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Renewable Energy Consumption and Agriculture: Evidence for Cointegration and Granger causality for Tunisian Economy

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Abstract: This paper uses the vector error correction model (VECM) and Granger causality tests to investigate short and long-run relationships between per capita carbon dioxide (CO_2) emissions, real gross domestic product (GDP), renewable and non-renewable energy consumption, trade openness ratio and agricultural value added (AVA) in Tunisia spanning the period 1980-2011. The Johansen-Juselius test shows that all our considered variables are cointegrated. Short-run Granger causality tests reveal the existence of bidirectional causalities between AVA and CO_2 emissions, and between AVA and trade; unidirectional causalities running from non-renewable energy and output to AVA and to renewable energy, and from CO_2 emissions to renewable energy. Interestingly, there are long-run bidirectional causalities between all considered variables. Our long-run parameters estimates show that non-renewable energy, trade and AVA increase CO_2 emissions, whereas renewable energy reduces CO_2 emissions. In addition, the inverted U-shaped environmental Kuznets curve (EKC) hypothesis is not supported. Our policy recommendations are to increase international economic exchanges because this gives new opportunities to the agricultural sector to develop and to benefit from renewable energy technology transfer. Subsidizing renewable energy use in the agricultural sector enables it to become more competitive on the international markets while polluting less and contributing to combat global warming.

Keywords: Renewable energy; Agriculture; Trade; Granger causality; Tunisia.

1. Introduction

The agricultural sector occupies an important place in the Tunisian economy because authorities consider that this sector could guarantee food safety and constitutes the main economic activity in many regions. The agricultural sector generates over 12% of gross domestic product (GDP) and actively contributes to job creation and to the balance of payments through exports, particularly olive and dates exports. This sector employs 16% of the total active labor force, food exports contribute 11% in goods exports, and the agricultural investments represent 10% of investments in the overall economy (Agence de Promotion des Investissements Agricoles, 2015). The area of agricultural land is estimated at 10 million hectares. The structure of agricultural production is dominated by farming, followed by tree crops (olives, dates, citrus fruits), market gardening and cereals. Tunisian agriculture has certain important advantages: a favorable climate and varied vegetation, an appreciable land and hydraulics potential, a coastline of 1300 km, and an important human potential. As part of the agreement signed between Tunisia and the European Union (EU) in 1995, the agreement signed in December 2000 provides facilities to access the European market for Tunisian agricultural products fresh or processed such as fresh vegetables, processed vegetables, fresh fruits, dried fruits, processed fruits, seafood, olive oil, and cut flowers.

In 2010, the agricultural sector accounts for 6% of the total energy consumed in Tunisia (Gestore dei Servizi Energetici—GSE S.p.A, 2013). Since, fossil energy sources cause environmental pollution and harm the fields used for agricultural activities, the use of renewable energy resources, such as solar, biomass, wind, geothermal and hydropower for agricultural activities can afford lots of economic, social and environmental advantages to the farmers. Bayrakcı and Kocar (2012) investigate the utility of renewable energies for agricultural activities. The use of the main renewable energy sources in agricultural activities are the following: *i)* solar energy applications in agriculture are greenhouse heating and cooling, lighting, product drying, and farm field irrigation; *ii)* modern biofuels like bioethanol and biogas can be used in agricultural activities. In addition, various agricultural residues, such as grain dust, wheat straw and hazelnut shells are sources of biomass energy; *iii)* agriculture and the food processing industry are promising fields for the use of geothermal energy, since there are many technologies which need more or less concentrated heat energy sources. Geothermal energy can be used in aquaculture, in barns, in soil improvement, in greenhouse, to heat the soil in open fields, and to dry agricultural products; *iv)* wind turbines have been used for many centuries by a number of cultures for watering livestock, land drainage and irrigation. Wind energy is mostly used to generate electricity, irrigate fields and grind some of the crops; *v)* there are lots of ways to use hydropower: water-wheels, the gained hydroelectricity energy from barrages, kinetic energies from rivers and barrages, tide power, the power of waves in open seas and oceans, the osmotic power gained by the flow rate between lakes and oceans. Hydropower often supports essential water services in agriculture such as irrigation, flood control and drinking water supplies, and facilitates the equitable sharing of a common vital resource.

Tunisia has gained practical experience in recent years in the field of using renewable energy for agricultural purposes. The use of photovoltaic systems in Tunisia was exclusively reserved for long years to isolated sites in the rural areas to provide electricity to homes or agricultural activities including water pumping. In Tunisia, anaerobic digestion has always attracted the attention of end consumers of energy, especially those active in agriculture or agribusiness. Incentives for the development of the production of bio-methane, including the national fund for the mastery of energy (fonds national pour la maitrise de l'énergie, FNME) grants were established to help project developers to tap this resource (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2013). The wood used in traditional ovens comes mainly from waste of regional agriculture (olive, palm ...) or forests.

Launched in 2009, the results of regional surveys on a sample of 103 farms and a study on "the development of energy efficiency in the agriculture and fisheries sector" (Agence Nationale pour la Maitrise de l'Energie, 2014) resulted in a first phase: *i)* to assess the energy consumption of the agriculture and fisheries in Tunisia reaching 385 ktoe in 2008 and a growth of about 7.7% annually since the 80s; *ii)* to highlight the intensive use of agricultural machinery and the evolution number of irrigation pumps. The average cost of energy accounted for about 14% of the production cost per hectare for rainfed crops; *iii)* to estimate the energy saving potential due to the production of biomass, biogas and biofuels in Tunisia to about 82 ktoe per year in agriculture (28% of the annual energy consumption) and about 32 ktoe relating to fisheries and aquaculture (nearly a third of the energy consumption).

Many projects related to the use of renewable energies in the agriculture sector have been realized so far. In the field of pumping of water by solar PV, a pilot project to supply drinking water to pasture has been realized. This project involved the establishment of 86 operating systems, with a total capacity of 224 kilowatts distributed among the governorates in the center and south of the country. The use of geothermal energy has created, in the south of the country, 380 hectares of greenhouse crops for the production of early vegetables (Réseau International d'Accès aux Energies Durables, 2008). On 17 November 2012, the small town of Om Somaa in the Kebili Governorate has inaugurated a solar micro-plant for pumping and irrigation of 105 hectares of palm. This is a valuable project for farmers in the region as 270 farmers will benefit from the dedicated power source. This project carries innovation: Oum Somaa station is the first Tunisian resort of concentrated photovoltaic electricity production, and is the result of cooperation between the Tunisian company of electricity and gas (société tunisienne d'électricité et du gaz, STEG) and the French company Soitec (Ambassade de France en Tunisie, 2013).

Insert Figure 1 here

Figure 1 reports the tendency of per capita CO_2 emissions, real GDP, renewable and non-renewable energy consumption, trade openness ratio, and AVA in Tunisia over the last three decades. It shows that the movement of emissions and output is clearly upward across time, whereas the other variables have an unstable evolution across time. Nevertheless, the general tendency of all variables is upward across the selected period 1980-2011.

The main objective of this paper is to study the causal relationships between agriculture and renewable energy. Though there are analytical studies dealing with agriculture and renewable energy (Bayrakcı and Kocar 2012, Mosher and Corscadden 2012), to the best of our knowledge, this paper is the first econometric study dealing with renewable energy and agriculture. The short and long-run dynamic causalities between per capita CO_2 emissions, economic growth, renewable and non-renewable energy consumption, trade openness and the agriculture value added (AVA) for the case of Tunisia is the subject of our study. In addition, we will evaluate the long-run elasticities of our considered variables on CO_2 emissions.

The remainder of the paper is organized as follows: Section 2 is a literature review. Section 3 deals with data, empirical methodology, and results. Section 4 concludes with policy recommendations.

2. Literature review

There are many empirical studies interested by the causal relationships between energy consumption (renewable and/or non-renewable) and economic growth with some of them have included other variables such as pollution emission or international trade (Ajmi et al., 2013; Al-mulali, et al., 2014; Ang, 2007; Apergis and Ozturk, 2015; Apergis and Payne, 2010a, 2010b, 2011; Arouri et *al*., 2012; Belloumi, 2009; Ben Jebli and Ben Youssef, 2015a, 2015b; Ben Jebli et al., 2015; Chebbi et al., 2011; Chouaibi and Abdessalem, 2011; Fallahi, 2011; Fodha and Zaghdoud, 2010; Halicioglu, 2009; Ozturk and Acaravci, 2010; Ozcan, 2013; Sadorsky, 2009a, b, 2011, 2012; Shahbaz et al., 2013, 2014; Tugcu et *al*., 2012).

Al-Mulali et al. (2014) study the effect of renewable and non-renewable electricity consumption on output for 18 Latin American countries. They show the existence of long-run bidirectional causality between output, renewable and non-renewable electricity consumption, capital, labor and trade. They also find that renewable electricity is more significant than non-renewable electricity in promoting economic growth in both the short and long-run for this considered panel of countries. Chebbi et al. (2011) examine the causality between the trade openness ratio, per capita GDP and per capita CO_2 emissions for Tunisia. They show the existence of long-run bidirectional causality between the three considered variables, and a short-run unidirectional causality running from the trade openness ratio to CO_2 emissions. Their results suggest that the direct effect of trade on emissions is positive in both the short and long-run. However, the indirect effect is negative at least in the long-run, and the overall effect is positive in both the short and long run. Sadorsky (2011) uses panel cointegration techniques to study how trade can affect energy consumption by considering a panel of 8 Middle East countries. He finds a unidirectional causality running from exports to energy consumption and a bidirectional causality between imports and energy, in the short-run. In the long-run, he highlights that an increase in both exports and imports affect the demand of energy.

Apergis and Ozturk (2015) study the EKC hypothesis for a panel of 14 Asian countries by using the GMM methodology. The multivariate framework includes CO_2 emissions, GDP, population density, land, industry shares in GDP, and four indicators measuring institutions' quality. Their findings confirm the inverted U-shaped EKC hypothesis. Apergis and Payne (2010a) study the causal relationships between renewable energy consumption, output, capital and labor by considering a panel of twenty OECD countries. Their Granger causality tests reveal the existence of short and long-run bidirectional causalities between renewable energy consumption and output. Ben Jebli and Ben Youssef (2015a) show the existence of short-run unidirectional causality running from trade (exports or imports), output, CO_2 emission and non-renewable energy consumption to renewable energy consumption for Tunisia. In the long-run, the inverted U-shaped EKC hypothesis is not verified graphically and analytically. Halicioglu (2009) examines the causal relationships between CO_2 emissions, energy consumption, GDP, and the trade openness ratio for the case of Turkey during. Granger causality tests show the existence of short and long-run bidirectional causality between GDP and emissions, and short-run bidirectional causality between energy consumption and emissions. The inverted U-shaped EKC hypothesis is verified for Turkey in the long-run.

There are few studies focusing on the causal relationships between agriculture and energy consumption. Karkacier et al. (2006) investigate the impacts of energy use on agricultural productivity in Turkey. They show the existence of a strong relationship between energy use and agricultural productivity. In addition, increasing energy use, increases agricultural productivity. These authors recommend that politicians should support the use of energy in the agricultural sector and propose as a support a per hectare fuel subsidy. Turkful and Unakitan (2011) estimate the relationship of per capita agricultural energy consumption (diesel, electricity), agricultural GDP, and energy prices using cointegration and error correction model (ECM) analysis for the case of Turkey. They show the existence of a unidirectional causality running from diesel and electricity consumption to agricultural GDP. In the long-run, increasing agricultural GDP, increases the consumption of diesel and electricity. Finally, these authors recommend that support for energy use in Turkish agriculture should be continued in the objective of increasing international market competitiveness, and balance the income of farmers.

Mushtaq et al. (2007) study the causal relationship between per capita agricultural energy consumption (oil, electricity, gaz), real agricultural GDP and energy prices in Pakistan. They show a unidirectional causal relationship running from agricultural GDP to oil consumption, and from electricity consumption to agricultural GDP. They recommend for governments to improve the infrastructure and to subsidize rural and agricultural electricity in order to significantly enhance agricultural GDP. Sebri and Abid (2012) investigate the causal relationships between agricultural value added, energy consumption (oil, electricity), and the trade openness ratio in Tunisia. Granger results show the existence of short and long-run unidirectional causality running from the total energy consumed and from the oil energy consumed to AVA. There is also a long-run unidirectional causality running from AVA to oil consumption. Thus, energy can be considered as a limiting factor to AVA and, therefore, shocks to energy supply should be handled carefully.

3. Data, empirical methodology and results

Annual data base on Tunisia spanning the period 1980-2011 are collected and concern time series of per capita carbon dioxide emissions (*e*) measured in metric tons, per capita real GDP (*y*) and its square (y^2) measured at constant 2005 US$, and per capita agricultural value added (AVA, *agr*) measured in constant US$. Per capita renewable energy consumption (*re*) is measured in billion kilowatt-hours and comprises geothermal, solar, wind, tide and wave, biomass and waste, and hydroelectric. Per capita non-renewable energy consumption (*nre*) is measured in billion kilowatt-hours and comprises oil, natural gas and coal. Trade openness ratio (*tr*) is measured as a share of GDP and is equal to the sum of exports and imports divided by GDP. Data on per capita emissions, GDP, trade and AVA are obtained from the Word Bank (2015), and those on per capita renewable and non-renewable energy are obtained from the U.S. Energy Information Administration (2015).

Our examination inspects, for the case of Tunisia, the dynamic association that may occur between per capita CO_2 emissions, real GDP, renewable and non-renewable consumption, trade openness and the agricultural value added. We take the natural logarithm of all the considered variables so that all the estimated coefficients can be interpreted as elasticities. In addition, and to be able to verify the EKC hypothesis, we introduce the square of per capita GDP as an explanatory variable. Thus, and following the methodology developed by Ang (2007) and Halicioglu (2009), among others, our long-run log linear quadratic EKC equation is represented as follows:

$$e_t = \alpha_0 + \alpha_1 y_t + \alpha_2 y_t^2 + \alpha_3 re_t + \alpha_4 nre_t + \alpha_5 tr_t + \alpha_6 agr_t + \varepsilon_t \quad (1)$$

Where t=1980,…, 2011 denotes the time, α_0 is a constant, α_i (i=1,…,6) present the long-run estimated parameters corresponding to each independent variable, and ε_t is the residual term.

Our empirical investigation follows the classical four steps beginning by stationary tests, cointegrations tests, long-run parameters estimates, and Granger causality tests.

3.1. Stationary tests

We start the analysis by testing the order of integration of each variable using three kinds of unit root tests. These tests are: augmented Dickey and Fuller (1979) (ADF test), Phillips and Perron (1988) (P-P test) and Zivot and Andrews (1992). The Akaike information criterion (AIC) is selected to detect the number of lag length in the ADF test, while in the P-P test we use the Newey-West Bartlett kernel to select the bandwidth. From the traditional integration tests, the null hypothesis argues that the series is non-stationary, while the alternative hypothesis suggests that the series is stationary. The integration order of analysis time series is tested for the case of intercept and deterministic trend.

It’s known that the stationary proprieties of the Zivot-Andrews unit root tests are more powerful than the traditional tests (DF-GLS, ADF, P-P tests, for example) because these later do not give information about structural break points in series and provide biased and spurious results (Baum, 2004). Moreover, detecting possible structural break points in time series leads to better economic understanding. The null hypothesis of a unit root with breaks argues that the variable is non-stationary, while the alternative hypothesis specifies that the variable is stationary with one-time break point.

Insert Table 1 here

The results from the ADF and P-P unit root tests reveal that, at level, all variables are non-stationary, while they become stationary after first difference at the 1% significance level. Thus, all our variables are integrated of order one (I(1)). According to the Zivot-Andrews test with structural breaks, all series are non-stationary at level, while they become stationary after first difference.

3.2. Cointegration tests

We examine the existence of long-run cointegration among variables by using Johansen and Juselius (1990) cointegration test. The utility of this test is related to the determination of the number of cointegrated equations, and is based on the trace statistic. By minimizing the computed value of the Akaike information criterion (AIC), we determine the maximum number of lag length for cointegration test. The cointegrated long-run equation is established for CO_2 emissions dependent variable by using the vector error correction model.

Insert Table 2 here

In Table 2, the Akaike information criterion (AIC), the Schwarz information criterion (SIC) and the Hannan-Quinn (HQ) information criterion mention that the lag length should be equal to one. In addition, the computed Johansen-Juselius cointegration tests indicate that the long-run relationship is established between all our considered variables.

3.3. Long-run parameter estimates

Therefore, it is possible to proceed to estimate the cointegrated equation for CO_2 emissions. The diagnostic tests of the cointegrated equation have been examined based on the serial correlation (Lagrange Multiplier, LM) of the residual and normality test. The results from diagnostic statistics tests reveal that the null hypothesis of no serial correlation in the residuals cannot be rejected at lag one (*LM-stat*=55.83; *p*=0.2336)[1]. The null hypothesis of residuals are multivariate normal is also verified and cannot be rejected[2].

The cointegrating estimation result is given as follows:

$$e_t = -83.27803 - 20.21416 y_t + 1.300942 y^2 - 0.047533 re_t + 0.740653 nre_t + 0.387006 tr_t + 0.361769 agr_t \quad (2)$$

(0.000)*** (0.000)*** (0.000)*** (0.000)*** (0.000)*** (0.000)*** (0.000)***

The long-run estimated coefficients are found to be significant at the 1% level. The long-run elasticity of CO_2 emissions with respect to income is 2.6*y*-20.21. Thus, the inverted U-shaped EKC hypothesis is not verified in the long-run for Tunisia. This result is similar to that of Ben Jebli and Ben Youssef (2015a), but is contrary to the result of Shahbaz et al. (2014). The long-run impact of renewable energy consumption on emissions is negative. Thus, encouraging the use of renewable energy reduces CO_2 emissions and enables Tunisia to contribute in combating global warming. This result is similar to that of Ben Jebli and Ben Youssef (2015a, export model) and Ben Salha and Sebri (2014). The long-run elasticity of non-renewable energy consumption is positive and important because non-renewable energy sources (oil, gas, coal) are very polluting. This result is similar to that of Ben Jebli and Ben Youssef (2015a) and Shahbaz et al. (2014).

Trade openness seems to contribute to global warming as it increases CO_2 emissions. Indeed, more trade openness means more exports and/or imports share of GDP necessitating increased fossil energy to produce, to transport to or from ports, and to consume these traded goods, implying an increase in carbon emissions. This result is similar to that of Chebbi et al. (2011) and Shahbaz et al. (2014). The long-run elasticity of agricultural value added is positive meaning that increasing agricultural production increases CO_2 emissions. This is due to the fact that the agricultural production still uses intensively fossil energy. This also means that, in Tunisia, increasing per capita AVA is not accompanied by an important increase in the energy efficiency or by an important increase in the use of renewable energy in place of fossil energy.

[1] LM-stat denotes the computed statistic value of Lagrange Multiplier test and p indicates the probability of the null hypothesis. Our results show that the null hypothesis of no serial correlation in the residuals cannot be rejected for lags one, two and three.

[2] The null hypothesis of residuals are multivariate normal is verified using Skewness, Kurtosis and Jarque-Bera methods.

3.4. Granger causality

The dynamic short and long-run causal links between our considered variables are investigated by applying the Engle and Granger (1987) two steps method. First, we recuperate the computed residuals after estimating the long-run equation (1). Then, we compute the coefficients associated to the short-run adjustment of Equations (3). The vector error correction model (VECM) is used to distinguish between the short and long-run relationships between analysis variables. Also, the utility of the VECM can identify the sources of causation. The VECM Granger causality method of the time series analysis can be presented as follows:

$$\begin{bmatrix} \Delta e_t \\ \Delta y_t \\ \Delta y_t^2 \\ \Delta re_t \\ \Delta nre_t \\ \Delta tr_t \\ \Delta agr_t \end{bmatrix} = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \\ \beta_7 \end{bmatrix} + \sum_{p-1}^{q} \begin{bmatrix} \delta_{11p} & \delta_{12p} & \delta_{13p} & \delta_{14p} & \delta_{15p} & \delta_{16p} & \delta_{17p} \\ \delta_{21p} & \delta_{22p} & \delta_{23p} & \delta_{24p} & \delta_{25p} & \delta_{26p} & \delta_{27p} \\ \delta_{31p} & \delta_{32p} & \delta_{33p} & \delta_{34p} & \delta_{35p} & \delta_{36p} & \delta_{37p} \\ \delta_{41p} & \delta_{42p} & \delta_{43p} & \delta_{44p} & \delta_{45p} & \delta_{46p} & \delta_{47p} \\ \delta_{51p} & \delta_{52p} & \delta_{53p} & \delta_{54p} & \delta_{55p} & \delta_{56p} & \delta_{57p} \\ \delta_{61p} & \delta_{62p} & \delta_{63p} & \delta_{64p} & \delta_{65p} & \delta_{66p} & \delta_{67p} \\ \delta_{71p} & \delta_{72p} & \delta_{73p} & \delta_{74p} & \delta_{75p} & \delta_{76p} & \delta_{77p} \end{bmatrix} \times \begin{bmatrix} \Delta e_{t-1} \\ \Delta y_{t-1} \\ \Delta y_{t-1}^2 \\ \Delta re_{t-1} \\ \Delta nre_{t-1} \\ \Delta tr_{t-1} \\ \Delta agr_{t-1} \end{bmatrix} + \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \\ \theta_5 \\ \theta_6 \\ \theta_7 \end{bmatrix} ect_{t-1} + \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \\ \mu_{4t} \\ \mu_{5t} \\ \mu_{6t} \\ \mu_{7t} \end{bmatrix} \quad (3)$$

Where Δ denotes the first difference operator, q indicates the number of lag length for VAR model; β_i, θ_i, and μ_{it} (i=1,…,7) are the constant vector, the vector of estimated coefficients of the lagged *ect*, and the vector of residual terms, respectively; ect_{t-1} is the lagged residual term or error correction term which is estimated from the long-run equation. The significance of the lagged residual term is examined using t-statistic to test the existence of long-run relationship between variables. The pairwise Granger causality tests are used to check for the significance of the short-run association among series which is based on the F-statistics. For example, CO_2 emissions may Granger-causes renewable energy consumption (δ_{41p} for all p) and renewable energy consumption may Granger-causes CO_2 emissions (δ_{14p} for all p).

Insert Table 3 here

The results of our Granger causality tests are reported in Table 3. It shows that there are short-run bidirectional causalities between AVA and CO_2 emissions, and between AVA and trade openness. This implies that any change in agricultural production has an immediate impact on CO_2 emissions because agriculture uses intensively fossil energy. In addition, any change in agricultural production has an immediate impact on the trade openness ratio because agricultural products represent an important share of the exported and imported goods in Tunisia. On the other hand, more trade openness gives more possibilities for exporting and importing agricultural products, which has an impact on agricultural production. This result is different from that found by Sebri and Abid (2012) as they show the absence of short-run causality between AVA and trade openness ratio for Tunisia.

There are also short-run unidirectional causalities running from output and non-renewable energy consumption to AVA. The first causality means that agricultural production depends on other economic sectors in Tunisia like the non-manufacturing sector. This goes in line with the finding of Chebbi (2010) who shows the existence of a short-run unidirectional causality running from the non-manufacturing sector to agricultural GDP in Tunisia. The second causality means that any change in the non-renewable energy consumption, in particular in fossil energy consumption, has an immediate impact on agricultural production. Thus, Tunisian authorities should take seriously into account the immediate impact on agriculture of any policy decided to reduce fossil energy consumption for environmental concerns (reduction of CO_2 emissions) or for reducing the importing bills of fossil energy. This result is similar to that of Turkekul and Unakıtan (2011) showing the existence of a unidirectional causality running from agricultural diesel consumption and from agricultural electricity consumption to agricultural GDP. There are also short-run unidirectional causalities running from output, non-renewable energy consumption, and CO_2 emissions to renewable energy consumption. These results are similar to those found by Ben Jebli and Ben Youssef (2015a).

In the long-run, the error correction terms are negative, comprised between -1 and 0, and statistically significant for all dependent variables indicating the existence of long-run bidirectional relationships between all our considered variables. The existence of a long-run bidirectional causality between agricultural value added and renewable energy consumption is a very interesting result because this is the first study focusing on the causal relationships between these two variables. This result means that, in the long-run, any increase in renewable energy consumption can contribute to increase agricultural production, and any increase in this latter, can stimulate renewable energy production and consumption.

4. Conclusion and Policy Implications

This paper uses cointegration techniques and Granger causality tests to investigate the short and long-run relationships between per capita CO_2 emissions, real GDP, square of real

GDP, renewable and non-renewable energy consumption, trade openness and agricultural added value using data on Tunisia for the period 1980-2011. We aim to check for the importance of renewable energy use in the Tunisian agricultural sector. In addition, we evaluate the long-run impact of renewable energy consumption and agricultural production on carbon dioxide emissions.

The long-run association among all our considered variables has been established according to the Johansen-Juselius cointegration test. The long-run equation corresponding to CO_2 emissions as dependent variable is estimated. Our long-run parameter estimates show that the inverted U-shaped EKC hypothesis is not verified for Tunisia. Moreover, more renewable energy consumption reduces CO_2 emissions in the long-run, while more non-renewable energy consumption, trade openness and agricultural value added increase CO_2 emissions in the long-run.

Our results show the existence of short and long-run bidirectional causality between AVA and trade openness indicating a strong causal relationship. Thus, any variation in agricultural value added has an impact on the trade openness ratio because agricultural production represents an important share of the exported and imported goods in Tunisia. Moreover, increasing trade openness gives more opportunities for exporting and importing agricultural goods, which has an impact on agricultural value added.

We also have short and long-run bidirectional causality between agricultural value added and CO_2 emissions indicative of a strong causal relationship. Therefore, any change in AVA has an impact on carbon dioxide emissions because the agriculture sector still uses intensively fossil energy in Tunisia.

All our error correction terms are negative, between -1 and 0, and statistically significant meaning the existence of long-run bidirectional causalities between all our considered variables. In particular, there is long-run bidirectional causality between agricultural value added and renewable energy consumption. Thus, in the long-run, increasing renewable energy consumption can contribute to increase production in the agricultural sector. In the other hand, increasing agricultural value added can stimulate the production and consumption of renewable energy.

Our policy recommendations are the following: *i)* because of the strong causal relationship between agriculture and trade openness and between agriculture and CO_2 emissions, increasing international economic exchanges gives new opportunities to the agricultural sector to develop and to benefit from the technology transfer enabling this sector to use more energy efficient and/or renewable energy technologies. In addition, giving subsidies, as paying a proportion of the equipment for renewable energy production or giving a payment for each unit of renewable energy consumed, enables the agricultural sector to become more competitive in international markets while polluting less and contributing to combat global warming; *ii)* because of the causal relationship between agriculture and renewable energy, encouraging renewable energy use at the national level will certainly impacts agricultural production while becoming more environmentally friendly.

References

Agence de promotion des investissements agricoles, 2015. Accessed at: http://www.apia.com.tn/.

Agence Nationale pour la Maitrise de l'Energie, 2014. Etude sur « le développement de la maîtrise de l'énergie dans le secteur agriculture et pêche ». Accessed at: http://www.anme.nat.tn/index.php?id=111.

Ajmi, A.N., El Montasser, G., Nguyen, D.K., 2013. Testing the relationships between energy consumption and income in G7 countries with nonlinear causality tests. Economic Modeling, 35, 126-133.

Al-Mulali, U., Fereidouni, H.G., Lee, J.Y.M., 2014. Electricity consumption from renewable and non-renewable sources and economic growth: Evidence from Latin American countries. Renewable and Sustainable Energy Review, 30, 290-298.

Ambassade de France en Tunisie, 2013. De l'énergie solaire pour l'agriculture tunisienne. Accessed at: http://www.ambassadefrance-tn.org/De-l-energie-solaire-pour-l.

Ang, J. B., 2007. CO_2 emissions, energy consumption, and output in France. Energy Policy, 35, 4772-4778.

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., Ozturk, I. 2015. Testing Environmental Kuznets Curve hypothesis in Asian countries. Ecological Indicators, 52, 16-22.

Arouri, M.E.H., Ben Youssef, A., M′henni, H., Rault, C., 2012. Energy consumption, economic growth and CO2 emissions in Middle East and North African countries. Energy Policy, 45, 342–349.

Baum, CF., 2004. A review of Stata 8.1 and its time series capabilities. International Journal of Forecasting, 20, 151–161.

Bayrakcı, A.G., Koçar, G., 2012. Utilization of renewable energies in Turkey's agriculture. Renewable and Sustainable Energy Reviews, 16, 618– 633.

Belloumi, M., 2009. Energy consumption and GDP in Tunisia: Cointegration and causality analysis. Energy Policy, 37, 2745-2753.

Ben Jebli, M., Ben Youssef, S., 2015a. 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., 2015b. Output, renewable and non-renewable energy consumption and international trade: Evidence from a panel of 69 countries. Renewable Energy, 83, 799-808.

Ben Jebli, M., Ben Youssef, S., 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.

Ben Salha, O., Sebri, M., 2014. A multivariate analysis of the causal flow between renewable energy consumption and GDP in Tunisia. Economics Bulletin, 34, 2396-2410.

Chebbi, H.E., 2010. Agriculture and economic growth in Tunisia. China Agricultural Economic Review, 2, 63-78.

Chebbi, H.E., Olarreaga, M., Zitouna, H., 2011. Trade openness and CO_2 emissions in Tunisia. Middle East Development Journal, 3, 29-53.

Chouaibi, N., Abdessalem, T., 2011. Causality between electricity consumption and economic growth in Tunisia: policy implications. International Journal of Economic Policy in Emerging Economies, 4, 211–226.

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2013. Réalisations du projet ''Promotion des Energies Renouvelables et de l'Efficacité Energétique en Tunisie''. Bureau de la GIZ à Tunis.

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

Energy Information Administration, 2015. International Energy Outlook. Washington, DC. Available online at: www.eia.gov/forecasts/aeo.

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

Fallahi, F., 2011. Causal relationship between energy consumption (EC) and GDP: a Markov-switching (MS) causality. Energy, 36, 4165-4170.

Fodha, M., Zaghdoud, O., 2010. Economic growth and pollutant emissions in Tunisia: An empirical analysis of the environmental Kuznets curve. Energy Policy, 38, 1150-1156.

Gestore dei Servizi Energetici—GSE S.p.A., 2013. Tunisia, energy country report: focus on electricity sector and renewable energy policies. Rome, Italy.

Halicioglu, F., 2009. An econometric study of CO_2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy, 37, 1156-1164.

Johansen, S., Juselius, K., 1990. Maximum likelihood estimation and inference on cointegration with applications to the demand for money. Oxford Bulletin of Economics and Statistics, 52, 169–210.

Karkacier, O., Goktolga, Z.G., Cicek, A., 2006. A regression analysis of the effect of energy use in agriculture. Energy Policy, 34, 3796-3800.

Mosher, J.N., Corscadden, K.W., 2012. Agriculture's contribution to the renewable energy sector: Policy and economics – Do they add up? Renewable and Sustainable Energy Reviews, 16, 4157– 4164.

Mushtaq, K., Abbas, F., Abdul Ghafour, A., 2007. Energy use for economic growth: cointegration and causality analysis from the agriculture sector of Pakistan. The Pakistan Development Review, 46, 1065–1073.

Ozcan, B., 2013. The nexus between carbon emissions, energy consumption and economic growth in Middle East countries: A panel data analysis. Energy Policy, 62, 1138-1147.

Ozturk, I., Acaravci, A., 2010. The causal relationship between energy consumption and GDP in Albania, Bulgaria, Hungary, and Romania: evidence from ARDL bound testing approach. Applied Energy, 87, 1938-1943.

Phillips, P.C.B., Perron, P., 1988. Testing for a unit root in time series regressions. Biometrika, 75, 335-346.

Réseau International d'Accès aux Energies Durables, 2008. Tunisie : perspectives d'utilisation des énergies renouvelables dans le domaine agricole. Accessed at: http://www.riaed.net/?Tunisie-perspectives-d-utilisation.

Sadorsky, P., 2009a. Renewable energy consumption, CO2 emissions and oil prices in the G7 countries. Energy Economics, 31, 456-462.

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

Sadorsky, P., 2011. Trade and energy consumption in the Middle East. Energy Economics, 33, 739-749.

Sadorsky, P., 2012. Energy consumption, output and trade in South America. Energy Economics, 34, 476-488.

Sebri, M., Abid, M., 2012. Energy use for economic growth: A trivariate analysis from Tunisian agriculture sector. Energy Policy, 48, 711-716.

Shahbaz, M., Tiwari, A.K., Nasir., M., 2013. The effects of financial development, economic growth, coal consumption and trade openness on CO_2 emissions in South Africa. Energy Policy, 61, 1452-1459.

Shahbaz, M., Khraief, N., Uddin, G.S., Ozturk, I., 2014. Environmental Kuznets curve in an open economy: A bounds testing and causality analysis for Tunisia. Renewable and Sustainable Energy Reviews, 34, 325-336.

Tugcu, C.T., Ozturk, I., Aslan, A., 2012. Renewable and non-renewable energy consumption and economic growth relationship revisited: Evidence from G7 countries. Energy Economics, 34, 1942-1950.

Turkekul, B., Unakitan, G., 2011. A co-integration analysis of the price and income elasticities of energy demand in Turkish agriculture. Energy Policy 39, 2416–2423.

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

Zivot, E., Andrews D., 1992. Further evidence of great crash, the oil price shock and the unit root hypothesis. Journal of Business and Economic statistics, 10, 251-270.

Tables

Table1. Unit root tests

	Variables	ADF test stat				P-P test stat			
		level	**k**	**1st diff**	**k**	**level**	**k**	**1st diff**	**k**
Intercept	*e*	-0.268925	1	-8.441873***	0	-0.113379	5	-13.72853***	8
	y	1.146994	0	-5.217786***	0	1.256863	1	-5.242012***	2
	y2	2.215941	0	-5.047280***	0	3.840873	6	-5.061808***	2
	re	-2.830858	0	-5.513023***	4	-2.733232	3	-12.91049***	18
	nre	-1.742645	0	-6.492349***	0	-1.742645	0	-6.698651***	2
	tr	-1.265131	0	-5.458426***	0	-1.265131	0	-5.467096***	3
	agr	-1.151362	0	-4.224980***	5	-0.742477	3	-7.393801***	3
Intercept and trend	*e*	-4.137897	0	-8.298604***	0	-4.116991	1	-14.01226***	9
	y	-2.153446	0	-5.842640***	0	-2.152306	2	-5.844605***	3
	y2	-3.056323	0	-6.872260***	0	-1.280855	2	-10.60516***	15
	re	-3.397663	1	-5.320194***	4	-3.450839	5	-12.75406***	18
	nre	-2.157570	0	-5.549784***	1	-2.046168	2	-6.784323***	3
	tr	-2.572331	0	-5.622784***	0	-2.510221	3	-5.800366***	5
	agr	-1.799552	0	-4.471889***	5	-1.392158	5	-15.77769***	8

Zivot-Andrews unit root test

Variables	level		1st diff	
	t-stat	**time break**	**t-stat**	**time break**
e	-4.928553	2000	-8.499234**	1987
y	-4.336216	1986	-6.873070*	1989
y^2	-3.697687	1988	-7.346539*	1989
re	-4.687232	1988	-5.886407*	1994
nre	-4.174116	1997	-7.009394**	1993
tr	-3.620435	1988	-6.867955**	1990
arg	-5.726551	1988	-1.926277*	2003

Notes:*, **, *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

ADF and P-P denote augmented Dickey-Fuller and Phillips-Perron, respectively. k is the lag length based on the Schwarz information criterion (SIC).

Table2. VAR Lag length selection and Johansen- Juselius cointegration test

a. Lag length selection

Number of Lag	LogL	LR	AIC	SIC	HQ
1	350.4407	NA	-21.53148	-19.20012*	-20.81876
2	409.5947	59.15398	-22.25676*	-17.59405	-20.83132*

b. Johansen- Juselius cointegration test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value
None [a]	0.934558	97.88121	95.75366
At most 1	0.747383	66.63623	69.81889
At most 2	0.686928	39.23861	47.85613
At most 3	0.569154	20.36134	29.79707
At most 4	0.448476	34.15672	29.79707
At most 5	0.279848	17.49477	15.49471
At most 6	0.256599	0.699781	3.841466

Notes: * indicates the number of lag selected. a indicates the rejection of the hypothesis at the 5% level. LogL=Log likelihood, LR= Log likelihood ratio, AIC=Akaike information criterion, SIC= Schwarz information criterion, and HQ=Hannan-Quinn information criterion.

Table 3. Granger causality tests

	Short-run						**Long-run**
Variables	Δe	$\Delta y, \Delta y^2$	Δre	Δnre	Δtr	Δagr	**ECT**
Δe	-	11.7210	0.18772	0.32864	0.51512	4.16422	-0.089538
		(0.0020)***	(0.6683)	(0.5712)	(0.4791)	(0.0534)*	[-2.12825]**
$\Delta y, \Delta y^2$	2.75522	-	1.51526	3.69860	0.04678	0.73413	-0.052614
	(0.1085)		(0.2286)	(0.0647)*	(0.8303)	(0.4900)	[-3.40570]***
Δre	5.15308	5.48792	-	7.38819	2.61259	0.49483	-0.186412
	(0.0314)**	(0.0265)**		(0.0111)**	(0.1172)	(0.6155)	[-2.46042]**
Δnre	1.03327	1.09714	0.60159	-	0.15012	0.15754	-0.438302
	(0.3184)	(0.3039)	(0.4445)		(0.7014)	(0.8551)	[-2.36784]**
Δtr	3.93248	5.51039	2.40265	1.13619	-	4.52940	-0.288616
	(0.0576)*	(0.0262)**	(0.1324)	(0.2956)		(0.0210)**	[-2.60044]**
Δagr	9.04029	5.47085	0.18072	4.52088	2.90074	-	-0.594452
	(0.0012)**	(0.0107)**	(0.8357)	(0.0211)**	(0.0991)*		[-4.17361]***

Notes:*, **, *** indicate statistical significance at the 10%, 5% and 1% levels, respectively. P-values are listed in parentheses.

Figures

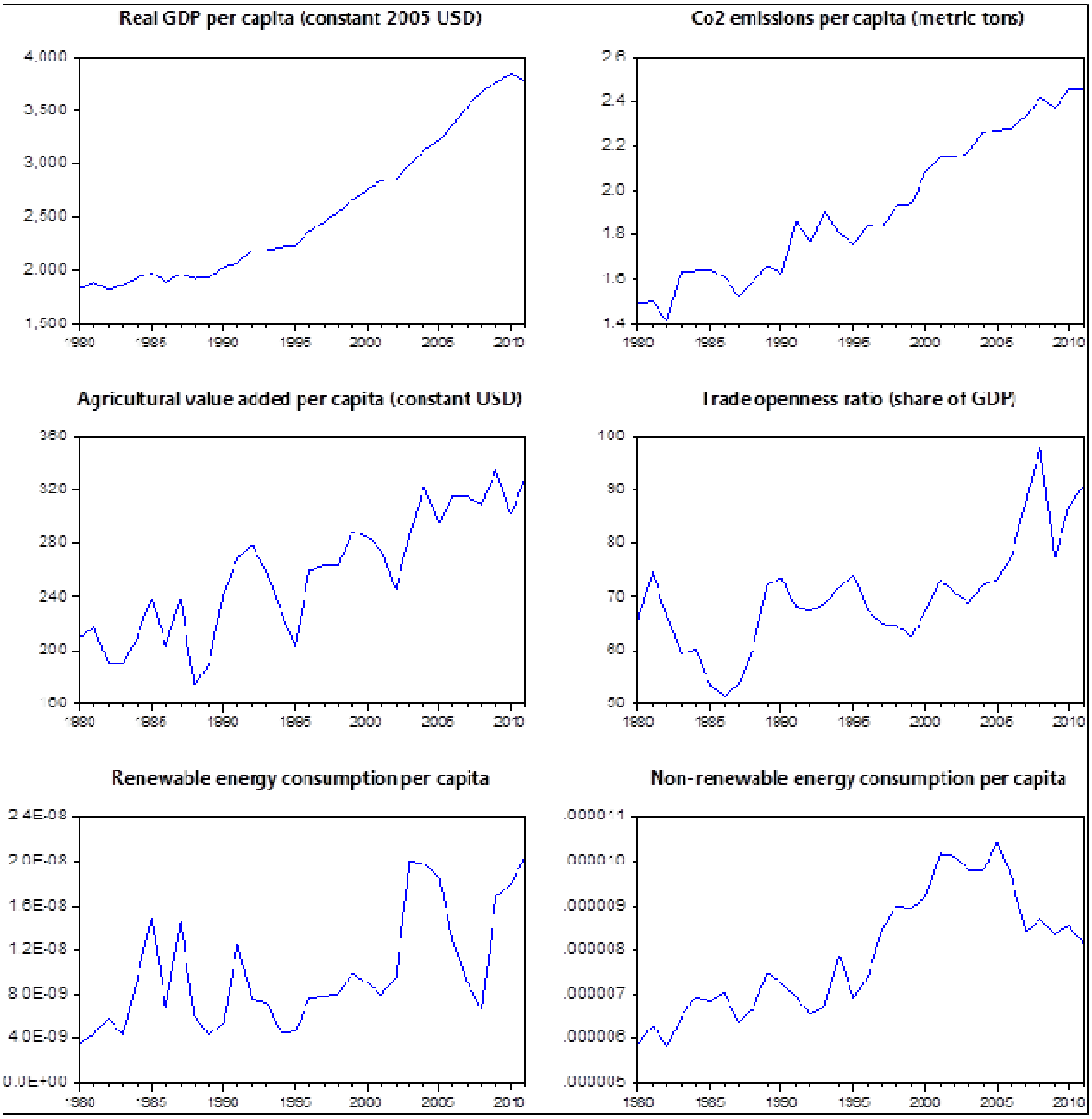

Figure 1. Plots of the variables considered between 1980 and 2011.