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Carbon Dioxide Emission and Developing Countries: A Dynamic Panel Data Analysis

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Abstract

This study investigates the determinants of carbon dioxide (CO_2) emissions in selected 126 developing countries based on a dynamic panel data model. It employs the Generalized Method of Moments (GMM) technique and the analysis covers countries situated in Africa, Latin America and the Caribbean, Middle East and North Africa, and Asia and the Pacific region from year 1971 to 2009. The results show per capita gross domestic product, energy usage, energy consumption from fossil fuel-based, foreign direct investment, urbanization, industrial production, agriculture production and education level have significant impact on the growth of carbon emissions. Government in developing countries seems to centralize their focus on energy conservation type of policies to cut carbon emission. The move to emphasize on stringent environmental regulations and energy policies is much needed as to ensure all aspects must be addressed to reduce the carbon emission in the region.

Keywords: CO_2, Developing countries, Dynamic panel data, GMM technique.

1. Introduction

Understanding the needs of developing countries' commitment to meet their social and economic development goals, the Kyoto Protocol established on 11 December 1997 in Kyoto, Japan has the parties agreed to adopt a principle of "common but differentiated responsibilities" for these countries. The reason given is that the share of global per capita emission in developing countries is still relatively low, hence in order to meet their development goals as stated by UNFCCC[1], the carbon emission is allowed to grow. However, since the year 1991 these nations are responsible for the rapid increase of the world's CO_2 emissions (Fig.1). Being identified to be the next potential largest emitters, the dramatic increase was contributed by their high demand for coal, oil and gas to cater their energy-intensive industrial production. It is even projected the future GHG emissions from these countries are expected to exceed the developed countries by year 2015. Subsequently, it is more significant to focus on these countries since majority of them belongs to the low-income and lower-middle income category and are still in their developing needs. There is also argument regarding their ability

[1] United Nations Framework Convention on Climate Change (UNFCCC). Background paper for the workshop on reducing emissions from deforestation in developing countries (Part II): Policy approaches and positive incentives. Workshop on reducing emissions from deforestation in developing countries Rome, Italy from 30 August - 1 September 2006.

to worry about climate change due to their heavy dependency on fossil and solid fuels that emit a lot of carbon (Han and Chatterjee, 1997).

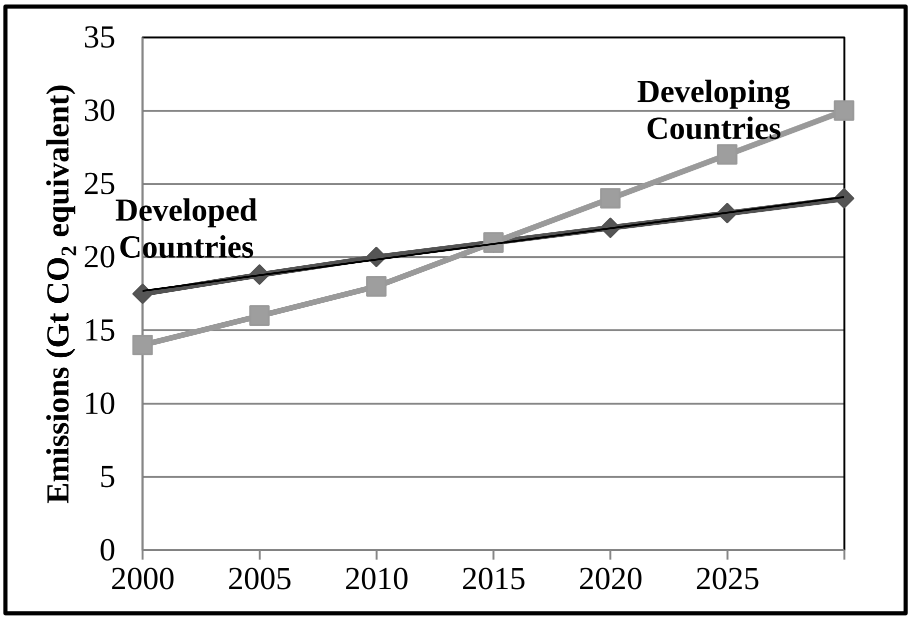

Fig. 1: Total Greenhouse Gas Emissions by Region[2]
(Source: http://epa.gov/climatechange/emissions/globalghg.html)

Essentially, being a signatory of the Kyoto Protocol has also demanded them to put effort in reducing the CO_2 emissions. This is because any effects of climate change are expected to be felt by these countries, the very countries that are least prepared to deal with them. GDP per capita is the most common indicator of a country's economic development and is believed to be the prime variable that affects the level of carbon emissions. In the 1990s, the concept of Environmental Kuznets Curve (EKC) is to investigate the relationship between economic growth measured by GDP and environmental degradation. Empirical studies by Shafik and Bandyopadhyay (1992), Selden and Song (1994), Grossman and Krueger (1995) and Panayotou (2003) centred on examining the relationship between these two variables aiming at either to establish their causal relations, prove its existence or identify the income level at which environmental degradation stabilizes or reaching its turning point.

It is believed that there is simply no single relationship between emissions and economic growth or energy consumption hitherto the evolution of emissions is bound to be dependent on a range of factors which vary according to circumstances. There are studies conducted to examine the relationship within a multivariate framework examining socio-economic variables such as capital stock, labor force, population, government expenditures, consumer prices and international trade that may have impact on the three variables, in particular CO_2 emissions. Variety of empirical techniques is applied by researchers aiming to analyze the sources of emissions growth such as ARDL, VAR and Decomposition methods. Recently, studies have also utilized the Generalized Method of Moments (GMM) technique as the empirical method to examine determinants of CO_2 emissions in the context of a multivariate framework. Since many economic relationships are dynamic in nature, the estimation procedure has evolved

[2]*Reference:* (1) SGM Energy Modeling Forum EMF-21 Projections, Energy Journal Special Issue, in press, reference case CO_2 projections. (2) Non-CO_2 emissions are from EPA's Global Anthropogenic Emissions of Non-CO_2 Greenhouse Gases 1990-2020.

over the years to better understand the process of adjustment. The GMM technique has profoundly impacted macroeconomic time series studies known to deal with dynamic panel models owing to its essentiality in a variety of applications. Unlike cross-sectional analysis, an advantage of a panel data approach allows control for individual heterogeneity and consequently removes the risks of biased results.

So long there is no concrete evidence on what determines the level of CO_2 emissions, and with the belief that different regions or countries may vary accordingly, this issue will remain open for discussion and it is to the best of our knowledge to explore all possible determinants in order to understand the complex process of the world's climate change. Therefore, the purpose of this study is firstly, to employ a multivariate framework in the context of a dynamic panel data model to investigate the eight factors that determine the level of per capita CO_2 emissions specifically in the developing countries. Several advantages of using a panel data are that it creates a large number of data point, increases the degrees of freedom and reduces the collinearity among explanatory variables of which would improve the efficiency of econometric estimates. Moreover, it allows researchers to analyze economic issues which cannot be addressed using cross-sectional or time series data. Secondly, we purposely include two sets of energy variable i.e. energy usage and energy consumption from fossil fuels in the scenario. Thirdly, this study employs the Arellano and Bond (1991), Arellano and Bover (1995), Blundell and Bond's (2000) GMM estimation which is rather limited in the area. The paper is organized as follows. Section 2 briefly reviews the theory and the empirical literature. Section 3 provides the methodology for the analysis. The main empirical findings are presented and discussed in Section 4. The final section concludes the study.

2. Literature Review

The issue on environmental problem was initially presented by two scientists Paul Ehrlich and John Holdren in 1971 by introducing the famous IPAT model. Extensive studies have been conducted linking the model with the socio-economic causes of deterioration in environmental quality in general before Cramer (1998) and York, Rosa and Dietz (2003a, 2003b) starting to give more attention to CO_2 emissions per se. Schmalensee, Stoker and Judson (1997), and Friedl and Getzner (2003) in their works clearly named CO_2 emissions to be the main cause of problem on a global scale. In the 1990s, the research began to focus on the concept of Environmental Kuznets Curve (EKC) to investigate the pattern of the relationship between economic growth or income of a nation and environmental degradation.

The study becomes widespread when energy consumption is identified to be closely linked to economic growth and CO_2 emissions and subsequently becomes a central attention for researches. There are many studies proven empirically on the relationship between economic growth, CO_2 emissions and energy consumption. However, these studies focus much on the causality running among the three variables. Then again, most researchers do not treat and regard fossil fuel energy as one independent variable that determines CO_2 emissions. Theoretical and empirical works have shown evidence of investment to be the key ingredient to promote economic growth for developing economies. Salim, Rafiq and Kamrul Hassan (2008) pointed out the issue that remains unsettled is the question whether economic growth is the cause or effect of energy consumption. Payne (2008) added the need to understand the impact of energy consumption on economic growth is crucial in the formulation of both energy and environmental policies. The various empirical evidences have one common outcome i.e. they have proved to show energy usage is indeed a critical factor in affecting the level of CO_2 emissions. Liu (2005) studied on 24 OECD countries and found that adding energy consumption implies a negative relation between income and CO_2 emissions. This outcome is supported by Lee and Oh (2006) in their research on 15 APEC countries (categorized into three income groups) who saw that energy intensity did contribute negatively to CO_2 emissions growth in developed countries but positively with developing countries except China.

A more recent research conducted by Aye and Edoja (2017) applying a dynamic panel threshold model found that economic growth has negative effect on CO_2 emission in the low growth regime but positively in the high growth regime. They also discovered that energy consumption and population exert positive and significant effect on CO_2 emission. The latest study by Shuai, Chen, Wu, Zhang and Tan (2019) which somewhat differ, applied a three-step strategy to decouple economic growth from carbon emission aim to investigate the global decoupling statuses of 133 countries as a way to promote low-carbon economy. Using data from 2000 until 2014, their findings showed that higher income-level group has the larger proportion of countries having reached their decoupling statuses. The findings may serve as valuable references to provide national governments, and global organizations with a more scientific basis for effective and targeted policy-making.

However, evidence showed that majority of the studies conducted focus on the unit root and co-integration approaches, and or estimates Granger causality between them. There are single country studies run by Soytas, Sari and Ewing (2007) on United States, Ang (2007, 2008) on France and Malaysia, and Zhang and Cheng (2009) and Li, Dong, Li, Liang and Yang (2011) on China while for multi-country studies by Liu (2005), Lee and Oh (2006), and Apergis and Payne (2009a, 2009b) showing mixed results of the existence and direction of Granger causality between economic growth, energy consumption and carbon emissions. Payne (2008) though, emphasized the need to understand the impact of energy consumption on economic growth is crucial in the formulation of both energy and environmental policies. The various empirical evidences have one common outcome i.e. they have proved to show energy usage is indeed a critical factor in affecting the level of CO_2 emissions. In this study, the Arellano and Bond's (1991) GMM estimator using a dynamic panel specification of lagged levels of CO_2 emissions would be apply. Study conducted by Martínez-Zarzoso and Bengochea-Morancho (2004), Aldy (2006) and Martínez-Zarzoso, Bengochea-Morancho and Morales-Lage (2007) have proven that pollution-income relationship is a dynamic one and assumed that last year's CO_2 emissions (given as CO_{2t-1}) will have an impact on this year's emissions. From the perspective of the developing region that is in need of sustainable growth, if a country emitted large amounts of CO_2 last year, this year's emission is prone to be high too.

It is believed that FDI is less prone to crisis because direct investors are perceived to have a long term perspective when they decide to tie up in a host country. Yanchun (2010) found in her study that FDI inflows have alleviated the pressure of carbon dioxide emissions in China resulting from FDI technology spillover, nevertheless at the same time the use of foreign technology has some extent improved their environmental problems. In the case of urbanization, most cities especially in developing nations are rapidly growing above the national average as endurance workers migrate from rural areas to urban areas in search of better jobs, education, and living standards even into believing it will promise a luxury life (Itoh, 2009; Deng, Huang, Rozelle & Uchida, 2008). It can be observed as population becomes more urbanized, they exert pressure on urban resources and environment leading to more pollution (Kahn & Schwartz, 2008). Hence, the more urbanized the city is the higher the pollution level, meaning a positive relationship is expected between the two variables.

Industrial production is a critical variable to be the main cause of the increase in the level of CO_2 emissions in developed and developing countries. A recent study by Halkos and Tzeremes (2011) included industrial production in their multivariate framework and found a significant positive correlation between industrial production and CO_2 emissions. It is observed that majority of the developing economies still depend on agricultural production to contribute to their GDP growth. Thus, it is not surprising that agricultural sector is reported to be one of the largest sources of CO_2 emissions after energy sector in these countries. In 2005, seventy four percent of total agricultural emissions were mostly contributed by developing countries from rice production and burning of biomass.[3] With this reported statement, a positive correlation between the two variables is anticipated.

Education is a continuous process of learning aiming to enhance one's ability to acquire knowledge, understand the know-how as a way to improve one's well-being. Although empirical studies with regards to the impact of education level on CO_2 emissions per se are rather limited. As Farzin and Bond (2006) argued, educated people are more aware and strongly prefer better environmental quality hence enable them to create a democratically-minded public policymaker and organization that are more receptive to public demands for environmental quality. This is also supported by Bimonte (2002) who found strong positive correlation between the level of education and the demand for environmental amenities. By contrast a recent study by Kinda (2010) on 85 countries suggests that education has no impact on the growth of air pollution in the developing countries but it does matter in the developed countries.

Stern (2004) has expressed concerned on the econometric works that fail to note testing different variables individually is subject to the problem of potential omitted variables bias. Noting this, there are studies conducted to examine the relationship not only among these three core variables CO_2 emissions, economic growth, and energy consumption but to look as well within a multivariate and integrated framework including other economic and socio-economic variables into the study. Alam, Fatima and Butt (2007) have added population and urbanization growth show a positive impact on environmental degradation yet negatively significant to Pakistan economic development in the long run. However, Zhang and Cheng's (2009) study on urban population in China does not show significant impact on carbon emissions. Sharma (2011) included trade openness and urbanization on 69 panels of countries divided into three income panels and found negative impacts on the CO_2 emissions from global perspective.

3. Econometric Analysis

3.1 Preliminary Analysis

The correlations matrix shown in Table 1 simply measures the degree of association between the variables representing the whole region. It has to be noted that it may differ slightly if one takes into consideration the regions individually. Moreover, any correlation between two variables does not correlate carbon emissions per capita for all the fourteen variables being studied. Ten of the variables show a positive association and only four indicate a negative association. A positive correlation may be interpreted as being where a high (low) per capita GDP is associated with a high (low) level of carbon emissions whereas a negative correlation

[3] Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, O. Sirotenko, 2007: Agriculture. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

implies a low Foreign Direct Investment (FDI) is being associated with a high level of carbon emissions and vice versa.

Table 1: Correlations of variables for the whole region

	CO_2 per cap	GDP Per cap	EUS	EFF	FDI	URB	IND	AGR	EDU
CO_2/cap	1.00								
GDP/cap	0.82	1.00							
EUS	0.69	0.34	1.00						
EFF	0.87	0.52	0.74	1.00					
FDI	-0.05	0.12	-0.60	-0.12	1.00				
URB	0.20	0.39	-0.13	0.20	0.29	1.00			
IND	0.51	0.36	0.60	0.63	-0.08	-0.12	1.00		
AGR	0.21	0.18	0.30	0.06	0.02	-0.16	0.11	1.00	
EDU	0.43	0.40	0.75	0.42	-0.55	0.25	0.43	0.28	1.00

Notes: EUS=Energy Usage; EFF=Fossil Fuel Energy; FDI=Foreign Direct Investment; URB=Urbanization; IND=Industrial Production; AGR=Agriculture Production; EDU=Education

A strong positive correlation is found between per capita carbon emissions with three variables, which are, Fossil Fuel Energy (0.8692), GDP per capita (0.8239) and Energy Usage (0.6871). On the other hand, the variable with a negative correlation, FDI, is rather ambiguous since any argument with regards to the variable can be discussed from different perspectives. Nevertheless, the variable shows a rather weak correlation i.e. 0.0525. The second column correlates GDP per capita with thirteen of the variables, excluding carbon emissions. This procedure continues for the rest of the columns and ends when the final variable is marked with a value of one. It must be noted that correlation values only quantify the relationship between two variables. However, to confirm or reject these correlation results, the way is to proceed with a deeper analysis through estimating and investigating the relevant equations employing the chosen GMM estimators and controlling other determinants of per capita carbon emissions before coming to any conclusions.

3.2 Empirical Model

A number of variables based on the literature of environmental economics are being considered in this research as possible determinants of carbon dioxide emissions, and subsequently the eight selected variables are GDP per capita, energy usage, fossil fuel energy consumption, foreign direct investment, urbanization, industrial production, agriculture production and level of education. The model begins with the proposed multivariate framework function i.e.:

$$CO_2 = f\ (GDP, EUS, EFF, FDI, URB, IND, AGR, EDU) \qquad (1)$$

where,
CO_2 = per capita CO_2 emissions (metric tons)
GDP = per capita GDP (USD$)
EUS = per capita total energy consumption
EFF = fossil fuel energy consumption
FDI = inflows of foreign direct investment
URB = urbanization
IND = industrial sector production
AGR = agricultural sector production
EDU = level of education proxy by education attainment for population age 15+

Equation (1) shows that these variables are possible factors which may affect the level of CO_2 emissions. Based on equation (1), the econometric model would be:

$$lnCO_{2i} = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 lnEUS_{it} + \beta_3 lnEFF_{it} + \beta_4 lnFDI_{it} + \beta_5 lnURB_{it} + \beta_6 lnIND_{it} + \beta_7 lnAGR_{it} + \beta_8 lnEDU_{it} + \varepsilon_{it} \quad (2)$$

The dependent variable is CO_2 emissions where *i* and *t* represent country (126 countries) and time frame (1971-2009) respectively. The variable per capita GDP, EUS and EFF are expected to have a positive effect on carbon dioxide emissions because an increase in EUS catered by EFF leads to more economic activities meaning higher GDP yet end up with higher CO_2 emissions. Similar positive relationship is also expected for FDI, URB, IND and AGR with CO_2 emissions. However, the variable EDU differs in such a way that the higher the level of education of a nation would mean a decrease in CO_2 emissions.

Since the analysis is based on a dynamic panel specification of which lagged levels of CO_2 emissions are taken into consideration, the Arellano and Bond (1991) GMM estimator would be appropriate for the study. Thus, the equation is:

$$lnCO_{2i} = \beta_0 lnCO_{2it-1} + \beta_1 lnGDP_{it} + \beta_2 lnEUS_{it} + \beta_3 lnEFF_{it} + \beta_4 lnFDI_{it} + \beta_5 lnURB_{it} + \beta_6 lnIND_{it} + \beta_7 lnAGR_{it} + \beta_8 lnEDU_{it} + \mu_{it} + \varepsilon_{it} \quad (3)$$

$i = 1,....., N; t = 1,...., T$

where,
$lnCO_{2i,t-1}$ = natural log of per capita CO_2 emissions of country *i* at time *t-1*
β = parameters to be estimated
μ = country-specific effects
ε = error term

Applying a dynamic panel specification would cause two problems to arise i.e. firstly, the country-specific effects and secondly, the correlation between the lagged dependent variable and the error term. If one uses the panel ordinary least square (OLS) estimator, it is problematic since the lagged dependent variable is correlated with the error term. Therefore, the appropriate option is to employ the Arellano and Bond estimator basically because the country-specific effects could be eliminated. This is so for the reason that the method first differences the regression model resulting with: $E\ (\varepsilon_{it} - \varepsilon_{it-1}) = 0$ but $(gCO_{2it-1} - gCO_{2i,t-2})$ is dependent of $(\varepsilon_{it} - \varepsilon_{it-1})$. Due to this, the Arellano and Bond method provides a better solution when one uses two or more lags of the first difference of CO_2 emissions.

However Blundell and Bond (2000) warned that the usage of first-differenced GMM estimator was found to have poor finite sample properties as they are bias and imprecise when the lagged levels of the series are only weakly correlated with subsequent first differences, thus the instruments available for the equations became weak. This will often occur in the case when the variables are highly persistent or show a close to random walk processes and the number of time series observations is small. Bond, Hoeffler and Temple (2001) did a simulation study to prove these features are typically present in empirical growth models of which output is a highly persistent series, and to avoid modeling cyclical dynamics, most growth applications consider only a small number of time periods, usually based on five year averages. Thus, they recommend the usage of a system GMM estimator introduced by Arellano and Bover (1995) and Blundell and Bond (2000) which exploits an assumption about the initial conditions to obtain moment conditions that remain informative even for persistent series.

Arellano and Bover (1995) have developed a framework for efficient instrumental variables (IV) estimators with information in levels which is capable of accommodating models with lagged dependent variables and other predetermined variables. On the other hand, Blundell and Bond (2000) explained using suitable lagged first differences of the variables as instruments for the equations in levels allow both sets of moment conditions be exploited as a linear GMM estimator in a system containing both first-differenced and levels equations. Thus, when both sets of moment conditions are combined, this provides what they call the system (SYS) GMM estimator. They wrapped up their research by advising future growth researchers (i) to preferable use the system GMM estimator rather than the first-differenced estimator in empirical growth work and (ii) researchers who report the standard first-differenced GMM estimates should probably check their results against those of alternative estimators. In the context of carrying out the research on CO_2 emissions, the characteristics described above seem to be apparently similar and could be predicted that the first-differenced GMM estimator will appear to be problematic. Thus, in order to promote a fair insight on the employment of the GMM estimations, the findings extracted from both the first-differenced and the system GMM estimators are illustrated and discussed in the analysis.

3.2 Sources of Data

The empirical study is based on data gathered for 126 countries (refer Appendix 1 for the list of countries) covering a time span from 1971-2009. The source of CO_2 emissions data valued in metric tons per capita comes from the Carbon Dioxide Information Analysis Centre, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, US. GDP per capita is based on PPP Converted GDP Per Capita (Chain Series), at 2005 constant prices and extracted from Penn World Table version 7.0. Energy usage refers to the usage of primary energy before transformation to other end-use fuels, is measured based on kt of equivalent of which the source is mainly from IEA and WDI. Similarly, data for fossil fuel energy consumption is measured as the percentage of total energy consumption is collected from the same source as energy usage.

FDI is measured by inward FDI flows based on percentage of GDP extracted from UNCTAD. Urban population computed as an annual percentage of urban population growth whilst industrial production valued as a percentage of GDP comprised of value added in mining, manufacturing, construction, electricity, water, and gas. Both data are collected from WDI. Agriculture is measured by the index of agriculture production merely because the data is available for all developing countries. The data is extracted from Food and Agriculture Organization of the United Nations (FAOSTAT). For a standard measurement on the level of education, new data set on educational attainment is utilized (Barro and Lee, 2010).

4. Empirical Findings

Before discussing the findings, three aspects worth noting; firstly, the full time period 1971-2009 is corresponding to a five-year average for example 1971-1975, 1976-1980 and so on, basically is a standard procedure to mitigate the persistence in the data. In addition, another advantage of using this five-year average is that it helps to control measures for the average years of schooling, which are only available in this periodical manner. Secondly, the results presented will exploit the first-difference-GMM and system-GMM robust approaches. Thirdly, the choice of estimating using alternative GMM methods is essential to have a more realistic, appropriate, efficient and feasible discussion of the outcomes.

Table 2 portrays the estimates for the eight determinants based on equation (3). The appropriate optimal lag period is determined based on the standardized average residuals autocovariance introduced by Arellano and Bond (1991) that is termed as m_j statistics where j is the order of autocorrelation with asymptotically N(0, 1) distributed under the null hypothesis of no autocorrelation. The reported first-differenced and system GMM estimates have treated per capita GDP, total energy usage and fossil fuels energy consumption rates (i.e. lagged values of the variables in levels) as potentially endogenous variables and the rest of the variables (i.e. FDI, URB, IND, AGR and EDU) to be strictly exogenous.

Table 2: Effect of socioeconomic factors on per capita CO_2 emissions

Log of carbon dioxide per capita emissions	GMM 1-DIF (1)	GMM 2-DIF (2)	GMM 1- SYS (3)	GMM 2- SYS (4)
Log of CO_{2t-1}	0.245*** (3.24)	0.238*** (10.11)	0.651*** (5.92)	0.642*** (39.46)
Log of GDP/cap	-0.137 (-0.63)	0.096 (0.94)	0.284** (2.43)	0.271*** (14.30)
Log of EUS	0.462* (1.88)	0.471*** (3.99)	0.031 (0.88)	0.023** (2.03)
Log of EFF	0.788** (2.40)	0.716*** (5.35)	0.264*** (4.06)	0.261*** (13.95)
Log of FDI	0.011 (1.30)	0.009* (1.87)	0.035*** (3.39)	0.351*** (12.91)
Log of URB	0.081 (0.42)	-0.004 (-0.03)	-0.136** (-2.47)	-0.114*** (-5.04)
Log of IND	0.130 (0.85)	0.143** (2.20)	0.092 (0.78)	0.139*** (4.38)
Log of AGR	-0.103 (-1.01)	0.004 (0.09)	0.162** (2.28)	0.179*** (7.79)
Log of EDU	-0.119 (-0.83)	-0.147*** (-2.76)	0.041 (0.65)	0.068*** (2.95)
Year Dummy	-0.007 (-0.19)	-0.027** (-1.96)	-0.054*** (-3.03)	-0.056*** (-21.25)
No. of observations	314	314	394	394
No. of countries	66	66	68	68
m_1-test	0.012	0.008	0.033	0.009
m_2-test	0.339	0.723	0.440	0.476
Hansen test	0.571	0.571	0.426	0.426
Difference-Hansen	0.546	0.546	0.260	0.260
No. of instruments	30	30	54	54

With lag (2 2) STATA is instructed to use only the second lag of the endogenous variables as instruments and since this lag is correlated with the current error term, the other second lag is required as it is uncorrelated. Examining the one-step and two-step difference-GMM, the results reported in columns (1) and (2) reveal a satisfactory significant m_1 (reject the null of no autocorrelation at 1 percent level) and m_2 (fail to reject the null of no autocorrelation) tests values. Simply, it means there is a first-order autocorrelation but no evidence of second-order

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autocorrelation in this estimation. A robust one-step difference-GMM test is performed producing the Hansen J-statistic for over-identification of which does not reject the null hypothesis that the error term is uncorrelated with the instruments. Even Difference-Hansen test fails to reject the null hypothesis of exogeneity of instrument subsets.

Both results of difference-GMM further imply previous years' carbon emissions do affect carbon emissions in the current year. Besides, it portrays the developing countries' dependency of their economy to the polluting carbon activities. Even though a few variables are insignificant in one-step difference-GMM, the two-step difference-GMM shows only three variables are not significant i.e. per capita GDP, urbanization and agriculture production. Interestingly. all the variables have the expected positive signs as explained theoretically except for urbanization and education having a negative sign nevertheless it is significant for education. It is somehow acceptable to argue that in the context of developing countries, a negative sign could mean an increase or improvement in the average level of total schooling may contribute to a reduction in carbon emissions since majority of these countries' population has a short time span of year in education. As for agricultural production, the negative value is only applicable for one-step GMM estimator besides it is insignificant.
As cautioned by Blundell and Bond relying on first-differenced GMM method to estimate autoregressive models for a series like per capita GDP may likely to perform poorly when dealing with series having close to random walk process causing the instruments to be rather weak. Taking this advice, it is acknowledged that this study utilizes per capita CO_2 emissions and lagged of per capita CO_2 emissions with eight time periods of five-year averages sample showing syndrome alike would foresee to have similar problems. Thus, using the system GMM estimates both one- and two-step as shown in Columns 3 and 4 of the table has five aspects to note. First, the lagged per capita CO_2 emissions rate has a positive and significant coefficient, whose size 0.65 and 0.64 each, disclosing this lagged dependent variable has a high degree of persistence. Second, the coefficient of energy usage in the one-step system GMM has shown an insignificant statistical value whilst the rest do not. In contrast the fossil fuels energy consumption coefficients reported a positive highly statistical significant for all GMM estimates. Third, coefficients of urbanization have turned from an insignificant (positive sign for one-step) value in differenced GMM to a significant negative value for both steps in system GMM. Fourth, industrial production has a positive coefficient yet highly significant only for two-step system GMM. Fifth, coefficients for education become a positive value in system GMM and statistically significant only for the two-step system GMM.

The two-step system GMM has preferably shown the coefficients of all estimators are significant at 1 percent significance level with only one exception that is energy usage at 5 percent significance level. More importantly, the Hansen J-statistic for over-identification does not reject the null, and the test for first-order serial correlation rejects the null of no first-order serial correlation, but it does not reject the null that there is no second-order serial correlation. Hence, these comply with the expected diagnostics. The results of the whole panel show evidence of the explanatory variables have a statistically significant positive effects on per capita CO_2 emissions except for urbanization having a significant negative effect on per capita CO_2 emissions. In the context of developing countries, the negative coefficient of urbanization could be due to the fact that for majority of the regions like Africa, South Asia and East Asia Pacific (covers 62 percent of the developing economies), their rate of urban population growth is still very low which may not have much impact on carbon emissions.

The results generally indicate the core variables that are per capita GDP, energy from fossil fuels, foreign direct investment, agriculture production and energy usage are crucial determinants of carbon emissions in these nations. It could be stated any increase (decrease) in GDP/cap, EFF, FDI, AGR and EUS would likely to increase (decrease) the amount of carbon released in these developing nations. Developing nations are largely dependent on mainstream industrial activities to boost their economy and this is achieved through attracting FDI to cater to this type of sector thus a positive significant result implies an increase in industrial activities lead to increase in per capita emissions. Agriculture production is still a core activity to these nations given the reason mentioned earlier; a strong significant positive sign indicates raising farming production might lead to a higher per capita emission. As for education which has overturned to a positive significant sign, it could mean developing nations with higher income may be prone to overconsumption of material goods that they are unaware of and would be harmful to the environment. In developing countries, it is rather a norm to interpret a higher level of education appears to be a means of earning higher income that basically increases their ability to demand more for goods leading more natural resources being exploited ending with higher carbon emissions. Thus, educating them further is one way to increase their awareness about environmental protection.

5. Conclusions

This study has attempted to examine the potential factors identified to be the key determinants of CO_2 emissions for selected 126 developing countries in four regions that are Africa, Latin America and the Caribbean, Middle East and North Africa, and Asia and the Pacific over the period of 1971–2009. Findings on these developing economies have indicated that the eight factors i.e. GDP per capita, energy consumption from fossil fuel (EFF), energy usage (EUS), inflows of foreign direct investment (FDI), urbanization (URB), industrial production (IND), agriculture production (AGR) and level of education (EDU) have portrayed a highly significant impact on the growth of carbon emissions. Martinez-Zarzoso and Maroutti (2011) have declared in their study that energy consumption is being singled out besides economic growth as having the most adverse impact on the environment globally. The conclusion is so long as output and population of developing nations grow in the name of prosperity to promote better standard of living and their welfare-being, carbon emissions will continue to rise persistently unless measures are taken by each country to control the emissions.

Although the policymaking to cut carbon emission has been centralized on energy conservation type of policies, a much broader scope that emphasizes on strict environmental and energy policies should be provided so as to ensure every aspect of method to cut carbon emissions must be addressed in these developing regions. It has to be noted that there is no single best solution for cutting CO_2 emissions, as Morancho, Tamarit and Zarzoso (2001) concluded that a uniform policy to control emissions is not suitable to reduce emissions problem. Thus, policymakers need to reinforce ways to achieve an ideal policy that able to balance their economic performance. A good reminder from Ahuja and Tatsutani (2009), to pursue a comprehensive set of policies all at once may not be possible unless the governments recognize an approach that is able to consider interactions of different policies and, leverages multiple opportunities at the same time responds to the specific needs and constraints of individual countries to attain maximum benefits.

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Appendix 1: List of developing countries representing the five regions

Africa	Latin America & the Caribbean	Middle East & North Africa	South Asia	East Asia & Pacific
Angola	Antigua & Barbuda	Algeria	Afghanistan***	Brunei
Benin	Argentina	Bahrain	Bangladesh	Cambodia
Botswana	Belize	Djibouti	Bhutan	China
Burkina Faso	Bolivia	Egypt	India	Fiji
Burundi	Brazil	Iran	Maldives	Indonesia
Cameroon	Chile	Iraq	Nepal	Kiribati
Cape Verde	Colombia	Jordan	Pakistan	Republic of Korea
Central African Rep.	Costa Rica	Kuwait	Sri Lanka	Lao PDR
Chad	Cuba	Lebanon		Malaysia
Comoros	Dominica	Libya		Marshall Islands
Congo, DR	Dominican Rep.	Morocco		Micronesia,Fed.Sts.
Côte d'Ivoire	Ecuador	Oman		Mongolia
Equatorial Guinea	El Salvador	Qatar		Myanmar
Eritrea	Grenada	Saudi Arabia		Palau
Ethiopia	Guatemala	Syria		Papua New Guinea
Gabon	Guyana	Tunisia		Philippines
Gambia	Haiti	UAE		Samoa
Ghana	Honduras	Yemen		Solomon Islands
Guinea	Jamaica			Singapore
Guinea-Bissau	Mexico			Thailand
Kenya	Nicaragua			Timor-Leste
Lesotho**	Panama			Tonga
Liberia**	Paraguay			Vanuatu
Madagascar	Peru			Vietnam
Malawi	St. Kitts & Nevis			
Mali	St. Vincent & the Grenadines			
Mauritania	Suriname			
Mauritius	Trinidad & Tobago			
Mozambique	Uruguay			
Namibia	Venezuela, RB			
Niger				
Nigeria				
Rwanda				
Sao Tome & Principe				
Senegal				
Seychelles				
Sierra Leone				
Somalia***				
South Africa				
Sudan				
Swaziland				
Tanzania				
Togo				
Uganda				
Zambia				
Zimbabwe				

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