Economic growth, combustible renewables and waste consumption and emissions in North Africa

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Economic Growth, Combustible Renewables and Waste Consumption, and CO_2 Emissions in North Africa

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Abstract: This paper uses panel cointegration techniques and Granger causality tests to examine the dynamic causal link between per capita real gross domestic product (GDP), combustible renewables and waste (CRW) consumption, and CO_2 emissions for a panel of five North Africa countries during the period 1971-2008. Granger causality tests results suggest short and long-run unidirectional causalities running from CO_2 emissions and CRW consumption to real GDP, and a short-run unidirectional causality running from CRW to CO_2 emissions. The results from panel long-run fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) estimates show that CO_2 emissions and CRW consumption have a positive and statistically significant impact on GDP. Our policy recommendations are that these countries should use more CRW because this increases their output, reduces their energy dependency on fossil energy and may decrease their CO_2 emissions.

Keywords: Combustible renewables and waste consumption; output; CO_2 emissions; panel cointegration; North Africa.

JEL Classification: C33; Q42; Q43

1. Introduction

Due to economic and population growth, the demand of energy attends an important growth rate. Several studies confirm that carbon dioxide (CO_2) emissions are increasing rapidly due to the important increase and inefficient use of fossil energy (coal, petroleum and natural gas). To face the international decreasing reserves in fossil energy and to avoid major damages caused by CO_2 emissions, it is necessary to use these energies more efficiently and to encourage the use of substitutable energies such as renewable energies.

The use of renewable energy is increasing rapidly mainly because of environmental and political concerns. It is expected that renewable energies play an important role in expanding economic activities and in improving the environment's quality. According to the International Energy Agency (IEA, http://www.energy.kth.se/compedu/webcompedu/Glossary/C/Combustible_Renewable_and_Waste.htm), combustible renewables and waste comprise solid biomass which covers organic, non-fossil material of biological origin which may be used as fuel for heat production or electricity generation. Wood, Wood Waste and other solid waste covers purpose-grown energy crops, a multitude of woody materials generated by an industrial process (paper industry in particular) or provided directly by forestry and agriculture as well as wastes such as straw, rice husks, nut shells, poultry litter, crushed grape dregs etc. Charcoal covers the solid residue of the destructive distillation and pyrolysis of wood and other vegetal material. Biogas comprises gases composed principally of methane and carbon dioxide produced by anaerobic digestion of biomass and combusted to produce heat and/or power). Liquid biofuels includes bio-based liquid fuel from biomass transformation, mainly used in transportation applications. Municipal waste comprises wastes produced by the residential, commercial and public services sectors and incinerated in specific installations to produce heat and/or power. Based on this definition, we can conclude that these alternative energies are not clean as new renewable energy sources such as solar, wind, geothermal, etc..., but it is proved that they pollute less than fossil energies.

According to a study conducted by the United Nations Economic Commission for Africa (UNECA, 2012), North Africa is facing an important increasing energy demand of the order of 6-8% per year and fossil fuels dominate the energy mix with a larger share for natural gas. Given the very high volatility of oil and gas prices, these countries are reviewing their energy policies by diversifying their energy mix and giving greater importance to renewable energies and energy efficiency. In addition, renewable energies have the advantage of offering the opportunity to serve isolated regions remote from the national electricity grid. The potential for energy efficiency and renewable energy is still largely under-exploited. For these countries, there is real energy efficiency potential as a 10% gain in the region's energy consumption could be made via improved energy efficiency measures by 2030. The contribution of renewable energies to the energy mix is still insufficient since it represented only 8% in 2006, the rest being composed of gas (67%), oil (19%) and coal (6%). Important reforms in the regulatory frameworks have been carried out in order to encourage greater participation by the private sector in renewable energy production. These countries have elaborated ambitious strategic objectives and launched large-scale integrated programs with the main objectives of reducing greenhouse gas (GHG) emissions, direct and indirect job creation, industrial development and the improvement of human capital. A number of current initiatives such as the Mediterranean Solar Plan (MSP) or the agreements existing between the European Union (EU) and some North Africa countries can improve technical and financial cooperation and expand regional markets for renewable energies.

2. Existing literature

It is worth interesting to discuss the dynamic causality between economic growth, CRW consumption and CO_2 emissions. The direction of causalities between these variables may leads to much motivating outcomes, and then may help economics and policy makers of CRW role in simulating economic activities. However, before analyzing this cause, we will proceed by the presentation of some literature review focused on this topic.

Many empirical studies debate the causal link between renewable energy consumption and economic growth (e.g. Apergis and Payne, 2010a, 2010b, 2011; Payne, 2011; Sadorsky, 2009b). The causality direction results vary depending on the country or the sample of countries selected, the time period considered, the empirical methodology used, and the variables included in the specified model. These studies are summarized in Table 1. Accordingly, the direction of causality between renewable energy consumption and economic growth follows four hypotheses: *i) the feedback hypothesis* argues that there is a bidirectional causal link between renewable energy consumption and economic growth. This means that renewable energy consumption Granger causes gross domestic product (GDP) and vice versa; *ii) the neutrality hypothesis* suggests that no causal relationship exists between the two variables in any direction. In this case, any increase in the use of renewable energy will not affect GDP, and any variation in the growth of production will not affect the use of renewable energy; *iii) the growth hypothesis* suggests that renewable energy consumption plays a vital role in explaining economic growth. Thus, any policy encouraging the use of renewable energy will affect economic growth; *iv) the conservation hypothesis* stipulates the existence of a unidirectional causality running from economic growth to renewable energy consumption. This hypothesis means that any increase in economic growth has an impact on the consumption of renewable energy.

Al-Mulali et al. (2013) resume the findings of 81 studies interested in the causal relationship between energy consumption and output. They come to the conclusion that 45% of these studies find bidirectional causality, 10% find no causal relationship, 25% find a one way causal relationship running from energy consumption to output, and 20% find a one way causal relationship running from output to energy consumption. Al-Mulali et al. (2014) explore the effect of renewable and non-renewable electricity consumption on economic growth for 18 Latin American countries. The results of the study reveal the existence of long-run bidirectional causality between economic growth, renewable and non-renewable electricity consumption, capital, labor and trade. They also show that renewable electricity consumption is more significant than non-renewable electricity consumption in promoting economic growth in both the short and long-run for this panel of countries. Using panel cointegration techniques, Apergis and Payne (2010a) examine the causal relationships between renewable energy consumption, GDP, capital and labor force for a panel of twenty OECD countries. The results from Granger causality tests reveal the existence of short and long-run bidirectional causalities between renewable energy consumption and economic growth. Apergis and Payne (2010b) conduct the same study for a panel of 13 Eurasia countries and find similar results. Sadorsky (2009b) uses a cointegration model for a panel of 18 emerging economies and shows a long-run unidirectional causality running from GDP to renewable energy consumption. Moreover, long-run estimates show that the increase in GDP has a positive impact on renewable energy consumption. Ben Aïssa et al. (2014) use cointegration techniques for a panel composed by 11 African countries. The results from panel error correction model reveal the existence of bidirectional causality between economic growth and trade (exports or imports) in both the short and long-run, and there is a long-run unidirectional causality running from renewable energy consumption to economic growth. Ocal and Aslan (2013) examine the causal relationship between renewable energy consumption and economic growth in Turkey. Their empirical results show that renewable energy consumption has a negative impact on economic growth, and there is a unidirectional causality running from economic growth to renewable energy consumption.

Insert Table 1 here

Since one of the most interesting effects of renewable energy is its impact on CO_2 emissions, studying the dynamic causal relationship between economic growth, CO_2 emissions, and renewable energy consumption is of great interest. We summarize some studies on this subject in Table 2. Apergis et al. (2010) examine the causal relationship between emissions, nuclear energy, renewable energy and economic growth for a group of 19 developed and developing countries. The results from the long-run estimates indicate that nuclear energy has a negative impact on emissions but renewable energy has a positive impact on emissions. They also show the existence of short and long-run bidirectional causalities between output, emissions and renewable energy consumption. Apergis and Payne (2014) examine the determinants of per capita renewable energy consumption for a panel of 7 Central America countries and find a long-run cointegration between per capita renewable energy consumption, output, carbon emissions, real coal prices, and real oil prices. Ben Jebli et al. (2014) examine the dynamic causal link between per capita CO_2 emissions, economic growth, renewable energy consumption and trade for a panel of 24 Sub-Saharan Africa countries. They find short-run bidirectional causality between emissions and economic growth, and long-run bidirectional causality between renewable energy and emissions. Long-run estimates don't support the environmental Kuznets curve (EKC) hypothesis. Farhani and Shahbaz (2014) investigate the causal relationship between renewable and non-renewable electricity consumption, output and CO_2 emissions for a panel of 10 Middle East and North Africa countries. Their long-run estimates show that renewable and non-renewable electricity consumption increase CO_2 emissions, and the EKC hypothesis is verified. Moreover, they find a long-run bidirectional causality between renewable and non-renewable electricity consumption and CO_2 emissions.

Insert Table 2 here

To our knowledge, the economic literature has not yet addressed the causal relationship between economic growth, CRW consumption, and emissions of CO_2. This paper tries to investigate the short and long-run causal links between per capita real GDP, per capita CO_2 emissions, and per capita CRW consumption for a panel of five North Africa countries spanning the period 1971-2008. To do that, we use panel cointegration techniques, Granger causality tests, and powerful methods of long-run estimates which are the fully modified ordinary least squares (FMOLS) and the dynamic ordinary least squares (DOLS).

This study is organized as follows: Section 3 reports the used data, the empirical results and their discussions. Section 4 concludes with policy implications.

3. Data, empirical results and discussions

The data set is a balanced panel of five North Africa countries which are Algeria, Egypt, Morocco, Sudan,[1] and Tunisia studied for the period 1971-2008. The annual data are collected from the World Bank (2011) Development Indicators online database and include real GDP per capita, combustible renewables and waste consumption per capita, CO_2 emissions per capita, and population number. The CRW variable used in this analysis includes solid biomass, liquid biomass, biogas, industrial waste, and municipal waste. Real GDP per capita is measured in constant 2000 US dollars. CO_2 emissions per capita are measured in metric tons. Combustible renewables and waste is measured in metric tons of oil equivalent per capita after the division by the population number to obtain the per capita unit. The dimension of the panel data set is selected to include as many countries of the North Africa region as possible. All the data are converted to the natural logarithm prior to conducting the empirical analysis. Computations are made using Eviews 7.0 software.

We consider the following linear equation which explores the long-run causality relationship between per capita real GDP, CRW, and CO_2 emissions:

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

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

where $i = 1,...,5$ denotes the country and $t = 1971,...,2008$ denotes the time period; ε_{it} indicates the estimated residuals which characterize deviations from the long-run relationship; α_i denotes the country's specific fixed effect, and ECT_{it} is the error correction term derived from the long-run cointegration relationship of Eq. (1).

3.1. Descriptive statistics

Table 3 reports some descriptive statistics (Mean, Median, Maximum, and Minimum) of each variable used for the empirical study. All these statistics are calculated before logarithmic transformation.

Insert Table 3 here

Fig.1 shows the variations of real GDP per capita for each country over the period 1971-2008. It is illustrated that there is an increase of real GDP per capita for all countries, and this growth differ from one country to another. For all the considered years, Sudan has the smallest per capita GDP, and Algeria has the biggest per capita GDP in 2008.

Insert Fig. 1 here

Fig. 2 shows the variations of per capita CRW for each country over the period 1971-2008 and indicates that the per capita CRW consumptions have not changed significantly across time. Sudan has the highest level of per capita CRW consumption during the considered period, while Algeria has the lowest level of per capita CRW consumption.

Insert Fig. 2 here

Fig.3 shows the evolution of CO_2 emissions per capita for each country during the period 1971-2008. During the considered period, per capita CO_2 emissions have increased significantly for all countries, excepted for Sudan. Over all the considered period, Algeria has the highest level of per capita CO_2 emissions, whereas Sudan has the lowest level.

Insert Fig. 3 here

3.2. Stationary tests

Our empirical analysis starts by testing the stationary proprieties of variables by using three panel unit root tests. The two tests suggested by Levin et al. (2002) (LLC test) and Breitung (2000) assume that there is a common unit root process across the cross-sections. The null hypothesis of these tests suggests that there is a unit root, while the alternative hypothesis argues that the series are stationary. For the Im et al. (2003) test (IPS test), the null hypothesis is that there is a unit root, while the alternative hypothesis is that there is no unit root. This test assumes individual unit root across the cross-sections.

The results of the LLC, Breitung and IPS tests are reported in Table 4. They indicate that all variables are not stationary at level, whereas, after first difference, all of them are stationary at the 1% significance level.

Insert Table 4 here

3.3. Cointegration tests

We check for long-run association between variables using three kinds of panel cointegration tests developed by 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 set is 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 set is based on three statistics and includes rho-statistic, PP-statistic, and ADF statistic. These tests are classified on the between-dimension and are based on the individual autoregressive coefficients for each country in the panel. In total, Pedroni (2004) suggests seven statistics for the cointegration tests which are based on the residual of Eq. (2). The null hypothesis assumes that there is no cointegration, while the alternative hypothesis assumes that there is cointegration between variables when real GDP is the dependent variable. The existence of a long-run relationship between variables has been tested in the case of intercept and intercept and trend. The results from these seven tests are reported in Table 5. In the case of intercept, the results show that all the weighted statistics of the within-dimension are statistically significant, and all the between-dimension statistics are statistically significant. In the case of intercept and trend, the results from Pedroni cointegration tests reveal that, for the within dimension, one test among four and two tests for the weighted statistics are statistically significant. Also, two tests among three for the between-dimension reject the null hypothesis of no cointegration. Thus, according to this test, there is a long-run cointegration between variables.

Insert Table 5 here

The second panel cointegration test proposed by Kao (1999) is based on the ADF statistic. The result of this test is reported in Table 6 and indicates that we can reject the null hypothesis of no cointegration between variables at the 1% significance level.

Insert Table 6 here

Based on the Fisher statistic (trace test statistics), the result of the Johansen cointegration test is reported in Table 7 and indicates the existence of cointegration between variables at the 1% significance level.

Insert Table 7 here

3.4. Granger causality tests

The finding of cointegration between variables supposes a long-run relationship between them. Thus, we estimate an error correction model. Two stages are suggested by Engle and Granger (1987) in order to investigate the short and long-run relationships between the considered variables. The first stage recovers 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:

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

$$\Delta CRW_{i,t} = \theta_{2,i} + \sum_{j=1}^{q} \theta_{2,1,i,j}.\Delta GDP_{i,t-j} + \sum_{j=1}^{q} \theta_{2,2,i,j}.\Delta CRW_{i,t-j} + \sum_{j=1}^{q} \theta_{2,3,i,j}.\Delta CO_{2i,t-j} + \lambda_{2,i}.ECT_{i,t-1} + u_{2,i,t} \quad (4)$$

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

where Δ denotes the first difference of the considered variable; the lagged *ECT* is the error correction term derived from the long-run cointegration relationship of Eq. (1) and is defined by Eq. (2); q denotes the lag length determined automatically by the Schwarz information criterion (SIC); the result from the vector autoregressive (VAR) lag order selection shows that all criteria suggest a maximum number of lag equal to one (VAR (q=1)).[2]

Insert Table 8 here

The short-run Granger causality tests are reported in Table 8 and suggest the existence of: *i)* a unidirectional causality running from CRW consumption to real GDP statistically significant at the 10% level; *ii)* a unidirectional causality running from CO_2 emissions to real GDP statistically significant at the 1% level; and *iii)* a unidirectional causality running from CRW consumption to CO_2 emissions statistically significant at the 10% level.

Insert Table 9 here

The long-run causality test results are presented in Table 9 and reveal that only the equation of per capita real GDP is significant given that the corresponding error correction term is between -1 and 0 and is statistically significant at the 1% level. This means that there is a long-run unidirectional causality running from CRW consumption and CO_2 emissions to economic growth.

Insert Fig. 4 here

Fig.4 assembles short and long-run causalities between per capita real GDP, CRW consumption and CO_2 emissions for our panel of North Africa countries during the period 1971-2008. For this panel of countries, any changes in CO_2 emissions have an impact on economic growth in both the short and long-run. This may be explained by the fact that increases in CO_2 emissions are mainly due to increases in fossil energy consumption which is considered as a stimulus for economic growth. However, more economic growth seems to have no impact on emissions. Indeed, per capita GDP increase makes people more sensitive to the protection of the environment and incites to use fossil energy more efficiently and/or to use renewable energies. This result is consistent with the long-run finding of Ozturk and Acaravci (2010) and with the result of Salim and Rafiq (2012) concerning India. However, this result 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 a bidirectional causality between GDP and emissions.

We also deduce that any variation in CRW consumption has an impact on economic growth in both the short and long-run. This result supports the growth hypothesis. This is due to the fact that CRW is an energy which is an essential input for production. Economic growth has no impact on CRW consumption because an increase in per capita GDP makes people more sensitive to environmental protection and incites to use CRW more efficiently and/or to use clean renewable energies (e.g. solar, wind). Our finding is consistent with the long-run result of Ben Aïssa et al. (2014), and with that of Payne (2011). However, it differs from those of Apergis and Payne (2010a, 2010b, 2011, 2012) who report that the interdependence between renewable energy consumption and economic growth is bidirectional in both the short and long-run.

Short-run Granger causality tests suggest a unidirectional causality running from CRW consumption to CO_2 emissions. This result indicates that an increase in the use of CRW affects CO_2 emissions in the short-run. This effect may be positive, i.e. increases emissions, because CRW are polluting energies and increasing their consumption may contribute to increase emissions. However, because of the substitutability that exists between CRW energy and fossil energy, and because the former are less polluting than the latter, an increase in CRW consumption may reduce fossil energy consumption and thus may reduce CO_2 emissions. An empirical estimate is necessary to get the overall effect of an increase in CRW consumption on emissions. Our result differs from that of Apergis et al. (2010) who find a bidirectional causality between renewable energy consumption and emissions in both the short and long-run.

3.5. Long-run estimates

The last step consists in estimating the long-run coefficients of Eq. (1) where the dependent variable is per capita GDP and independent variables are per capita CRW consumption and per capita CO_2 emissions. We will use the FMOLS and DOLS techniques proposed by Pedroni (2001, 2004) because they are more efficient than the traditional ordinary least squares (OLS) technique. Since our variables are measured in natural logarithm, the estimated coefficients can be interpreted as long-run elasticities.

Insert Table 10 here

Table 10 reports the results of FMOLS and DOLS panel estimates of Eq. (1). The two techniques used give very close results. The estimated coefficients are positive and statistically significant at mixed significance levels of 1% and 5%. A 1% increase in per capita CRW consumption increases per capita real GDP by 0.07%. A 1% increase in per capita CO_2 emissions increases per capita real GDP by 0.81%. It appears that the long-run impact of CRW consumption on output is very small, whereas the impact of emissions is very important. This can be explained by the fact that CRW represent a small fraction of the total energy used for production in the panel of considered countries. Indeed, in 2008 the proportion of CRW with respect to the total energy used was (World Bank, 2011): Algeria (0.2%), Egypt (2.1%), Sudan (71%), Tunisia (13.2%), Morocco (3.2%). However, fossil fuels represent an important proportion of the total energy used for production, implying that CO_2 emissions have an important long-run effect on economic growth.

4. Conclusion and policy implications

In this paper, we investigate the causal relationship between per capita economic growth, combustible renewables and waste consumption, and CO_2 emissions for a balanced panel of five North Africa countries over the period 1971-2008.

Granger causality tests show the existence of short and long-run unidirectional causalities running from per capita CO_2 emissions and from per capita CRW consumption to per capita real GDP. There is also a short-run unidirectional causality running from per capita CRW consumption to per capita CO_2 emissions. Our FMOLS and DOLS long-run estimates establish that CO_2 emissions and CRW consumption have a positive impact on economic growth.

For this panel of countries, a policy focalized only on reducing fossil energy consumption to combat GHG emissions is a wrong policy because this will reduce output. However, encouraging the use of combustible renewables and waste has at least three advantages for these countries. First, and as shown by our long-run estimates, this increases economic growth. Second, and because CRW pollute less than fossil energy while being substitutable, this may reduce fossil energy consumption and thus may reduce CO_2 emissions. Third, this reduces their energy dependency on fossil energy. Therefore, these North Africa countries should reinforce their strategic plans in order to exploit more combustible renewables and waste and to use more efficiently fossil energy because this protects from global warming and stimulates economic growth.

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Figures

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

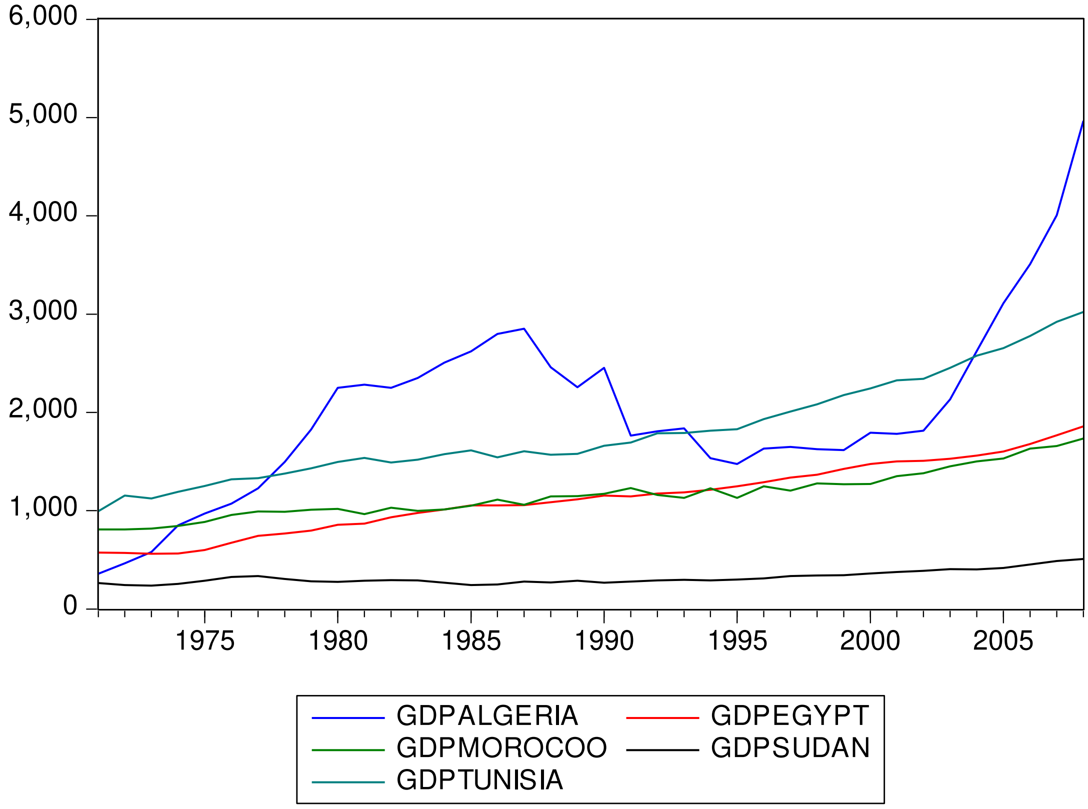


Fig. 2. Combustible renewables and waste consumption per capita (in metric tons of oil equivalent) from 1971 to 2008

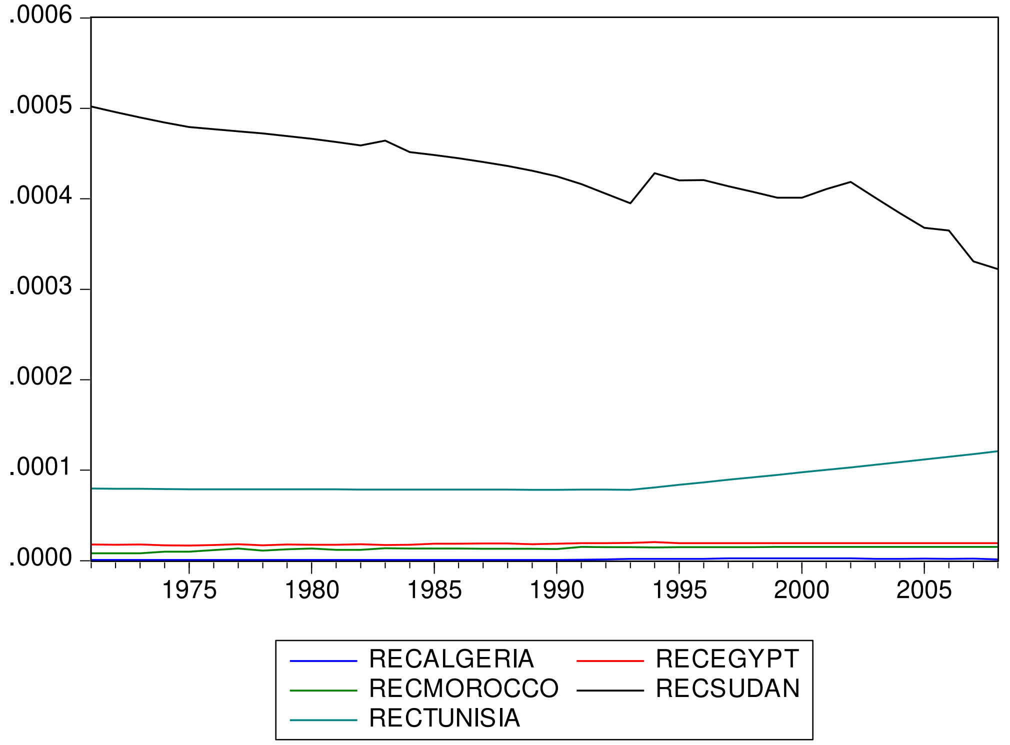


Fig. 3. CO_2 emissions per capita (in metric tons) from 1971 to 2008

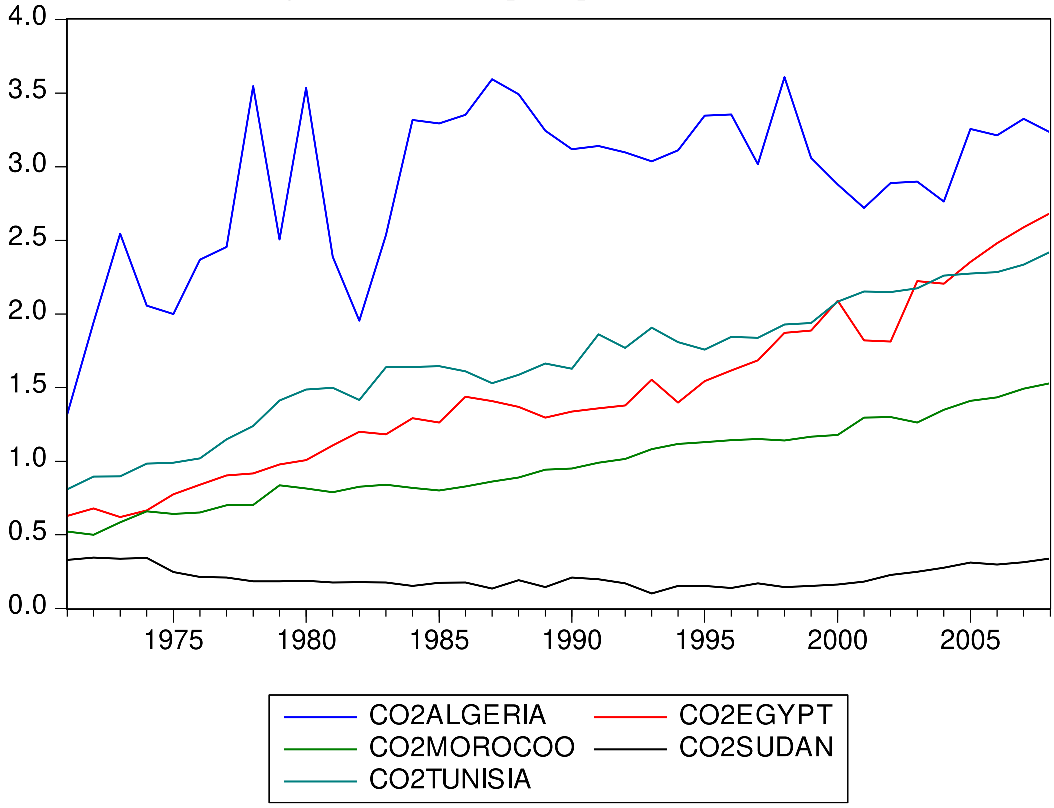
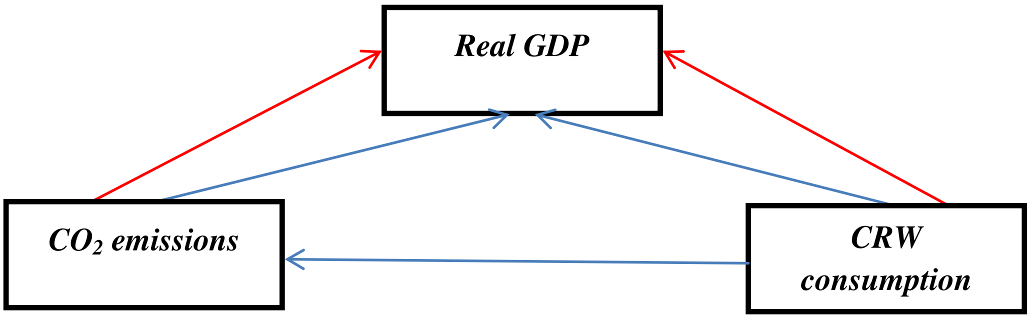


Fig. 4. Short (in blue) and long-run (in red) causality between real GDP, combustible renewables and waste consumption and CO_2 emissions



Tables

Table 1. Economic growth and renewable energy nexus

Author (s)	Direction of causality	Methodology	Hypothesis
Al-Mulali et al. (2014)	GDP↔RE	Panel cointegration	Feedback
Apergis and Payne (2010a)	GDP↔RE	Panel cointegration	Feedback
Apergis and Payne (2010b)	GDP↔RE	Panel cointegration	Feedback
Apergis and Payne (2011)	GDP↔RE	Panel cointegration	Feedback
Apergis and Payne (2012)	GDP↔RE	Panel cointegration	Feedback
Ben Aïssa et al. (2014)	GDP←RE	Panel cointegration	Growth
Menekagi (2011)	GDP≠RE	Panel cointegration	Neutrality
Payne (2011)	GDP←RE	Toda-Yamamoto causality test	Growth
Ocal and Aslan (2013)	GDP→RE	ARDL and Toda-Yamamoto causality test	Conservation
Sadorsky (2009b)	GDP→RE	Panel cointegration	Concervation
Salim and Rafiq (2012)	GDP↔RE	Panel cointegration	Feedback
Tugcu et al. (2012)	GDP↔RE	ARDL approach	Feedback

GDP and RE denote gross domestic product and renewable energy consumption, respectively. ↔ indicates short and long-run bidirectional causal links, → and ← indicate short and long-run unidirectional causal link from GDP to RE or from RE to GDP, respectively. ≠ indicates no causal link between GDP and RE.

Table 2. CO_2 and renewable energy consumption nexus

Author	Sample	Methodology	Causality and long-run estimates
Apergis et al. (2010)	19 developed and developing countries	Panel cointegration and Granger causality	Short and long-run bidirectional causalities between RE and CO_2. RE affects positively CO_2 emissions.
Apergis and Payne (2014)			
Ben Jebli and Ben Youssef (2013)	Tunisia	ARDL approach and Granger causality	Short-run causality from CO_2 to RE. RE affects negatively CO_2.
Ben Jebli et al. (2013)	xOECD countries	Panel cointegration	No short-run causality between RE and CO_2 . RE contributes to the decrease of CO_2.
Ben Jebli et al. (2014)	24 Sub-Saharan Africa countries	Panel cointegration	Short-run bidirectional causality between GDP and CO_2. Long-run bidirectional causality between RE and CO_2. EKC not verified.
Farhani and Shahbaz (2014)	10 MENA countries	Panel cointegration	Long-run bidirectional causality between RE and CO_2. RE consumption increases CO_2.
Menyah and Wolde-Rufael (2010)	United States	Panel cointegration and modified Granger causality	No causality running from RE to CO_2 emissions.

Sadorsky (2009a)	G7 countries	Panel cointegration	CO_2 contributes to the increase of RE.
Shafiei and Salim (2014)	OECD countries	STIRPAT model	RE consumption decreases emissions.

Table 3. Descriptive statistics for analysis variables

Variables	Mean	Median	Maximum	Minimum	Cross sections
GDP	1287.273	1208.349	4966.572	236.5653	5
CRW	0.000110	1.91E-05	0.000502	5.91E-07	5
CO_2	1.446479	1.308321	3.608586	0.101656	5

Source: World Bank (2011). GDP per capita is measured in constant 2000 dollars, per capita CO2 is measured in metric tons, and per capita CRW is measured in metric tons of oil equivalent.

Table 4. 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.

Table 5. Pedroni residual cointegration tests results (GDP as dependent variable)

				Weighted	
	Alternative hypothesis: common AR coefs. (within-dimension)				
		Statistic	Prob.	Statistic	Prob.
	Panel v-Statistic	0.847558	0.1983	2.505796	0.0061***
	Panel rho-Statistic	-0.668786	0.2518	-1.970188	0.0244**
intercept	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.
	Panel v-Statistic	3.519518	0.0002***	2.405537	0.0081***
	Panel rho-Statistic	0.122113	0.5486	-0.897836	0.1846
intercept	Panel PP-Statistic	-0.882828	0.1887	-2.040118	0.0207**
and	Panel ADF-Statistic	-0.802092	0.2112	-1.197301	0.1156

trend	*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 assumptions: 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.

Table 6. Kao residual cointegration test (GDP as dependent variable)

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

Null hypothesis: No cointegration.

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

Table 7. 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): 11

"a" indicates statistical significance at 1% level.

* Probabilities are computed using asymptotic Chi-square distribution.

Table 8. Panel pairwise Granger causality test results

Null Hypothesis:	Fisher stat	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% levels, respectively.

Table 9. 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 islisted in brackets.

Table 10. 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)**

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

P-value listed in parentheses.

* Corresponding author.

[1] This study concerns both Sudan and South Sudan because of lack of data concerning each country taken separately.

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