Does Renewable Energy Consumption and Health Expenditure Decrease Carbon Dioxide Emissions? Evidence for sub-Saharan Africa Countries

Apergis, Nicholas and Ben Jebli, Mehdi

1 August 2015

Does Renewable Energy Consumption and Health Expenditure Decrease Carbon Dioxide Emissions? Evidence for sub-Saharan Africa Countries

Nicholas Apergis

University of Piraeus, Piraeus, Greece

napergis@unipi.gr

Mehdi Ben Jebli

University of Jendouba, FSJEG de Jendouba, Tunisia

benjebli.mehdi@gmail.com

Does Renewable Energy Consumption and Health Expenditure Decrease Carbon Dioxide Emissions? Evidence for sub-Saharan Africa Countries

Abstract

This paper employs a number of panel methodological approaches to explore the link between per capita carbon dioxide emissions, per capita real income, renewable energy consumption and health expenditures for a panel of 42 sub-Saharan African countries, spanning the period 1995-2011. The empirical findings provide supportive of a long-run relationship among the variables. Granger causality reveals the presence of a short-run unidirectional causality running from real GDP to CO_2 emissions, a bidirectional causality between renewable energy consumption and CO_2 emissions, a unidirectional causality running from real GDP to renewable energy consumption, and a unidirectional causality running from real GDP to heath expenditure, while long-run estimates document that both renewable energy consumption and health expenditures contribute to the reduction of carbon emissions, while real GDP leads to the increase of emissions in these countries. The results are expected to be of high importance for policymakers in the region. Both renewable energy consumption and expansionary health expenditures are the major drivers of pollution declines. In that sense the findings imply that a substantial part of the state budget in relevance to health expenditures would be a good path to combat global warming in these countries.

Keywords: carbon emissions; renewable energy consumption; health expenditures; panel data; Sub-Saharan countries.

1. Introduction

The World Health Organization (WHO, 2015) argues that the International Energy Agency has recorded that 18% of global carbon dioxide (CO_2) emissions are attributed to energy and the fuel use by the residential sector. The expansion of greenhouse gases emissions caused by these substances will made a serious danger on the environmental situation and on human health. As a result, the adoption of other clean fuel technologies (renewables, such as biogas) or clean renewable technologies (renewable energy, such as solar, wind, and geothermal) can substantially reduce emissions of climate change pollutants by about 0.4-0.9 billion tons of CO_2 between 2010 and 2020.

It is quite important to display that renewable energy investments began to be progressively significant in the international markets. Numerous empirical studies have considered the vital role of renewable energy sources in the simulation of economic growth and in the reduction of the pollution degree in African countries. Empirically, Ben Jebli et al. (2016) examine the role that renewable energy consumption can play in the mitigation of emissions. The authors consider a panel of 24 sub-Saharan Africa countries and make use of panel cointegration methodologies in their analysis. They recommend that the benefits from technology transfers (i.e., trade exchanges) are a good path to increase their renewable energy sources and decrease carbon emissions level. Additionally, for a panel of 51 sub-Saharan Africa countries, Ozturk and Bilgili (2015) examine the long-run dynamics between GDP growth and biomass energy consumption. Their evidence shows a significant impact of biomass consumption on GDP growth.

Moreover, there is much consideration that health care facilities play an important role in the stability of climate changes. In fact, health care facilities have been estimated to represent between 3% and 8% of the climate change footprints in developed country (the US and the UK National Health Service, 2009). However, there are no health sector estimates on a national level across South-East Asian and sub-Sahara African countries. While no such health sector estimates exist elsewhere on a national level, both electricity access and hospital electricity consumption data in countries of South-East Asia and sub-Saharan Africa reflect far lower energy use rates (Energy Efficiency in Hospital, 2009). In addition, it has been estimated that between 200.000 and 400.000 hospitals and health clinics in developing countries have no electricity or have unreliable electric supplies (WHO, 2015).

The paper considers the dynamic causal links between carbon dioxide (CO_2) emissions, economic growth (i.e., real output), renewable energy consumption and health expenditures in the case of a panel framework. In this work, we consider another driver that may control the environmental situation. Thus, it is really interesting to think about the role of health expenditures in the mitigation of emissions when renewable energy is used for production. In other words, the expansion of health expenditures is significant if growth in renewable energy is strong enough. The installation of solar photovoltaic or wind mills could be a good idea to feed health facilities in electricity. Moreover, encouraging developing countries to adopt clean technologies turns out to be a good policy to stimulate higher health quality and decreased carbon emissions levels. In particular, this study will investigate the dynamic causal links between CO_2 emissions, real GDP, renewable energy consumption and health expenditure for a panel of sub-Saharan Africa countries, using panel methodological approaches. We chose a panel of sub-Saharan African countries because there is not any empirical study so far that explores this region. In addition, these countries are rich in renewable resources, while investment projects in renewable technologies are crucially needed for the development of their economies.

In this paper, we attempt to discuss the interaction that may exist between renewable energy consumption and health expenditures along with the impact on their environmental footprint in the case of sub-Saharan African countries. We firmly believe that there are no empirical studies that have considered the dynamic links between these variables in this area. In addition, policymakers are expected to gain from the empirical findings in this analysis, while they will push them to consider seriously the health conditions of their citizens through the increase in health spending and the integration of clean technologies in their production round. Therefore, these projects will allow the further stimulation of their production growth, advancing their health quality and eliminating pollution levels caused by carbon emissions.

Earlier empirical analysis discusses the bidirectional interdependence between renewable energy consumption and economic growth (e.g., Sadorsky, 2009; Apergis and Payne, 2010a, 2010b, 2011; among others) or between renewable energy consumption and CO_2 emissions (e.g., Apergis et al., 2010; Menyah and Rufael, 2010; Ben Jebli et al., 2015; Ben Jebli et al., 2016; Ben Jebli and Ben Youssef, 2015; among others). These previous empirical studies document that the presence of Granger causality as well as the direction of causality between output, renewable energy consumption and carbon emissions depends on the selected data, period under study and the methodologies used. Moreover, the strongest bidirectional causality between renewable energy and economic growth supports the feedback hypothesis either for the short or the long-run association among variables. Several other determinants (i.e., trade, tourism) of carbon emissions have been also taken into consideration in the recent literature, i.e. Ben Jebli and Ben Youssef (2015) and Ben Jebli et al. (2015) for the case of Tunisia. Trade is one of the decisive factors that influence the growth of pollution caused by those emissions. For a panel of OECD countries, Ben Jebli et al. (2015) illustrate that increasing trade or renewable energy reduces carbon emissions, while they recommend that more trade and more renewable energy consumption are efficient strategies to combat global warming in these countries. Other studies have considered that tourism may also have an impact on the degradation of environmental conditions. Ben Jebli et al. (2015) provide a model that investigates the dynamic causal links between CO_2 emissions, output, combustible renewable, waste consumption and international tourism in the case of Tunisia. Their results highlight that combustible renewable, waste consumption and international tourism all contribute to the increase of carbon emissions.

In the literature, there are no sufficient empirical studies that investigate the relationship between health expenditures and any other determinant, such as real output and carbon emissions). Jerret et al. (2003) explore the relation between healthcare expenditures and environmental factors in Canada (i.e., for 49 counties of Ontario) using a sequential two stage regression model to control for variables that may affect such expenditures. Their results document that both total toxic pollution output and per capita municipal environmental expenditures display significant relationships with health expenditures. In addition, the authors suggest that counties with higher pollution output levels demonstrate higher per capita health expenditures, while those that spend more on defending environmental quality levels demonstrate lower expenditures on health care.

The remaining of the paper is organized as follows. Section 2 describes the data set used and the empirical methodology employed. Section 3 presents the empirical results, while Section 4 provides a discussion of the findings obtained. Finally, Section 5 concludes the paper.

2. Data and empirical methodology

2.1. Data

Annual data are obtained from the Word Bank Development Indicators (WDI, 2015) online database for a panel of 42 sub-Saharan Africa countries[1], spanning the period 1995-2011. The variables used for the empirical study are per capita carbon dioxide emissions (*CO2*),

[1] The selected countries are: Angola – Benin - Botswana – Burkina Faso - Burundi - Capo Verde - Cameroon – Central Africa - Chad - Comoros – Congo Dem – Congo Rep – Ivory Cost – Equatorial Guinea - Eritrea - Ethiopia - Gabon - Gambia - Ghana - Guinea – Guinea-Bissau - Kenya - Madagascar - Malawi - Mali - Mauritania - Mauritius – Mozambique- Namibia - Niger - Nigeria - Rwanda - Seychelles – Senegal - Sierra Leonne – South Africa - Sudan - Swaziland - Tanzania - Togo - Uganda – Zambia.

measured in metric tons of oil equivalent, per capita real gross domestic product (*Y*), measured in constant 2005 prices, renewable energy consumption (*RE*), measured as a share of total final energy consumption, health expenditures (*HE*), measured as a share of total GDP. Depending on data availability, the empirical analysis includes the maximum number of observations.

2.2. Empirical methodology

The empirical analysis considers a model that examines the dynamic causalities between CO_2 emissions, real GDP, renewable energy consumption and health expenditures. Precisely, we have considered that health expenditures can have an important impact on the environmental situation. Thus, our empirical model is developed as follows:

$$CO_{2it} = f(Y_{it}, RE_{it}, HE_{it}) \tag{1}$$

The natural logarithmic transformation of Eq. (1) yields the following equation:

$$LNCO_{2it} = \alpha_i + \beta_i t + \delta_{1i} LNY_{it} + \delta_{2i} LNRE_{it} + \delta_{3i} LNHE_{it} + \varepsilon_{it} \tag{2}$$

where *LN* denotes logarithmic transformations, $i = 1,...,N$ for each country in the panel, $t = 1,...,T$ denotes the time period and ε denotes the stochastic error term. The parameter α_i allows for the possibility of country-specific fixed effects.

Before testing the integration order of the analysis time series, it is essential to proceeds through testing the degree of cross-sectional dependence (CD) through the statistic recommended by Pesaran (2004). The residual statistic test of Pesaran (2004) allows selecting which panel unit root tests can be chosen: either first-generation unit root tests (traditional panel unit root tests) or second-generation unit root tests. Traditional panel unit root tests of the first generation used on the present study are five: Breitung (2000), Levin et al. (2002), Im et al. (2003), Fisher Augmented Dickey and Fuller (ADF) (1979), and Phillips and Perron

(1988). The employment of second generation unit toot test by Pesaran (2007) is more suitable for testing the stationary proprieties of variables. The cross-sectional augmented IPS (CIPS) unit root test, developed by Pesaran (2007), supports the null hypothesis of a unit root, while the alternative hypothesis suggests that the variable is stationary. The Pesaran (2004)'s test is computed from the augmented Dickey-Fuller (1979) regression corresponding to each variable in the model. This statistic is measured as an average of all pair-wise correlation estimated coefficients. The null hypothesis of the CD test suggests that residual cross-section is independent, while the alternative hypothesis reveals that residual is dependent.

Next, to determine the integration order of the analysis variables is needed to examine the cointegration between them. If the variables are integrated of order one then we investigate the presence of a long-run association within a heterogeneous panel using Pedroni's (2004) panel cointegration approach. The null hypothesis is that there is no cointegration, while the alternative hypothesis is that variables are cointegrated. All the tests are running with individual intercept and deterministic trend. The deviation to the long-run relationship is determined by the residuals presented in equation (2).

If there is a long-run relationship between variable, then we estimate the long-run coefficients using both the fully modified OLS (FMOLS) approach proposed by Pedroni (2001, 2004) and the dynamic OLS (DOLS) methodological approach developed by Kao and Chiang (2000) and Mark and Sul (2003). Both of these methodologies are substantially effective, given that they take explicitly into account the endogeneity of regressors, while they correct for serial correlation.

The last step of the empirical analysis involves the testing of both the short- and long-run causalities between CO_2 emissions, real GDP, renewable energy consumption and health expenditures through the two steps procedure recommended by Engle and Granger (1987). The estimation of the dynamic vector error correction model (VECM) is given as follows:

$$
\begin{bmatrix} \Delta LNCO_{2it} \\ \Delta LNY_{it} \\ \Delta LNRE_{it} \\ \Delta LNH_{it} \end{bmatrix} = \begin{bmatrix} \chi_1 \\ \chi_2 \\ \chi_3 \\ \chi_4 \end{bmatrix} + \sum_{p-1}^{q} \begin{bmatrix} \theta_{11p} & \theta_{12p} & \theta_{13p} & \theta_{14p} \\ \theta_{21p} & \theta_{22p} & \theta_{23p} & \theta_{24p} \\ \theta_{31p} & \theta_{32p} & \theta_{33p} & \theta_{34p} \\ \theta_{41p} & \theta_{42p} & \theta_{43p} & \theta_{44p} \end{bmatrix} \tag{3}
$$

$$
\times \begin{bmatrix} \Delta LNCO_{2it-1} \\ \Delta LNY_{it-1} \\ \Delta LNRE_{it-1} \\ \Delta LNH_{it-1} \end{bmatrix} + \begin{bmatrix} \varphi_1 \\ \varphi_2 \\ \varphi_3 \\ \varphi_4 \end{bmatrix} ect_{it-1} + \begin{bmatrix} \mu_{1it} \\ \mu_{2it} \\ \mu_{3it} \\ \mu_{4it} \end{bmatrix}
$$

where Δ is the first difference operator; the autoregression lag length, q, is determined by the Schwarz Information Criterion (SIC); μ is a random error term; *ect* is the error correction term derived from the long-run relationship of equation (2). We consider the pairwise Granger causalities tests for the short-run relationships. These tests are established by the significance of the F-statistics. Moreover, the computed t-statistics of the lagged *ect* corresponding to each equation presented in the VECM are designed to examine the significance of the long-run relationships.

3. Empirical analysis

The results of the CD test are reported in Table 1 and indicate the rejection of the null hypothesis of no cross-section dependence in the panel.

[Insert Table 1 about here]

Thus, the traditional unit root tests (first-generation) provide bias of estimation. So, it is desirable to use the second generation unit root tests to check for the order of integration of each analysis variable. The panel unit root tests results of the first and the second generation are reported in Table 2. These findings indicate that all variables under investigation are integrated of order one.

[Insert Table 2 about here]

Next, the long-run cointegration properties are explored through Pedroni (2004)'s cointegration tests. Table 3 reports the results of the seven tests proposed by Pedroni (2004). They illustrate and confirm the presence of cointegration across the variables under study.

[Insert Table 3 about here]

In the following stage of the empirical analysis, The long-run elasticities are computed using both FMOLS and DOLS methodologies. The estimations include both an intercept and a deterministic trend. The results are reported in Table 4 and they document that all coefficients are statistically significant at the 1% level. According to these elasticity estimates, real GDP is positively associated with increased pollution levels caused by carbon emissions, while both renewable energy consumption and health expenditures contribute to lower levels of emissions in the long-run. In particular, the FMOLS long-run estimates highlight that a 1% increase in real GDP leads to increases in carbon emissions by 1.09%, while a 1% increase in both renewable energy consumption and health expenditures leads to lower carbon emissions by 0.29% and 0.21%, respectively. In terms of the DOLS methodological approach, the log-run estimates indicate that a 1% increase in carbon emissions leads to increases in real GDP by 1.05%, while a 1% increase in both renewable energy consumption and health expenditures leads to lower emissions by 0.32% and 0.17%, respectively.

[Insert Table 4 about here]

Next, the results of the causality tests for both the short- and the long-run relationships are reported in Table 5. According to the significance of the F-statistics of the pairwise Granger causality results, in the short-run, there is *i)* a unidirectional causality running from real GDP to carbon emissions; *ii)* a bidirectional causality between carbon emissions and renewable energy consumption; *iii)* a unidirectional causality running from real GDP to renewable energy consumption; and *v)* a unidirectional causality running from real GDP to health expenditures. In the long-run, the significance of the error correction terms in each equation records that the error correction terms in both the carbon emissions and health expenditures equations are statistically significant at the 1% level, indicating that there is a bidirectional long-run causality between carbon emissions and health expenditures.

[Insert Table 5 about here]

Finally to provide robust evidence to the above causality tests, we will attempt to identify the direction and sign of causality through the panel causality test developed by Canning and Pedroni (2008). The test makes use of the corresponding to panel cointegration error correction model. However, the test, as well as the algorithm associated with it, is valid only for bivariate modeling approaches. Therefore, we will explore the size of causality between: i) carbon emissions and heath expenditures, ii) real income and carbon emissions, iii) real income and renewable energy, iv) carbon emissions and renewable energy, and v) real income and health expenditures. The coefficients λ_1 and λ_2 correspond to the error correction equations (i.e., for the two variables each time in the model) and they show the speed of adjustment to equilibrium. In order to get the presence of the long-run relationship, causality implies that at least one of the λ coefficients must be different from zero. According to the test of Canning and Pedroni, the null hypothesis is that there is no panel causality. They report two tests in order to investigate the validity of the null hypothesis. First, they report the group mean (GM) test which yields:

$$\bar{\lambda}_1 = \sum_{i=1}^{N} \lambda_{1i} / N$$

with N being the number of countries in the panel. The test assesses the null hypothesis that variable X does not cause variable Y. The test statistic has a standard normal distribution. The second test they develop is the Lambda-Pearson (LP) panel test, which yields:

$$p_{\lambda} = -2 \sum_{i=1}^{N} \ln p\lambda_{2i}$$

where $\ln p\lambda_{2i}$ is the log of the p-value coming from the t-test statistic used to test the null hypothesis. This test combines p-values associated with each of the individual countries that make up the panel. The LP statistic follows a chi-square distribution with 2N degrees of freedom. For each country i if a causal connection exists, then the sign of the long run impact is equal to sign($-\lambda_1/\lambda_2$). The estimates for λ_{1i} and λ_{2i} are normally distributed, so the ratio will be Cauchy distributed. Canning and Pedroni (2008) develop a bootstrap test based on the median of these ratios. The sign on $-\lambda_1/\lambda_2$ is considered as a test of the impact of the long-run as well as a test of the sign of that long-run effect. Table 6 reports the long-run Granger causality tests and they document the following findings:

- In terms of panel long-run causality running from real income to carbon emissions, both GM and LP statistics recommend the rejection of the null hypothesis of no causality at the 1% significance level, while the reverse causality does not hold. In addition, the same holds for causality running from real income to renewable energy consumption, as well as for causality running from real income to health expenditures.
- In terms of panel long-run causality running from carbon emissions to renewable energy consumption, the results reveal the presence of bidirectional causality between these two variables.
- By contrast, in terms of panel long-run causality between carbon emissions and health expenditures, the findings document the absence of any causality between these two variables.
- In terms of the sign effect, based on the ratio of lambda coefficients reported in the last column, the evidence reveals a positive sign across all combinations under investigation.

Overall, the new causality tests, not only confirm the causality links obtained earlier, but also they reveal that the sign of causality remains consistently positive, indicating that: i) the growth paths followed by the Sub-Sahara African countries contribute to higher carbon emissions levels, ii) these growth paths lead to the adoption of higher levels of energy consumption coming from renewable sources, iii) higher growth rates can sustain higher expenses going to the healthcare sector, iv) the adoption of more renewable energy sources leads to lower carbon emissions levels, while v) it seems that there is no link between carbon emissions and health expenditures (probably to the inadequate resources spent on the health care sector).

[Insert Table 6 about here]

4. Discussion

In this section we discuss the results reached earlier in the empirical study. The dynamic causal linkages between carbon emissions, real GDP, renewable energy consumption and health expenditures have been investigated for sub-Saharan countries. The directions of causalities results are reported in a simple figure presentation (Figure 1). They point out that the presence of a unidirectional short-run causality running from real GDP to carbon emissions is consistent with those reached by Ben Jebli et al. (2015) in the case of Tunisia; Jalil and Mahmud (2009) in the case of China; and Ben Jebli and Ben Youssef (2015) in the case of Tunisia. These findings imply that any variation in the expansion of economic growth is expected to affect the environmental footprint in the region, which is consistent given that the majority of sub-Saharan African countries have not yet reached the required level of real GDP that allows reduced emissions levels.

Causality results also reveal a bidirectional short-run causality between renewable energy consumption and carbon emissions, indicating that renewable energy consumption causes carbon emissions, while carbon emissions cause renewable energy consumption as well in the short-run. In other words, any increases in the share of renewable energy consumption affect the variation of pollution in the region. Moreover, if the degree of pollution caused by carbon emissions increases, this can generate certain changes in the share of renewable energy used for production purposes. These findings are consistent with those reached by Apergis et al. (2010) in the case of a panel of 19 developed and developing countries, but not in line with those presented by Menyah and Rufael (2010) who find the absence of causality between carbon emissions and renewable energy consumption in the case of the US.

The short-run interaction between economic growth and renewable energy consumption is unidirectional without any feedback. In other words, causality findings suggest that only renewable energy consumption affects economic growth, finding that is consistent with the growth hypothesis. Otherwise, the evolution of economic activities across the countries in the sub-Saharan region has an impact on the conservation share of renewable energy in the short-run. In addition, there is no direct or indirect short-run causal link between health expenditures and renewable energy consumption, a finding that has not been previously investigated in the literature. These finding point out the role that renewable energy can play in the health footprint of sub-Saharan population, given that the region is characterized by a wealth of renewables sources unexploited. Moreover, access to health care can be improved and turn to be more reliable through renewable energy systems. If the countries in the area exploit their share of natural resources, then this can be substantially beneficial for their savings levels, allowing them to significantly reduce air pollution levels and then, to improve the quality of the health conditions of their citizens. In the sub-Saharan African countries, energy challenges impact extremely on the global performance of the region's social and economic indicators. In fact, the region's relatively poor health indicators can be greatly improved with the provision of modern energy services. Moreover, the installation of the modern renewable energy projects is not used only to heat water, or to cook, but also to transform it into electrical energy (i.e., solar, wind, geothermal). This phenomenon is extremely vital for the poor countries in the region, because access to electricity from health facilities can lead to better health care conditions (ICSU, 2007). More specifically, in remote and resources-poor locations, renewable energy can supply electricity for lifesaving processes that might not otherwise be possible (WHO, 2015).

Furthermore, causality results illustrate the presence of a short-run unidirectional causality running from real output to health expenditures, indicating that, in the short-run, real growth can cause health expenditures, while the reverse does not hold. Any augmentation in the economic activities added values in the area shortly contributes to increases in expenditures reserved to healthcare. The long-run interdependence between carbon emissions and health expenditures is found to be bidirectional, indicating that there is a strong correlation between the expansion of pollution and the growth of health expenditures.

5. Conclusions and policy implications

This paper investigated the dynamic causal links between carbon emissions, real output, renewable energy consumption and health expenditures for a panel of 42 sub-Saharan African countries, spanning the period 1995-2011. The empirical analysis made use of a number of methodologies in relevance to panel data, including 2^{nd} generation panel unit root tests, panel cointegration approaches, panel long-run estimates, and panel causality tests to check out for the interaction between the variables. The primary goal of this study was to: i) examine the impact of both renewable energy consumption and health expenditures on the environmental conditions in the area, and ii) to investigate the short- and long-run association among the variables under study.

The empirical findings documented that the variables under consideration were cointegrated, while the FMOLS and DOLS long-run estimates documented that both renewable energy consumption and health expenditures contributed to lower carbon emissions levels. Interestingly, causality suggested that there were no short- and long-run relationships between renewable energy consumption and health expenditures. However, there was a bidirectional long-run causality between carbon emissions and health expenditures.

The policy recommendations raised by the empirical findings are associated with: i) more renewable energy could be a policy strategy that motivates economic sectors, while it would significantly reduce carbon emissions levels in the region; ii) policy makers in these countries should devote a substantial part of the state budget to health expenditures, since such expenses could be a good path to combat global warming; and iii) the use of renewable energy as well as the expansion of health expenditures seems to be the major drivers for reduced pollution levels.

Although the easy recommendation is the expansion of renewable sources of energy, this is not highly viable for these countries, because of cash constraints and lack of supply infrastructure. Similarly, clean-burning biofuels may be also appropriate solutions in the long-run, but are not likely to satisfy household energy needs for poor rural consumers. Therefore, it would be a very good opportunity for further research to explore potential financing mechanisms that will promote renewable energy expansion, without jeopardizing the growth path of those countries in the sun-Saharan African region.

References

Apergis, N., Payne, J.E., 2010a. Renewable energy consumption and economic growth evidence from a panel of OECD countries. Energy Policy, 38, 656-660.

Apergis, N., Payne, J.E., 2010b. Renewable energy consumption and growth in Eurasia. Energy Economics, 32, 1392-1397.

Apergis, N., Payne, J.E., 2011. The renewable energy consumption-growth nexus in Central America. Applied Energy, 88, 343-347.

Apergis, N., Payne, J.E., Menyah, K., Wolde-Rufael, Y., 2010. On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. Ecological Economics, 69, 2255-2260.

Ben Jebli, M., Ben Youssef, S., 2015. The environmental Kuznets curve, economic growth, renewable and non-renewable energy, and trade in Tunisia. Renewable and Sustainable Energy Reviews, 47, 173-185.

Ben Jebli, M., Ben Youssef, S., Apergis, N., 2015. The dynamic interaction between combustible renewables and waste consumption and international tourism: the case of Tunisia. Environmental Science and Pollution Research, 22, 12050-12061.

Ben Jebli, M., Ben Youssef, S. and Ozturk, I., 2015. The Role of Renewable Energy Consumption and Trade: Environmental Kuznets Curve Analysis for Sub-Saharan Africa Countries. African Development Review, 27, 288–300. doi: 10.1111/1467-8268.12147.

Ben Jebli, M., Ben Youssef, S., Ozturk, I., 2016. Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries. Ecological Indicators, 60, 824-831.

Breitung, J., 2000. The Local Power of Some Unit Root Tests for Panel Data, in: B.Baltagi (Ed.) NonStationary Panels, Panel Cointegration, and Dynamic Panels, Advances in Econometrics, 15, 161-178, JAI Press, Amsterdam.

Canning, D. and Pedroni, P. 2008. Infrastructure, long-run economic growth and causality tests for cointegrated panels. The Manchester School, 76, 504-527

Dickey, D. and W. Fuller 1979. Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74, 427-431.

Energy efficiency in hospitals., 2009. Best practice guide. New Delhi, USAID/India, 2009. (http://eco3.org/energy-efficiency-in-hospitals-bestpractice- guide-2/).

Engle, R.F., Granger C.W.J., 1987. Co-integration and error correction: Representation, estimation, and testing. Econometrica, 55, 251-276.

Im, K.S., Pesaran, M.H., Shin, Y., 2003. Testing for unit roots in heterogeneous panels. Journal of Econometrics, 115, 53-74.

International Council for Science., 2007. Sustainable Energy in sub-Saharan Africa. ICSU Regional Office for Africa, Science Plan. Accessed at: www.icsu-africa.org.

Jalil, A., Mahmud, S.F., 2009. Environment Kuznets curve for CO_2 emissions: A cointegration analysis for China. Energy Policy, 37, 5167-5172.

Jerrett, M., Eyles, J., Dufournaud, C., Birch, S., 2003. Environmental influences on health care expenditures: an exploratory analysis from Ontario, Canada. Journal of Epidemiology and Community Health, 57, 334–338.

Levin, A., Lin, C.F., Chu, C.S., 2002. Unit root tests in panel data: asymptotic and finite-sample properties. Journal of Econometrics, 108, 1-24.

Mark, N.C., Sul, D., 2003. Cointegration vector estimation by panel DOLS and long-run money demand. Oxford Bulletin of Economics and Statistics, 65, 655-680.

Menyah, K., Wolde-Rufael, Y., 2010. CO_2 emissions, nuclear energy, renewable energy and economic growth in the US. Energy Policy, 38, 2911-2915

Pedroni, P., 2001. Purchasing power parity tests in cointegrated panels. The Review of Economics and Statistics, 83, 727-731.

Pedroni, P., 2004. Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Econometric Theory, 20, 597-625.

Pesaran, M., 2007. A simple panel unit root test in the presence of cross-section dependence. Journal of Applied Econometrics, 22, 265-312.

Pesaran, M. 2004. General diagnostic tests for cross section dependence in panels. Cambridge Working Papers in Economics 435, and CESifo Working Paper Series 1229.

Pesaran, M.H., Shin, Y., Smith, R.J., 2001. Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16, 289–326.

Sadorsky, P., 2009. Renewable energy consumption and income in emerging economies. Energy policy, 37, 4021-4028.

World Bank, 2015. World Development Indicators. Accessed at: http://www.worldbank.org/data/onlinedatabases/onlinedatabases.html.

World Health Organization, 2015. Health in the green economy. Accessed at: http://www.who.int/hia/green_economy/en/index.html.

Tables

Table 1. Pesaran (2004) Covariate Augmented Dickey-Fuller (CADF) tests

Variables	t-bar	cv10	cv5	cv1	Z[t-bar]	P-value
$LNCO_2$	-2.028	-2.030	-2.110	-2.250	-1.893	0.029**
LNGDP	-2.158	-2.030	-2.110	-2.250	-2.720	0.003***
LNRE	-1.993	-2.030	-2.110	-2.250	-1.673	0.047**
LNH	-2.073	-2.030	-2.110	-2.250	-2.176	0.015**

Notes: "**", "***" indicate statistical signficance at the 5% and 1%, respectively. The estimates included both a constant and a trend. t-bar test indicates the truncated values of student statistic, N,T = (42,17), with "N" denoting the number of countries and "T" indicating the time span. Number of observations = 630. Under the null of cross-sectional residual independent, the Pesaran (2004) test is augmented by one lag. "cv" denotes the critical value provided by Pesaran (2004) at the 10%, 5% and 1% significance levels.

Table 2. Panel unit root tests

Variables	LLC	Breitung	IPS-Wstat	ADF-Fisher	PP-Fisher	CIPS
$LNCO_2$	-4.78529***	0.18632	-0.997	112.097**	124.921***	-0.941
$\Delta LNCO_2$	-18.3929***	-8.82959***	-15.0842***	339.582***	406.300***	-1.893**
LNGDP	-0.97333	3.65085	3.67476	95.6005	330.571	-1.375
ΔLNGDP	-15.8750***	-5.34773***	-12.3034***	283.222***	395.982***	-2.720***
LNRE	-1.92367**	2.11714	1.89343	80.5532	112.239**	-0.890
ΔLNRE	-16.3697***	-6.58400***	-12.9784***	300.337***	423.476***	-1.673**
LNH	-0.97333	3.65085	0.12066	96.4758	77.0851	-2.176**
ΔLNH	-15.8750***	-5.34773***	-12.3034***	283.222***	395.982***	-3.816***

Notes: "**", "***" denote statistical significance at the 5% and 1%, respectively. Δ denotes first differences.

Table 3. Pedroni panel cointegration tests

Alternative hypothesis: common AR coefs. (within-dimension)				
			Weighted	
	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	0.690224	0.2450	-1.181825	0.8814
Panel rho-Statistic	0.816451	0.7929	1.007946	0.8433
Panel PP-Statistic	-5.592538	0.0000***	-5.743409	0.0000***
Panel ADF-Statistic	-6.243037	0.0000***	-6.244811	0.0000***
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic	Prob.		
Group rho-Statistic	3.563427	0.9998		
Group PP-Statistic	-6.673381	0.0000***		
Group ADF-Statistic	-6.068990	0.0000***		

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

Table 4. Long-run panel estimates

Variables	*LNGDP*	*LNRE*	*LNH*
FMOLS	1.091937 (0.0000)***	-0.289687 (0.0000)***	-0.210902 (0.0000)***
DOLS	1.047998 (0.0000)***	-0.321844 (0.0000)***	-0.174733 (0.0003)***

Notes: "***" indicates statistical significance at the 1% level. p-values are in parentheses.

Table 5. Panel causality results

Dependent variable	**Short-run**				**Long-run**
	ΔLNCO₂	*ΔLNGDP*	*ΔLNRE*	*ΔLNH*	*ECT*
ΔLNCO₂	-	14.0653 (0.000)***	2.33007 (0.0981)*	0.75342 (0.4712)	-0.022163 [-2.60600]***
ΔLNGDP	0.33763 (0.7136)	-	0.28296 (0.7536)	1.07810 (0.3409)	0.004517 [1.35238]
ΔLNRE	3.72682 (0.0246)**	6.33115 (0.0019)***	-	0.68090 (0.5065)	0.007282 [3.60173]
ΔLNH	1.02720 (0.3586)	2.30900 (0.1000)*	0.67698 (0.5085)	-	-0.011391 [-2.54914]***

Notes: "***", "*" indicate statistical significance at the 1% and 10%, respectively. p-values are parentheses. Statistics are computed for the case where both an intercept and a deterministic trend are included. Lag length selection was based on the SIC criterion with a max lag of 2.

Table 6. Long-run panel Granger causality tests

Test	λ_1	GM	LP	λ_2	GM	LP	sign (-λ1/ λ2)
LNY →$LNCO_2$	-0.16	-4.13*	77.44*	0.02	-0.92	1.80	0.24(0.09)
LNY →LNRE	0.24	-3.85*	86.26*	-0.05	-0.64	2.61	0.38(0.07)
LNCO2→LNRE	-0.19	-4.62*	73.59*	-0.26	-5.12*	58.92*	-0.32(0.10)
LNY→LNH	-0.27	-3.29*	91.04*	0.03	-0.39	1.49	0.26(0.05)
LNCO2→LNH	0.02	-0.71	2.13	-0.08	-0.26	1.53	0.19(0.22)

Notes: λ_1 = first variable causes second variable, λ_2 second variable causes first variable. Figures in parentheses denote standard errors. * denotes statistical significance at the 1% level.

Figures

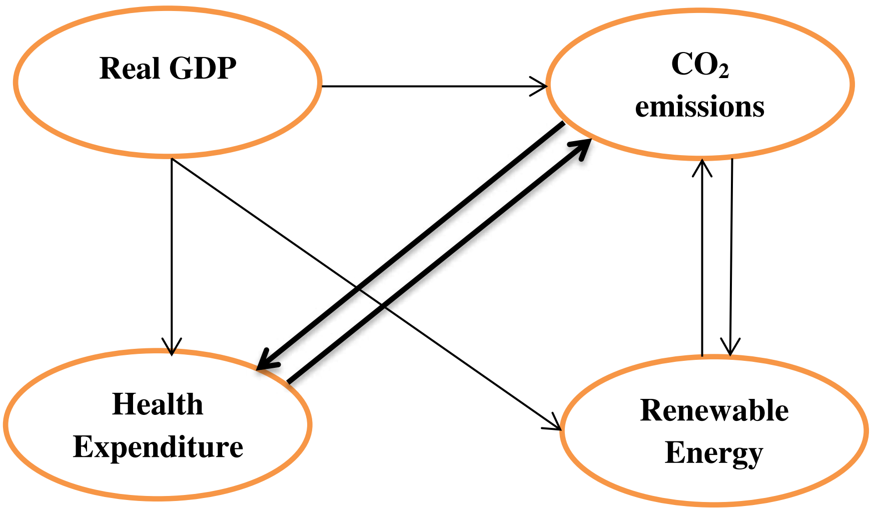

Fig.1. Short- (discrete line) and long-run (intense line) Granger causality