Renewable Energy, Economic Growth, Carbon Dioxide Emissions and Human Development Index in Algeria

الطاقة المتجددة, النمو الاقتصادي, الانبعاث الغاز الثاني الأكسيد و مؤشر التنمية البشرية في الجزائر

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Abstract: The objective of this paper is to study the effect of renewable energy consumption (REC), economic growth (GDP), and carbon dioxide emissions (CO_2) on Human Development Index (HDI) in Algeria over the period of 1995-2016. We employed the procedure of GMM estimation and Toda-Yamamoto causality to study the dynamic effect between variables. We found with GMM estimation that GDP had a positive and significant effect on (HDI), while the two variables of (REC) and (CO_2) were positive and insignificant. We established with Toda-Yamamoto test that there is bidirectional causality between CO_2 and HDI at the level of 1%, while we concluded for three unidirectional causalities at the level of 1%, which were running from REC to HDI and from REC to GDP and from REC to CO_2.

Keywords: renewable energy consumption; economic growth; carbon dioxide emissions; Human Development Index; Algeria.

Classification JEL: Q01, C30.

الملخص: الهدف من هذه الدراسة هو تحليل أثر الطاقة المتجددة, النمو الاقتصادي و الانبعاث الغاز الثاني الأكسيد على المؤشر التنمية البشرية في الجزائر خلال الفترة 1995-2016. لقد تم استعمال المنهجية GMM و السببية Toda-Yamamoto لدراسة العلاقة ما بين المتغيرات. لقد عثرنا بالنموذج GMM على أن المعامل GDP له أثر موجب و معنوي على HDI و لكن المتغيرين المتبقيين لهما أثر ايجابي و غير معنوي. و لقد استخلصنا بالسببية Toda-Yamamoto بأن هناك علاقة في اتجاهين ما بين CO2 و HDI على المستوى 1%. أيضا هناك 3 علاقات السببية في الاتجاه واحد على المستوى 1% الأولى من المتغير الطاقة المتجددة الى المؤشر التنمية البشرية و الثانية من المتغير الطاقة المتجددة الى المتغير النمو الاقتصادي و الثالثة من المتغير الطاقة المتجددة الى المتغير CO_2

الكلمات المفتاحية: الطاقة المتجددة, النمو الاقتصادي, الانبعاث الغاز الثاني الأكسيد, المؤشر التنمية البشرية, الجزائر

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1. INTRODUCTION:

According to **World Bank**[1] in 2018, the oil and natural gas sector have long been the backbone of the Algerian economy, accounting for roughly 60% of budget revenues, 30% of GDP, and over 95% of export earnings. Their exports have enabled Algeria to maintain macroeconomic stability and accumulate large foreign currency reserves and a large budget stabilization fund available. In addition, Algeria's external debt is extremely low at about 2% of GDP. However, Algeria is now struggling to develop non-hydrocarbon industries because of its regulations and policies.

On the other hand, the renewables are taken a central interest in the World, as they play a key role in the recognition of sustainable development goals, and can give added-value to the socio-economic factors by satisfying the energy demand, mitigate the effect of pollution and improve the level of well-being of the population.

The United Nations[2], have proposed the human development index (HDI), which used the arithmetic mean or geometric mean of the indexes of 3 dimensions – life expectancy, education level, and gross national income (GNI) – to measure human welfare in different countries and different regions relying to **Harttgen and Klasen (2013)**.

According to the last report of World Bank and BTI[3] in 2018, the social situation has been improved in Algeria by achieving 20% poverty reduction in the past two decades, and the level of socioeconomic development revealed that the country's rating that the (HDI), while improving, remains relatively mediocre (with an index of 0.745, Algeria was ranked 83 out of 188 countries) and the life expectancy was 75.9 years.

The social exclusion has been caused by a significant increase in the urban population. Mass displacements during the 1990s due to insecurity in rural zones have led to increased problems in housing and access to jobs and public services in the cities.

Consequently, the Algerian situation appears uncomfortable and is looking to improve its socio-economic situation and introduce some new concept that can boost the level of economic growth, preserve the environment and increase the energy production to attain several objectives of United Nations Sustainable Development Goals, such as food security, end of poverty, access to energy, improve security and health of population.

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[1] - https://www.bti-project.org/en/reports/country-reports/detail/itc/dza/

[2] - https://www.undp.org/content/undp/en/home.html

[3] - https://www.undp.org/content/undp/en/home.html

In this paper, we shall develop with generalized method of moments (GMM) approach and Toda-Yamamoto causality to study the effect of renewable energy consumption, economic growth and carbon dioxide emissions on Human Development Index in Algeria during the period of 1995-2016. This work is divided into 5 sections, introduction, literature revue, data and methodology, empirical results and conclusion.

2. LITTERATURE REVIEW:

The following table summarise different studies about energy, economic, environment and social sector. Some researchers found that there is a positive relationship or a negative link between gross domestic product (factor of economic growth) and (HDI). Other investigations demonstrate the importance to include the renewable energy into energy system and how it can affect the living condition of population. There are also some studies about the greenhouse gas (GHG) and carbon dioxide emissions (CO_2), which are variables of environment aspect, so in every country, they should try to avoid and mitigate their effect because these two variables may create pollution, increasing the health problems, cause respiratory diseases, cancer, tuberculosis, as well as weight loss and eye diseases among newborns.

Table 01. Literature review

Study	Period	Data	Method	Conclusion
Wang et al. (2018)	1990 - 2014	Pakistan	GMM, (2SLS) and (VEC) Granger causality	The CO2 emission per capita was positive and significant at level of 5% on HDI, while GDP per capita had a negative and significant at level of 10% on HDI. Also, there is unidirectional causality running from CO_2 emissions to HDI.
Zang et al. (2017)	2003 - 2015	9 South-East Asia Countries	Delphi method	The HDI increased steadily, with an average annual growth rate between 0.29% and 2.50%. Singapore, Brunei Darussalam, Malaysia and Thailand were the top 4 countries ranked in descending order, whereas Cambodia always ranked in last place.
Grubaugh (2015)	1980 - 2010	83 countries	GMM	The initial level of GDP, population, average population growth over the five-year periods and life expectancy are found statistically significant. The sign of GDP per capita and population were positive. However, the coefficient of life expectancy and

				initial GDP were negative.
Frugoli et al. (2015)	2002	106 countries	Scatter plots and the Spearman correlation coefficient	The GDP is inadequate for monitoring sustainable societal development. Also, none of the indices studies encompass all perspectives needed to guide societies to sustainable development and the combinations of biophysical and socioeconomic indices improve the information provided
Roy et al. (2015)	1985 – 2011	60 countries	Panel cointegration and Granger causality	Bidirectional causality between HDI and energy consumption, indicating that the development in energy consumption will increase the Human Development Index especially for poorer and developing nations
Kazar and Kazar (2014)	1980 – 2010 And 2005 – 2010	154 countries	Panel regression and Granger causality	With the long-run test, they found that the renewable electricity is significant for all dataset except for countries with high HDI. They also showed that there's no causality between RE and HDI for the group of very high HDI and low HDI. Meanwhile, there was unidirectional causality running from HDI to RE for the group of all countries, and high HDI. However, bidirectional causality was established for the countries with middle HDI. With the short-run test, they concluded for the group of all countries, middle HDI and low HDI that RE was significant, but insignificant for other groups. Likewise, they found bidirectional causality for all countries, while unidirectional causality running from HDI to RE for the group of high HDI and. However, for the group of middle HDI, the unidirectional relationship was running from RE to HDI, but for the other group there is no causality.
Hafner and Mayer-Foulkes (2013)	1980 - 2007	72 countries	Dynamic ordinary least square (DOLS)	GDP had an influence positive and significant at the level of 1% on HDI, but no significant effect of energy consumption on human development.
				An increase by 1% in per capita energy consumption may reduce the

Ouedraogo (2013)	1988 - 2008	15 developing countries	Panel cointegration and Granger causality	HDI by 0.08%. A rise by 1% in energy price elasticity may decrease the HDI by around 0.11%. An increase by 1% in electricity consumption could increase HDI by 0.22%. She concluded for unidirectional causality running from energy consumption to HDI
Pîrlogea (2012)	1997 - 2008	six European countries	Panel regression	In the 1st equation, the fossil fuel consumption had a negative impact on the HDI for Romania and Bulgaria. However, in the countries with very high HDI, there is a positive impact between fossil fuel and HDI. The renewable energy consumption had a positive impact on human development in the case of Poland and Ireland. In the 2nd equation, the energy intensity had a negative effect on HDI on six countries, but the CO_2 intensity had a negative impact for Romania, Bulgaria and Poland, while a positive influence for Portugal, Ireland and Netherlands.
Abraham and Ahmed (2011)	1975 - 2008	Nigeria	The error correction model (ECM)	In the short-run, there is a negative and insignificant relationship between (GDP) and (HDI). However, in the long-run, the relationship was statistically accepted.
Steinberger and Roberts (2010)	1975 – 2005	156 countries	Panel regression	A negative relationship energy use, CO_2 and HDI
Martinez and Ebenhack (2008)	…	120 countries	correlation matrix	A high value of HDI is corresponding to greater energy consumption patterns.

Source: Done by the researchers

The previous table gave us a brief description about 12 studies. These topics investigated several factors that may influence the level of human development index with different methodologies with several methods according to models, panel analysis for group of countries, Granger causality is for long and short-run link between variables, 2SLS and GMM are for endogenous variables and system of equations. Moreover, in relation they employed almost the same control variables CO_2 emissions per capita, GDP per capita, Human Development Index (HDI), renewable energy consumption per capita, trade, urbanisation, land area

per capita, forest coverage rate, food production index, fresh water per capita, urbanisation rate, mortality of Children under age 5, education investment rate, GNI per capita, car penetration rate, chemical fertilizer utilisation rate, particle emission intensity, CO_2 emissions intensity, GDP/national land area, national saving rate, fixed asset investment rate, energy, mineral consumption rate, the growth of GDP per capita, population, average growth rate of population, fraction of population living in urban areas, exports plus imports (% of GDP), investment (% of GDP), government consumption (% of GDP), average investment price level, life expectancy at birth, index of political right (scale 1 to 7), and index of civil liberties (scale of 1 to 7).

These investigations established different outcomes. **Wang et al. (2018)** established a positive and negative relationship between CO_2 and HDI. However, **Grubaugh (2015)** found a positive link amongst GDP and HDI. **Roy et al. (2015)** concluded for a positive impact of energy consumption on (HDI). **Kazar and Kazar (2014)** concluded for a positive link amongst renewable energy and (HDI). Also, we concluded for different causalities, **Wang et al. (2018)** found a unidirectional causality running from CO_2 to HDI. **Kazar and Kazar (2014)** established multiple causalities among renewable energy and (HDI).

Ouedraogo (2013) determined that that only energy prices can determine the level of energy consumption not the level of development and neither the level of development nor the energy prices have a statistically significant impact on electricity consumption. She also said that a growing economy needs to diminish the level of energy consumption as production shifts toward less energy intensive service sectors or an inefficient energy supply. **Pîrlogea (2013)** demonstrated that the countries with very high HDI have a strong dependence on fossil fuel energy. Also, When she studied the data as an individual variable, the energy consumption, in the most cases, have established a positive relationship with HDI, but when she included the energy intensity variable, the contribution was negative. **Abraham and Ahmed (2011)** said that when GDP affect negatively HDI, the policies aimed at accelerating growth would have a negative impact on human development. **Steinberger and Roberts (2010)** demonstrated that a dropping in the energy and carbon thresholds for growth will not automatically resolve the problem of climate change, energy supply or human development losses. However, the industrialized nations must significantly moderate their consumption and emissions. **Martinez and Ebenhack (2008)** concluded that the relationship of human development to energy access becomes certain and they speculated that some reasons for the good performance in energy-poor nations comprise quantities and kind of foreign aid, relatively stable governments and a considerable decrease in fire-wood (biomass) use for primary energy.

3. DATA AND METHODOLOGY:

The following table displays all variables used in this study over the period 1995-2016 in Algeria:

Table 02. Variables description

Variables	Unites	Source of Data
REC: Renewable energy consumption	Million tonne equivalent of petrol	British Petroleum (Bp)
CO_2 : Dioxide carbon emission	Million tonne carbon dioxide	Bp
GDP: Gross domestic product	Current US $	World Bank
HDI: Human Development Index	Indices on the scale of 0 to 1	UNDP

Source: made by the researchers

The following table can define several instrument list or control variable that can support the GMM model:

Table 03. Instrument list

Variables	Unites	Source of Data
FEC: Fossil energy consumption	Million tonne equivalent of petrol	Bp and International Energy Agency (IEA)
FEP : Fossil energy production	Million tonne equivalent of petrol	Bp database and IEA
REP: Renewable energy production	Million tonne equivalent of petrol	Bp
GFCF: Gross fixed capital formation	Current US $	World Bank
TRADE: External balance on goods and services	Current US $	World Bank
LF: Labour force	Total of employment	World Bank

Source: done by the researchers

The particular model is imitated from several literatures described previously. We took the variables of HDI, GDP, REC and CO_2, which are transformed into natural logarithm specification, because the coefficient on the natural-log scare is directly interpretable as approximate proportional differences and as elasticity. This transformation has provided us with the following benefits, problems related to dynamic qualifications of the data set are avoided log-linear specification and it gives more consistent and efficient empirical results. In this model, we shall develop the non-linear GMM specification with estimating weighting matrix of two-stage least squares, due to high level of endogeneity of GDP, CO_2 and HDI. Then, we shall perform the Toda-Yamamoto causality, the model can be written as following:

$$LNHDI_t = \beta_1 + \beta_2 LNGDP_t + \beta_3 LNCO2_t + \beta_4 LNREC_t + V_{t1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The (HDI) measures the average achievement in Algeria in three basic dimensions of human development:

- A long and healthy life, as measured by life expectancy at birth;
- Knowledge, as measured by the adult literacy rate (with two-thirds weight) and the combined primary, secondary, and tertiary gross enrolment ratio (with one-third weight);
- A decent standard of living, as measured by gross domestic product (GDP) per capita at PPP (purchasing power parity) in USD.

β_1: is the intercept that represents all variables which are not defined or introduced in this model such as ecological footprint, fertility rate…etc.

$LNGDP_t$: represents the economic variable in Algeria that designs the economic growth or the economic factor of sustainable development because it takes into consideration the population over time (t).

$LNREC_t$: designs the variable of renewable energy consumption in Algeria, especially the consumption of solar photovoltaic, hydropower and geothermal over time (t).

$LNCO_{2t}$: indicates the level of dioxide carbon emissions and it represents the factors of pollution which is emitted by from industrial sector and fossil fuel energy.

V_{t1} is the error term of each equation in the short and long-term, respectively.

In time-series models, we usually start with the unit root procedure with the Augmented **Dickey-Fuller test (1981)** and **Phillips-Perron test (1988)** which can identify if the variables are stationary or not and to verify if the series are integrated in the same order. In the case, when the series have the same order of integration, we shall make the procedure of Granger causality, **Granger (1969)**. However, **Toda-Yamamoto** (**1995)** developed an alternative test (as an Augmented Granger causality) to study the long-run relationship amongst the variables, which haven't the same order of integration, irrespective of whether series are integer (0) or I(1) or I(2), non-cointegrated or cointegrated of an arbitrary order. Also, this procedure can provide the possibility of testing for causality between integrated variables.

Before testing the causality, we shall perform the long-run estimation with OLS and GMM to see the difference between these two methods in the presence of multicollinearity, which it leads to unreliable and biased result. The method of GMM came after the simplest and the most common estimation method for the simultaneous equations model, which is the so-called two-stage least square method (2SLS). This method was introduced more or less independently by **Theil [(1953a; 1953b; 1961)**, and **Sargan (1958)** who used in the case of data with small sample size and to resolve the problem of multicollinearity with various macroeconomic variables that are very high correlated. Then, **Arellano and Bond**

(1991) proposed the Generalized Method of Moments (GMM) estimator and it is paying particular attention to issues of weighting matrix estimation and coefficient covariance calculation. After, we shall check the level of exogeneity with the test of **Hausman (1978)**, this test permits to detect the correlation between error terms and the exogenous variables, so in this case we can't afford OLS estimation, because it gives non-convergent results and the estimators are blue, so we need to estimate such variables and models with Generalized Method of Moment (GMM).

4. EMPIRICAL RESULTS:

- **OLS estimation:**

$$LNHDI_t = 0.012 + 0.108 * LNGDP_t - 0.010 * LNREC_t + 0.113 * LNCO2_t + e_{t1}$$

.....(2)

- **GMM estimation:**

$$LNHDI_t = -0.027 + 0.091 * LNGDP_t + 0.0090 * LNREC_t + 0.006 * LNCO2_t + e_{t2}$$

…….(3)

4.1. The coefficient diagnostic:

The long-run estimation with OLS (equation 2) indicates that the model contains a good statistic coefficient, but the correlation coefficient between variables was high, so there is a problem of multicollinearity, so we need to verify with the test of variance inflation factors, which showed that the value of the regressors are greater than 10. Therefore, these variables cannot be used in the OLS estimation, so we need to re-estimate the model with GMM equation.
The GMM model (equation 3) showed that the regression coefficient was equal to 0.861, indicating that 86.1% of exogenous variables explain the endogenous variable and 13.9% were explicated by the other factor that are not determining in the model. Also, the probability of J-statistic is superior to 1%, indicating that the GMM specification is well identified and the test of endogeneity specifies (difference in J-stat) indicate that the probability is inferior to 5%, so we can't reject the alternative hypothesis, and we can say that LNGDP, LNREC, $LNCO_2$ are endogenous.

4.2. The residual diagnostic:

We made only the test of **Ljung-Box (1978)** and it showed that we can't reject the null hypothesis at level of 5%, so the residual follow white noise process. Also, the normality test showed that the probability estimated is superior to 1%, 5% and 10%, demonstrating that we reject the alternative hypothesis rather than we accept the null hypothesis, so the residuals are normally distributed.

4.3. Discussion:

In the GMM equation, the coefficient of LNGDP was positive and significant at level of 1%, so a rise by 1 unit in this variable will increase the elasticity of HDI by 0.090, showing that in this period, the economic growth supported the development of the HDI, by improving the level of education and facilitate the access to energy and offering a health security and higher life expectancy. Also, we can say that the policies aimed at accelerating growth would have a positive impact on the HDI in the long-run. This result is on line with the main literature of **Grubaugh (2015)**, and **Hafner and Mayer-Foulkes (2013)**.

However, the sign of other variables appeared insignificant, so we tried to avoid them in the GMM model to have a significant variable of renewable energy or carbon dioxide emissions, but it gave an inconsistent result. Therefore, we provide an explanation according to model.

The coefficient of LNREC was positive and insignificant, meaning that the renewable energy consumption has not a significant impact on improving the human development index or the REC is inelastic to HDI. The same result was found in the studies of **Wang et al. (2018)** and **Ouedraogo (2013)**. Consequently, the energy cannot contribute to the human development process, which may be due to the reason that the use of renewable energy is inefficient for socio-economic purpose and it won't affect considerably the level of human health, education and generation of income. Also, Algeria is relying on energy consumption to expanse their socio-economic situation and to attain the sustainable development in the future. Indeed, the energy in all forms is important for modern technologies and economic growth as well, but it is also vital for certain basic activities in daily life of population such as lighting, refrigeration and the running of household appliances.

The sign of $LNCO_2$ was positive and insignificant; this finding appears very strange, because logically the pollution gas affect negatively the well-being of the population. Therefore, we can say that the environmental factor support the improvement of the human development in Algeria, which may occur due to the reason that growing carbon dioxide emissions imposed policy makers to focus on clean energy. It may also be the reason of the positive role of the carbon dioxide emissions in the Human Development Index, so more production of clean energy will improve the level of the HDI. This result can be justified as it may be possible that green energy initiative by taken up and this has been taken due to the growing amount of carbon emissions in Algeria, which imposed the policymakers to introduce green energy initiatives, to get healthier Human Development Index results **Wang et al. (2018)**.

4.4. The Augmented-Granger causality:

We found with Toda-Yamamoto test that there is bidirectional causality between $LNCO_2$ and LNHDI and between LNGDP and $LNCO_2$ at level of 1%, suggesting that the carbon dioxide emissions affects the level of the human development process in Algeria, conversely low human development in this country cause the environmental pollution **Wang et al. (2018)**.

We also found that there are four unidirectional causalities, which were running from LNGDP to LNHDI, and from LNREC to LNHDI, and from LNREC to LNGDP, and from LNREC to CO_2, approving that the renewable energy consumption can have a serious impact on level of economic, environment and social factors (the main elements of Sustainable Development), however it depends on how the country use renewables. Consequently, this result indicates that the resources from national income allocated to activities contributing to human development index and this latest can support the socio-economic and it may help to increase the national income and production. Besides, a well-educated and healthy human capital is a significant factor of state competitive advantage formation. It influences too the labour efficiency which in its turn attracts foreign direct investment into Algeria. The same conclusions were found in the studies of **Zang et al. (2017)**, **Kazar and Kazar (2014)** and **Martinez and Ebenhack (2008)**.

5. CONCLUSION:

In this paper, we studied the importance to include the renewable energy on (HDI) and the influence of economic and environment sector on social aspect, which is the third pillar of sustainable development goals. Several researchers found that an increase in the renewable energy and GDP, while a decrease in the CO_2 emissions can enhance the level of human development by improving education and well-being of population. However, in this study, we found that the renewable energy is not affecting significantly the level of HDI, indicating that Algerian population is still depending on combustible and traditional renewables in biomass for certain basic activities in daily life such as lighting, refrigeration and the running of household appliances.

We also recognized that the economic factor had a positive sign on human development index, indicating that Algeria is going to shift it economic growth development and its energy dependence to focus more on socio-economic development. Therefore, the country needs to improve the access of adequate energy, health and education service to reach the sustainable development goals, which are crucial for economic growth, human development and for the fight against climate change.

Appendix:

Table 04. OLS estimation

Variables	Coefficient	t-statistic	Probability	VIF
C	0.0124	0.0121	0.99	NA
LNGDP	0.1083***	5.185	0	1052.083
LNREC	-0.0100	-1.019	0.321	1533.112
$LNCO_2$	0.1136	1.715	0.103	27455.57

Source: Made on EViews 9.

*,**,***, indicate that we can't reject the alternative hypothesis and the coefficients are significant at the level of 10%, 5% or 1%.

Table 05. Correlation matrix

Variables	LNCO2	LNGDP	LNHDI	LNREC
LNCO2	1	…	…	…
LNGDP	0.855	1	…	…
LNHDI	0.867	0.937	1	
LNREC	0.381	0.447	0.351	1

Source: Made on EViews 9.

Table 06. GMM estimation

Variables	Coefficient	t-statistic	Probability
LNGDP	0.091***	3.278	0.004
LNREC	0.009	0.600	0.555
$LNCO_2$	0.069	0.825	0.419
C	-0.027	-0.021	0.983
R^2	0.861	J-statistic	2.849
Prob of J-statistic	0.827		

Source: Made on EViews 9.

***, indicate that we can't reject the alternative hypothesis and the coefficient is significant at the level of 1%.

Table 07. Endogeneity test

Test	Value	Probability
Difference in J-stats	7.928**	0.0475

Source: Made on EViews 9.

**, indicate that we can't reject the alternative hypothesis and the coefficient is significant at the level of 5%.

Table 08. Ljung-Box test

Lag	Q statistic (residuals squared)	probability
12	12.312	0.421

Source: made on EViews 9

Table 09. Normality test

Skewness Value	Kurtosis Value	Jarque-Bera Value	Prob. J-B
-0.608	3.093	1.365	0.505

Source: made on EViews 9

Table 10. Unit root test of LNGDP

LNGDP						
Phillips-Perron			Augmented Dickey-Fuller			
Models	On level	1st difference	Models	On level	1st difference	Decision
Model 3	-0.628	-3.631*	Model 3	-0.384	-3.631*	I(1)
Model 2	-1.288	-3.509**	Model 2	-1.295	-3.509**	I(1)
Model 1	1.383	-3.352***	Model 1	1.501	-3.352***	I(1)

Source: made on EViews 9.

Table 11. Unit root test of LNREC

LNREC						
Phillips-Perron			Augmented Dickey-Fuller			
Models	On level	1st difference	Models	On level	1st difference	Decision
Model 3	-3.545*	-8.087***	Model 3	-3.545*	-5.937***	I(1)
Model 2	-3.184**	-8.455***	Model 2	-3.184**	-6.108***	I(1)
Model 1	-0.085	-8.651***	Model 1	-0.101	-6.275***	I(1)

Source: made on EViews 9.

Table 12. Unit root test of $LNCO_2$

$LNCO_2$						
Phillips-Perron			Augmented Dickey-Fuller			
Models	On level	1st difference	Models	On level	1st difference	Decision
Model 3	-6.112***	-3.344*	Model 3	-3.266*	-3.488*	I(1)
Model 2	0.945	-3.183**	Model 2	…	-3.263**	I(1)
Model 1	-1.907*	-2.678**	Model 1	…	-2.733***	I(1)

Source: made on EViews 9.

Table 13. Unit root test of LNHDI

LNHDI								
Phillips-Perron				Augmented Dickey-Fuller				
Models	lvl	1st dif	2nd dif	Models	lvl	1st dif	2nd dif	Decision
M 3	0.567	-2.103	-3.741**	M 3	-0.222	-3.082	-3.719**	I(2)
M 2	…	-0.880	-3.704**	M 2	-2.606	…	-3.704**	I(2)
M 1	…	-1.329	-3.654***	M 1	-1.680	…	-3.654***	I(2)

Source: made on EViews 9.

*, **, ***, indicate that we can't accept the null hypothesis at the level of 10%, 5% or 1%.

Table 14. Toda-Yamamoto causality

LNHDI		
Excluded	**Chi-square**	**Probability**
LNGDP	458.924***	0
LNREC	82.858***	0
$LNCO_2$	179.596***	0
$LNCO_2$		
Excluded	**Chi-square**	**Probability**
LNGDP	95.575***	0
LNREC	1394.105***	0
LNHDI	183.922***	0
LNGDP		
Excluded	**Chi-square**	**Probability**
LNHDI	5.760	0.123
LNREC	24.926***	0
$LNCO_2$	11.902***	0.007
LNREC		
Excluded	**Chi-square**	**Probability**
LNGDP	0.545	0.908
LNHDI	1.917	0.589
$LNCO_2$	0.753	0.860

Source: Done on Eviews 9.

***, indicate that we can't reject the alternative hypothesis, indicating the existence of causality at the level of 1%.

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