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Abstract: This paper examines the causal relationship between economic growth, combustible renewables and waste consumption, and CO_2 emissions for a balanced panel of five North Africa countries during the period 1971-2008. The panel cointegration test results indicate that, in the short-run, there is evidence of unidirectional causality running from CO_2 emissions to real GDP, unidirectional causality from combustible renewables and waste consumption to real GDP without feedback, and unidirectional causality from combustible renewables and waste to CO_2 emissions. However, there is evidence of no short-run causality between combustible renewables and waste consumption and CO_2 emissions. In the long-run, we find that there is evidence of a unidirectional causality running from CO_2 emissions and combustible renewables and waste consumption real GDP. The results from panel FMOLS and DOLS estimates show that CO_2 emissions is the most significant variable in explaining economic growth in the region which is followed by the consumption of combustible renewables and waste. In the long-run, increases in combustible renewables and waste consumption and emissions lead to increase economic growth. The finding of this paper is that North Africa region can use renewable energy as a substitutable energy to the fossil one and avoid the disaster on atmosphere and stimulate economic growth in the long-run.

Keywords: Combustible renewables and waste consumption; panel cointegration; North Africa.

JEL Classification: C33, Q43

1. Introduction

Due to the exponential growth of population, the demand of energy attends an exponential growth rate. However, more the consumption of energy (fossil fuels, oil, natural gas …) increases more the CO_2 emissions of the world are increasing at worrying rates. Several studies and econometric analysis confirm that emissions are increasing rapidly due to the inefficient energy consumption (e.g. Ramanathan, 2005; DeCanio, 2009; Reddy and Assenza, 2009; among other). To avoid disaster caused by emissions of carbon dioxide and greenhouse

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gases, it is necessary to find a substitutable energy to the fossil one such combustible renewables and waste energy.

The use of renewable energy has become increasingly strong in the world. There are several environmental and political issues that affect the expansion of the renewable energy exploitation. However, the impact of renewable sources on economic activities depends on the climate condition, renewable technology markets, investment policy in green technologies considered for production, and renewable capacity installations.

To our knowledge, the economic literature has not yet addressed the causal relationship between economic growth, combustible renewables and waste consumption and emissions of CO_2, since there is no processing of empirical studies based on these sources of "green" energy devoted for production. There is much consideration that renewable energy plays a vital role in the expansion of economic activities and environment. However, there are numerous empirical studies that debate the causal links between renewable energy and economic growth. These studies investigate the direction of causality between these two variables, and the results are different depending on the selected country or sample, period, empirical methodology, and variables included in the specific model. In our study, we aim to examine the short and long-run relationship between economic growth, combustible renewable and waste consumption and CO_2 emissions and to observe the contribution of renewable energy on economic activity expansions for a panel of North African countries. According to the previous existing literature that discuss the direction of short-run causal links between economic growth, renewable energy and CO_2 emissions can be summarized on three hypotheses as follow: *i*) economic growth Granger causes emissions, emissions Granger causes economic growth, or no causal links which indicates that any increase in economic activities may disrupt the degradation of environmental condition and any upsurge in emissions will affect economic growth or no interaction between them; *ii*) economic growth Granger causes renewable energy, renewable energy Granger causes economic growth or no short-run correlation between them. This reading explains the short-run interdependence that may exist between these variables and fluctuation of any one of these two variables leads to affect the other or no short-run causal relationship; and *iii*) renewable energy Granger causes emissions, emissions Granger causes renewable energy or no causality argues that there is a unidirectional causality from renewable energy to emissions or from emissions to renewable energy. This result suggests that increasing of renewable energy use will affect emissions or any renewable energy conservation will interrupt the environmental degradation. In the long-run association, the relationship between three variables is determined by the significance of the error correction term. Also, the direction of causality in the long-run can be unidirectional, bidirectional or no causality between economic growth, renewable energy and emissions. However, the empirical analysis results seem to be different on the direction of causality. Ozturk (2010) argues these causal differences in the different data set, econometric methodologies, and the sample of countries.

The combustible renewables and waste include biogas, biomass (liquid or solid) and waste (industrial or municipal). It means that these sources of energies are not purely clean as renewable energy sources (solar, wind …), but not too pollutant as non-renewable energy (fossil fuel, oil, coal…), since in this study we consider the combustible renewables and waste as a substitutable to renewable energy sources. However, in this section we debate the existing studies that investigate the causal relationship between economic growth, renewable energy consumption and between economic growth, renewable energy consumption and emissions of CO_2.

2. Existing literature

2.1. Renewable energy-growth nexus

The dynamic causal links between economic growth and renewable energy consumption have been investigated in several econometric studies. These studies can be classified on two sets. The first set examines the relationship that may exist only between renewable energy and real GDP (e.g. Al-mulali et al. 2013; Apergis and Payne, 2010a, 2010b; Menegaki, 2011; Ocal and Aslan, 2013; Sadorsky, 2009b, Salim and Rafiq, 2012), and the second set includes the existing literature that negotiate the relationship between renewable energy, economic growth and other additional variables such as energy consumption, electricity consumption, nuclear energy, non-renewable energy consumption, trade, real oil price… (e.g. Al-mulali et al. 2014 ; Apergis and Payne, 2012 ; Apergis et al. 2010; Ben Aïssa et al. 2014; Bowden and Payne, 2010; Payne, 2009; Sari et al. 2008; Tugcu et al. 2012). According to these empirical literatures, the direction of causality between renewable energy consumption-economic growths varies between four hypotheses. a) The feedback hypothesis argues that there is bidirectional causal links between renewable energy and growth. b) The neutrality hypothesis suggests that no causal relationship exists between the variables. c) The growth hypothesis suggests that renewable energy consumption plays a vital role in the expansion of economic growth and any policy reduction in renewable energy will affect negatively the development of economic activities. d) Conservation hypothesis recommends the existence of unidirectional causality from economic growth to renewable energy consumption. This hypothesis is supported if the increase in economic growth leads to an increase in renewable energy consumption.

In the context of the causal connection between renewable energy consumption and economic growth, Al-mulali et al. (2013) use the fully modified OLS procedure to examine the bidirectional long-run relationship between renewable energy consumption and GDP growth in high income, upper middle income, and lower middle income countries. They suggest that 79% of countries have a positive bidirectional long-run relationship between renewable energy consumption and GDP growth (feedback hypothesis). Also, the result suggests that 19% of the countries support the neutrality hypothesis which indicates that no causal links between two variables. Besides, 2% of the countries show the existence of unidirectional causality from growth to renewable energy and from renewable energy to growth, which support the conservation hypothesis and growth hypothesis, respectively. Al-mulali et al. (2014) explore the effect of renewable and non-renewable electricity consumption on economic growth for 18 Latin American countries using vector error correction model and Granger causality tests. The result of the study revealed the existence of bidirectional causality between economic growth, renewable and non-renewable electricity consumption, capital, labor and trade. They also suggest that renewable electricity consumption is more significant than non-renewable electricity consumption in promoting economic growth for the selected countries. Using a panel cointegration tests, Apergis and Payne (2010a) examine the causal relationship between renewable energy consumption for a panel of twenty OECD countries. The result from Granger causality reveals the existence of bidirectional causality between renewable energy consumption and economic growth. Apergis and Payne (2010b) examine the causal relationship between renewable energy consumption and economic growth for a panel of Eurasia countries using panel cointegration techniques over the period 1992-2007. The authors show that the interaction between renewable energy consumption and economic growth is bidirectional and support the feedback hypothesis. For a panel of six Central American countries, Apergis and Payne (2011) use panel cointegration techniques to examine the causality between renewable energy consumption and economic growth over the period 1980-2006. The empirical results suggest bidirectional causality between renewable energy consumption and economic growth in both short and long-run. To examine the relationship between renewable and non-renewable energy consumption and economic growth, Apergis and Payne (2012) use heterogeneous panel cointegration test for 80 countries over the period 1990-2007. The result from the test suggests bidirectional causality between renewable and non-renewable energy consumption and economic growth in both the short and long-run. it means that the feedback hypothesis is supported for both energy sources (renewable or non-renewable). They also show bidirectional causality between renewable and non-renewable energy consumption. Ben Aissa et al. (2014) use panel cointegration techniques for a panel composed by 11 African countries over the period 1980-2008. The result from panel error correction model reveals bidirectional causality between economic growth and trade (exports and imports) in both the short and long-run. Also, the result shows no causal between renewable energy consumption and economic growth. For the US, Bowden and Payne (2010) examine the relationship sectorial renewable and non-renewable energy consumption and economic growth over the period 1949-2006 using Toda-Yamamoto causality test for the log-run. The analysis result suggests no causal links between real GDP and renewable energy consumption for industrial and commercial sectorial and bidirectional causal links between real GDP and commercial and residential non-renewable energy consumption. Menekagi (2011) investigates the causality between renewable energy consumption and GDP for 27 European countries using a multivariate framework random effect model for the period 1997-2007. The result from the empirical analysis reveals no causal relationship between renewable energy consumption and GDP. Ocal and Aslan (2013) examine the relationship between renewable energy consumption and economic growth in Turkey using ARDL approach and Toda-Yamamoto causality test. They find that the interaction between two variables support the conservation hypothesis because the direction causality reveals a unidirectional causality funning from economic to renewable energy consumption. Payne (2011) investigates the causal links between biomass and real GDP using the Toda-Yamamoto causality tests for Granger causality for the US. He finds a unidirectional causality from biomass to economic growth. This result supports the growth hypothesis. For a panel of 18 emerging economies during the period 1994-2003, Sadorsky (2009b) uses a panel cointegration model and shows evidence of unidirectional causality running from economic growth to renewable energy consumption and economic growth. This result supports the conservation hypothesis. The long-run estimates show that increase in real income per capita increases the consumption of renewable energy per capita in emerging economies. Based on the FMOLS and DOLS techniques for estimation and Granger causality tests, Salim and Rafiq (2012) study the causality between renewable energy consumption and economic growth in Brazil, China, India, Indonesia, Philippines, and Turkey during the period 1980-2006. The empirical results reveal that, in the long-run, renewable energy consumption is statistically significant and determined by economic growth. By using the ARDL approach, Tugcu et al. (2012) investigate the long-run and causal relationships between renewable and non-renewable energy consumption and economic growth in the G7 countries over the period 1980-2009. The result shows bidirectional feedback hypothesis between renewable and non-renewable energy and economic growth for all countries. Thus, they agree on the vital role of renewable energy in the growths of the GDP.

2.2. Economic growth-renewable energy consumption-CO2 emissions nexus

The dynamic causal relationship between economic growth, CO_2 emissions, and renewable energy consumption is one of the most interesting topics that we ought to study. The causal relationship focused between these variables have been examined by researchers and then published in some econometric reviews (e.g.; Apergis and Payne, 2014; Apergis et al., 2010; Menyah and Wolde-Rufael, 2010; Sadorsky, 2009a; Shafiei and Salim, 2014). For a group of 19 developed and developing countries, Apergis et al., (2010) examine the causal relationship between emissions, nuclear energy, renewable energy, and economic growth for the period 1984-2007. The results from the long-run estimates indicate that nuclear energy is statistically significant and have a negative impact on emissions but renewable energy is statistically significant and have a positive impact on emissions. In the short-run, the results from panel Granger causality tests suggest that nuclear energy contribute to reductions in emissions while renewable energy do not involve in the reduction of emissions. Apergis and Payne (2014) examine the determinants of renewable energy consumption per capita for a panel of 7 Central American countries over the period 1980 to 2010. The result from the empirical analysis shows a long-run cointegration between renewable energy consumption per capita, real GDP per capita, carbon emissions per capita, real coal prices, and real oil prices with the restrictive coefficients positive and statistically significant. Menyah and Wolde-Rufael (2010) examines the long-run relationship between CO_2 emissions, nuclear energy, renewable energy, and economic growth in the US. The results from a modified version of the Granger causality test indicate a unidirectional causality running from nuclear energy consumption to CO_2 emissions but no causality running from renewable energy to emissions. An empirical model of renewable energy consumption for the G7 countries has been presented and estimated by Sadorsky (2009a). The results from the panel cointegration estimators show that in the long-run, increases in real GDP per capita and CO_2 per capita are found to be major drivers behind per capita renewable energy consumption. Shafiei and Salim (2014) examine the relationship between renewable and non-renewable energy consumption and CO_2 emissions for OECD countries using the STIRPAT model and data from 1980 to 2011. The authors find that non-renewable energy consumption contributes to increase emissions of CO_2 while renewable energy consumption decreases emissions.

This paper tries to investigate the short and long-run causal link between real GDP per capita, CO_2 emissions per capita, and per capita combustible renewables and waste energy consumption for five North Africa countries using panel cointegration techniques, Granger causality tests, and more powerful methods of long-run estimation so-called fully modified OLS and dynamic OLS.

In the light of the discussion above, the rest of the study is organized as follows: Section 3 describes the data. Section 4 designates for descriptive statistics. Section 5 presents the empirical methodology and results. Section 6 concludes.

3. Data

For this study, the data set is a balanced panel of five North Africa countries (Algeria, Egypt, Morocco, Sudan, and Tunisia) for the period 1971-2008. The annual data is collected from the World Bank (2011) Development Indicators online database and includes real GDP per capita (GDP), combustible renewables and waste consumption per capita (CRW)[1], and CO_2 emissions per capita (CO_2). All of the data are converted to the natural logarithms prior to conducting the empirical analysis.

Real GDP per capita is measured in constant 2000 US$, and CO_2 emissions per capita is measured in metric tons. Combustible renewables and waste is measured in metric tons of oil equivalent per capita through dividing by the population. The dimension of the panel data set

1 According to the World Development Indicators, the combustible renewables and waste consumption variable used in this empirical analysis includes solid biomass, liquid biomass, biogas, industrial waste, and municipal waste.

is selected to include as many countries of North Africa region with analysis variables and period.

4. Descriptive statistics

Table 1 presents some descriptive statistics (Mean, Median, Maximum, and Minimum) of each selected variable. All these statistics are calculated after logarithmic transformation. Fig (1)-(3) report time series graphs of the natural logarithms of per capita real GDP, per capita combustible renewables and waste, and per capita CO_2 emissions.

Table 1. Descriptive statistics for analysis variables

Variables	Mean	Median	Maximum	Minimum	Cross sections
GDP	1287.273	1208.349	4966.572	236.5653	5
CRW	2188.660	630.8855	12054.89	8.812000	5
CO_2	1.446479	1.308321	3.608586	0.101656	5

Source: Authors (EViews.7 software). GDP per capita is measured in constant 2000 dollars, per capita CO2 is measured in metric tons, and CRW is measured in metric tons of oil equivalent.

Fig 1. Real GDP per capita (constant 2000 US$) from 1971 to 2008

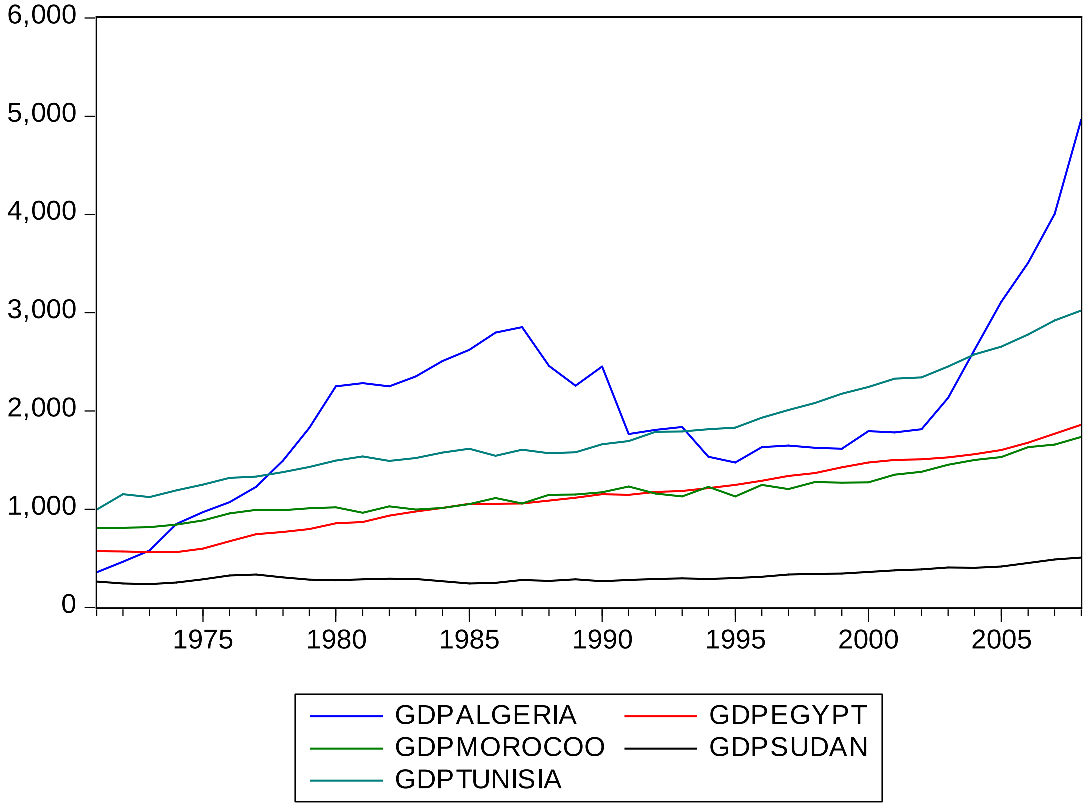

Fig.1 shows the variation of natural logarithms of real GDP per capita (measured in constant 2000 US dollars) between countries over the period 1971-2008. For each of the countries studied, GDP per capita increases across time while the increase varies with different degree between countries. Algeria has the biggest with 4966.572 US dollars in 2008 and Sudan was the smallest with 236.5653 US dollars in 1973.

Fig 2. Combustible renewables and waste consumption (metric tons of oil equivalent) from 1971 to 2008

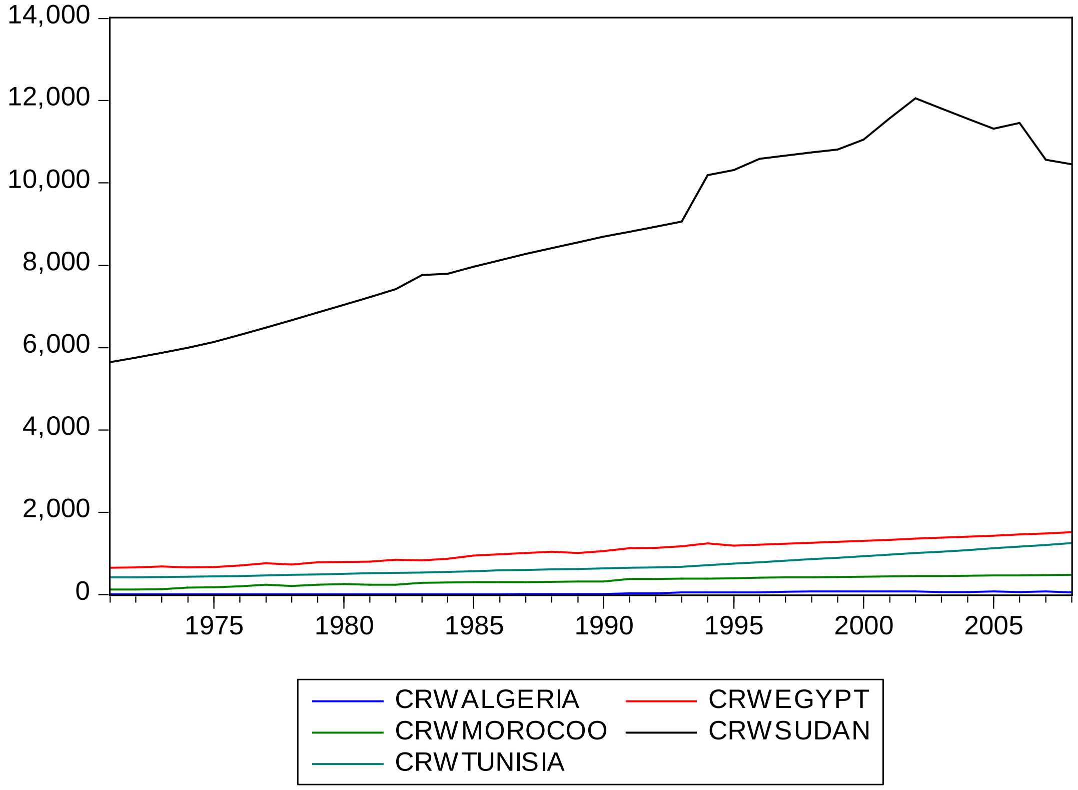

Fig. 2 shows the variation of combustible renewables and waste (measured in metric tons of oil equivalent) between countries and indicates that practically the consumption of the combustible renewables and waste energy consumption is stable cross time. Sudan is the largest consumer of combustible renewables and waste energy consumption in 2002 with 12054.89 metric tons while Algeria is the smallest with 8.812 metric tons in 1971.

Fig 3. CO_2 emissions per capita (metric tons) from 1971 to 2008

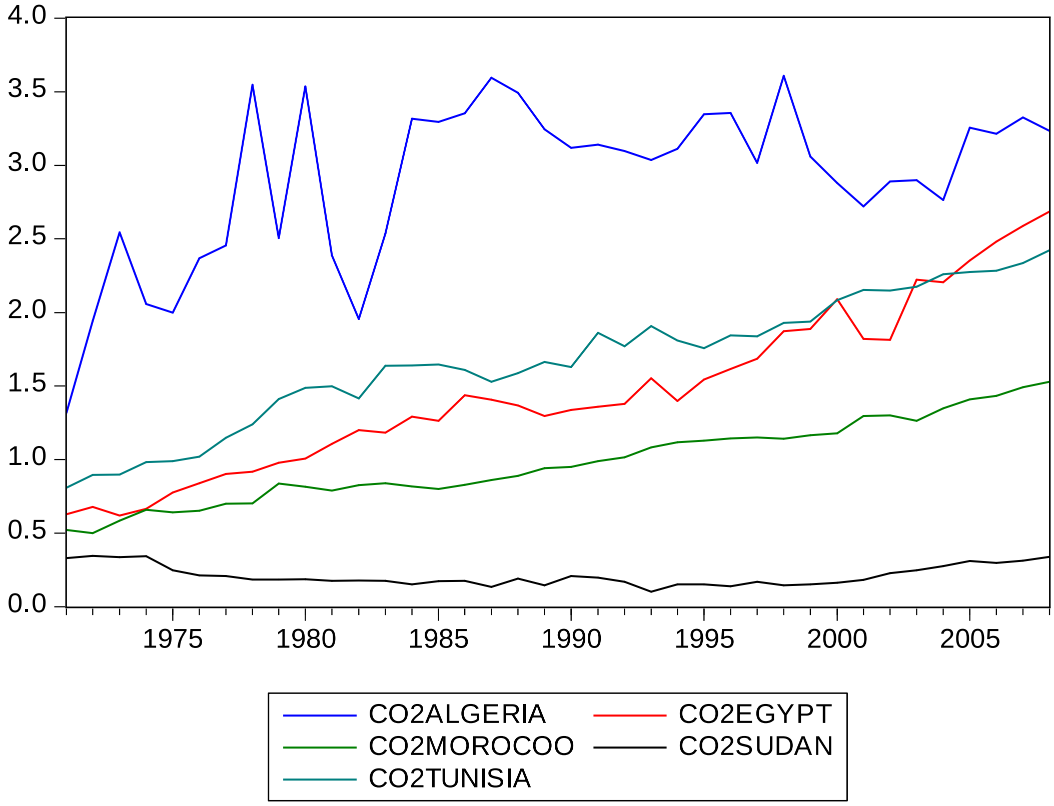

Fig.3 shows the variation of CO_2 emissions per capita (measured in metric tons) between countries. The biggest polluting country is Algeria with 3.60 metric ton per capita in 1998 and Sudan is the smallest with 0.10 metric tons per capita in 1993.

5. Empirical methodology and results

We consider the following linear equation which explores the long-run causality relationship between the natural logarithm of real GDP per capita (GDP), logarithm of combustible renewables and waste energy consumption per capita (CRW), and the logarithm of CO_2 emissions per capita (CO_2):

$$GDP_{it} = \alpha_i + \beta_i CRW_{it} + \delta_i CO_{2_{it}} + \varepsilon_{it} \tag{1}$$

$$ECT_{it} = GDP_{it} - \hat{\beta}_i CRW_{it} - \hat{\delta}_i CO_{2_{it}} \tag{2}$$

where $i = 1,...,5$ denotes the country and $t = 1971,...,2008$ denotes the time period; ε_{it} indicate the estimated residuals which characterize deviations from the long-run relationship; α_i denotes the country specific fixed effects, and from Eq. (2) which corresponding to the error correction term (ECT_{it}) derived from the long-run cointegration relationship of Eq. (1).

5.1. Panel unit root

The empirical analysis starts through testing the presence of a unit root for the three variables which are real GDP per capita, per capita combustible renewables and waste energy consumption, and CO_2 emissions per capita using three types of panel unit root tests[2]. The first unit root test is developed by Levin et al. (2002) noted LLC test. This test discussed individual unit root tests have limited power against alternative hypotheses with highly obstinate deviations from equilibrium. This hypothesis is severe particularly for small sample. The preserved hypothesis is that:

$$\Delta y_{it} = \theta_i + \rho y_{i,t-1} + \sum_{j=1}^{p_i} \lambda_{ij} \Delta y_{i,t-j} + \varepsilon_{it} \qquad (3)$$

where $i = 1, . . .,N$ and $t = 1, . . .,T$. p_i designates the number of lag selected for each country. The LLC test is based on the statistic of Augmented Dickey Fuller (ADF). The first step consists to perform separate ADF regressions for each cross-section *i*.

$$\Delta y_{it} = \theta_i + \rho_i y_{i,t-1} + \sum_{j=1}^{p_i} \lambda_{ij} \Delta y_{i,t-j} + \varepsilon_{it} \qquad (4)$$

Once p_i is determined, we compute the orthogonalized residuals $\hat{e}_{it}$ and $\hat{\upsilon}_{it-1}$ obtained by the two auxiliary regressions Δy_{it} and Δy_{it-1}, respectively. By normalizing these two residuals for different variances across country, we get: $\tilde{e}_{it} = \frac{\hat{e}_{it}}{\hat{\sigma}_{\varepsilon i}}$ and $\tilde{\upsilon}_{it-1} = \frac{\hat{\upsilon}_{it}}{\hat{\sigma}_{\varepsilon i}}$ where $\hat{\sigma}_{\varepsilon i}$ is the standard error from each ADF regression for each *i*.

In the second step, we estimate the ratio of long-run to short-run standard deviations. The long-run variation of Eq.(3) can be estimated, under the null hypothesis of unit root (non-stationary), by $\hat{\sigma}_{yi}^2 = \frac{1}{T-1}\sum_{t=2}^{T} \Delta y_{it}^2 + 2\sum_{j=1}^{k} \omega_{kj}\left[\frac{1}{T-1}\sum_{t=2+j}^{T} \Delta y_{it} \Delta y_{it-j}\right]$; where *k* is a truncation lag that can be data-dependent, $\omega_{kj} = 1 - \left(\frac{j}{k+1}\right)$ is determined for Bertlett kernel. The average standard deviation is estimated is given by $\hat{S}_N = \frac{1}{N}\sum_{i=1}^{N} \hat{s}_i$, where $\hat{s}_i = \frac{\hat{\sigma}_{yi}}{\hat{\sigma}_{\varepsilon i}}$ indicates the fraction of the long-run standard deviation to the innovation standard deviation for each country *i*. in the last step, we compute the panel test statistics by running the pooled regression $\tilde{e}_{it} = \rho \tilde{\upsilon}_{it-1} + \tilde{\varepsilon}_{it}$.

The second unit root test is suggested by Im et al. (2003) and noted IPS test. This test takes into accounts information from the time series dimension with that from the cross section dimension. The IPS test starts by specifying a separate ADF regression for each cross-section with individual effects and without trend.

Im, Pesaran and Shin (IPS, 2003) test is based on the ADF statistics averaged across groups. After estimation the Eq.(4) we recover the average of t_{ρ_i} to perform the following statistic:

$$\frac{(\bar{t}_{NT} - \tau)\sqrt{N}}{\sqrt{\sigma^2}} \rightarrow N(0,1) \qquad (6)$$

Where $\bar{t}_{NT} = \frac{1}{N}\sum_{i=1}^{N} t_{\rho_i}$, τ and σ are the average of t_{ρ_i} , the mean and the variance, respectively. The null hypothesis is that all individuals follow a unit roots:

[2] The stationarity of variables have been tested for each country using the Augmented Dickey Fuller (ADF) and Phillips Perron (PP) tests. The result from these tests suggests that all the variables for each country stationary after first difference. Thus, all the variables for each country are integrated of order one I(0).

$H_0 : \rho_i = 0 \forall i$

The alternative hypothesis allows some of the individuals to have unit roots:

$$H_1 : \begin{cases} \rho_i < 0 \;\; for\; i = 1,...,N_1 \\ \rho_i = 0 \;\; for\; i = N_1 + 1,...,N \end{cases}$$

The third unit root test is proposed by Breitung (2000) which is characterized by its great power and usually has smallest size distortions. Breintung (2000) find that LLC test of Levin et al. (2002) and IPS test of Im et al. (2003) suffer from a dramatic loss of power if individual-specific trends are included. This is due to the bias correction that also removes the mean under the sequence of local alternatives. The procedure of the Breitung's test follows the same first step developed by Levin et al. (2002), except that we do not include deterministic trend. In the second step, we estimate residuals $\hat{e}_{it}$ and $\hat{\upsilon}_{it-1}$. In the last step, we run the pooled regression given by $e^*_{it} = \rho \upsilon^*_{it-1} + \varepsilon^*_{it}$ in order to obtain the t-statistic for H_0: $\rho = 0$ which is asymptotically N(0,1) distributed.

Table 2. Panel unit root tests

Method		*GDP*	*CRW*	*CO_2*
LLC-t:	*Level*	0.71642 (0.7631)	-0.31229 (0.3774)	-2.25546 (0.0121)
	First difference	-8.86269 (0.0000)***	-4.07410 (0.0000)***	-16.2351 (0.0000)***
Breitung-t:	*Level*	-0.42501 (0.3354)	1.62587 (0.9480)	-0.11500 (0.4542)
	First difference	-3.03721 (0.0012)***	-3.09840 (0.0010)***	-10.0651 (0.0000)***
IPS-W-stat:	*Level*	2.18422 (0.9855)	0.33109 (0.6297)	-1.33922 (0.0902)
	First difference	-11.6766 (0.0000)***	-7.19509 (0.0000)***	-14.9980 (0.0000)***

Null hypothesis: Unit root (non-stationay)

All the variables are expressed in natural logarithms

Automatic lag selection based on Schwarz Information Criteria (SIC)

Tests induce intercept and individual trend

"***", indicates statistical significance at 1% level.

For these tests the null hypothesis is that there is a unit root (non-stationary) while the alternative is that there no unit root (stationary). The results of the LLC, Breitung and IPS tests are reported in Table 2. The results indicate that all three variables are panel non-stationary at log-levels. However, when we apply the first difference of the log-levels of all variables we can reject the null hypothesis of unit root, and then real GDP per capita, combustible renewables and waste energy consumption per capita, and CO_2 emissions per capita are stationary at 1% significance level. It means that all variables are integrated of order one (I(1)).

5.2. Panel cointegration

On the basis of the panel unit root test results we proceed by applying the cointegration test using three kinds of panel cointegration tests, i.e. Pedroni (2004), Kao (1999), and Johansen (1988). Pedroni (2004) proposes two sets of cointegrartion tests classified on the within-dimension and the between-dimension. The first is a panel set based on four statistics and includes v-statistic, rho-statistic, PP-statistic and ADF-statistic. These statistics are classified on the within-dimension and take into account common autoregressive coefficients across countries. The second is a group set based on three statistics and includes rho-statistic, PP-statistic, and ADF statistic. These tests are classified on the between-dimension and based on the individual autoregressive coefficients for each country in the panel. In total, Pedroni

(2004) suggests seven statistics for the cointegration tests based on the residual of Eq.(2). The null hypothesis is that there is no cointegration while alternative hypothesis is that there is cointegration between variables. The existence of long-run relationship between variable have been tested for the case of intercept and intercept and trend when GDP is the dependent variabl. The results from the Pedroni cointegration tests are reported in Table 3. For the case of intercept, the result shows that all weighted statistic of the within-dimension are statistically significant, and all the between-dimension statistics are statistically significant, which indicate the presence of long-run relationship between three variables. For the case of intercept and trend, the result from Pedroni cointegration tests reveals that, for the within dimension, one test among four (panel v-statistic) and two tests for the weighted statistics (panel v-statistic and pp-statistic) are statistically significant, and two tests among three (group pp-statistic and group ADF-statistic) for the between dimension reject the null of no cointegration. Thus, there is a long-run cointegration between variable when GDP is the dependent variable. Finally, we conclude than the long-run relationship between GDP, combustible renewable and waste consumption and CO_2 emissions is supported.

Table 3. Pedroni residual cointegration test results (GDP as dependent variable)

	Alternative hypothesis: common AR coefs. (within-dimension)				
				Weighted	
		Statistic	Prob.	Statistic	Prob.
intercept	Panel v-Statistic	0.847558	0.1983	2.505796	0.0061***
	Panel rho-Statistic	-0.668786	0.2518	-1.970188	0.0244**
	Panel PP-Statistic	-0.487677	0.3129	-2.307036	0.0105**
	Panel ADF-Statistic	-0.467417	0.3201	-1.972788	0.0243**
	Alternative hypothesis: individual AR coefs. (between-dimension)				
	Group rho-Statistic	-2.087841	0.0184**		
	Group PP-Statistic	-3.341097	0.0004***		
	Group ADF-Statistic	-3.059685	0.0011***		
	Alternative hypothesis: common AR coefs. (within-dimension)				
				Weighted	
		Statistic	Prob.	Statistic	Prob.
intercept and trend	Panel v-Statistic	3.519518	0.0002***	2.405537	0.0081***
	Panel rho-Statistic	0.122113	0.5486	-0.897836	0.1846
	Panel PP-Statistic	-0.882828	0.1887	-2.040118	0.0207**
	Panel ADF-Statistic	-0.802092	0.2112	-1.197301	0.1156
	Alternative hypothesis: individual AR coefs. (between-dimension)				
	Group rho-Statistic	-0.676989	0.2492		
	Group PP-Statistic	-2.592520	0.0048***		
	Group ADF-Statistic	-1.806098	0.0355**		

Null hypothesis: No cointegration.

"***" and "**" indicate statistical significance at 1% and 5% levels, respectively.

Trend assumption: we consider the two cases: intercept – intercept and deterministic trend.

Automatic lag length selection based on SIC with a max lag of 8.

Newey-West automatic bandwidth selection and Bartlett kernel.

The second panel cointegration test proposed by Kao (1999) is based on the ADF test. The result of this test is reported in table 4 indicates that we can reject the null hypothesis of no cointegration between real GDP per capita, combustible renewables and waste consumption per capita, and CO_2 emissions per capita. It means that all three variables are cointegrated at the 1% level of significance.

Table 4. Kao residual cointegration test (GDP as dependent variable)

	t-statistic	Prob.
ADF	-2.888567	0.0019***

Null hypothesis: No cointegration

"***", indicates statistical significance at 1% level.

Based on the Fisher test (trace test statistics), Johansen (1988)'s cointegration test results reported in Table 5 and indicate the existence of long-run cointegrated relationship between variables at the 1% level of significance.

Table 5. Johansen Fisher panel cointegration test

Hypothesized No of CE(s)	Fisher stat* (trace test)	Prob.
None[a]	34.19	0.0002
At most 1	18.80	0.0428
At most 2	17.52	0.0636

Trend assumption: Linear deterministic trend

Lags interval (in first differences): 1 1

"a" indicates statistical significance at 1% level.

* Probabilities are computed using asymptotic Chi-square distribution.

5.3. Granger causality tests

In this subsection we examine the direction of causality between economic growth, renewable energy, and emissions in a panel context. The finding of long-run relationship between variables specifies the existence of causality and an error correction model must be estimated. Two stages are suggested by Engle and Granger (1987) in order to investigate the short-run and the long-run relationship between these variables. The first stage is to recover the estimated residuals in Eq. (1) and the second stage estimates the parameters related to the short-run adjustment.

The Granger causality test is based on the following regressions:

$$\Delta GDP_{i,t} = \theta_{1,i} + \sum_{j=1}^{q} \theta_{1,1,i,j}.\Delta GDP_{i,t-j} + \sum_{j=1}^{q} \theta_{1,2,i,j}.\Delta CRW_{i,t-j} + \sum_{j=1}^{q} \theta_{1,3,i,j}.\Delta CO2_{i,t-j} + \lambda_{1,i}.ECT_{i,t-1} + u_{1,i,t} \quad (5)$$

$$\Delta CRW_{i,t} = \theta_{2,i} + \sum_{j=1}^{q} \theta_{2,1,i,j}.\Delta GDP_{i,t-j} + \sum_{j=1}^{q} \theta_{2,2,i,j}.\Delta CRW_{i,t-j} + \sum_{j=1}^{q} \theta_{2,3,i,j}.\Delta CO2_{i,t-j} + \lambda_{2,i}.ECT_{i,t-1} + u_{2,i,t} \quad (6)$$

$$\Delta CO2_{i,t} = \theta_{3,i} + \sum_{j=1}^{q} \theta_{3,1,i,j}.\Delta GDP_{i,t-j} + \sum_{j=1}^{q} \theta_{3,2,i,j}.\Delta CRW_{i,t-j} + \sum_{j=1}^{q} \theta_{3,3,i,j}.\Delta CO2_{i,t-j} + \lambda_{3,i}.ECT_{i,t-1} + u_{3,i,t} \quad (7)$$

where Δ denotes the first difference of the variable, the lagged *ECT* is the error correction term derived from the long-run cointegration relationship of Eq.(1) and noted in Eq.(2), q denotes the lag length determined automatically by the Schwarz Information Criterion (SIC). The result from VAR lag order selection shows that all criteria suggest a maximum number of lag one (VAR (q=1))[3].

[3] The criteria used for the lag order selection are: Sequential modified LR statistic test (LR), Final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SIC), Hannan-Quinn

Table 6. Panel pairwise Granger causality test results

Null Hypothesis:	F-Statistic	Prob.
CRW *does not Granger Cause* GDP	1.76840	0.0508*
GDP *does not Granger Cause* CRW	0.00882	0.8137
CO_2 *does not Granger Cause* GDP	3.83755	0.0066***
GDP *does not Granger Cause* CO_2	0.37463	0.2290
CO_2 *does not Granger Cause* CRW	0.15228	0.9184
CRW *does not Granger Cause* CO_2	1.42380	0.0706*

Null hypothesis: No causality

Lag selection: 1

"***", and "*" indicate statistical significance at the 1% and 10% level, respectively.

Table 6 reports the results of the short-run Granger causality test between variables and indicates that there is evidence of *i)* unidirectional causality from combustible renewables and waste energy consumption to GDP without feedback at the 10% significance level, *ii)* unidirectional causality from CO_2 emissions to GDP at the 1% significance level, and *iii)* unidirectional causality from combustible renewables and waste energy consumption to CO_2 emissions at the 10% significance level.

Table 7. Panel long-run causality test results

Dependent variable	ECT	
ΔGDP	-0.213321	[-3.07332]***
ΔCRW	0.000121	[0.02188]
ΔCO_2	0.024202	[0.43222]

"***", indicates statistical significance at the 1% level.

The t-statistic listed in brackets.

The long-run causality test results are presented in table 7 which indicates that only the equation of GDP is significant given that the corresponding error correction term is negative and statistically significant at the 1% level. It means that there is a long-run relationship running from combustible renewables and waste energy consumption and CO_2 emissions to economic growth. This result implies that combustible renewables and waste energy consumption and emissions may affect economic growth in the long-run equilibrium.

information criterion (HQ). Based on all of these criteria, the optimal number of lag selected for VAR model is one.

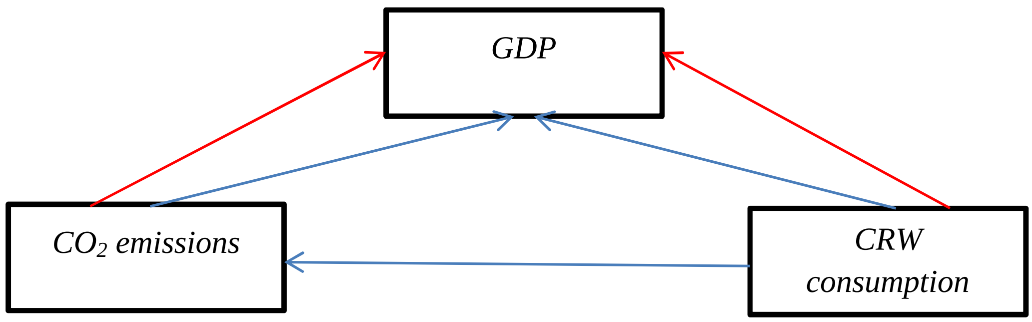

Fig 4. Short and long-run causality between GDP, combustible renewables and waste consumption and CO_2 emissions[4]

Fig 4 reports the short and long-run relationship between GDP, combustible renewables and waste consumption and emissions of CO_2 for North African countries during the period 1971-2008. As mentioned in table 6, the result from Granger causality tests show the existence of unidirectional causality from CO_2 emissions to economic growth but there is no causality from economic growth to CO_2 emissions. In other words, in this region, the variations of CO_2 emissions are correlated with changes in economic activities. It means that, in the short-run, any increase in emissions will directly have an impact on economic growth. This result is consistent with the finding of Salim and Rafiq (2012) for India. However, our finding is contrary to the results of Apergis et al. (2010), Menyah and Wolde-Rufael (2010), Salim and Rafiq (2012) for Brazil and China, who find bidirectional causality between GDP and emissions.

Short-run Granger causality suggests unidirectional causal link running from combustible renewables and waste consumption to emissions. This result indicates that increase in renewable energy may reduce emissions in the short-run. This finding is not similar to the result of Salim and Rafiq (2012) and Apergis et al. (2010) who find bidirectional causality between renewable energy consumption and emissions in the short-run. Also, our finding of unidirectional short-run causality from renewable energy consumption to emissions of CO_2 is contrary to the short-run result of Menyah and Wolde-Rufael (2010) who find no causality running from renewable energy consumption to emissions.

Granger causality tests suggest that there is an evidence of short-run causality from combustible renewables and waste consumption to economic growth without feedback in the short-run. This result supports the growth hypothesis. However, any increase in the consumption of renewable energy will have a positive impact on economic growth but any increase in the development economics may not affect the expansion of renewable energy. This finding is contradictory with Apergis and Payne (2010a, 2010b, 2011) who reported that the interdependence between renewable energy consumption and economic growth is bidirectional in both short and long-run. Nonetheless, our finding is online with Payne (2011) who suggests that the relationship between biomass and economic growth is unidirectional and support the growth hypothesis.

In the long-run, Granger causality shows that there is evidence of unidirectional causality from emissions of CO_2 to economic growth without feedback. This result has been supported in the short-run. Thus, in the North Africa region, the contribution of pollution indicator (CO_2) in explaining economic growth is important in both short and long-term. Granger causality also suggests evidence of unidirectional causality running from combustible renewables and waste consumption to economic growth in both short and long-run term. This

[4] The directions of causality of the short and long-term are indicated by the arrows in blue and red, respectively.

result is quite interesting because it approves a substantial input of renewable energy consumption in GDP growth.

Table 8. Individual Granger causality test results

Country	Dependent variable	Short-run			Long-run
		ΔGDP	*ΔCRW*	*ΔCO2*	*ECT*
Algeria	*ΔGDP*	-	0.16406	0.75794	0.036866
			(0.6880)	(0.3901)	[1.46031]
	ΔCRW	0.01630	-	0.42671	-0.015181
		(0.8991)		(0.5180)	[-1.09329]
	ΔCO_2	3.85984	0.56506	-	-0.811276
		(0.0577)*	(0.4574)		[-4.16451]***
Egypt	*ΔGDP*	-	8.64749	11.2434	-0.087390
			(0.0059)***	(0.0020)***	[-0.89187]
	ΔCRW	12.1274	-	10.4664	-0.327417
		(0.0014)***		(0.0027)***	[-1.70495]
	ΔCO_2	4.54843	0.21259	-	-0.467233
		(0.0403)**	(0.6477)		[-3.09067]*
Morocco	*ΔGDP*	-	1.42020	0.01131	-0.031711
			(0.2570)	(0.9888)	[-2.36304]***
	ΔCRW	1.30261	-	1.92978	-0.701540
		(0.2863)		(0.1622)	[-5.98007]***
	ΔCO_2	5.14758	8.61362	-	0.055605
		(0.0117)**	(0.0011)***		[1.57035]
Sudan	*ΔGDP*	-	1.41930	6.19771	-0.178924
			(0.2572)	(0.0054)***	[-2.69093]***
	ΔCRW	1.29600	-	7.28180	0.060961
		(0.2880)		(0.0026)***	[1.30789]
	ΔCO_2	4.14956	2.10793	-	-0.409397
		(0.0253)**	(0.1386)		[-2.75173]***
Tunisia	*ΔGDP*	-	4.72034	5.35299	0.236666
			(0.0162)**	(0.0101)**	[1.87861]
	ΔCRW	1.78645	-	1.31710	-0.730399
		(0.1844)		(0.2825)	[-3.89662]***
	ΔCO_2	1.80222	0.91496	-	0.015779
		(0.1818)	(0.4111)		[0.67664]

"***", "**", and "*" indicate statistical significance at the 1%, 5% and 10% level, respectively.

The optimal number of lag selected is based on SIC and AIC.

The t-statistic listed in brackets and p-value in parentheses.

The short-run and long-run relationships between variables have been examined for each country and the results are reported in table 8. In the case of Algeria, it is clear that there is unidirectional causality from real GDP to CO_2 emissions in the short-run. In the long-run, there is a unidirectional causality from real GDP and combustible renewables and waste consumption to CO_2 emissions. In Egypt, short-run causalities between real GDP and combustible renewables and waste consumption and between real GDP and CO_2 emissions are found to be bidirectional. Also, there is a unidirectional causality running from CO_2 emissions to combustible renewables and waste consumption in the short-run. In the long-run, there is unidirectional causality from combustible renewables and waste consumption and real GDP to CO_2 emissions. In Morocco, the short-run Granger causality test suggests evidence of unidirectional causality running from real GDP and combustible renewables and waste to CO_2 emissions, whereas bidirectional causality between real GDP and combustible renewables and waste consumption have been supported in the long-run. A bidirectional short-run causality between real GDP and CO_2 emissions and unidirectional causality from CO_2 emissions to combustible renewables and waste consumption have been supported in the case of Sudan. However, in the long-run, there is evidence of bidirectional causal links between real GDP and CO_2 emissions. Short-run causalities are found to be unidirectional from combustible renewables and waste consumption and CO_2 emissions to real GDP in Tunisia. However, in the long-run, only the error correction term of combustible renewables and waste consumption is found to be significant indicating a unidirectional causality from real GDP and CO_2 emissions to combustible renewables and waste consumption. In summary, only in Egypt and Tunisia, the influence of combustible renewables and waste consumption and CO_2 emissions are both significant and may affect economic growth in the short-run. Besides, in Morocco and Sudan, both combustible renewables and waste consumption and CO_2 emissions significantly contribute to the expansion of real GDP in the long-run. Our short-run causalities results show that the consumption of renewable energy causes economic growth only in Tunisia and Egypt. This result indicates the positive correlation between renewable energy consumption and economic growth in both two countries.

5.4. Panel long-run estimates

After having established the existence of a cointegration relationship and the direction of causality between economic growth, combustible renewables and waste consumption and CO_2 emissions, we proceed to estimate the long-term structural coefficients using various methods of panel estimation which are more efficient than the OLS method. Pedroni (2001, 2004) proposed various techniques to estimate systems of cointegrated variables using the fully modified OLS (FMOLS). The dynamic OLS (DOLS) is another approach of panel estimation improved by Kao and Chiang (2000) and Mark and Sul (2003) of the case of panel data.

Table 9. Panel FMOLS and DOLS long-run estimates

Panel A: FMOLS estimates				
GDP = 7.639215	+	0.066973CRW	+	0.806827CO_2
(0.0000)***		(0.0000)***		(0.0107)**
Panel B: DOLS estimates				
GDP = 7.636211	+	0.067966CRW	+	0.806674CO_2
(0.0000)***		(0.0000)***		(0.0173)**

"***", "**" indicate statistical significance at the 1% and 5% level, respectively.

P-value listed in parentheses.

Table 9 reports the results of FMOLS and DOLS panel estimates of Eq. (1). All two coefficients are positive and statistically significant at mixed significance levels of the 1% and 5%. A 1% increase in combustible renewables and waste consumption per capita increases real GDP per capita by 0.06% and a 1% increase in CO_2 emissions per capita increases real GDP per capita by 0.80%. We conclude that the impact of emissions on economic growth is more important than the impact of combustible renewables and waste consumption on economic growth given that the emissions elasticity for the panel is greater than the combustible renewables and waste consumption elasticity.

Table 10. Individual FMOLS and DOLS long-run estimates

Variables	*CRW*				*CO2*			
Country	*FMOLS*		*DOLS*		*FMOLS*		*DOLS*	
Algeria	-0.087057	(0.5753)	0.010413	(0.9525)	2.417267	(0.0001)***	1.734822	(0.0015)***
Egypt	1.031602	(0.0009)***	0.874081	(0.0042)***	0.746348	(0.0000)***	0.755293	(0.0000)***
Morocco	-0.251147	(0.1110)	-0.130919	(0.3653)	0.799758	(0.0000)***	0.722453	(0.0000)***
Sudan	-1.509639	(0.0000)***	-1.521164	(0.0000)***	0.183939	(0.0579)*	0.133578	(0.1437)
Tunisia	0.886796	(0.0000)***	0.881928	(0.0000)***	0.580467	(0.0000)***	0.599744	(0.0000)***

Cointegrating equation deterministics: Constant

"*", indicates statistical significance at the 1% level.

"***", indicates statistical significance at the 10% level.

P-value listed in parentheses.

The individual FMOLS and DOLS long-run estimates results are presented in Table 10 and indicate that the coefficient of combustible renewables and waste consumption is positive and statistically significant in Egypt and Tunisia. The FMOLS and DOLS long-run elasticities suggest that, for Egypt, a 1% increase in the consumption of combustible renewables and waste consumption generates 1.03% and 0.87% increase in real GDP, respectively. The FMOLS and DOLS long-run elasticities suggest that, in Tunisia, a 1% increase in combustible renewables and waste consumption increases economic growth by 0.88%. However, from Sudan the coefficient on combustible renewables and waste consumption is negative and statistically significant at the 1% level. However, the FMOLS and DOLS long-run elasticities suggest that, for Sudan, a 1% increase in the consumption of combustible renewables and waste consumption decreases economic growth by 1.50% and 1.52%, respectively.

Turning to the effect of emissions on real GDP, we find that for all countries the impact of CO_2 emissions on real GDP is positive and statistically significant at the 1% level, except for Sudan, where real GDP are affected by emissions at the 10% significance level. The degree of the impact ranges from 2.41% in the case of Algeria to 0.18% in the case of Sudan. For Egypt, Morocco and Tunisia the degree of the impact on real GDP is relatively low.

As we mentioned previously in Fig (2)-(3) that in Algeria, the level of emission is high enough while the consumption of combustible renewables and waste consumption is very low and this finding has been proven empirically (Table 10). We notice that, according to the individual tests, we find that the estimated coefficient of CO_2 emissions for Algeria is the highest, while the estimated coefficient of combustible renewables and waste consumption is statistically not significant. We apply the same reasoning in the case of the Sudan. However, the estimated coefficient of CO_2 emissions is very low because the emission level is not large enough. It seems that only in Tunisia and Egypt that the consumption of renewable energy positively affects economic growth in the long term. This finding confirms the result of the individual Granger causality test on the unidirectional causal link from combustible renewables and waste to economic growth.

6. Conclusion

In this paper, we investigate the causal relationship between economic growth, combustible renewables and waste consumption, and CO_2 emissions for a balanced panel of five North Africa countries for the period 1971-2008. This empirical analysis is interesting because it aims to explore the role of combustible renewables and waste consumption and emissions on economic growth.

The main findings of this paper is that, for the panel of five North Africa countries, there is evidence of unidirectional causality running from CO_2 emissions to economic growth and from combustible renewables and waste to economic growth, in both the short and long--run. It means that CO_2 emissions Granger cause real GDP and combustible renewables and waste Granger cause real GDP. Thus, in this region, changes in emissions may affect economic growth in the short and the long-run relationship. Also, energy conservation can influence economic activities of the region in the short and long-run. Our finding improves that the emissions are the great generator of economic growth for each country given that the use of renewable energy is not high enough. Besides, there is a unidirectional causal link from combustible consumption and CO_2 emissions in the short-term. However, there is no long-run relationship between renewable energy and emissions. This result may be explained by the fact that the share of renewable energy used is very weak with respect to the total energy use. The managers and policy makers of the North Africa region have to invest more in green technologies that use renewable resources for production and decrease the share of fossil fuels energy to protect the environment from damage caused by pollution.

The results of panel FMOLS and DOLS estimates show that all coefficients are positive and statistically significant. However, for the panel as a whole, any increase in the consumption of the combustible renewables and waste or CO_2 emissions increases the economic growth. Our recommendation is that North Africa countries have to use more renewable energy for production and a policy of substitutability of non-renewable energy by renewable is necessary not only to avoid the disaster on atmosphere but also to stimulate economic growth in the long-run.

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