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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 a unidirectional causality running from real GDP per capita to per capita CO_2 emissions. However, there is evidence of no causality between combustible renewables and waste consumption and real GDP and 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 to real GDP. The results from panel FMOLS and DOLS estimates show that 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 combustible renewables and waste as a substitutable energy to the fossil one and avoid the disaster on atmosphere by reducing emissions without impeding 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 gases, it is necessary to find a substitutable energy to the fossil one such combustible renewables and waste energy.

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Given that the economic literature has not yet addressed the causal relationship between economic growth, emissions and combustible renewables and waste consumption, since there is no processing of empirical studies based on these sources of energy as that energy used for production. 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 emissions.

The relationship between economic growth, 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. Sadorsky, 2009; Apergis et al., 2010; Menyah and Wolde-Rufael, 2010). An empirical model of renewable energy consumption for the G7 countries has been presented and estimated by Sadorsky (2009). 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. 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. 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.

Our paper is similar to the previous econometric studies. It negotiates the causal relationship 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.

In the light of the discussion above, the rest of the study is organized as follows: Section 2 describes the data. Section 3 designates for descriptive statistics. Section 4 presents the empirical methodology and results. Section 5 concludes.

2. 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)[2], and CO_2 emissions per capita (CO_2). All of the data are converted to the natural logarithms prior to conducting the empirical analysis.

2 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.

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

3. 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. Summary statistics

Variables	Mean	Median	Maximum	Minimum	Cross sections
GDP	6.941501	7.097001	8.510485	5.466224	5
CRW	-10.60036	-10.86715	-7.596791	-14.34130	5
CO2	0.031929	0.268718	1.283316	-2.286163	5

Source: Authors (EViews.7 software). All variables are in natural logarithms.

Fig 1. Natural log of real GDP per capita (constant 2000 US$) from 1971 to 2008

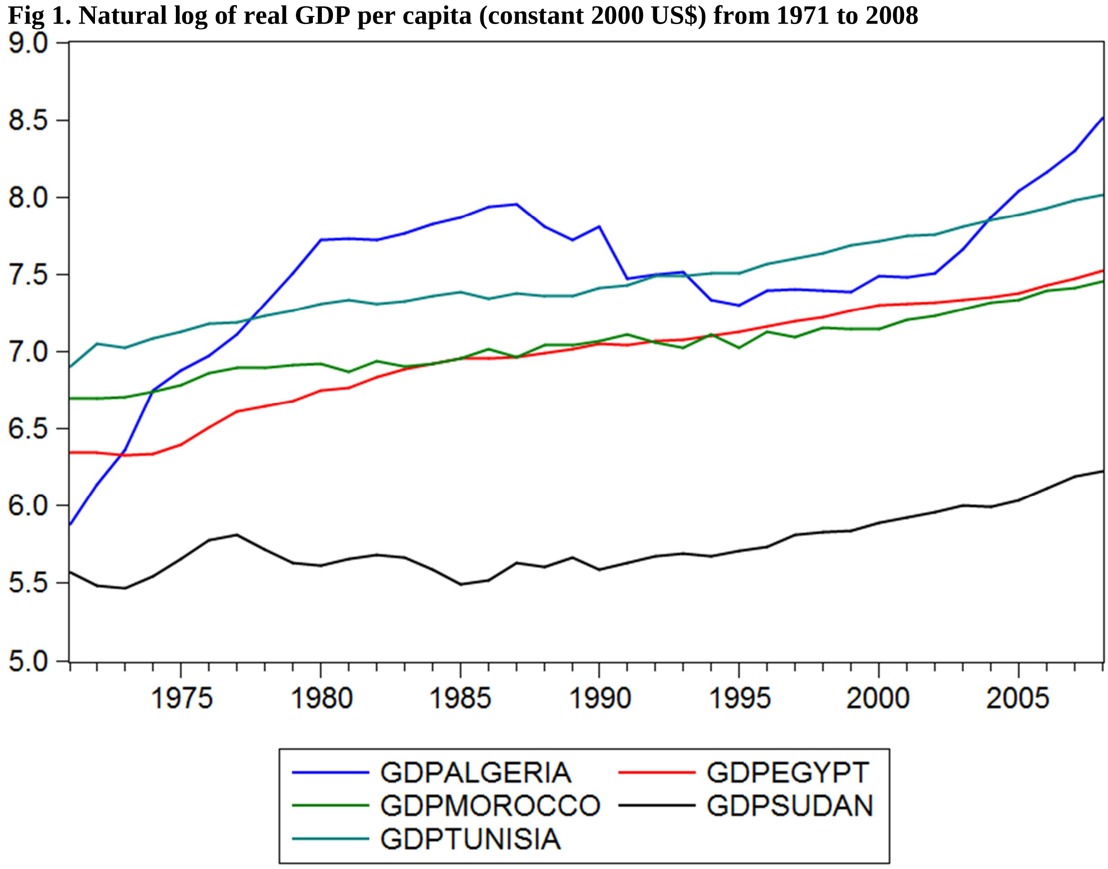

Fig.1 shows the variation of natural logarithms of real GDP per capita (measured in constant 2000 US$) between countries over the period 1971-2008. For each of the countries studied, GDP per capita increases across time while the increase varies with different degree between countries.

Fig 2. Natural log of combustible renewables and waste consumption per capita (metric tons of oil equivalent) from 1971 to 2008

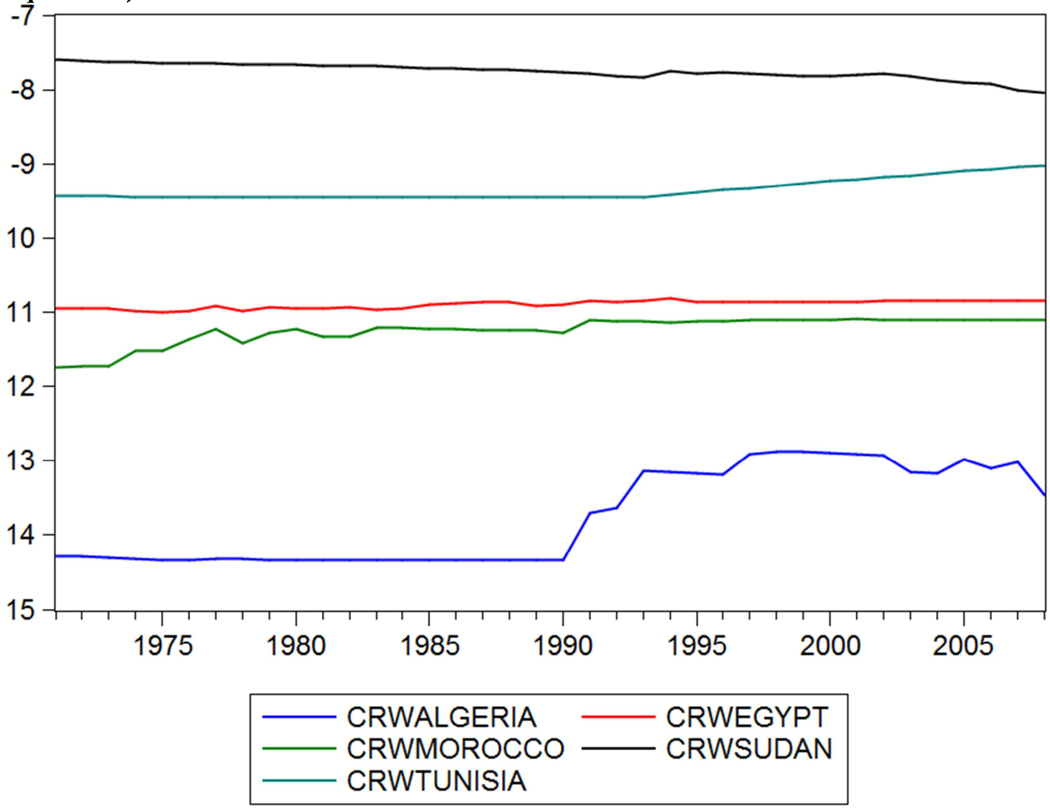

Fig. 2 shows the variation of natural logarithms of CRW per capita (measured in metric tons of oil equivalent) between countries and indicates that practically the per capita consumption of the CRW energy is stable cross time. Sudan is the largest consumer of CRW energy while Algeria is the smallest.

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

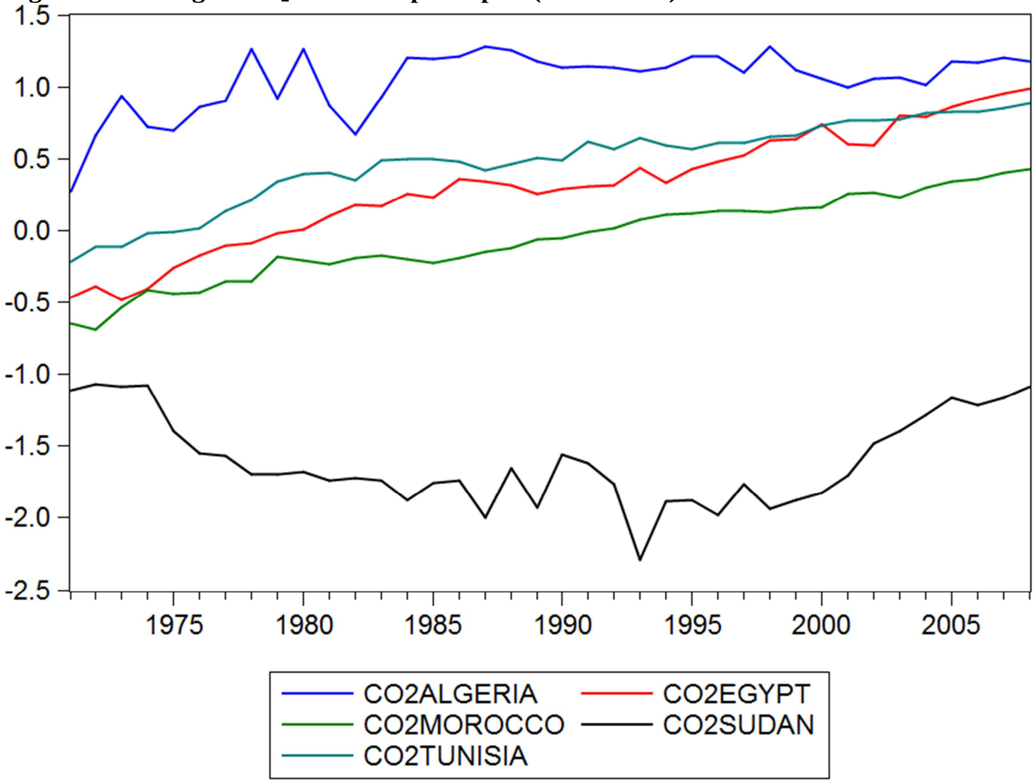

Fig.3 shows the variation of natural logarithms of CO_2 emissions per capita (measured in metric tons per capita) between countries. The biggest polluting country is Algeria and Sudan is the smallest.

4. 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):

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

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

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).

4.1. 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 two types of panel unit root tests. The first unit root test is proposed by Breitung (2000) which is characterized by its great power and usually has smallest size distortions. The second test is suggested by Im et al., 2003 that take 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:

$$\Delta y_{it} = \theta_i + \rho_i y_{i,t-1} + \sum_{j=1}^{p} \lambda_{ij} \Delta y_{i,t-j} + \mu_{it} \quad (3)$$

Where $i = 1, \ldots, N$ and $t = 1, \ldots, T$.

Im, Pesaran and Shin (IPS, 2003) test is based on the Augmented Dickey-fuller (ADF) statistics averaged across groups. After estimation the Eq.(3) we recover the average of t_{ρ_i} to perform the following statistic:

$$\frac{(\bar{t}_{NT} - \tau)\sqrt{N}}{\sigma} \to N(0,1) \quad (4)$$

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:

$H_0 : \rho_i = 0 \forall i$

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

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

For these two 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 these tests are reported in Table 2 which indicates 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, CRW energy 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)).

Table 2. Panel unit root tests

Method		**GDP**	**CRW**	**CO_2**
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)

Automatic lag selection based on Schwarz Information Criteria (SIC)

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

4.2. 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 results from the Pedroni (2004) test are reported in Table 3 and indicate that one within-dimension test and two between-dimension tests providing the presence of cointegration.

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

	Statistic	**Prob.**
Alternative hypothesis: common AR coefs. (within-dimension)		
Panel υ-stat	3.519518	0.0002*
Panel r-stat	0.122113	0.5486
Panel PP-stat	-0.882828	0.1887
Panel ADF-stat	-0.802092	0.2112
Alternative hypothesis: individual AR coefs. (between-dimension)		
Group r-stat	-0.676989	0.2492
Group PP-stat	-2.592520	0.0048*
Group ADF-stat	-1.806098	0.0355**

Null hypothesis: No cointegration

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

Trend assumption: Deterministic intercept and 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 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, CRW energy 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 5% 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	34.19[a]	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.

4.3. 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 cointegration between variables indicates 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, *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).

Table 6. Pairwise Granger causality test results

Null Hypothesis:	F-Statistic	Prob.
CRW *does not Granger Cause* GDP	1.76840	0.1735
GDP *does not Granger Cause* CRW	0.00882	0.9912
CO_2 *does not Granger Cause* GDP	3.83755	0.0233**
GDP *does not Granger Cause* CO_2	0.37463	0.6881
CO_2 *does not Granger Cause* CRW	0.15228	0.8589
CRW *does not Granger Cause* CO_2	1.42380	0.2435

Null hypothesis: No causality

Lag selection: 2

"**", indicates statistical significance at the 5% level.

Table 6 reports the results of the Pairwise Granger causality test results and indicates that there is evidence of short-run relationship running from CO_2 emissions to economic growth. However, there is no evidence of Granger causality between CRW consumption and economic growth or between CRW consumption and CO_2 emissions in the short-run. It means that economic growth will be influenced by the emissions of CO_2.These results show that any changes in emissions may changes economic growth but the increase of CRW consumption may not increase economic growth.

Table 7. Long-run causality test results

Dependent variable	ECT

ΔGDP	-0.242696	[-3.18216]*
ΔCRW	-0.000121	[-0.06198]
ΔCO_2	0.015576	[0.25613]

"*", 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 economic growth is significant given that the corresponding error correction term is negative statistically significant at the 1% level. It means that there is a long-run relationship running from CRW consumption and CO2 emissions to economic growth. This result implies that GRW energy consumption and emissions may affect economic growth in the long-run equilibrium.

4.4. Panel long-run estimates

After having established the existence of a cointegration relationship and the direction of causality between economic growth, CRW energy 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 (2001) and Mark and Sul (2003) of the case of panel data.

Table 8. Panel FMOLS and DOLS long-run estimates

Panel A: FMOLS estimates				
GDP = 7.639215	+	0.066973CRW	+	0.806827CO2
(0.0000)*		(0.0000)*		(0.0107)**
Adjusted R-squared = 0.854615 DW= 0.288784				
Panel B: DOLS estimates				
GDP = 7.636211	+	0.067966CRW	+	0.806674CO2
(0.0000)*		(0.0000)*		(0.0173)**
Adjusted R-squared = 0.856675 DW= 0.290481				

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

P-value listed in parentheses.

Table 8 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 CRW 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 CRW consumption on economic growth given that the emissions elasticity for the panel is greater than the CRW consumption elasticity.

Table 9. 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 9 and indicate that the coefficient of CRW 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 CRW 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 CRW consumption increases economic growth by 0.88%. However, from Sudan the coefficient on CRW 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 CRW 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 CRW is very low and this finding has been proven empirically (Table 9). We notice that, according to the individual tests, we find that the estimated coefficient of CO2 emissions for Algeria is the highest, while the estimated coefficient of CRW consumption is statistically not significant. We apply the same reasoning in the case of the Sudan. However, the estimated coefficient of CO2 emissions is very low because the emission level is not large enough.

5. Conclusion

In this paper, we investigate the causal relationship between economic growth, CRW 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 there is no previous study that worked on the causal link between these variables.

The main findings of this paper is that for the panel of five North Africa countries there is evidence of unidirectional causality running from real GDP to CO_2 emissions in the short-run. It means that CO_2 emissions Granger cause real GDP and changes in emissions may affect economic growth in the short-run relationship. This result improves that the emissions is the great generator of economic growth for each country given that the use of CRW energy is not higher enough. However, in the short-run, there is no causality between CRW consumption and economic growth, and between CRW consumption and CO_2 emissions. In the long-run, we find that only the error correction term corresponding to the real GDP equation is negative and statistically significant. It means that there is evidence of long-run relationship running from CRW consumption and emissions to economic growth.

The results of panel FMOLS and DOLS tests show that all coefficients are positive and statistically significant. However, for the panel as a whole, any increase in the consumption of the CRW or emissions increases the economic growth. The finding of this paper is that North Africa region can use combustible renewables and waste as a substitutable energy to the fossil one and avoid the disaster on atmosphere by reducing emissions without impeding economic growth in the long-run.

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