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Original Article

The role of renewable energy and agriculture in reducing CO_2 emissions: Evidence for North Africa countries

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ABSTRACT

This paper uses panel cointegration techniques and Granger causality tests to investigate the dynamic causal links between per capita renewable energy consumption, agricultural value added (AVA), carbon dioxide (CO_2) emissions, and real gross domestic product (GDP) for a panel of five North Africa countries spanning the period 1980–2011. In the short-run, Granger causality tests show the existence of bidirectional causality between CO_2 emissions and agriculture; a unidirectional causality running from agriculture to GDP, from GDP to renewable energy consumption, and from renewable energy consumption to agriculture. In the long-run, there is bidirectional causality between agriculture and CO_2 emissions; a unidirectional causality running from renewable energy to agriculture and to emissions, and from output to agriculture and to emissions. Long-run parameter estimates show that an increase in GDP or in renewable energy consumption (including combustible and waste) increases CO_2 emissions, whereas an increase in agricultural value added reduces CO_2 emissions. As policy recommendation, North African authorities should encourage renewable energy consumption, and especially clean renewable energy such as solar or wind, as this improves agricultural production and help to combat global warming.

1. Introduction

During several decades, developed and developing countries have used fossil energy intensively for growth purposes in almost all economic sectors such as manufacturing industry, tourism, transport, and agriculture. This led to important carbon dioxide (CO_2) emissions in almost all regions of the world. The agricultural sector contributes between 14% and 30% of the world greenhouse gas (GHG) emissions because of its intensive fossil energy use (Reynolds and Wenzlau, 2012). Indeed, using farm equipment powered by fuel, pumping water for irrigation, raising livestock in indoor facilities, and applying nitrogen-rich fertilizers contribute to agriculture's high GHG emissions. However, the United Nations food and agriculture organization (FAO) believes that the agricultural sector has a substantial potential to decrease its emissions, including removing 80%–88% of CO_2 emissions that it currently produces (Reynolds and Wenzlau, 2012). Indeed, many agricultural activities, such as irrigation, could be powered by renewable energy sources.

The use of the main renewable energy sources in agricultural activities are detailed in Bayrakcı and Koçar (2012): *i*) solar energy can be used for greenhouse heating and cooling, lighting, product drying, and farm field irrigation; *ii)* modern biofuels like bioethanol and biogas, and various agricultural residues such as grain dust, wheat straw and hazelnut shells can be used as sources of energy; *iii*) geothermal energy can serve in aquaculture, in barns, in soil improvement, in greenhouse, to heat the soil in open fields, and to dry agricultural products; *iv)* wind energy can be used to generate electricity, irrigate fields and grind some of the crops; *v)* hydropower can be used for electricity production, irrigation, drinking water supplies, and facilitates the equitable sharing of water between farmers.

The North Africa region is facing an important increasing energy demand between 6% and 8% per year and fossil fuels dominate the energy mix with a greater share for natural gas (United Nations Economic Commission for Africa, 2012). Because of the high volatility of oil and gas prices, North Africa countries are reviewing their energy policies by diversifying their energy mix and giving greater importance to energy efficiency and renewable energies. The potential for energy efficiency and renewable energy in this region is still largely under-exploited. Indeed, there is real energy efficiency potential as a 10% gain in this region's energy con-

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sumption could be made by 2030 via improved energy efficiency measures (United Nations Economic Commission for Africa, 2012). Renewable energies' contribution to the energy mix is still weak since it represented only 8% in 2006, while the contributions of gas, oil and coal are 67%, 19% and 6%, respectively (United Nations Economic Commission for Africa, 2012). Many reforms concerning the regulatory frameworks have been made in order to encourage more participation by the private sector in renewable energy production. In addition, these countries have elaborated ambitious strategic objectives and launched large-scale integrated programs with the main objectives of GHG reduction, creation of direct and indirect jobs, industrial development and human capital improvement. Current initiatives such as the Mediterranean solar plan (MSP) or the agreements signed between the European Union (EU) and some North Africa countries are expected to improve technical and financial cooperation and expand renewable energies' regional markets.

Agriculture is a major activity in the North Africa region at the economic and social levels. An important dualism between traditional and modern agriculture still prevails. Modern agriculture is found largely in irrigated areas devoted to fruits, vegetables, and in cultivated plains of grain and olive trees. This type of agriculture consists mainly of large farms oriented toward exporting. North African countries have made considerable efforts to improve their agricultural production. However, until now, these efforts have not been enough to cope with ever increasing food demand. Indeed, these countries still experience important population growth and are highly dependent on imports of basic agricultural products such as cereals, meat, and milk. Agricultural trade balance of the region is negative because trade coverage[1] reached 1% in Algeria, 21% in Egypt, 37% in Morocco, and 61% in Tunisia (Alvarez-Coque, 2012). Unfortunately, the progress of the situation indicates no sign of reversal. The absence of a good rural transport infrastructure, the dry climatic, and soil conditions of this region can partially explain this deficiency in agricultural production. Despite the significant development of irrigated areas due to the building of various categories of dams, particularly in Egypt, grain yields are still very low in Morocco, Tunisia, and Algeria. Indeed, the yield per hectare is between 1 and 2 tons in these countries, which is significantly lower than yields in other countries of the Euro-Mediterranean region (Alvarez-Coque, 2012).

In the present paper, we investigate the dynamic causal links between per capita renewable energy consumption, agricultural value added (AVA), CO_2 emissions, and real gross domestic product (GDP) for a panel of five North African countries spanning the period 1980–2011. We also evaluate the long-run impact of renewable energy consumption, agricultural value added, and economic growth on CO_2 emissions. The present paper differs from that of Ben Jebli and BenYoussef (2016) mainly by the fact that we consider a panel of countries and we use panel cointegration techniques.

This paper is organized as follows: Section 2 is a literature review. Section 3 presents the data and some descriptive statistics. Section 4 reports the empirical results and their discussion. Finally, Section 5 concludes with policy recommendation.

2. Literature review

There are several factors explaining the evolution of carbon dioxide emissions such as economic growth, energy consumption, renewable energy consumption, international trade, tourism, and urbanization. Many econometric studies have investigated the causal relationships of CO_2 emissions and concluded various recommendations related to the progression of pollution in developed and developing countries (e.g. Ang, 2007; Apergis and Ozturk, 2015; Ben Jebli and Ben Youssef, 2015; Ben Jebli et al., 2015; Chebbi, 2010b; Chebbi et al., 2011; Dogan and Seker, 2016; Farhani and Shahbaz, 2014; Fodha and Zaghdoud, 2010; Halicioglu, 2009; Sadorsky, 2009; Shahbaz et al., 2014). The conclusions reached by these studies depend on the considered variables, the considered countries and time period, and the used empirical methodology. Indeed, some variables seem to affect CO_2 emissions positively and lead to their increase, whereas other variables contribute to CO_2 emissions reduction.

Halicioglu (2009) uses the autoregressive distributed lag (ARDL) approach and cointegration techniques to investigate the dynamic causal links between CO_2 emissions, energy consumption, output, and foreign trade in the case of Turkey. The results reveal the existence of two forms of long-run relationship between the variables. The first form suggests that CO_2 emissions are determined by energy consumption, income and foreign trade. The second form suggests that income is determined by CO_2 emissions, energy consumption and foreign trade. Sadorsky (2009) uses panel cointegration techniques to estimate an empirical model of renewable energy consumption for the Group of 7 (G7) countries, which are Canada, France, Germany, Italy, Japan, United Kingdom, and the United States of America. The empirical results show that, in the long-run, real GDP and CO_2 emissions are two major drivers behind renewable energy consumption. For the case of Tunisia, Chebbi (2010b) provides some insights into the relationships between energy consumption, carbon emissions and the sectoral components of the output growth (agriculture, industry and services). The results of the long-run estimates reveal the existence of bidirectional causality between energy consumption and output growth, and between energy consumption and CO_2 emissions. However, the short-run results suggest that the interaction between GDP and energy consumption and between GDP and CO_2 emissions are not uniform across sectors. Farhani and Shahbaz (2014) study the causal relationship between renewable and non-renewable electricity consumption, economic growth and CO_2 emissions by considering a panel of 10 Middle East and North Africa countries. They find long-run bidirectional causality between renewable and non-renewable electricity consumption and CO_2 emissions. Long-run estimates support the inverted U-shaped environmental Kuznets curve (EKC) hypothesis and show that renewable and non-renewable electricity consumption increase CO_2 emissions.

Shahbaz et al. (2014) examine the validity of the EKC hypothesis and investigate the causal links between CO_2 emissions, GDP, energy consumption, and trade openness for the case of Tunisia. The results reveal that the inverted U-shaped EKC hypothesis is supported and that a long-run cointegration between variables is established. Using the ARDL approach and the Granger causality tests, Ben Jebli and Ben Youssef (2015) examine the dynamic causal links between per capita CO_2 emissions, real GDP, square of real GDP, renewable and non-renewable energy consumption and trade (exports or imports) for the case of Tunisia by specifying two models. They show that non-renewable energy consumption and trade affect positively emissions, while renewable energy consumption affects negatively but weakly the emissions of CO_2. In addition, these authors prove that the inverted U-shaped EKC hypothesis is not verified. Apergis and Ozturk (2015) use the generalized method of moments (GMM) methodology to study the EKC hypothesis for a panel of 14 Asian countries. Their multivariate framework comprises carbon dioxide emissions, economic growth, population density, land, industry shares in growth, and four indicators indicating institutions' quality. Their results validate the inverted U-shaped EKC hypothesis.

Our study is concerned by the relationship between energy consumption and agriculture. Karkacier et al. (2006) investigate the

[1] Trade coverage is measured by the percentage of agricultural exports with respect to agricultural imports, for the year 2010.