Human capital, energy consumption, 〖CO〗_2 emissions and economic growth in Cameroon: an ARDL approach

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Abstract- This paper examines the dynamic relationship between human capital, energy consumption, CO_2 emissions and economic growth in Cameroon over the period 1980-2014. The autoregressive error correction method (ARDL) was used to estimate the coefficients of the specified models. The results show the existence of a long term relationship between the variables. This allowed us to estimate an *Error Correction Model* (*ECM*). In the long term, emissions of CO_2 emissions positively and significantly influence economic growth while energy consumption negatively and significantly influences human capital. The same results are observed in the short term with, in addition, a positive and significant influence of economic growth on CO_2. The Cameroonian state would benefit from encouraging initiatives aimed at reducing CO_2emissions, while supporting those that develop and promote renewable energies such as solar and biomass.

Index Terms- human capital, energy consumption, emissions CO_2emissions, economic growth, ARDL

JEL Classification: J24, Q43, Q53, Q56

I. INTRODUCTION

Slightly discussed in national and international debates, environmental issues have been at the heart of bilateral and multilateral diplomacy for three decades. In 1972, the Meadows report commissioned by the Club of Rome was published. This text, published in French under the title *Halte à la croissance?* launched the debate on zero growth by highlighting the dangers linked to the depletion of natural resources and pollution. In 1979, the United Nations organised its first climate conference in Geneva. In 1987, the G. H. Brundtland report was published, popularising the concept of sustainable development. This report paved the way for the Earth Summit in Rio de Janeiro in 1992. Since 1995, more than a hundred countries from all over the world have been meeting every year at the Conferences of the Parties (COP) to discuss the climate and the fight against global warming. Because of the complexity of the subject and the issues at stake, it is a long process in which environmental, economic, social and diplomatic issues are intertwined.

Indeed, it should be noted that the relationship between energy consumption, greenhouse gas emissions and economic growth has received considerable and special attention from researchers, international organisations and institutions in recent years. CO_2 emissions and economic growth has received considerable and special attention from researchers, international organisations and institutions in recent years[1]. The work on this relationship can be seen from three angles:

The first concerns those on the relationship between CO_2 and economic growth (Ang, 2008; Richmond and Kaufmann, 2006; Fodha and Zaghdoud, 2010; Jaunky, 2010; Menyah and Wolde-Rufael, 2010; Pao and Tai, 2011; Lee, 2013; Kivyiro and Arminen, 2014; Jammazi and Aloui, 2015; Al-Mulali and al, 2016b). The second is related to work studying the causality between energy consumption and economic growth (Akinlo, 2008); Chien and Hu, 2008; Hye and Riaz, 2008; Odhiambo, 2009; Mishra and al, 2009; Ozturk and Acaravci, 2010; Ozturk and al. 2010; Peng and Sun, 2010; Abid and Sebri, 2011; Azis, 2011; Wang et al. 2011; Zhang, 2011; Shaari and al. 2012; Borozan, 2013; Dergiades and al. 2013; Ocal and Aslan, 2013; Balibey, 2015; Solarin and al. 2016). The third focuses on energy consumption, greenhouse gas emissions and economic growth (Ang, 2007). CO_2 emissions and economic growth (Ang, 2007; Bozkurt and Akan, 2014; Mustapa and Bekhet, 2015; Tan and Tan, 2015; Saidi and Hammami, 2015; Shahbaz and al., 2016; Wang and al., 2016; Magazzino, 2016; Al-Mulali and al., 2016a; Bimanatya and Widodo, 2018; Nugraha and Osman, 2019).

One of the major challenges facing many developing countries today, and especially Cameroon, is to achieve sustainable economic growth without considerable and systematic environmental degradation. On the other hand, there is an acceleration in the volume of economic activities and an increase in the world's population requiring increased energy consumption and abusing natural and mineral resources. While energy is an

[1] Some major events can explain this renewed interest: the oil crisis of the 1970s, the conclusions of the Brundtland Report in Rio in 1992 and the adoption of the Kyoto Protocol in 1997, the food crisis of 2008, the various Conferences of the Parties (COP) organised each year and particularly the resolutions of the 21st COP in November 2015 in Paris, etc.

important factor in the development process, as it stimulates and supports economic growth and development (Khalid and al., 2018), when it comes from fossil fuels, it produces greenhouse gases responsible for climate change.

Environmental pollution not only negatively affects the development of the natural world, but is one of the causes of population discomfort that affects health and well-being (Nguyen and Le, 2018). Hence, there is a need to educate this population on the consequences of climate change, for adaptation and resilience. However, the vision of each country is the achievement of sustainable economic development; economic development that can be achieved if supported by high human capital (Bashir and al., 2019).

Human capital, at its core, comprises the components education and health (Matthew, 2011; Matthew and al., 2018). Matthew (2011) defines human capital as health and education, two closely related components that are necessary for human productivity. For Van Leeuwen (2007), human capital includes formal and informal education, as well as other natural and related events, such as expenditure on children's education, health costs and skills (in other words, factors that help capital, education and health).

The relationship between human capital, energy consumption, greenhouse gas emissions and economic growth has rarely been studied in the African context and in Cameroon in particular. CO_2 emissions and economic growth has been rarely studied in the African context in general and Cameroon in particular. A similar study was conducted by Bashir and al (2019) in the context of Indonesia. These authors used the vector error correction method (VECM) on time series from 1985 to 2017. The particularity of this work is to contribute to the literature in the field of environmental economics and more specifically on environmental topics by applying the staggered lag autoregressive method (SLAM).

After this first introductory part, the second part of our study focuses on the existing literature, the third part outlines the methodology of data analysis. The results, as well as the discussion and conclusion, constitute the fourth and fifth parts respectively.

II. Review of the Literature

In addition to the "classic" concepts such as economic growth and human capital which have been the subject of much research, others such as environmental pollution, energy consumption, etc., have been the focus of much debate and research in recent years. Ogujiuba (2017) and Adawo (2011), Dauda (2010) examined the importance of human capital development to the Nigerian economy using the endogenous growth theory developed by Mankiw and al (1992). The study used the cointegration approach and the error correction mechanism (ECM). The results of the study showed that there was a response mechanism between human capital development and the Nigerian economy.

Akin (2014), Ogujiuba (2017) and Adawo (2011), Amassoma and Nwosa (2011) conducted a study that assessed the causality between human capital investment and growth in the Nigerian economy. The study used the error correction model (ECM) and Granger causality econometric techniques. The results of the study showed that there was no causal relationship between human capital investment and economic growth in Nigeria. Based on this result, the study recommended increasing the budgetary percentages allocated to the education and health sectors, as well as the provision of related infrastructure, such as buildings and supplies, to increase human capital.

Bildirici (2016) analyses the link between economic growth and hydropower consumption. Based on the short-run causality results obtained, there is evidence to support the growth hypothesis in high-income OECD countries. Fatai (2014) reassessed the causal links between energy consumption and economic growth in 18 sub-Saharan African countries over the period 1980-2011. The results of cointegration tests show that energy consumption and economic growth have a stable equilibrium relationship in the long run.

Cheng and Wei (1997) studied the relationship between energy consumption and economic growth in the Taiwanese context from 1955 to 1993 using a modified version of the Granger causality test. Ajlouni (2015) investigates the causality between energy consumption and economic growth in Jordan using annual data over the period 1980-2012. The ARDL method was used to estimate the elasticities of the traditional neoclassical aggregate production function. The empirical results showed a positive long-run and short-run elasticity of output with respect to energy.

Ozturk and Acaravci (2010), using the ARDL model and the ECM method, investigated the causality between energy consumption and economic growth in Albania, Bulgaria, Hungary and Romania over the period 1980-2006. The results of the Granger causality test revealed bidirectional causality only for Hungary. Hye and Riaz (2008) use data from Pakistan and examined the relationship between economic growth and energy consumption for the period 1971-2007, based on the Granger causality form of the ARDL method. In the short run, the causality test shows a bidirectional relationship between the variables and a causality from economic growth to energy consumption in the long run. Energy consumption does not influence economic growth in the long run, as higher energy prices may lead to higher costs of doing business, which will lead to a negative use of energy consumption. Chaudhry and al (2012) study the relationship between energy consumption and economic growth in Pakistan based on annual data for the period 1972-2012. They stated that energy demand is increasing rapidly worldwide. Most of the countries are facing energy scarcity, which seriously affects economic growth.

Ang (2008), Menyah and Wolde-Rufael (2010) use different estimation techniques to examine the causal relationships between CO_2 emissions and economic growth in Malaysia and South Africa, respectively. They find a unidirectional causality from CO_2 emissions to economic growth. Jaunky (2010) examines the CKE (Environmental Kuznets Curve) hypothesis for a sample of 36 high-income economies over the period 1980-2005. The result is a unidirectional causality from GDP (Gross Domestic Product) per capita to CO_2 emissions (per capita) in the short and long term. Fodha and Zaghdoud (2010); Pao and Tsai (2011) have also examined the causality between CO_2 emissions and economic growth using Granger causality tests based on the vector error correction model (VECM), they obtain evidence of unidirectional causality links from economic growth to CO_2. Soytas and Sari (2009) use the Toda and Yamamoto (1995) test to examine the causality between CO_2 emissions and economic growth in Turkey over the period 1960-2000, and find evidence to support the *feedback hypothesis.* Ghosh (2010) also finds bidirectional links between CO_2 emissions and economic growth in India over the period 1971-2006.

Akbostancı and al (2009) testing the existence of CKE in Turkey using cointegration analysis of time series data from 1968 to 2003, in their research, find that there is a monotonically increasing relationship between CO_2 emissions and per capita income. The conclusion of this study indicates that CKE does not apply to Turkey. According to another study conducted by Ozturk and Acaravci (2010) established that conservation energy policies such as rationing energy consumption and reducing carbon emissions, should not have a negative effect on Turkey's real output growth. This result confirms Stern's (2004) view that developing countries are currently believed to perform better than developed countries in combating environmental degradation.

III. Method and Quantitative Approach

1.1. Data and source

This study uses annual data covering the period from 1980 to 2014 from the World Bank database (2017). The variables are emissions of CO_2emissions, energy consumption, human capital and economic growth. An explicit presentation of these data, along with their symbol, measure, source and period covered, is summarised in Table 1 below:

Table 1: Presentation and source of variables

Variable	Symbol	Measure	Source	period
Emissions of CO_2	CO_2	Emissions of CO_2 (metric tonnes per capita)	World Bank	1980-2014
Energy consumption	EC	Energy use (kg oil equivalent per capita)	World Bank	1980-2014
Human capital	CH	School enrolment, secondary (% gross)	World Bank	1980-2014
Economic growth	Y	GDP per capita growth (annual percentage)	World Bank	1980-2014

Source: the authors

1.2. Specification of the models to be estimated and analysis procedures

1.2.1. Model specification

This research builds on the work of Bashir and al (2019) and formulates a system of equations. These simultaneous regression equations are formulated as follows:

$$\boldsymbol{Y_t = f\left(CE_t, CH_t, CO_{2_t}\right)} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \textbf{(1)}$$

$$\boldsymbol{CO_{2_t} = f(CE_t, CH_t, Y_t)} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \textbf{(2)}$$

$$\boldsymbol{CH_t = f\left(CE_t, Y_t, CO_{2_t}\right)} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \textbf{(3)}$$

$$\boldsymbol{CE_t = f\left(Y_t, CO_{2_t}, CH_t\right)} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \textbf{(4)}$$

The introduction of the neperian logarithm (ln) transforms the previous relations into the following forms:

$$\boldsymbol{ln(Y_t) = \alpha_0 + \alpha_1 ln(CE_t) + \alpha_2 ln(CH_t) + \alpha_3 ln\left(CO_{2_t}\right) + \mu_t} \cdots\cdots\cdots\cdots\cdots \textbf{(5)}$$

$$\boldsymbol{ln\left(CO_{2_t}\right) = \beta_0 + \beta_1 ln(CE_t) + \beta_2 ln(CH_t) + \beta_3 ln(Y_t) + \varepsilon_t} \cdots\cdots\cdots\cdots\cdots \textbf{(6)}$$

$$\boldsymbol{ln(CH_t) = \delta_0 + \delta_1 ln(CE_t) + \delta_2 ln(Y_t) + \delta_3 ln\left(CO_{2_t}\right) + \pi_t} \cdots\cdots\cdots\cdots\cdots \textbf{(7)}$$

$$\boldsymbol{ln(CE_t) = \vartheta_0 + \vartheta_1 ln(Y_t) + \vartheta_2 ln\left(CO_{2_t}\right) + \vartheta_3 ln(CH_t) + \tau_t} \cdots\cdots\cdots\cdots\cdots \textbf{(8)}$$

Where $ln(Y_t), ln\left(CO_{2_t}\right), ln(CH_t)$ and $ln(CE_t)$ are the natural logarithm of economic growth (Y), emissions of CO_2 (CO_2), human capital (CH) and energy consumption (EC). $\mu_t, \varepsilon_t, \pi_t$ and τ_t are the error terms at time t.

With the proliferation of information and communication technologies in recent years, the number and sophistication of econometric software and analysis methods have been innovated. The methodology used in this work is based on the autoregressive lag method ("ARDL method") initially developed by Pesaran and Shin (1999) and improved after some years by Pesaran et al. It has the advantage over the traditional cointegration models of Engel and Granger (1987) or those of Johansen (1988, 1991). According to Pesaran and al. (2001); Davoud and al. (2013); Nkoro and Uko (2016); Nguyen and Le (2018), the ARDL estimation method has a number of advantages:

(i) the variables in the model only have to be stationary at level and in first difference, which means that they can be stationary at different levels: I(0) or I(1) ;

(ii) endogeneity can be avoided and small sample results are more reliable because lagged dependent variables are added as independent variables;

(iii) the long-run and short-run coefficients can be estimated simultaneously, the error correction model (ECM) can combine short-run adjustments and a long-run equilibrium without lacking information in the long run;

(iv) the model "personally" chooses the optimal lag length and allows different optimal lag lengths for different variables, thus remarkably improving the compatibility of the model.

Following Pesaran and al (2001), the ARDL models of the (5), (6), (7), and (8) can be written as follows:

$$\boldsymbol{\Delta ln(Y_t) = \theta_0 + \theta_1 ln(Y_{t-1}) + \theta_2 ln(CE_{t-1}) + \theta_3 ln(CH_{t-1}) + \theta_4 ln(CO_{2t-1}) + \sum_{i=0}^{k} \theta_{5i}\, \Delta ln(Y_{t-i}) + \sum_{i=0}^{k} \theta_{6i}\, \Delta ln(CE_{t-i}) + \sum_{i=0}^{k} \theta_{7i}\, \Delta ln(CH_{t-i}) + \sum_{i=0}^{k} \theta_{8i}\, \Delta ln(CO_{2t-i}) + \iota_t} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \textbf{(9)}$$

$$\Delta ln(CO_{2t}) = \omega_0 + \omega_1 ln(CO_{2t-1}) + \omega_2 ln(CE_{t-1}) + \omega_3 ln(CH_{t-1}) + \omega_4 ln(Y_{t-1}) + \sum_{j=0}^{m} \omega_{5j}\, \Delta ln(CO_{2t-j}) + \sum_{j=0}^{m} \omega_{6j}\, \Delta ln(CE_{t-j}) + \sum_{j=0}^{m} \omega_{7j}\, \Delta ln(CH_{t-j}) + \sum_{j=0}^{m} \omega_{8j} \Delta ln(Y_{t-j}) + \upsilon_t \cdots\cdots\cdots\cdots\cdots\cdots (10)$$

$$\Delta ln(CH_t) = \delta_0 + \delta_1 ln(CH_{t-1}) + \delta_2 ln(CE_{t-1}) + \delta_3 ln(Y_{t-1}) + \delta_4 ln(CO_{2t-1}) + \sum_{p=0}^{n} \delta_{5p}\, \Delta ln(CH_{t-p}) + \sum_{p=0}^{n} \delta_{6p}\, \Delta ln(CE_{t-p}) + \sum_{p=0}^{n} \delta_{7p}\, \Delta ln(Y_{t-p}) + \sum_{p=0}^{n} \delta_{8p}\, \Delta ln(CO_{1t-p}) + \zeta_t \cdots\cdots\cdots\cdots\cdots\cdots (11)$$

$$\Delta ln(CE_t) = \varphi_0 + \varphi_1 ln(CE_{t-1}) + \varphi_2 ln(Y_{t-1}) + \varphi_3 ln(CO_{2t-1}) + \varphi_4 ln(CH_{t-1}) + \sum_{r=0}^{f} \varphi_{5r}\, \Delta ln(CE_{t-r}) + \sum_{r=0}^{f} \varphi_{6r}\, \Delta ln(Y_{t-r}) + \sum_{r=0}^{f} \varphi_{7r}\, \Delta ln(CO_{2t-r}) + \sum_{r=0}^{f} \varphi_{8r}\, \Delta ln(CH_{t-r}) + \varsigma_t \cdots\cdots\cdots\cdots\cdots\cdots (12)$$

Note : Δ is the first difference operator.

$\theta_d, \omega_d, \delta_d, \varphi_d\ (avec\ d = 1, 2, 3, 4)$ are the regression coefficients that explain the long-run impact in equations (9), (10), (11) and (12) respectively; k, m, n and f are the optimal lag numbers, ι_t, υ_t, ζ_t and ζ_t are the error terms.

If cointegration relationships exist between the variables in equations (9), (10), (11) and (12), the regression coefficients will be estimated with the error correction method (ECM) based on the following equations

$$Y_t = \lambda_0 + \psi ECT_{t-1} + \sum_{i=0}^{p} \lambda_{1i} \Delta ln(Y_{t-i}) + \sum_{i=0}^{p} \lambda_{2i} \Delta ln(CE_{t-i}) + \sum_{i=0}^{p} \lambda_{3i} \Delta ln(CH_{t-i}) + \sum_{i=0}^{p} \lambda_{4i} \Delta ln(CO_{2t-i}) + \mathfrak{z}_t \cdots\cdots\cdots\cdots\cdots\cdots (13)$$

$$CO_{2t} = \mathfrak{a}_0 + \psi ECT_{t-1} + \sum_{j=0}^{s} \mathfrak{a}_{1j} \Delta ln(CO_{2t-j}) + \sum_{j=0}^{s} \mathfrak{a}_{2j} \Delta ln(CE_{t-j}) + \sum_{j=0}^{s} \mathfrak{a}_{3j} \Delta ln(CH_{t-j}) + \sum_{j=0}^{s} \mathfrak{a}_{4j} \Delta ln(Y_{t-j}) + \mathfrak{y}_t \cdots\cdots\cdots\cdots\cdots\cdots (14)$$

$$CH_t = \varpi_0 + \psi ECT_{t-1} + \sum_{p=0}^{h} \varpi_{1p} \Delta ln(CH_{t-p}) + \sum_{p=0}^{h} \varpi_{2p} \Delta ln(CE_{t-p}) + \sum_{p=0}^{h} \varpi_{3p} \Delta ln(CO_{2t-p}) + \sum_{p=0}^{h} \varpi_{4p} \Delta ln(Y_{t-p}) + \mathfrak{v}_t \cdots\cdots\cdots (15)$$

$$CE_t = \rho_0 + \psi ECT_{t-1} + \sum_{r=0}^{l} \rho_{1r} \Delta ln(CE_{t-r}) + \sum_{r=0}^{l} \rho_{2r} \Delta ln(CH_{t-r}) + \sum_{r=0}^{l} \rho_{3r} \Delta ln(CO_{2t-r}) + \sum_{r=0}^{l} \rho_{4r} \Delta ln(Y_{t-r}) + \text{ŧ}_t \cdots\cdots\cdots\cdots\cdots\cdots (16)$$

Note: p, s, h, l are the optimal delay orders calculated by the ARDL method according to information criterion(s)[2] . $\mathfrak{z}_t, \mathfrak{y}_t, \mathfrak{v}_t, \text{ŧ}_t \sim \mathcal{N}(0, \sigma^2)$ are the error terms. ψ is the coefficient of the error correction term whose value must be negative and significant. It is the recall force, which represents the speed of adjustment of the dependent variables to the long-run equilibrium after each short-run shock.

1.2.2. Analysis procedures

After the study of the stationarity by the Augmented Dickey-Fuller (ADF) test of the different variables, the descriptive statistics stage will follow, then the correlation stage. The third step is devoted to the determination of the optimal lag order, the stationarity test of the error term will allow us to approach the test of the existence of the cointegration relation by the "bound test" before bringing out the long and short term equations. The bound test for equation (9) requires the following hypotheses to be tested: Null hypothesis (no cointegration) $H_0: \theta_1 = \theta_2 = \theta_3 = \theta_4 = 0$. against the alternative hypothesis (presence of cointegration)

[2] These include AIC (Akaike information criterion), SC (Schwarz information criterion), HQ (Hannan-Quinn information criterion) or FPE (final error of prediction).

$H_1: \theta_1 \neq \theta_2 \neq \theta_3 \neq \theta_4 \neq 0$. The same formulation applies to equations (10), (11) and (12). The test used is the F-statistic. Pesaran and al (2001) have shown that this test does not follow a normal distribution. They therefore set up two bounds: I(0) and I(1). The decision to be taken depends on the position of F-statistics in relation to these bounds. Three cases are to be expected:

(i) If the F-statistic value is less than I(0), we accept H_0. There is no cointegration relationship and no ricochet, no long term equilibrium relationship;

(ii) If the F-statistic value is between I(0) and I(1), we cannot conclude ;

(iii) If the F-statistic value is greater than I(1), the alternative hypothesis is accepted. There is a cointegrating relationship and we can deduce the existence of a long-term relationship.

After the results of the cointegration test, the estimation of the long and short term coefficients will follow. The diagnostic tests on the residuals will be the last step of this part.

IV. Empirical results and discussion

1.3. Descriptive statistics and correlation between variables

From Table 2 below, it can be seen that over the study period, the average[3] emissions of CO_2 emissions is 4036 metric tonnes per capita, energy consumption is 403 kg of oil equivalent per capita. It is also noted that all variables are normally distributed at the 1% (LNCE) and 5% (LNCH, $LNCO_2$LNY). Moreover, between energy consumption and human capital, there is a strong negative and significant correlation. On the other hand, the relationship between energy consumption and CO_2 emissions is marked by a weak negative and significant correlation.

Table 2: Statistical results and correlations

variables	LNCE	LNCH	$LNCO_2$	LNY
Mean	5,992	3,348	8,303	7,201
Maximum	6,094	4,079	8,940	7,514
Minimum	5,790	2,849	7,006	6,963
Standard deviation	0,096	0,311	0,469	0,149
Jarque-Bera	6,007	3,878	3,663	1,758
Probability	**(0,049)*** **	**(0,143)***	**(0,160)***	**(0,415)***
Observation	32	32	32	32
LNCE	1			
LNCH	-0,879 **(0,00)***	1		
$LNCO_2$	-0,394 **(0,02)***	0,283 (0,11)	1	
LNY	0,247 (0,17)	-0,22 (0,20)	0,124 (0,49)	1

() = probability; **= significant at 5% level, *= significant at 1% level**

Source: the authors

This result gives no information on the nature of the stationarity of the variables. The result of the ADF test presented below will tell us where we stand.

1.4. Result of the unit root test

Table 3 below shows that some variables are stationary at level and others at first difference at the 5% and 10% thresholds. This result is of interest for the rest of our study; in the sense that in order to apply the bound test, the variables must be integrated either I(0), I(1) or both.

Table 3: ADF test result for each variable (1980-2014)

variables	C		C and T		SC and ST	
level	DFA test	Prob	DFA test	Prob	DFA test	Prob
LNCE	0,411	0,980	-1,557	0,7874	-1,913	**0,0543***
$LNCO_2$	-1,456	0,5419	-3,365	**0,0737***	0,053	0,6923
LNY	-3,144	**0,0335****	-2,594	0,2850	-0,269	0,5812
LNCH	-5,842	**0,0007****	-1,127	0,2675	-0,208	0,5859

[3] The data has been transformed using the neperian logarithm. To obtain the values in the text, the relation : $ln(x) = y \Longrightarrow x = e^x$

primary difference						
DLNCE	-5,601	**0,0001****	-5,788	**0,0002****	-5,041	**0,0000****
$DLCO_2$	-6,880	**0,0000****	-6,957	**0,0000****	-6,994	**0,0000****
DLNY	-2,130	0,2347	-3,495	**0,0609***	-2,158	**0,0317****
DLNCH	-6,536	**0,0000****	-6,894	**0,0000****	-6,198	**0,0000****

C= constant, C and T= constant and trend, SC and ST= no constant and no trend; prob=probability; ** and * = significant at the 5% and 10% levels respectively

Source: the authors

1.5. Selection of the optimum number of delays

In time series analysis, the choice of the optimal lag number is of vital importance. If the lag is too high, the estimates will be inefficient. On the other hand, if the lag is too small, the residuals of the estimates will not be white noise, which would distort the analysed results. There are a few criteria for selecting the optimal number of lags: Akaike criterion (AIC), Schwarz criterion (SC) and Hannan-Quinn information criterion (HQ). According to AIC, SC and HQ, the optimal delay number has the smallest value. Table 4 below gives the statistical results of this number for equations (1), (2), (3) and (4). According to the AIC and SCR criteria, the optimal delay number that will be used for the estimations is 1.

Table 4: Result of the optimal delay number

Delay	LogL	LR	FPE	AIC	SC	HQ
0	41,603	NA	8,01-07	-2,685	-2,495	-2,627
1	146,714	172,682*	1,40e-09*	-9,051*	-8,099*	-8,760*

indicates the order of delay selected by each criterion at the 5% threshold

Source: the authors

1.6. Bound test for cointegration

According to the results of the bound test (Table 5 below), the F-statistic of equation (9) =5.447 > I(1) at 5% and 10%; that of equation (10) = 6.096 > I(1) at 1%, 5% and 10%; its value for equation (11) = 4.036 > I(1) at 10%; equation (12) = 0.371 < I(0)) 1%, 5% and 10%. The hypothesis H_0 is rejected for equations (9), (10), (11) and accepted for equation (12).

Table 5: Result of the cointegration "bound test

Models	Equations	Statistics of F	Significance threshold					
			1%		5%		10%	
			I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
(9)	$LNY/LNCE, LNCH, LNCO_2$	**5,447****	4,29	5,61	3,23	4,35	2,72	3,77
(10)	$LNCO_2/LNCE, LNCH, LNY$	**6,096****	4,29	5,61	3,23	4,35	2,72	3,77
(11)	$LNCH/LNCE, LNY, LNCO_2$	**4,036***	4,29	5,61	3,23	4,35	2,72	3,77
(12)	$LNCE/LNY, LNCH, LNCO_2$	0,371	4,29	5,61	3,23	4,35	2,72	3,77

**** and * = significant at the 5% and 10% levels respectively**

Source: the authors

We can therefore conclude that there is a long-term cointegration relationship between the variables in the first three equations. This allows us to consider an estimation of the coefficients of the error correction model (ECM) of these equations.

1.7. Estimation of the long-term coefficients and the ECM model

Referring to Table 6 below on the results of the long-run coefficients, emissions of CO_2 emissions positively influence economic growth at 5% (model (13)). This can be explained by the fact that Cameroon is still in the first phase of its economic development and aims at its emergence at a predefined time horizon (2035). From a theoretical point of view, this situation can be explained by the Environmental Kuznets Curve (EKC): during the first stages of economic development, agents care little for the environment. Also, from equation (15), we note a negative and significant influence at the 5% threshold, of energy consumption on human capital. This result is different from the one obtained by Bashir and al (2019). The latter, using a vector error correction model (VECM) on time series from 1985 to 2017 in the context of Indonesia, find no long-term effect of energy consumption on human capital. As for Cameroon, being very little oriented towards the consumption of renewable energies, it is mostly satisfied with those from fossil fuels. These are one of the causes of climate change, which affects the health and education of populations (Djepang, 2017).

Table 6: Results of the estimation of the long-term coefficients

Models	(13)	(14)	(15)	(16)
LNY		0,54	0,36	4,48
		(0,27)	(0,43)	(0,98)
$LNCO_2$	0,91		-0,03	4,85
	(0,04)**		(0,78)	(0,98)
LNCH	-0,83	-0,47		-1,99
	(0,21)	(0,49)		(0,98)
LNCE	-0,77	-3,67	-3,83	
	(0,66)	(0,11)	**(0,00)****	
C	7,14	28,03	24,11	-62,50
	(0,55)		**(0,00)****	(0,98)

()=probability; ** and * = significant at 5% and 10% respectively.
Source: the authors

In the short term (Table 7), it can be observed that, just as the emissions of CO_2 emissions positively and significantly influence economic growth at 5%, the latter also influences CO_2. We can also note, as in the long term, a negative and significant influence of energy consumption on human capital at the 5% threshold.

The adjustment coefficient (recall force) is globally negative and significant at the 5% level (equation (13), (14), (15)). These results are consistent with the theory of the error correction mechanism. These models will return to their equilibrium path after each shock.

Table 7: ECM model results

Models	(13)	(14)	(15)	(16)
DLNY		4,49	0,09	0,01
		(0,04)**	(0,40)	(0,77)
$DLNCO_2$	0,04		-0,009	0,01
	(0,01)**		(0,78)	(0,40)
DLNCH	-0,07	-0,47		-0,004
	(0,10)	(0,49)		(0,92)
DLNCE	-0,070	1,57	-0,96	
	(0,64)	(0,53)	**(0,00)****	
ECT	-0,09	-0,99	-0,25	-0,002
	(0,03)**	**(0,00)****	**(0,00)****	(0,98)
R^2	0,95	0,50	0,94	0,92
R^2 *ajusté*	0,95	0,37	0,93	0,91
Fisher	118,35	4,01	99,61	76,83
statistics	**(0,00)****	**(0,00)****	**(0,00)****	**(0,00)****

()=probability; ** = significant at 5%.
Source: the authors

1.8. Diagnostic tests

According to the results in Table 8, for equations (13), (14), (15), the residuals are normally distributed, so the Breusch-Godfrey test shows no autocorrelation and the Breusch-Pagan-Godfrey test shows no heteroscedasticity at the 5% threshold. This would mean that the mean of the error term is zero and its variance constant over time. Moreover, the Ramsey test shows the excellent stability of the models over time at the 5% threshold.

Table 8: Results of diagnostic tests

Models	(13)	(14)	(15)	(16)
Autocorrelation [Breusch-Godfrey].	2,27	0,0024	4,41	7,20
	(0,14)**	**(0,96)****	**(0,057)****	(0,012)
Heteroscedasticity [Breusch-Pagan-Godfrey].	1,26	1,90	0,57	1,30
	(0,31)**	**(0,12)****	**(0,68)****	**(0,29)****
Normality [Jarque-Bera].	2,21	3,49	1,91	21,38
	(0,33)**	**(0,17)****	**(0,63)****	(0,00)

Model stability [Ramsey RESET Test].	0,19 **(0,65)****	1,83 **(0,18)****	0,016 **(0,89)****	10,93 (0,002)

[]=test used; () = probability; **=significant at 5%; statistic used is Fisher's
Source: the authors

V. Conclusion and Recommendations

The objective of this paper was to examine the dynamic relationship between human capital, energy consumption, greenhouse gas emissions and economic growth in Cameroon over the period 1980-2014. CO_2 emissions, and economic growth in Cameroon over the period 1980-2014. The staggered lag autoregressive method is used for the empirical analysis. The results show that there is a long-run cointegration relationship between the variables. This allowed us to determine the coefficients of the specified models in both the long and short run. In the long term, the emissions of CO_2 emissions positively and significantly influence economic growth while energy consumption negatively and significantly influences human capital. The same results are observed in the short term with, in addition, a positive and significant influence of economic growth on CO_2. From the above results, it can be recommended that the Cameroonian state turn to other energy sources that emit less CO_2. From another point of view, it should support and encourage structures (start-ups for example) whose initiatives are aimed at promoting and developing renewable energies such as solar, wind and biomass. Also, raise awareness among the population on the causes and consequences of climate change, while educating them on the notion of rationing energy consumption, particularly that of hydraulic energy, such as turning off lights in unoccupied rooms, and unplugging any appliance (electronics and household appliances) that is no longer functional. Focus on the quality of vehicles entering the country. Taxing all energy-intensive and highly polluting companies and giving facilities to those that fight environmental pollution while reducing emissions. CO_2.

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