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CARBON EMISSION AND ECONOMIC GROWTH NEXUS: EMPIRICAL EVIDENCE FROM THE FIVE LARGEST CARBON EMITTERS

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Abstract

The mad rush for rapid economic growth led by industrialization in emerging economies is having a negative impact on ecological management. Rapid economic growth and expansion of economic activities in most developed countries have resulted in acceleration of global warming and climate change. The direction of causality between carbon emission and economic growth varies from one country to the other depending on the data set and methodology employed by the researcher. In this paper, we examine the causal relationship between carbon emission and economic growth in five selected countries namely China, United States, Russia, India, and Japan. These countries are selected because they are the largest carbon emitters in the world. The study used two types of unit root test technique Levin-Lin-Chu (LLC) and Im-Pesaran-Shin (IPS) unit-root tests to ascertain the order of integration. Johansen Fisher Panel cointegration techniques and Pairwise Dumitrescu Hurlin Panel Causality Tests were applied to determine the existence of a long run relationship causal relationship between carbon emission and economic growth. Using panel cointegration approach, Fully Modified OLS and panel granger causality test, we found that there is a unidirectional causal flow from carbon emission to economic growth in most of the largest carbon emitters in the world in the long run. Therefore, the five most significant carbon emitters need to strengthen their carbon management and efficiency policies to avoid further environmental damages associated with rapid economic growth.

Key Words: Carbon Emission, Economic Growth, Panel Cointegration Test

JEL Classification: Q43; Q53; O16

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1. Introduction

One of the important challenges facing global leaders, policymakers, and environmental economist is how to achieve sustainable economic growth without adversely affecting the environment through energy consumption. This ever-increasing consumption demand would have global side effects such as high emissions leading to global warming, greenhouse effects and destruction of forests. The environmental degradation can also add to the problems of imposing higher costs on the poor by increasing the expenditure on health-related issues.

Carbon emission effects are far-reaching and cause an international externality. Thus, incentives to reduce it are undermined by the free-rider problem and make the study of Carbon emissions particularly interesting. Furthermore, Carbon emissions are directly related to the use of energy, which is an essential factor in the world economy, both for production and consumption. Therefore, the relationship between carbon emissions and economic growth has significant implications for environmental and economic policies. Grossman and Kruger (1995) showed that the link between economic growth and environmental pollution follows an inverted U-shaped pattern, referred to as the Environmental Kuznets Curve (EKC). This finding suggests that lower income regions are 'too poor to be green,' and only when they become rich enough will the benefits from a clean environment outweigh its costs. Despite rigorous theoretical and empirical explorations, there is yet to be an unequivocal result as regards this relationship. The results of the empirical literature are controversial (Stern, 2004; De Bruyn and Sander, 2000; Dinda 2004). As far as studies on Carbon emissions are concerned, the existence of a bell-shaped relationship between pollutants and income, postulated by the EKC hypothesis, has only been confirmed in some panel studies for Organization for Economic

Co-operation Development (OECD) countries (For an exhaustive review of the empirical literature on carbon emissions (Galeotti et al., 2006).

There have been three main strands in the literature that focused on the relationship between carbon emission and economic growth. The first schools of thought concentrated on the economic growth and environmental pollutant nexus, which mainly focused on the Environmental Kuznets Curve (EKC) or Carbon Kuznets Curve (CKC). The studies examined whether economic growth can be separated from one of the critical challenges facing global leaders, policymakers, and environmental economist is how to achieve sustainable economic growth without adversely affecting the environment through energy consumption. The inverted U-shaped relationship between per capita income Greenhouse gases (GHG emissions per capita (Grossman and Kruger, 1995; Dinda 2004; Stern, 2004; Müller-Fürstenberger & Wagner 2007; Kaika & Zervas, 2013a, 2013b, Furuoka, 2015). The second strand literature examined the link between carbon emission, energy use, and economic growth. They assets that economic growth may be predominantly determined by the causality between the two variables (Kraft & Kraft, 1978; Wolde-Rafael, 2009, Narayan & Smyth, 2008). The third group consisted of studies that combine the other two school of thought and examined the causal relationship between energy consumption, carbon emission and economic growth (Ang, 2008; Apregis & Payne, 2009; Halicioglu, 2009; Wang& Yang, 2015).

The objective of this study is, therefore, to examine the causal relationship between carbon emission and economic growth in five selected countries (China, United States, Russia, India, and Japan). These countries are chosen because they are the most significant carbon emitter in the world. The study employed the dynamic panel cointegration approach; we find that there is a unidirectional causal flow from economic growth to carbon emission in most of the selected countries. In other

words, there is evidence that there is a unidirectional relationship between economic growth to carbon emission in both long run and short run.

2. Literature review

2.1 Theoretical Literature Review

Greenhouse gasses are good absorbers of heat radiation coming from the Earth's surface, keeping it warmer than it otherwise would be. Enhanced Greenhouse effect accelerates the warming impact beyond acceptable levels. Potential impacts include changes in the global climate, rising sea level, water resources, food supply, biodiversity and human health. Many scientific uncertainties, however, remain concerning the timing and degree of the enhanced greenhouse effect. Despite these difficulties, climate change is real and favors early action in tune with the precautionary principle (Garnaut Climate Change Review, 2008).

Smulders (2000) asserts that economic growth, which has brought about significant improvements in the standard of living during the past decades have not been without a dark side. Air pollution, municipal waste problems, loss of wilderness areas, habitat destruction, threats to biodiversity, resource depletion, and the global greenhouse problem seem to be linked to economic growth. Growing awareness of these issues raises questions as to whether economic growth is still desirable. Doomsday scenarios become imaginable, in which the success of growth leads to its demise and the collapse of the world economy because of environmental problems.

On the other hand, economic growth has created richer and more productive economies, which have access to more advanced levels of technological knowledge. Productivity per unit of natural resource use has increased which allows, in principle, larger volumes of production at lower rates of

environmental degradation. Technological progress and economic growth have created the opportunities and resources to finance investments in new environmentally friendly technologies, to solve waste problems and to reduce material and resource use.

In the context of a small open economy, Friedl and Getzner (2003) estimate an EKC for Austria over the period 1960-1999. They obtain a so-called N-shaped or cubic relationship, which exhibits the same pattern as the inverted-U curve initially, but beyond a certain income level, the relationship between emissions and income is positive again. The existence of an N-shaped curve suggests that at very high-income levels, the scale effect of economic activity becomes so large that its negative impact on the environment cannot be counterbalanced by the positive effect of the composition and induced technique effects mentioned above. Lantz and Feng (2006) look at the EKC relationship for carbon emissions in Canada using a region-level panel data set (5 regions) with region fixed effects for the period 1970-2000. Their results show that carbon emissions are unrelated to GDP. Interestingly, they find an inverted U-shaped relationship between CO₂ emissions and population and a U-shaped relationship between CO₂ emissions and technology.

Narayan and Narayan (2010) tested the EKC hypothesis for 43 developing countries long run and short-run between carbon emissions and economic growth. Their results showed that it is evident that a country reduces carbon dioxide emissions as its income increases. Also, the author has examined the EKC hypothesis for panels of countries constructed based on regional location using the panel cointegration and the panel long-run estimation techniques. These authors found that only for the Middle East and South Asia panels that income elasticity, in the long run, is smaller than that of the short run, implying that CO₂ emission falls with increased revenues.

Halicioglu (2008) examines causal relationships between carbon emissions, energy consumption, income, and foreign trade in the case of Turkey using the time series data for the period 1960-2005. He tests the interrelationship between the variables using the bounds testing to cointegration procedure and concludes that income is the most significant variable in explaining the carbon emissions in Turkey, which is followed by energy consumption and foreign trade. Gomez-Lopez (2009) concludes that energy consumption and pollutant emissions in Latin America are converging, a monotonic relationship between the level of pollution and the level of development was also found. Annicchiarico et al. (2009) examine the relationship between economic growth and carbon emissions in Italy for the period 1861 – 2003 using the error correction model and find a positive relationship between them, and a reasonable turning point. Although Aslanidis (2009) does not apply empirical data, he discusses issues related to the Environmental Kuznets Curve and concludes that there is still no clear-cut evidence of the EKC for carbon emissions.

2.2 Empirical Literature Review

Lee (2005) examines the causal relationship between energy consumption and economic growth in 29 countries between 1975 and 2001. Their results show that economic growth causes energy consumption per capita in most countries. Soytaş et al. (2007) also analyze the effect of energy consumption and increase on carbon emission in the United States, using granger causality. Their result shows that income does not granger carbon emission in the US.

Narayan and Popp (2012) investigated the long-run relationship between energy consumption and real GDP for 93 countries. They found a mixed result, but most of their result shows that energy consumption has an adverse long-run effect on real GDP. Akinlo (2008) also got a mixed result for 11 African countries where energy consumption has a significant long-run effect on real GDP. Wold-

Rufael (2005) also had similar result showing a directional result between energy consumption and real GDP in 19 African countries.

Jo and Hong (2000) test for the existence of the inverted U-shape relationship between economic growth and air pollution for the pollutants Sulphur and Nitrogen in Korea and found it present, using the simple ordinary least squares method. Chousa et al. (2008) investigate whether the decline in environmental quality in Brazil, India, China and Russia (BRIC economies) is due to high-energy consumption level which a result of rapid economic growth is. Through the panel data, feasible general least squares (FGLS) procedure was employed to estimate the environmental degradation caused by the increase in energy consumption. Pooled regression analysis was used to determine the relationship between energy consumption and growth variables. Results revealed that higher energy consumption indeed leads to CO₂ emission in the countries under consideration.

The second strand concentrates on the link between economic growth, carbon emission, and energy consumption. Following the seminal study of Kraft and Kraft (1978), many empirical studies have evaluated this relationship employing Granger causality, cointegration model Bound test and VEC. The bivariate model is criticized in many studies for having the problem of omitted variables bias. Stern (1993), a considerable number of studies has tested the causal relationship between the energy consumption, carbon emission and economic output in a multivariate context. Zhang and Cheng (2009) examined the causal relationship between carbon emission, energy consumption and economic growth in China between 1960 and 2007. Evidence shows that neither carbon emission nor energy consumption leads economic growth. Wang et al. (2011) reexamined the causal relationship between carbon emission, energy consumption and economic growth in China between 1995 and

2007. They assert that there is a bidirectional relationship between carbon emission and economic growth and between carbon emission and economic growth.

Most previous studies have shown that economic growth might lead to changes in CO₂ emissions. Wang et al. (2011) insist that energy consumption and CO₂ emissions are inseparable. Therefore, it is essential that most studies should investigate the relationships between the three variables in a modeling framework. Ang (2007); Belloumi (2009); Soytas and Sari (2007) and Apergis and Payne (2009) have all done an excellent analysis in examining the relationship between energy consumption, CO₂ emissions, and economic growth. Belke et al. (2011) investigated the causal relationship between carbon emission, energy consumption and economic growth in 25 OECD countries using panel cointegration approach. The empirical finding shows a bidirectional result between energy consumption and real GDP. Lau (2011) reexamined the case of 17 Asian countries; the result indicates that economic growth granger causes energy consumption in most of the countries. However, the multivariate studies also produce conflicting results.

3. Estimation techniques and empirical analysis

This study uses data from the World Bank Development Indicators and Statistical Review of World energy to obtain annual data for the five largest world's carbon emitters from 1990 to 2015. All variables are expressed in Logarithmic form while per capita CO₂ emission is measured in metric tons of carbon dioxide. To test for panel causality, two-panel unit root test were employed to ascertain the order of integration.

3.1 Panel unit root tests:

To identify the stationary properties of our variables, this study used two-panel unit root tests namely, Im-Pesaran-Shin (IPS) test and Levin-Lin-Chu (LLC) test. The various panel unit tests all have their strengths and weaknesses. For instance, LLC test takes care of heterogeneity but has low power for small samples but can eliminate serial correlation in the model. IPS test takes care of both the heterogeneity and serial correlation both in small and large samples. Table 1 shows that all the variables are becoming stationary after first differencing. We can conclude that GDP and CO₂ are integrated of order one, $I(1)$.

Table 1: Results of panel Unit root tests

Variables	Levin-Lin-Chu unit-root test		Im-Pesaran-Shin unit-root test	
	Levels	1 st Difference	Level	1 st Difference
InGDP	-1.25558 (0.1046)	- 4.10619***(0.0000)	1.55412(0.939 9)	- 3.37828***(0.0000)
InCO ₂	0.26452 (0.6043)	- 4.72209***(0.0000)	1.42330(0.922 7)	- 5.72207***(0.0000)

P values are in brackets, *** represents significance at 5%

3.2 Panel Cointegration test

The panel cointegration method was employed to estimate the long run relationship between CO₂ and GDP. Since all the variables are integrated of order one, we can go ahead and ascertain the long run relationship between the variables. Johansen (1988) suggests two approaches to measuring cointegration vectors in time series variables, likelihood ratio trace statistics and the other one is maximum eigenvalue statistics. The results of Johansen Fisher panel cointegration test are shown in table 3.

Table 2: Johansen Fisher Panel Cointegration test

Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	22.23	0.0140	18.58	0.0459
At most 1	17.07	0.0728	17.07	0.0728
* Probabilities are computed using asymptotic Chi-square distribution.				
Notes: ** denotes the rejection of the null of no cointegration at the 5% level.				

Table 2 shows that in both cases of Fisher trace test and Fisher max-eigen test at most 1 variable has a long run relationship. The result supports the existence of cointegration relationship.

The Fully Modified OLS (FMOLS) Estimator

To correct the problem of non-exogeneity and serial correlation problems in panel series, the study used FMOLS proposed by Pedroni (1999) and Kao and Chiang (2001) to estimate long-run cointegration non-stationary panel vector. FMOLS estimator is meant to correct the problem of non-exogeneity and serial correlation problems in panel series. The result of FMOLS is presented in table

6. Since the explanatory variables are cointegrated with a time trend, and thus a long-run equilibrium relationship exists among these variables through the panel unit root test and panel cointegration test.

Table 3: Fully Modified OLS (FMOLS) Regression

Country	CO2 (dependent variable)	GDP(dependent variable)
China	0.43(12.26**)	2.25(12.62**)
India	0.43(18.12**)	2.28(16.82**)
Japan	0.03(0.41)	0.98(0.82)
Russia	0.06(2.47**)	8.75(3.46**)
USA	-0.15(-2.20*)	-1.90(-1.90*)
Panel Group	0.362 (4.05**)	0.04 (4.75**)

Note: The null hypothesis for the t -ratio is $H_0=\beta_i=0$; Figures in parentheses are t -statistics. * and ** significant with 95% (90%) confidence level.

Given the evidence of panel cointegration, the long run relationship between CO2 and GDP can be further estimated using fully modified OLS (FMOLS) estimation. In Table 3, we found that the coefficient for the estimators is positive and statistically significant at the 95% confidence level for all the individual countries except USA and Japan. Japan has a positive coefficient (0.03) but statistically insignificant at 1% level. USA has a negative coefficient (0.15) but statistically

significant at 1% level. We conclude that there is a long run relationship between CO2 and GDP for China, India, Russia, and USA. Table 3 also shows that there is a long run cointegration between CO2 and GDP for the five biggest emitters of coal in the world.

3.3 ECM Panel Granger causality tests

In this study, ECM based granger causality test is used:

$$\Delta CO_{i,t} = \alpha_{it} + \sum_{j=1}^k \theta_{1ij} \Delta CO_{i,t-j} + \sum_{j=1}^k \varphi_{1ij} \Delta GDP_{i,t-j} + \vartheta_{1i} ECT_{1i,t-1} + \mu_{1i,t} \quad (3.1)$$

$$\Delta GDP_{i,t} = \alpha_{2t} + \sum_{j=1}^k \theta_{2ij} \Delta CO_{i,t-j} + \sum_{j=1}^k \varphi_{2ij} \Delta GDP_{i,t-j} + \vartheta_{2i} ECT_{2i,t-1} + \mu_{2i,t} \quad (3.2)$$

where Δ is the first difference operator; $\alpha_{1,t}$ and $\alpha_{2,t}$ represent the coefficient of the equations ; k is the optimal lag length; $ECT_{1i,t-1}$ and $ECT_{2i,t-1}$, represent the lagged values of the error correction terms from the cointegration regressions while ϑ_{1i} and ϑ_{2i} are the speed of adjustment to the long run equilibrium path. CO is the CO₂ emission per capita, and GDP is the per capita.

Table 4: Results of panel Granger causality tests

Dependent variables (Short run)	ΔCO	ΔGDP	ECM (long run)
ΔCO	-	-0.3503	(-0.0179) -0.0316 ***
ΔGDP	0.3603	-	(0.0041) 0.0123**

Notes: ** and *** represent p-value statistics significance of 5% and 1% respectively. The ECM coefficient is in parenthesis.

Tables 4 depicts the results of the panel short-run and long-run granger causality test. The results of Table 4 show that there is a unidirectional relationship from CO₂ to economic growth for the five most significant emitters of coal in the world. The speed of adjustment running from CO₂ to GDP will take 1.79% annually. However, the result also shows there is no causality from CO₂ and economic growth in the short run.

Dumitrescu Hurlin Panel Causality Tests

Table 5: Pairwise Dumitrescu Hurlin Panel Causality Tests

Null Hypothesis	Lags	W -stats	Z-stat	P-value	
DLCO₂ does not homogeneously cause DLGDP	1	2.8300**	2.2359**	(0.0254)	Do not reject H₀
	2	2.0300	-0.2060	(0.8307)	
	3	4.0100	-0.31317	(0.7542)	
DLGDP does not homogeneously cause DLCO₂	1	5.416	5.8600**	(2.E-08)	Reject the H₀
	2	8.5700	5.3900**	(7.E-11)	
	3	14.4000	6.8987**	(5.E-12)	

Note: Figures in parentheses are *f*-statistics. * and **significant with 95% (90%) confidence level

The result of Table 5 depicts the panel short-run and long-run granger causality test. The results of Table 5 show that there is a unidirectional causal flow from CO₂ to economic growth for the five most significant emitters of coal in the world.

4. Conclusion and policy implication

The objective of this study is to examine the causal relationship between carbon emission and economic growth in five selected countries (China, United States, Russia, India, and Japan) by employing annual data over the period 1980- 2015. These countries were selected because they are the most significant carbon emitter in the world. The study used two types of unit root test technique Levin-Lin-Chu (LLC) and Im-Pesaran-Shin (IPS) unit-root tests to ascertain the order of integration. Johansen Fisher Panel cointegration techniques, and Pairwise Dumitrescu Hurlin Panel Causality Tests were applied to determine the existence of a long run relationship causal relationship between carbon emission and economic growth. Using panel cointegration approach, Fully Modified OLS and panel granger causality test, we found that there is a unidirectional causal flow from carbon emission to economic growth in most of the largest carbon emitters in the world in the long run. The robustness of the panel cointegration technique was checked. The study concludes that there is a unidirectional relationship from CO₂ emission to economic growth for the five most significant emitters of coal in the world. This happens to be the case in the long run but not in the short run.

Therefore, the five largest carbon emitters need to strengthen their carbon management and efficiency policies to avoid further environmental damages associated with rapid economic growth. There is an urgent need for developed countries to be committed to innovation in green energy to reduce the level of CO₂ emission.

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