaş (2016). The relationship between energy demand and economic growth was examined in 17 transition economies; 8 of which are from the CIS countries. Economic growth was seen to increase energy demand, due to a fossil-fuel dependent energy source (Apergis and Payne, 2010a). The findings show that an increase in the economic performance of the CIS leads to an increased level of CO_2 emissions through increased energy demand from 1992–2005.

Despite contrasting results in Çetintaş (2016), the empirical work of Apergis and Payne (2009) show a promising future for environmental sustainability in the CIS. Having established a feedback hypothesis between energy consumption and economic growth, Apergis and Payne (2009) proposed that the implementation of energy efficiency policies that will not retard growth but improve environmental effects of production in the CIS countries.

On the whole, it is clear from the empirical studies that there exists a dearth in the literature. To the best of our ability, not even one study could be cited on the trilemma faced by the transition economies involving many countries as presented in this study (CEE, CIS and east Balkans). This work is therefore of enormous importance as it seeks to answer the question of whether the transition economies could implement conservation policies without hampering economic performance.

3. Data and methodology

3.1. Data

This study investigates the nexus between CO_2 emissions, GDP per capita, renewable and nonrenewable power generation, and income from natural resources in several blocs from 1992–2014. This includes commonwealth of independent states (Armenia; Azerbaijan; Belarus; Georgia; Kazakhstan; Kyrgyzstan; Moldova; Russia; Tajikistan; Turkmenistan; Ukraine); Central and Eastern European states (Albania; Bosnia and Herzegovina; and Macedonia); and New Member states of the European Union (Bulgaria; Croatia; Czech Republic; Estonia; Hungary; Latvia; Lithuania; Poland; Romania; Slovakia; Slovenia).

3.2. Model and methods

3.2.1. Theoretical framework

The EKC supposition is that, at the initial stage of the growth, there is a direct relationship between CO_2 emissions and growth, but at a certain level of income, emissions subside owing to improvement in the production process (Sarkodie and Strezov, 2019). This is the explanation of the inverted-U shape of the EKC. This work entails the environmental consequences of the quest for growth across the transition economies. Before transition, the economies are considered to be at their initial stage where both growth and CO_2 exhibit a positive monotonic trend. But after the activation of the transition protocol, it is natural to expect a decline in emissions across these countries. Therefore, the EKC is used as the theoretical framework in answering whether there are differences across these economies in the level of emissions through the period of their transition.

3.2.2. Econometric model

Given the foregoing, we specify our EKC model as follows:

$$CO2 = f\,(GDP, REG, NREG, NRR, RGDPSQ) \tag{1}$$

$$\begin{aligned} LCO2_{it} &= \alpha_0 + \beta_1 LCO2_{it-1} + \beta_2 LGDP_{it} + +\beta_3 LREG_{it} + \beta_4 LNREG_{it} \\ &+ \beta_5 LNRR_{it} + \beta_6 LRGDPSQ_{it} + \varepsilon_{it} \end{aligned} \tag{2}$$

where LCO_2 is the logarithmic transformation (L) of CO_2 emissions; α_0 is the intercept term; $\beta_1, \ldots, \beta_6$ represent the slope coefficients; LGDP represents the gross domestic product; LREG is renewable energy generation; LNREG is nonrenewable energy generation; LNRR represents the natural resource rents, and LRGDPSQ is the squared of real GDP; i represents the sampled countries in the panel and t represents time. ε_{it} is the error term. The variables covered are described in Table 1 in line with their source.

3.2.3. Panel GMM

The Generalized Method of Moment (GMM) is the estimation procedure incorporates various instrumental variables to deal with endogeneity. The GMM technique provides reliable, consistent and proficient coefficient estimates despite heteroscedasticity see (Adedoyin et al., 2017; Usman et al., 2019; Usman and Yakubu, 2019). Furthermore, the post-estimation tests discussed in this study were conducted to validate the robustness of the hypothesized study claim as outlined in Eqs. (1) and (2). We used Hansen's test to test the overidentifying constraints to validate the authenticity of instruments. From the Hansen statistics, we could not reject the null hypothesis of instruments validity at a 10% level of significance. Also, the Durbin–Wu–Hausman test was used to test for endogeneity in the model. Given the P-values, the invalid theory was rejected, prescribing that the standard least-squares evaluations might be uneven and, in this way, the Ordinary Least Square (OLS) was not an appropriate estimation strategy.

In this particular condition, we use the GMM procedure to survey the nexus among CO_2 emissions, GDP per capita, renewable and nonrenewable power generation, and natural resource rent by using yearly information with the benefit that our panel estimation methodology can control for potential endogeneity that may ascend out of instructive components.

4. Results and discussions

This section provides a detailed account of the pre-estimation tests carried out, findings from the regression equation as well as the robustness checks. The results presented are for all sample and the three sub-samples of the NMS, CIS and CEE.

Table 1
Variable description.

Variable	Abbreviation	Description	Source
Carbon dioxide emissions (emissions per capita)	LCO_2	"*Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring*".	The World Bank
GDP per capita (constant 2010 dollars)	LGDP	"*GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products*".	The World Bank
Renewable power generation (billion kilowatt-hours)	LREG	Total Renewables Electricity Net Generation (Net generation excludes the energy consumed by the generating units and also excludes generation from hydroelectric pumped storage)	The U.S. Energy Information Administration
Nonrenewable power generation, (thousand barrels per day)	LNREG	This is a sum of Oil production; Liquefied petroleum gas production; and Gasoline production	The U.S. Energy Information Administration
Income from natural resources (percentage of GDP)	LNRR	"*Total natural resources rents are the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents*".	The World Bank

4.1. Pre-estimation diagnostics

4.1.1. Descriptive statistics

It can be observed in Table 2 that the CEE countries have the lowest level of LCO2 emission on the average, followed by the NMS. On the other hand, the CIS countries have recorded more than 16- and 3-times higher level of emissions compared to the CEE and NMS respectively. This is the reflection of the type of energy consumption in the three blocs of countries. The CIS appears to be heavily dependent on the NREG as its source of energy. Their mean consumption surpasses that of both the CEE and the NMS by 163 and 17 folds respectively.

The CIS proceeds of natural resource rent are unmatchable with that of either the CEE or the NMS. Notwithstanding, the average GDP figures of the CEE countries (which consist of only 4 countries) are more competitive than that of the CIS (10 countries) and NMS (9 countries).

4.1.2. Correlation matrix

Evidence from Table 3 shows a significant relationship between the level of CO_2 emissions and all the independent variables in the sample of all countries as well as the CIS sub-sample with NREG having the strongest correlation in both cases. However, in the CEE subsample, NREG is not related to the level of emission, whereas, the GDP levels has a negative relationship with the CO_2 levels in the NMS.

Except for CEE, the NREG has the strongest association compared to other independent variables in all samples. This is not surprising as it conforms to the *apriori* expectation. Also, REG has the weakest association with CO_2 in all samples and the CIS.

4.1.3. Bin scatter plots

To further understand the relationship between the environmental consequence of growth, we employed bin scatter plots, which shows how fitted the values of a regression equation is (Cattaneo et al., 2019). The rule of thumb here is that, if the binned scatter points are tight to the regression line, the slope estimate is precise, hence, the standard error is small. Contrariwise is the case if the bin scatter points are dispersed around the regression line (Stepner, 2014).

In the first panel which contains all samples, the binned scatter points in all the four figures are largely fitted around the regression line (see Fig. 1). This indicates that the regression estimated showing the relationship between emission and the independent variables are precise. In the CIS, except that of the REG, all the regression equations estimated between CO_2 and the independent variables of GDP, NREG and NRR appear to be less erroneous. The bin scatter points of the CEE sample countries are contrary to the result of all samples and the CIS as all points are largely scattered far away from the regression lines between CO_2 emissions and GDP, NREG, REG and NRR. However, the relationship can be considered average in the NMS as the binned scatter points of GDP and NRR are moderately around the regression line as against those of the NREG and REG which are dispersed around it (see Fig. 1).

4.2. Two step General Method of Moments (GMM) estimations

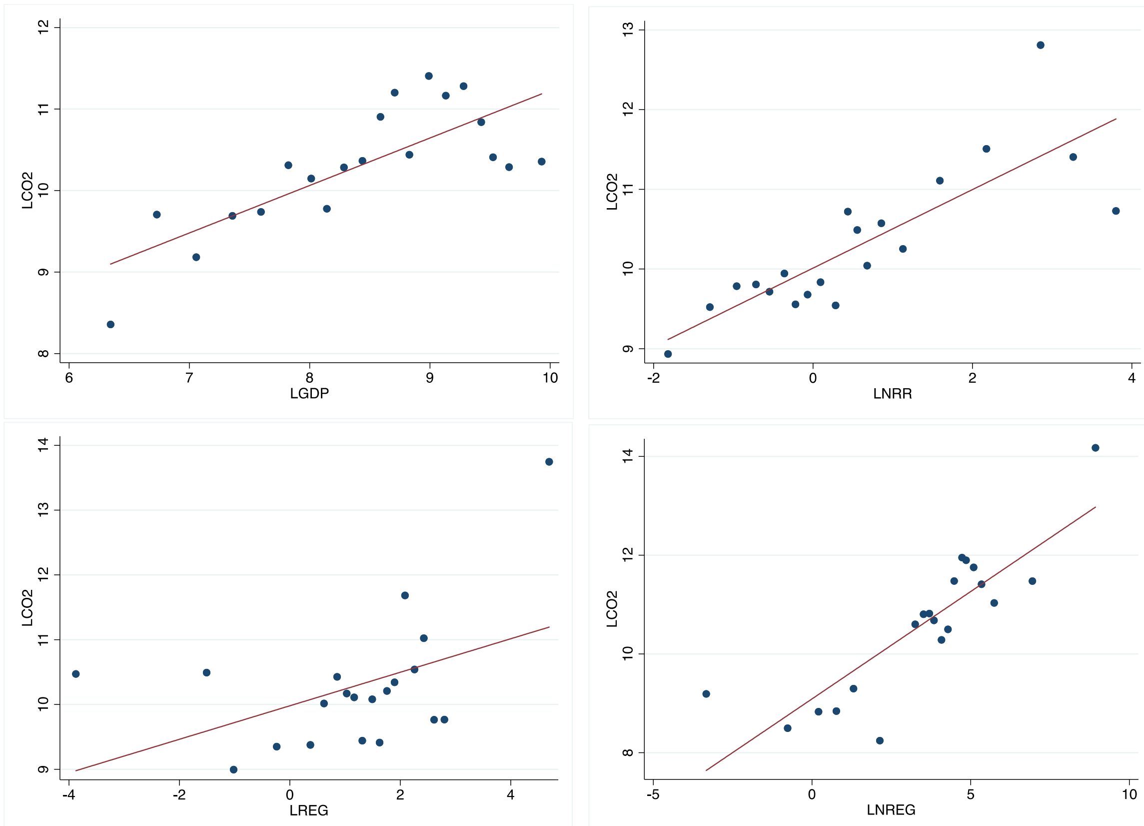
The results of step two-GMM estimates are presented in Table 4. The results are discussed accordingly which are consistent with the findings of previous studies and subsequently policy direction were rendered.

All Countries Sample

The results for the all country sample regression in Table 4 show a positive and negative sign in LGDP and LGDPsq, respectively. This confirms the presence of the EKC hypothesis in the transition economies. This outcome illustrates that before transition, income levels are associated with increased emissions but after transition, higher levels of income are followed by a reduction in emissions. Specifically, at the early stage of development, a 1% increase in national income is likely to increase emission (LCO2) by about 2.4%, but at the later stage of development, a 1% increase in national income is likely to reduce emission by about 0.14%. Similar findings are documented in the work of Ketenci (2018) for Russia and Apergis and Payne (2010b) for the CIS countries.

Renewable energy (LREG) has a negative but insignificant impact on CO_2 emissions. On the other hand, income from natural resource rent (LNRR) is likely to reduce emissions. Specifically, a 1% increase in LNRR declines emissions by about 0.04%. The results further illustrate a positive relationship between nonrenewable energy use and CO_2emissions. This entails that an increase in fossil fuel consumption in the transition economies spur emissions.

The post-estimation tests reveal the absence of high order autocorrelation (AR (2)) from the model and the instrument validity



The Commonwealth of Independent States (CIS)

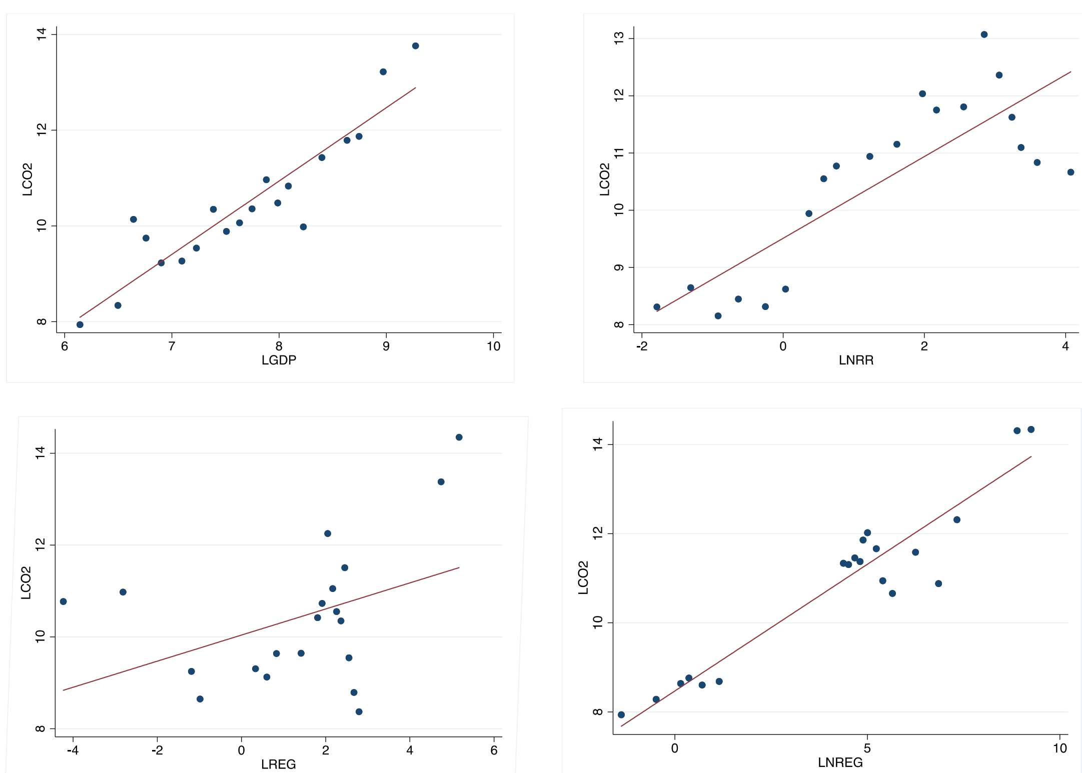
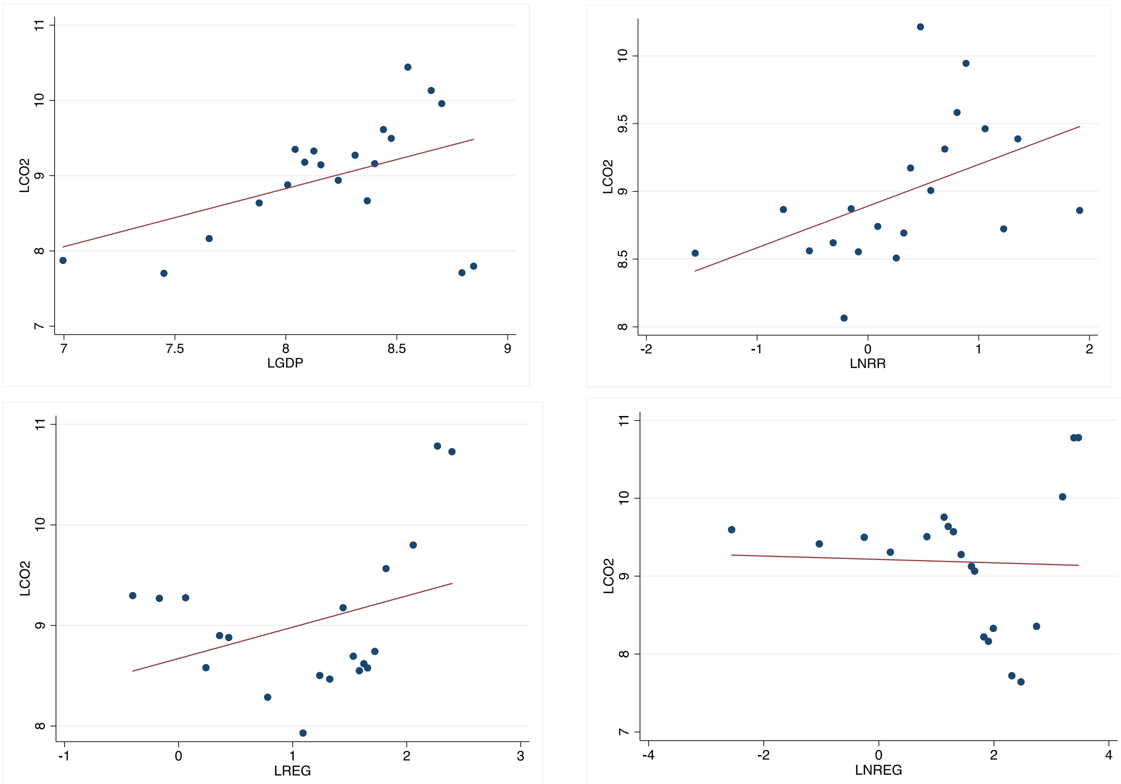


Fig. 1. Bin scatter plots.

The Central and Eastern European States (CEE)



The new Member States of the European Union

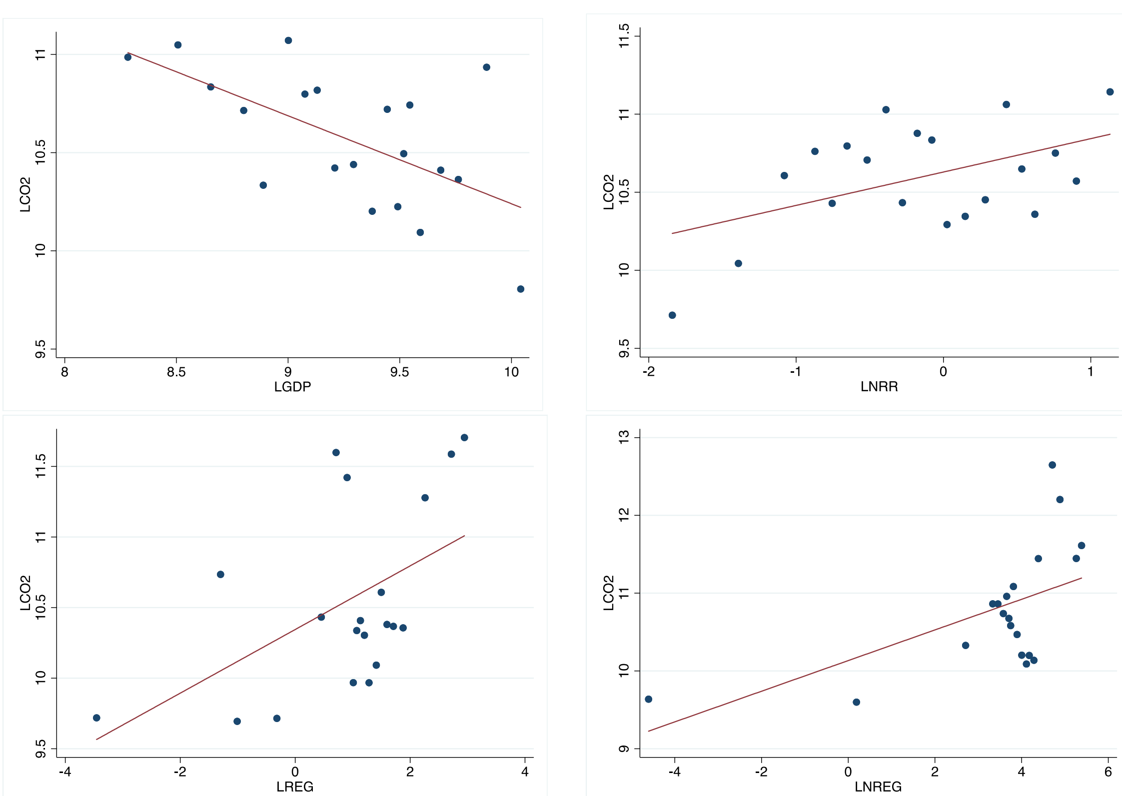


Fig. 1. (*continued*).

Table 2
Summary statistics.

Variable	All countries		CIS		CEE		NMS	
	Mean	Sd.	Mean	Sd.	Mean	Sd.	Mean	Sd.
CO2	122782.3	318913.3	207755.	455017.1	12657.5	13210.2	68389.1	86620.4
GDP	6540.41	5391.72	3064.91	2635.46	4037.74	1442.22	11547	4934.43
NRR	5.89	11.57	11.66	15.47	1.64	1.60	1.10	0.79
NREG	418.69	1673.16	913.89	2454.76	5.60	8.58	53.17	56.82
REG	11.29	31.62	19.67	45.54	4.11	2.82	4.55	4.82

Table 3
Pairwise correlation.

All sample						CIS countries					
	LCO2	LNRR	LGDP	LREG	LNREG		LCO2	LNRR	LGDP	LREG	LNREG
LCO2	1					LCO2	1				
LNRR	0.4493*	1				LNRR	0.6318*	1			
	0						0				
LGDP	0.3547*	−0.1602*	1			LGDP	0.6603*	0.4742*	1		
	0	0.0001					0	0			
LREG	0.2852*	0.2045*	−0.0691	1		LREG	0.3134*	0.2099*	0.0448	1	
	0	0	0.0962				0	0.0007	0.4752		
LNREG	0.7589*	0.5780*	0.2000*	0.0858	1	LNREG	0.9051*	0.7008*	0.7893*	0.0568	1
	0	0	0	0.0583			0	0	0	0.4099	
CEE countries						NMS countries					
	LCO2	LNRR	LGDP	LREG	LNREG		LCO2	LNRR	LGDP	LREG	LNREG
LCO2	1					LCO2	1				
LNRR	0.2599*	1				LNRR	0.1559*	1			
	0.0157						0.0161				
LGDP	0.3736*	0.2171*	1			LGDP	−0.1930*	−0.5954*	1		
	0.0004	0.0309					0.0026	0			
LREG	0.2652*	0.1875	−0.0007	1		LREG	0.3138*	0.0348	0.006	1	
	0.0136	0.0877	0.9949				0	0.5953	0.9261		
LNREG	−0.0355	0.0698	−0.0389	0.3403*	1	LNREG	0.4722*	0.6045*	−0.5201*	0.0238	1
	0.7705	0.566	0.749	0.0039			0	0	0	0.7345	

Note: *** p<0.01, ** p<0.05, * p<0.1 denotes statistical significance level accordingly.

test, using Hansen and Sargan confirm that the instruments for the estimation are valid.

The Commonwealth of Independent States (CIS)

The results for the CIS countries (Table 4, column 3) support the inverted U-shape relationship of the EKC hypothesis. This implies that at the early stage of development CO_2 increases with growth in income but emissions decline at a later stage of development with growth in income. This phenomenon is plausible because, for a socialist economy to transit to a market-oriented one, the abolishment of price regulation is necessary. When this happens, the energy price subsidies will be deregulated, energy prices will go higher, and producers will be forced to opt for a sustainable and economical source of energy — the LREG. Consequent upon this, the level of emissions will reduce as the economy expands.

The results for the CIS countries further illustrate that an increase in both renewable energy (LREG) and non-renewable energy is responsible for high emissions (LCO2). Specifically, a 1% increase in the use of renewables and fossil fuels is likely to increase LCO2 by ∼0.04% and 0.03% respectively. Although the positive relationship between fossil fuels and CO_2 is a commonplace knowledge, the most likely reason for the low level of significance of fossil fuels on the level of emissions is the EKC hypothesis. Inherent in the literature of the EKC is the understanding that, as an economy develops the rate of emission decreases because of the need for sustainable energy which tilts the economy away from its dependence on fossil fuels.

In like manner, a rise in income from natural resources (LNRR) leads to a rise in emissions. This is expected because as transition economies, resource rents are largely government-owned which are used to expand the output base. Because an increase in output leads to an increased level of emissions at the initial stage of economic development, it is therefore established that for every 1% increase in LNRR, there is a likelihood that emission would increase by 0.07%.

The Central and Eastern European States (CEE)

For CEE countries (Table 4, column 4), the relationship between emission and LCO2 assumes a U-shape, contrary to the EKC hypothesis. This signifies that, at the early stage of development, emissions decrease as income rises while at the later stage, emissions increase with income. Considering elasticities, we see that at the initial stage of development, a 1% increase in LGDP is likely to reduce emission (LCO2) by ∼1.8%, but as income increases, a 1% increase in LGDP likely increases LCO2 by ∼0.09%. This is in line with recent studies for other blocs of countries confirming the EKC hypothesis such as Adedoyin et al. (2019) for selected European Union countries and Adedoyin et al. (2020) for the BRICS countries. It is also very practical in the sense that, any economic improvement above a particular threshold of LGDP, Apergis and Payne (2010b) views that increase as a potential solution to environmental degradation rather than a problem. This is because, with an increase in growth and emissions, people become more concern and proactive on the effect of environmental degradation accompanying growth which will lead to increase demand for environmental sustainability. Hence, the greater the positive significance of LGDP on LCO2 at a lower level of economic performance. However, no matter the derive to reduce the level of emission, without adequate substitution of LNREG with LREG, as observed in the CEE, the result will still be a direct relationship between LCO2 and growth, as the economy expands. This explains why the dependence on NREG in the CEE as an engine of growth is unsustainable.

Additionally, the U-shaped pattern of relationship between emission and growth is an indication of the existence of a "*growth hypothesis*" in the CEE. This means that the CEE is energy-dependent and as such an energy-led growth bloc. Therefore, any

Table 4
Result of dynamic panel-data estimation, two-step system GMM.

Dependent variable: *LCO2*	All countries	CIS	CEE	NMS
LCO2	0.708**	0.923***	1.040***	1.063***
	(0.275)	(0.052)	(0.061)	(0.078)
LGDP	2.390**	2.775***	−1.798**	2.729***
	(1.002)	(0.952)	(0.728)	(0.842)
LREG	−0.017	0.0400**	0.0201**	−0.0177
	(0.014)	(0.019)	(0.009)	(0.019)
LNREG	0.054	0.0263	−0.00304**	−0.02
	(0.082)	(0.042)	(0.001)	(0.021)
LNRR	−0.043	0.0670***	0.037	0.0249
	(0.026)	(0.026)	(0.033)	(0.020)
LGDPSQ	−0.143**	−0.175***	0.0878***	−0.147***
	(0.058)	(0.062)	(0.033)	(0.046)
Constant		−10.31***	8.476***	−13.23***
		(3.556)	(3.217)	(4.419)
Observations	343	204	57	192
Number of country ID	23	10	4	9
Firm effect	YES	YES	YES	YES
Year effect	NO	NO	NO	NO
Post-estimation diagnostics				
Hansen_test	7.451	1.533	0	3.054
Hansen Prob	0.682	1	1	1
Sargan_test	7.895	34.2	5.952	19.23
Sargan Prob	0.639	0.00319	0.114	0.203
AR (1) _test	−2.022	−1.779	−1.716	−2.291
AR (1) _P-value	0.043	0.0753	0.0862	0.0219
AR (2) _test	−0.563	0.43	−0.236	−1.199
AR (2) _P-value	0.574	0.667	0.814	0.23
No. of instruments	16	22	10	22

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

conservation policy aimed at reducing energy consumption will inhibit growth. This underlines the importance of energy in the productive process of the CEE countries.

Also, an increase in renewable energy (LREG) leads to a rise in emissions, while high consumption of fossil fuels (LNREG) is likely to reduce emissions. For LREG, a one percent increase in its use would increase LCO_2 by about 0.02 percent, while a percent increase in the use of LNREG is likely to reduce emission by 0.03 percent. This is direct opposite to our apriori expectation. Owing to the very low level of income from natural resources as described in Table 2, the LNRR is found to be positively related to LCO2, however, the effect is not statistically significant.

The New Member States (NMS) of the European Union

NMS countries (Table 4, column 5), just like CIS countries, follow the pattern of the EKC hypothesis. A 1% increase in income at low income (LGDP) level likely increases emission (LCO2) by 2.7% and at high-income level, a one percent increase in LGDP reduces LCO2 by 0.15%. This could be attributable to the fact that, in the NMS bloc, output expansion leads to increased demand for REG. This is consistent with the supposition from the work of Furuoka (2017). Another reason is the EU Pre-accession protocol activated by the whole of the NMS which was the gateway to the EU necessitated a reduction in the level of emissions. Because to join the EU, the Kyoto Protocol and the Paris agreement must be ratified. This is an indication that their alignment and adoption of the EU environmental policies in guaranteeing a greener environment has yielded positive results.

Both renewable (LREG) and non-renewable energy (LNREG) negatively affect LCO2, however, this effect is not statistically significant. Contrarily, income from a natural resource (LNRR) rent positively influences LCO2, but also not statistically significant.

5. Conclusion

This study employs the Two-step GMM estimation technique in analyzing the environmental consequences of economic growth in the transition economies. This study differs from previous studies by considering the peculiarities of the transition economies in the areas of economic, political and institutional structures, and emission intensity. Hence, we investigated the scope by utilizing data from 1992–2014 for Central and Eastern Europe, Commonwealth of Independent States and the New Member States of the EU.

Findings reveal a significant relationship between measures of GDP, renewable energy, non-renewable energy, natural resource rent, and CO_2 emissions in the transition economies. The relationship between economic growth follows an inverted U-shaped EKC for the full sample and for all sub-groups except the CEE countries. We find that natural resource rent, renewable and non-renewable energy generation are likely to escalate emissions in the transition economies. Considering energy as a driver of economic activities and fossil fuel led environmental degradation, countries are often divided between pursuing economic growth while maintaining a clean environment. However, the increasing use of renewable energy will help the transition economies achieve both goals of economic growth and clean environment. This can be achieved by increasing the share of non-combustible energy into the energy mix and instituting stringent policies on clean energy for firms and households.

Furthermore, we adopted the CO_2 emissions in this study as a measure of environmental degradation. However, further studies could widen the scope by utilizing ecological footprint to capture a wider representation of environmental quality. Similarly, more detailed studies can be carried out for individual countries to aid tailor country-specific policies in the energy-emissions nexus targeted at achieving environmental sustainability.

CRediT authorship contribution statement

Festus Adedoyin: Conceptualization, Software. **Isah Abubakar:** Methodology, Data curation. **Festus Victor Bekun:** Software, Visualization. **Samuel Asumadu Sarkodie:** Writing - review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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