Urbanization, CO2 Emissions, and Science-Technology-Society in Cameroon

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Abstract

Important advances have been made in theoretical and econometric research in the relationship between CO2 and urbanisation. However, scanty attention has been focussed on the role and importance of science and technology as one of the major factors reducing CO2 emissions. For example, to our knowledge, Cameroon has never been chosen as a case study. Therefore, the statistical and econometric analyses undertaken in this paper aims at filling this gap. We begin our analysis by employing statistical tools and econometric tests such as unit root tests, Cointegration tests, Error Correction tests and the Granger short and long run causality tests. Our results related to the causal relationship between CO2, urbanization and science and technology indicate that while there is a bidirectional causality between the latter variables in the long run, there is no causality between the studied variables in the short run.

Keywords: Urbanization, CO2 emissions, science and technology and ecological modernisation

I. INTRODUCTION

CO2 emissions are currently the greatest puzzling problems of the world. It is not surprising that factors affecting CO2 emissions are one of the most investigated ones in economic literature. The level of CO2 emissions, in Africa, from urbanization is significantly increasing due to the fact that uurbanization is the growth of urban area in a specific country followed with the population growth living in those areas. Urban populations interrelate with the environment through their exhaustion of food, energy, water, and land causing a fast polluted urban environment which will then generate many problems such as excessive air pollution, high demand of housing, poor water quality, climate change, loud noise, waste management and poor health. In response to unregulated urbanization, environmental degradation has been occurring at a rapid rate. For example, the human Development Indices (2018) reported that high human development countries are the biggest contributors to environmental degradation with 10.7 tons average carbon dioxide emissions per capita. Small countries, on the other hand, with 0.3 tons of carbon dioxide emissions per capita have been found to pollute less. According to the World Bank (2019), the population of Cameroon grew at the rate of 3% from 2005 to 2015 while during the same period carbon dioxide emissions per capita has increased at the rate of 4%. Science and technology, on the other hand, appear to exert an inverse effect on CO2 emissions. In the 1970s, contributions on the relationship between CO2 emissions and science and technology were fragmented. The emergence of ecological modernisation in the 1990s provided a common platform to major researchers such as Huber (2004) and Sonnenfeld (2002). Furthermore, utilising the contribution of Beck (1986, 1992) on science and risk, and that of Schot (1992); Geels (2005); Shove (2003) on science and technology studies, ecological modernization theorists nowadays have made significant contributions to the role and importance of science and technology on environmental policy. Mol et al. (2009), on the other hand, also significantly contributed to articles related to the changing role of technology in ecological modernization studies.

Overall, the previous theoretical and empirical studies as will be depicted in the next section, analyzing the relation between CO2 emissions, urbanization and science and technology have concentrated more on the relationship between CO2 emissions and urbanization and less on the relationship between CO2 emission and science and technology. Currently, none of the scholars analyzing the latter relationship focusses on Cameroon and very few focus on Africa. This calls for developing CO2 models for the case of Cameroon that will contribute to environmental policy aiming at reducing CO2 emissions. this paper contributes to the existing knowledge and suggests empirically tested model on the relationship between CO2, urbanization and science and technology. Based on the case of Cameroon with data covering the 2005-2015 period, we endeavour to employ econometric tests such as unit root tests, the augmented Dickey Fuller, Johensen Cointegration tests, Error Correction tests the modified Wald (MWald) test of Toda and Yamamoto (1995) for Granger causality to examine the causal relationship between the above variables of interest.

The present paper is structured as follows: Section 2 outlines methods, results and authorship contributions. Section 3 undertakes major discussions and concludes. Section 4 list relevant tables and Section 5 focusses on selected references.

II. METHODS, RESULTS AND AUTHORSHIP CONTRIBUTIONS

2.1. Literature Review

Three major theories underline the impact of urbanization on the environment. Namely, the Urban Environmental Transition theory, the Ecological Modernisation Theory and Impact City Theory.

The theory of urban environmental transition developed by McGranahan et al (1996) suggests an association between urban environmental burdens and industrial pollution. That is the increase in urbanisation leads to the demand of high energy intensive products which will then contribute to the increase in CO2 emissions. In the present context, we could say that industrial pollution may be reduced via environmental regulations and science and technological innovations. The latter relationship shall be analysed in the present article.

According to Newman and Kenworthy (1989)], the compact city theory supports the increase of urbanization leading to economies of scale related to public infrastructure such as public buses, hospitals, water and electricity supplies. They went on to say that the utilisation of public rather than private services will reduce environmental degradation. Moreover, Ma (2015) explored the energy-saving effect due to increase in urbanization causing the reduction in energy consumption since more public transport, for example, will be used in bigger cities. There will therefore be an increasing utilisation of public services. Although the present theory has been tested in various countries as indicated in our empirical literature survey, such test, to our knowledge has not been carried out in Cameroon. This article endeavours to elucidate this lacuna by examining the causal relationship between urbanization and CO2.

The Ecological Modernisation Theory was developed by Joseph Huber (1982) and Martin Janicke (1985). They argued that ecological disaster should be avoided as the result of the transformation of modern society institution. According to Mol and Spaargaren (1993) the Ecological Modernisation Theory central tenet is the inverse relationship between CO2 and science and technology. Mol and Spaargaren (2013) went on to argue that technologies are motivating drives for environmental fluctuations. The works of ecological modernization theorists such as Beck (1986, 1992), Giddens (1990, 1991), Latour (1993), Urry (2000), Schot (1992), Geels (2005) and Shove (2003) have constituted the basis of the examination of the role and importance of science and technology on the environment. As mentioned earlier, the test of the above theory has never been undertaken in Cameroon. The present article therefore breaks new ground by examining the causal relationship between science and technology and CO2 in Cameroon.

Table 1 indicates that the causal relationship between Urbanization, CO2 Emissions, and Science-Technology-Society has been tested in various countries. However, only two out of ten tests were carried out in Africa on the relationship between CO2 emissions and Urbanization. While no test has been carried out in relation to CO2 and Science and Technology. The present paper therefore aims at feeling the latter gap.

economies of scale and U urbanization.

→ denotes uni-directional and □ bi-directional causality.

Overall, the econometric evidence on the causal relationship between Urbanization and CO2 Emissions is very mixed. No tests with regard to the relationship between Science and Technology and CO2 Emissions was carried in Africa. Although sample periods and specification differ somewhat, it is difficult not to conclude that the wide variety of results reflects problems with the data. For example, in developing countries, the low quality of data and lack of sufficiently long series pose degree of freedom problems. It seems, therefore, highly probable that these econometric models were mis-specified and thus the estimates presented were unreliable for policy analysis. It may also be argued that specific variables such as Science and Technology are not considered in almost all studies summarised in Table 1. In the next subsection we show that Science and Technology contribute significantly to the reduction of CO2 in Cameroon. The next subsection attempts, therefore, to reduce the above shortcomings by specifying a CO2 model that considers Science and Technology as one of the major factors in Cameroon to reduce CO2 emissions.

2.2. Statistical and Econometric Analyses

Regardless the fact that, important advances have been made in theoretical and econometric research in the relationship between CO2 and urbanisation as indicated in the previous subsections, scanty attention has been focussed on the role and importance of science and technology as one of the major factors reducing CO2 emissions. For example, to our knowledge, Cameroon has never been chosen as a case study. Consequently, the CO2 model for the case of Cameroon may be better specified if its reflects Cameroon specific factors as emphasised in the Ecological Modernisation Theory which argues that increase in science and technology reduce CO2 emissions. In these circumstances, CO2 models that do not include the science and technology effect will fail to capture its fluctuations and could be considered as a specification shortcoming for the case of Cameroon. The following econometric analysis aims at filling this gap by investigating the role of science and technology and urbanization through estimation of our proposed CO2 model. We begin our analysis by employing statistical tools such as descriptive statistics, interval estimate and hypothesis testing to have preliminary insight into our data. We then proceed with econometric tests such as unit root tests, the augmented Dickey Fuller, Johensen Cointegration tests, Error Correction Model and the modified Wald (MWald) test of Toda and Yamamoto (1995) for Granger causality.

It should be noted that in developing countries, the low quality of data and lack of sufficiently long series pose serious problems. Thus, our results must be interpreted with care. Nevertheless, this potential source of misspecification error also applies to empirical studies in all developing countries. Our data are mainly taken from the World Bank, World Development Indicators (2019). Our analyses for the case of Cameroon cover the period 2005-2015.

2.2.1. Statistical Analysis

The main goal of the present analysis is to provide summaries related to the sample and the measures of location and variability in order to investigate existing instability in our variables. On the basis of the point estimator of the population mean calculated, we use hypothesis testing to determine whether Cameroon could be considered as a big or a small pollutant. We proceed with Interval Estimate to confirm the latter hypothesis results at the 95% confidence that the interval contains the population mean

Table 1: Summaries of Econometric Tests of Urbanization, CO2 Emissions, and Science-Technology-Society

No	Authors	Time Period	Study Area	Variables	Long Run Causality
1	Afawbo and Ntouko (2016)	1960-2014	142 countries Low-income, Lower-middle-income, Upper-middle-income, High income non-OECD, High-income OECD	CO2 emissions, urbanization, industrialization	No in low and lower income countries Yes in the remaining countries of studies
2	Ameer and Munir (2016)	1980-2014	Pakistan, India, Bangladesh, Indonesia, Thailand, Malaysia, Philippines, Sri Lanka, Iran, Singapore, and Hong Kong	GDP, openness, urbanization, technology	E↔C U↔C U↔E T↔C
3	Çetin and Ecevit (2015)	1985-2010	Panel data of nineteen Sub Saharan African countries	CO2 emissions, urbanization, Energy consumption	E↔C U↔C U↔E
4	Kasman and Duman (2015)	1992-2010	new EU members	CO2 emissions, urbanization GDP per capita, Energy consumption, , openness	E↔C U→C U→E
5	Begum et al. (2015)	1970-2009	Malaysia	CO2 emissions, Energy consumption, GDP per capita, population	No
6	Shahbaz et al. (2014)	1975-2011	United Arab	CO2 emissions, Emirates, urbanization, GDP per capita, Energy consumption, exports	E↔C U↔C
7	Wang et al. (2014)	1995-2011	30 Chinese provinces	CO2 emissions, Energy consumption, urbanization	E↔C U↔C U↔E
8	Hossain (2012)	1960-2009	Japan	CO2 emissions, urbanization, Energy consumption,	E↔C U→C

Measures of Location and Variability

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Table 2: Coefficient of Variation Determination

	CO_2=	Urban	Tech	Cons
Mean	0.292	10,361,445	17.64	7.93
Variance	300.33	1,610,483,294,653	7.37	0.69
standard deviation	18.18	1,330,988.96	2.85	0.87
Coefficient of Variation	0.75	0.13	0.16	0.11

Source: World Development Indicators (WDI)

Where CO_2 stands for carbon dioxide emissions per capita, Urban for Urban Population, Tech for Access to Clean Fuels and Technologies for Cooking (% of population) and Cons Construction Industry (% manufacturing value added)

Table 2 indicates that CO_2 emissions fluctuate more rapidly than those of the remaining variables. The latter results reflect the existing instability in environmental variables.

Hypothesis Testing

In the introductory subsection of the paper, we stated that the Human Development Indices (2018) pointed out that that high human development countries are the biggest contributors to environmental degradation with 10.7 tons average carbon dioxide emissions per capita. Small countries on the other hand with 0.3 tons carbon dioxide emissions per capita have been found to pollute less. We use CO_2 emission per capita for the case of Cameroon in order to test the latter claims. 0.292 tons is the estimated average CO_2 in Cameroon for the period of 2005 to 2015.

$H_o : \mu \leq 0.3$

$H_a : \mu > 0.3$

Rejection Rule assuming a .05 level of significance,

Reject H_o if $t < -2.262$ or if $t > 2.262$

Df =n-1 = 10 – 1 = 9

$$t = \frac{\bar{x}-\mu}{s/\sqrt{n}}$$

$$t=\frac{.29-.3}{.04/\sqrt{10}} = -0.79$$

Since $-0.79 > -2.262$, we do not reject H_o.

Conclusion: We are 95% confident that the sample mean CO_2 in Cameroon, is 0.3. Therefore, Cameroon, with 0.292 tons carbon dioxide emissions per capita can be considered as a country polluting less. The low pollution level in Cameroon may be due to its environmental policies implemented in sectors such as electricity generation where more focus is placed on renewable energy such as hydroelectricity, solar and gas to power plants.

Interval Estimation

The sample mean of CO_2 above for the case of Cameroon has been estimated at 0.292 tons, the present subsection will develop a 95% confidence interval estimate for the population mean of small pollutant.

$$\bar{x} \mp t\alpha/2 \frac{\sigma}{\sqrt{n}}$$

$$0.292 \mp 2.262 \frac{0.04}{\sqrt{10}}$$

0.26 tons to 0.32 tons

Conclusion: The present results confirms the hypothesis results since we are 95% confident that the interval contains the population mean of 0.3.

We now turn to the econometric analyses of the above variables in order to explore their causal relationship.

2.2.2. Econometric Analysis

The present Econometrics analysis is an attempt to reduce the shortcomings due to no CO2 models that test the causal relationship between CO2 emissions and urbanisation and science and technology in Cameroon. We aim at investigating the relationship and the direction of short and long run causalities between the latter variables using the unit root tests, the augmented Dickey Fuller, Johensen Cointegration tests, Granger causality test within Error Correction Model and the Toda and Yamamoto (1995) Granger causality. In line with the theoretical thoughts outlined in our literature review, our CO2 model is specified as follows:

$$CO2_i = \alpha_0 + \underset{+}{\alpha_1 Urban_i} + \underset{-}{\alpha_2 Tech_i} + \underset{+}{\alpha_3 Cons_i} + \varepsilon_i \quad (1)$$

Where CO2 is Greenhouse Gas Emissions, Urban is Urban Population, Tech is Access to Clean Fuels and Technologies for Cooking and Cons Industry construction.

Multiple Regression Analysis

The present multiple regression analysis will enable us to assess the significance of the relationship between our variables of interest. The outcome of this analysis will permit us to identify the main factors that affect CO2 in Cameroon by capturing the strength that they exert on CO2 emissions. Our results will be used to forecast the significance of the changes. Equation (2) presents the results of estimation by OLS of CO2 emissions which test the validity of the Ecological Modernisation Theory in Cameroon.

$$CO2 = \underset{(-3.91)}{-480.89} + \underset{(2.90)}{00017 Urban} - \underset{(-2.85)}{80.03 Tech} + \underset{(3.47)}{14.99 Cons} \quad (2)$$

$R^2 = 0.82$ DW = 1.33

The results of the proposed CO2 equation presented in equation (2) show that the estimated coefficient on Tech is negative and statistically significant at the 5 per cent level. The performance of this appears to accord with the Ecological Modernisation Theory. The estimated coefficients on Urban and Cons are significant at the 5 and 1 per cent levels respectively and display positive signs as anticipated.

From the Durbin–Watson tables, we find that for 11 observations and one explanatory variable, dL = 0.595 and dU = 1.928 at the 5 percent level. Since the calculated d of 1.559 lies between dL and dU, we are in the zone of indecision and cannot therefore conclude about the serial correlation of our error terms in our time series.

The Unit Root Test

A test of stationarity that has become extensively widespread over the past several years is the unit root test. We estimate the following equation:

$$\Delta Y_t = \beta Y_{t-1} + u_t$$

Where $\beta = (\rho - 1)$ and, Δ is the first-difference operator. The Ho hypothesis that $\beta = 0$ is tested. If $\beta = 0$, then $\rho = 1$, that is we conclude that there is unit root, indicating that the time series employed is non-stationary.

Ho: β = 0 (unit root)
Ha: β > 0 (no unit root)

Should the ut is found to be correlated, we shall then employ the augmented Dickey–Fuller (ADF) test using the following regression:

$$\Delta y_t = \gamma + \beta t + \alpha y_{t-1} + \sum_{j=1}^{K} \theta_j \Delta y_{t-j} + u_t$$

Table 3 : Unit Root Tests

	ADF	
Variable	Test Statistic	5% Critical Value
CO2	-7.163	-3.000
ΔΔUrban	-2.39	-1.950
Tech	-3.227	-3.000
Cons	-22.559	-3.000

Table 3 presents the unit root tests for the relevant series. The null hypothesis is accepted if the t*0.05 < critical ADF τ value. It can be seen that all t*0.05 < critical ADF τ value = -3.000 for all variables. The null hypothesis is rejected for all variables. We conclude that while CO2, Tech and Cons are I(0), Urban is I(2).

Cointegration Tests

Though some quantitative methods for testing cointegration have been recommended in the literature, we contemplate here the ADF unit root test on the residuals estimated from the cointegrating regression. It should be noted that the ADF test in the existing situation is known as Engle–Granger (EG) and augmented Engle–Granger (AEG) tests. The cointegration test has the following hypothesis.

Ho: β = (cointegrated)

Ha: β ≠ 0 (not cointegrated)

The null hypothesis is not rejected if the critical value (t*0.05) is less than the test statistic of the error term. To implement the test, we first regressed CO2 emission on Urban, Tech and Cons. We obtained the following regression:

Table 4: Cointegrating Regression Estimates

Variable	Coefficient	Test statistic
Dependent (CO2)		
CO2	-480.892*	-3.91
Urban	0.0001736**	2.91
Tech	-80.031**	-2.85
Cons	14.988*	3.57
R^2	0.82	

*Notes: * and ** denote respectively statistical significance at the 1 per cent and 5 per cent level.*

Since, CO2, Urban and Tech are individually stationary, there is therefore no prospect that this regression is spurious. Furthermore, when we undertook a unit root test on the residuals obtained from the cointegrating regression, we obtained the following results:

Table 5: Unit Root Tests on the Residuals

	ADF	
Variable	Test Statistic	5% Critical Value
Residuals	-3.64	-3.000

Table 5 presents the unit root tests on the residuals. It can be seen that the augmented Engle–Granger test statistic < t*0.05 = -3.000. We reject the null hypothesis of unit root since the calculated τ (= t) value is lower than -3.000, we conclude that the residuals from the regression of, CO2, Urban Cons and Tech are stationary. We, therefore, conclude that there is a unique cointegrating vector in all CO2 combinations. That is there is a long term, or equilibrium, association between CO2, Urban Cons and Tech.

Error Correction Mechanism (ECM)

The error-correction term estimates the deviation of the series from the long run equilibrium relation. It was mostly employed by Sargan and, Engle and Granger who made it widespread. Relating to the Granger Representation Theorem, the association between two variables A and B can be expressed as ECM when they are cointegrated. Statistically, if the error term is negative and significant, we will infer that the changes in A (dependent variable), adjust to changes in B (independent variable) in the short run. Returning to the case presented in this paper, we have the following results:

Table 6 : ECM Regression Estimates

Variable	Coefficient	Test statistic
Dependent (D.CO2)		
Constant	49.938	0.73
D.Urban	0.0001264	1.25
D.Tech	-114.3558	-1.94
D.Cons	21.874**	2.92
U_{t-1}	-0.8545*	-1.96
R^2	0.80	

*Notes: * and ** denote respectively statistical significance at the 10 per cent and 5 per cent level. D stands for First Differences of our dependent and independent variables.*

Table 6 presents the ECM Regression Estimates where the error term is negative and significant at the 5% level. We conclude that the changes in CO2 emissions, with a negative coefficient of -0.9, do adjust to changes in Urban, Tech and Cons at a speed of 80% in the short term.

The Granger Causality Test

The Granger test undertaken in this paper will provide answers to the question of the direction of causality between CO2, Urban, Tech and Cons. For example, the direction of causality inference between W and Z will be made by estimating the following pair of regressions:

$$= \sum_{i=1}^{n} \propto_i Z_{t-i} + \sum_{j=1}^{n} \beta_j W_{t-J+u_{1t}}$$

$$Z_t = \sum_{i=1}^{n} \gamma_i W_{t-i} + \sum_{j=1}^{n} \beta_j Z_{t-J+u_{1t}}$$

Table 7: Short Run Granger Causality Test

Direction of causality	F	Df	Prob
CO2 → Urban	6.15	4	0.0603
CO2→ Tech	0.23	4	0.8044
CO2→Cons	0.11	4	0.9020
Urban → CO2	2.93	4	0.1649
Urban → Tech	1.07	4	0.4252
Urban → Cons	4.35	4	0.0992
Tech → CO2	0.45	4	0.6647
Tech → Urban	0.50	4	0.6390
Tech → Cons	1.27	4	0.3750
Cons → CO2	0.28	4	0.7667
Cons → Urban	3.40	4	0.1373
Cons → Tech	0.08	4	0.9258

Table 8: Long Run Granger Causality Test

Direction of causality	Chi-square	df	Prob
CO2→ Urban	25.01	4	0.0000**
CO2→ Tech	12.82	4	0.0003**
Urban → CO2	19.24	4	0.0000**
Urban → Tech	13.59	4	0.0002**
Tech → CO2	6.39	4	0.0115*
Tech → Urban	7.90	4	0.0050*

*Notes: * and ** denote respectively statistical significance at the 5 per cent and 1 per cent level.*

Tables 7 and 8 report the results about the causal relationship between CO2, urban, Tech and Cons. The above tables suggest that while there is a bidirectional causality between the latter variables (except industry construction) in the long run, there is no causality between the studied variables in the short run. All variables in Table 8 Granger-cause each other in the long run.

III. DISCUSSION AND CONCLUSION

3.1. Discussion

The bidirectional causality between Tech and CO2 indicates that due to the inverse and significant relationship between the latter variables shown in equation (2), an increase in Tech will reduce CO2 significantly. This may be due to environmental friendly considerations of new technologies in Cameroon. For example, in Cameroon, in terms of electricity generation, more focus is on renewable energy such as solar, hydroelectricity and gas to power plants rather than Diezel plants. The double causality in Table 8 shows that where CO2 is increasing, Science and Technology access is declining due to the neglect of the latter. For example, in Chad where 90% of electricity is generated via diesel power plants, Science-Technology-Society access via renewable energy is merely inexistent. Thus, policies that would help to reduce emissions are undoubtedly required major Science and Technology contribution.

The bidirectional causality between Tech and Urban, together with results in equation (2) indicate that increase in science and technology will create more wealth which will in turn increases urban population. On the other hand, in the long term, more urban population will stimulate science and technology to generate productivity.

The bidirectional causality between Urban population and CO2 Emissions indicates that urban population are in greater emission levels needs. Due to the increase in productivity related to greater emissions, more population will move from the rural to the urban areas. The urban population will then increase.

3.2. Conclusion

This paper has demonstrated that environmental policies implemented in Cameroon to reduce CO2 may not be reliable due to limited or no publication on the causal relationship between CO2 and science and technology supported in the ecological modernisation theory. Our statistical analysis has not rejected the null hypothesis of Cameroon being considered as a small pollutant. Moreover, the unit root tests have indicated that CO2 emissions, Urban population and science and technology are I(0). While, the cointegration tests have found short and long run equilibrium within the latter variables. Furthermore, the Granger and Toda and Yamamoto (1995) causality tests have suggested that while there is a bidirectional causality between the latter variables in the long run, there is no causality between the studied variables in the short run. Our results are amenable to the recommendation that policy makers in Cameroon should design policies controlling urbanization due to it positive and significant effect of CO2 emission. On the other hand, policies encouraging science and technology should be encouraged due to the inverse and significant relation between CO2 emission and science and technology.

IV. TABLES

Table 1: Summaries of Econometric Tests of Urbanisation, CO2 Emissions, and Science-Technology-Society

Table 2: Coefficient of Variation Determination

Table 3 : Unit Root Tests

Table 4: Cointegrating Regression Estimates (2005-2015)

Table 5: Unit Root Tests on the Residuals

Table 6 : ECM Regression Estimates

Table 7: Short Run Granger Causality Test

Table 8: Long Run Granger Causality Test

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