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Abstract: The autoregressive distributed lag (ARDL) bounds approach to cointegration and Granger causality tests are used to investigate the dynamic short and long-run causality relationships between per capita renewable energy (RE) consumption, carbon dioxide (CO_2) emissions, real gross domestic product (GDP), agricultural value added (AVA), and arable land use (LUSE) for the case of Morocco during the period 1980-2013. Two models are used: the first with the AVA variable, and the second with the LUSE variable. The Wald test confirms the existence of a long-run relationship between variables for each considered model. Our long-run estimates indicate that an increase in economic growth, agricultural production, and arable land use contribute to increase the use of renewable energy, while a decrease in CO_2 emissions increases renewable energy consumption. Granger causality tests reveal the existence of a short-run unidirectional causality running from AVA and from LUSE to RE consumption; a long-run unidirectional causality running from LUSE to RE, and a long-run bidirectional causality between AVA and RE. We recommend that Morocco should continue to encourage renewable energy use because this latter is not in competition with agricultural production for land use, but rather it is a complementary activity.

Keywords: Autoregressive distributed lag; Granger causality; renewable energy; agricultural value added; arable land use; Morocco.

JEL classifications: C32; O55; Q15 ; Q42 ; Q54.

1. Introduction

It is largely accepted that renewable energy is a cleaner and unlimited energy source with beneficial effects on the environment, economic growth, employment, etc. However, some types of renewable energy like solar or wind need large land surfaces which could be used for agricultural production. Thus, it is interesting to know whether renewable energy production and agricultural production are in competition for land use or not. The causal relationship between land use and renewable energy production has not been studied before, and this is the main objective of this paper. We choose Morocco as a case study because this country is among the top countries which have realized considerable efforts in renewable energy production during the last decade.

1.1. Renewable energy in Morocco

In 2011 Morocco imported 95.6% of its energy consumption. Petroleum imports represented 20% of the country's imports and 50% of the trade deficit (World Future Council, 2015). The energy mix of Morocco is dominated by oil (67.6%), followed by Coal (16.1%), biofuels and waste (7.4%), natural gas (5.7%), net imports of electricity (2.2%), hydropower (0.7%), and wind (0.3%) (International Energy Agency, 2014). The demand for energy, particularly electric power, is in a steady rising because of economic growth, industrialization, and a growing population. Energy imports impact Morocco's trade balance negatively, while energy subsidies are a burden for national economy. Thus, the transition to more renewable energy is extremely beneficial for this country on the environmental, economic, and social sides.

The last decades, political decisions at the top level have been taken to move Morocco towards a green economy. Morocco has ratified the Kyoto Protocol in 2002, and in 2009 the National Plan to Combat Climate Change set the first targets for reducing greenhouse gas (GHG) emissions. Among these decisions we can cite (International Energy Agency, 2014): *i)* the diversification of the energy mix, especially in electricity, mainly by encouraging renewable energy production; *ii)* opening the power sector to foreign investment; *iii)* reduce progressively subsidies for fuel; *iv)* encouragement of energy efficiency. This would increase the country's energy independence and reduce GHG emissions. In addition, a legal and institutional framework has been established to provide support for energy efficiency and renewable energy. We can cite the Agency for the Development of Renewable Energy and Energy Efficiency, the Moroccan Agency for Solar Energy, and the Institute for Research in to Renewable and Solar Energies.

In fact, Morocco is now aware about its geography extremely favorable to both wind and solar power, and has set very ambitious programs. Kousksou et al. (2015) present the renewable energy potential in Morocco and its national policy directions for sustainable development. The overall target of 2 GW wind power, 2 GW solar power, and an increase to 2 GW hydropower capacity by 2020 are its objectives. This will make renewables represent 42% of electrical power by 2020, save 2.5 million tons of oil-equivalent (Mtoe) in fossil fuels, and avoid the emission of nearly 9 million tons (Mt) of carbon dioxide (CO_2) (International Energy Agency, 2014). On February 4, 2016, one of the world's largest solar farms, Noor I, situated near the desert was inaugurated. It has a production capacity of 160 MW and is the first unit of a giant solar farm which should produce more than 500 MW of solar energy in 2018 and provide electricity for one million households. Its construction began in 2013, has cost of more than €600 million, and is financed by a public-private and local-foreign partnerships (COP 21).

1.2. Agriculture in Morocco

In Morocco, agriculture represents 15% of gross domestic product (GDP), 23% of exports, employs 46% of the total workforce and 80% of the rural workforce. The third of the production is transformed and grain production dominates and covers 60% of the needs in average. This sector uses 18.7% of the total energy consumed in 2010 and is responsible of a great proportion of GHG emissions (United Nations Economic Commission for Africa, Office for North Africa, 2015).

The Green Morocco Plan (Plan Marocain Vert, PMV) is a multidimensional approach for inclusive and environmentally-compliant agriculture. It is planned for 2008-2020 and aims to make the agricultural sector a major force for economic growth and for poverty reduction by increasing its GDP, exports, and job creation. The PMV aims to expand efficient and high value added agriculture by transferring agricultural lands owned by the State to national or foreign private operators for long period lease up to 40 years. This plan also aims to remove a number of constraints in the agricultural sector such as financing, access to land, and farm size (farm areas can reach 2000 ha), and to promote risk sharing, skills transfer, and trade capacity. On the environmental level, the PMV is consistent with the national water strategy for developing the use of efficient irrigation water systems. In this respect, thousands of hectares have been equipped with drip irrigation systems, and thousands of photovoltaic pumping systems have been installed. The PMV's large financing needs have been realized by special funds like the Agricultural Development Fund, the involvement of national banks like the Crédit Agricole du Maroc, international financial partners, and private investors (United Nations Economic Commission for Africa, Office for North Africa, 2015).

Our paper has the following structure. Section 2 is a literature review. Section 3 is for data and descriptive statistics. Section 4 deals with the empirical methodology, econometric results and their discussion. Finally, Section 5 concludes with policy recommendations.

2. Literature review

To the best of our knowledge, there is no econometric study focusing on the causal relationships of renewable energy consumption and/or agricultural production and/or land use with other economic variables for the case of Morocco. However, there are some non-econometric studies concerned by renewable energy in Morocco (de Arce et al., 2012; Fritzsche et al., 2011; Kousksou et al., 2015). We divide our literature review in that concerned by renewable energy, that concerned by energy consumption and agriculture, and that concerned by renewable energy and agriculture or by renewable energy and land use.

2.1. Renewable energy

There is a rich literature, not concerned by the Morocco case, interested by the causal relationships between renewable energy and other economic variables as gross domestic product, emission of pollution, or labor force (Al Mulali et al. , 2016a; Apergis and Payne, 2010b, 2011; Ben Jebli, 2016; Ben Jebli and Ben Youssef, 2015; Ben Jebli et al., 2015; Dogan, 2016; Menyah and Wolde-Rufael, 2010; Pao and Fu, 2013a; Sadorsky, 2009b; Tugcu et al., 2012). Apergis and Payne (2010a) investigate the causal relationships between renewable energy, economic growth, capital, and labor for a panel of twenty OECD (organization for economic cooperation and development) countries. They prove the existence of short and long-run bidirectional causalities between renewable energy consumption and GDP. Pao and Fu (2013b) study the relationships between economic growth and different types of energy resources in Brazil. They come to the conclusion of short and long-run negative bidirectional causality between fossil fuels and new renewables indicative of substitutability between these two energy resources. Omri et al. (2015) consider a panel of 64 countries and show that the dynamic panel data model provides more efficient estimators than the static one. In addition, renewable energy consumption is mainly driven by CO_2 emissions and trade with foreign partners. However, they find that oil prices have limited effects on renewable energy consumption.

2.2. Energy and agriculture

Many econometric studies have investigated the relationship between energy consumption and agriculture (Dogan et al., 2016; Karkacier et al., 2006; Mushtaq et al., 2007; Rafiq et al., 2016; Shahbaz et al., 2016; Tang and Shahbaz, 2013). The relationship between per capita energy consumption (diesel, electricity) for agriculture, agricultural GDP, and the prices of energy in Turkey are investigated by Turkeful and Unakitan (2011). They find a unidirectional causality running from electricity consumption and diesel to agricultural GDP. In addition, diesel and electricity consumption increase in the long-run when agricultural GDP is increased. These authors advise continued encouragement to energy consumption for Turkish farmers in order to increase competitiveness of Turkish agricultural products in the international market, and equilibrate farmers' income.

Sebri and Abid (2012) study for the case of Tunisia the causal relationships between agricultural value added (AVA), energy (oil, electricity) consumption, and trade openness. Short and long-run unidirectional causality running from total energy and from oil energy to AVA is proved. In addition, a long-run unidirectional causality running from AVA to oil consumption occurs. They advise to manage carefully shocks to energy supply because energy is a limiting factor to agricultural production. Qureshi et al. (2016) examines the impact of energy demand, air pollution, fossil fuel energy, and GHG emissions on agricultural production in Pakistan. Their results show that CO_2 emissions have a positive impact on AVA, while energy sources have a negative impact on AVA. Moreover, GHG emissions badly affect agricultural production including cotton, wheat, and rice productions, while energy consumption exerts a positive impact on cotton, wheat, and rice productions. These authors recommend reinforcing farmers' education on new agricultural practices that enables them to increase agricultural productivity.

2.3. Renewable energy-agriculture, Renewable energy-land use

Few studies have been interested by renewable energy consumption and agriculture (Ben Jebli and Ben Youssef, 2016, 2017a, 2017b). Ben Jebli and Ben Youssef (2017a) investigate the short and long-run relationships between per capita CO_2 emissions, GDP, renewable and non-renewable energy consumption, trade openness, and AVA in Tunisia. They prove the existence of long-run bidirectional causalities between all considered variables, and short-run bidirectional causalities between agricultural production and pollution emissions, and between agricultural production and trade openness. Their long-run parameter estimates confirm that non-renewable energy, international trade, and AVA increase CO_2 emissions, whereas renewable energy consumption reduces it. Finally, they advise subsidizing renewable energy use in the agricultural sector to help this sector becoming more competitive on the international markets, while being less polluting. Our present research differs from these papers concerned by renewable energy and agriculture by the fact that we introduce the variable land use to be able to study the causal relationships between these three variables suspected to be in a close relationship, and essentially to know whether renewable energy and agriculture are in competition for land use or not.

To the best of our knowledge, Al Mulali et al. (2016b) is the only econometric study interested by the relationship between renewable energy production and land use. These authors study the impact of renewable energy production on water and land footprint for a panel of 58 developed and developing countries. Their results show that economic growth, urbanization, and trade openness have a harmful effect on water and land use because they increase the water and land footprint. In addition, renewable energy production increases the water and land inefficiency. Moreover, the square of renewable energy production shows that, in the future, renewable energy production will continue to increase water and land footprint. These authors recommend for these countries to replace current renewable energy technologies with new ones that improve water and land use efficiency. Our paper differs from Al Mulali et al. (2016b) study mainly by integrating the agricultural value added variable. In addition, these authors have not studied the causal relationships between renewable energy and land use, while we do this in our paper, and we evaluate the impact of land use on renewable energy consumption, while this question has not been investigated by these authors.

3. Data and descriptive statistics

Data on Morocco are collected to get the maximum number of observations according to their availability and cover the period 1980-2013. The annual data set include: *i)* per capita renewable energy (RE) consumption measured in billion kilowatt hours (kWh), and comprises all types of renewable electricity consumption; *ii)* per capita carbon dioxide emissions measured in metric tons; *iii)* real GDP per capita measured in constant 2010 US $; *iv)* per capita agricultural value added measured in constant 2010 US $. Agriculture includes livestock production, cultivation of crops, forestry, hunting, and fishing. Adding up all outputs and subtracting intermediate inputs of a sector gives its value added (net output); and *v)* per capita arable land use (LUSE) measured in hectares. Arable land comprises land temporary fallow, under temporary crops, temporary meadows for mowing or for pasture, and land under market or kitchen gardens. Land abandoned because of shifting cultivation is excluded. To get the per capita unit, the selected data on AVA and RE consumption are divided by the population number. Data on renewable energy consumption are collected from the US Energy Information Administration (2016) and all the other data, including those concerning population numbers, are collected from the World Bank (2016). All data are converted into natural logarithms prior to conducting empirical analysis.

Insert Figure 1 Here

Figure 1 presents the tendency of our primary variables of interest for Morocco over the period 1980-2013. The progress of all series has a trend upward across time except for per capita arable LUSE plot which is characterized by a nearly constant declining across the selected period of time. This could be explained by productivity increase for agricultural land because at the same time we have a trend upward for per capita agricultural value added. In fact, there is a negative variation rate of 36% between 1980 and 2013 for per capita arable land use, while at the same period per capita agricultural value added (in constant 2010 US $) has proven a fluctuating growth with an overall increase of 87.9%. Within the same period, per capita GDP (in constant 2010 US $) has increased of 131.3% equivalent to an annual average increase of 3.98%. This respectable economic growth was possible by an increase in fossil energy use. Indeed, per capita CO_2 emissions have increased of 120.4% meaning an annual average rate increase of 3.6% between 1980 and 2013. To mitigate climate change, Morocco has also realized a fluctuating growth of per capita renewable energy consumption equal to 61.9% between 1980 and 2013 equivalent to an annual average increase of 1.87%.

4. Empirical methodology, econometric results, and discussion

This paper tries to study the causal relationships between per capita renewable energy consumption, arable land use, agricultural value added, real GDP, and CO_2 emissions for the case of Morocco. We will also try to evaluate the long-run elasticity of each variable, and particularly arable land use and of agricultural production, on renewable energy consumption. Our empirical analysis follows four steps: *i)* testing the stationary proprieties of each variable by using the Zivot and Andrews (1992) unit root test with structural break; *ii)* the autoregressive distributed lag (ARDL) bounds approach of Pesaran et al. (2001) is considered to check for cointegration between variables; *iii)* the short and long-run elasticities consistent with each cointegrated equation are estimated by using the ordinary least square (OLS) method; and *iv)* Granger causality tests are employed in order to illustrate the direction of causalities between variables.

4.1.Zivot and Andrews's unit root test

The order of integration of our considered variables are examined at level and after first difference by using the Zivot and Andrews (1992) unit root test with structural break. This latter appears to be more efficient than oldest stationary tests such as Dickey and Fuller (1979) (ADF-Fisher) and Phillips and Perron (1988) (P-P Fisher) because it provides more information about structural break properties and might help policy makers to supply economic recommendations. The null hypothesis suggests that the series is non-stationary with one-time break point, while the alternative hypothesis suggests that the series is stationary with one-time break point. Three different unit root test models have been developed by Zivot and Andrews statistics tests: the first model reveals that, at level, there is a one-time change in the variable; the second model suggests that there is a one-time change in the trend coefficient; and the third model allows that there is a one-time change in both intercept and deterministic trend.

Insert Table 1 Here

The results of the Zivot and Andrews's unit root test with structural break indicate that, at level, all variables are non-stationary except the LUSE variable. However, after first difference, all the variables are stationary except the LUSE variable. Therefore, RE consumption, CO_2 emissions, real GDP, and AVA variables are integrated of order one, i.e. I(1), while the arable LUSE variable is integrated of order zero, i.e. I(0).

4.2. ARDL cointegration test

Several cointegration methods in the macroeconomic literature considered the long-run association between considered variables. The two steps procedure of Engle and Granger (1987), Johansen (1988), Johansen and Juselius (1990) based on full information maximum likelihood, and Stock and Watson (1993) based on dynamic OLS involve that series should be integrated at the same order. These methods do not provide good results for small samples and require large samples. Numerous empirical readings have employed the ARDL bounds approach to check for cointegration between variables and realized that it provides very interesting results. The advantages of the ARDL approach can be summarized as follows: (*i*) the series can be either integrated of order zero or one, or even fractionally integrated; (*ii*) the short and long-run parameters are estimated with the same model; and (*iii*) it provides powerful estimates even with small sample size. For all these reasons, we choose the ARDL method to examine the long-run cointegration between our considered variables.

We consider two models. The first one considers per capita RE consumption, CO_2 emissions, real GDP, and AVA variables. The second one considers per capita RE consumption, CO_2 emissions, real GDP, and arable LUSE variables.[1] The representations of the ARDL equations are modeled as follows:

$$\Delta RE_t = \alpha + \sum_{i=1}^{q} \alpha_{1i} \Delta RE_{t-i} + \sum_{i=1}^{q} \alpha_{2i} \Delta GDP_{t-i} + \sum_{i=1}^{q} \alpha_{3i} \Delta CO_{2t-i} + \sum_{i=1}^{q} \alpha_{4i} \Delta AVA_{t-i} \\ \alpha_5 RE_{t-1} + \alpha_6 GDP_{t-1} + \alpha_7 CO_{2t-1} + \alpha_8 AVA_{t-1} + \varepsilon_t \quad (1)$$

$$\Delta RE_t = \theta + \sum_{i=1}^{q} \theta_{1i} \Delta RE_{t-i} + \sum_{i=1}^{q} \theta_{2i} \Delta GDP_{t-i} + \sum_{i=1}^{q} \theta_{3i} \Delta CO_{2t-i} + \sum_{i=1}^{q} \theta_{4i} \Delta LUSE_{t-i} \\ \theta_5 RE_{t-1} + \theta_6 GDP_{t-1} + \theta_7 CO_{2t-1} + \theta_8 LUSE_{t-1} + \omega_t \quad (2)$$

Where Δ and (ε, ω) are the first difference operator and error terms, respectively. The parameter q denotes the number of lags. For the two equations, the joint significance of long-run relationships between selected variables is tested by using the Fisher statistics of the Wald test. The null hypothesis assumes that the long-run estimated coefficients of the lagged variables are not jointly significant, while the alternative hypothesis suggests that the estimated coefficients of the lagged variables are jointly significant. The optimum number of lag length is estimated by using various criteria which are Likelihood ratio sequential modified test statistic (LR), final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SIC), and Hannan-Quinn information criterion (HQ). In our case, the optimum number of lags will be considered by using only the AIC and SIC criteria.

The long-run relationships between the selected variables are tested by using the advanced ARDL bounds approach to cointegration of Pesaran et al. (2001). This statistic is established based on the joint significance of long-run estimated coefficients. The null hypothesis of no long-run cointegration for each equation ($\alpha_5 = \alpha_6 = \alpha_7 = \alpha_8$; $\theta_5 = \theta_6 = \theta_7 = \theta_8$), against the alternative hypothesis of long-run cointegration ($\alpha_5 \neq \alpha_6 \neq \alpha_7 \neq \alpha_8$; $\theta_5 \neq \theta_6 \neq \theta_7 \neq \theta_8$). The

[1] It is not possible to consider AVA and LUSE variables in the same model. Indeed, if we consider only one model comprising the five variables (RE, AVA, LUSE, CO_2, and GDP), then the Wald test and the ECT would be statistically not significant, implying the absence of cointegration between the five considered variables.

estimated F-statistic of the Wald test will be then compared to two terminal critical values: the lower critical value assumes that series are integrated of order zero, i.e. I(0), and the upper critical value assumes that series are integrated of order one, i.e. I(1). Thus, three assumptions can be considered to conclude this investigation. If the computed value of the F-statistic is higher than the upper critical value, then the null hypothesis of no cointegration is rejected. If the computed F-statistic falls between the lower and upper critical values, then the result is inconclusive. In this case, we estimate the vector error correction model (VECM) to test the significance of the error correction term (ECT) for the long-run cointegration. Finally, if the computed value of the F-statistic is lower than the lower critical value, then the null hypothesis of no cointegration is not rejected. After estimating these statistics, we check for the residual diagnostic tests concerning serial correlation, heteroscedasticity, and normality.

Insert Tables 2a and 2b Here

Given that our analysis variables are stationary at level or after first difference, then the optimal number of lags for the vector autoregressive (VAR) model is required. The optimal lag selection criteria results are reported for both models in Tables 2a and 2b. For the model with AVA, with two as a maximum number of lags, the AIC suggests that the optimal number of lags is equal to 2. For the model with LUSE, the AIC discloses that the optimal number of lags is also equal to 2. Thus, we adopt a VAR (p=2) for both models.

Insert Table 3 Here

The results from the Wald test are reported in Table 3. The computed Fisher statistics of the Wald test are statistically significant for both models. In fact, for the model with AVA variable, the estimated Fisher statistic is equal to 3.819 confirming that per capita renewable energy consumption, CO_2 emissions, real GDP, and AVA are statistically cointegrated at the 10% significance level. For the model with LUSE variable, the estimated Fisher statistic is equal to 5.886 indicating that per capita renewable energy consumption, CO_2 emissions, real GDP, and LUSE variables are statistically cointegrated at the 1% significance level. These results are due to the fact that the computed values of the Wald statistics are higher than the lower and upper bounds values. The number of lags two suggested by the AIC criterion is sufficient, and has selected an ARDL (2, 0, 0, 0) and (2, 0, 1, 0) for the models with AVA and LUSE variables, respectively.

4.3. ARDL elasticities and their stability

In this step, we run the ARDL models presented in equations 1 and 2 by using the OLS method to estimate the short and long-run elasticity of parameters where renewable energy consumption is the dependent variable. Parameter estimates of the model with per capita AVA, real GDP, and CO_2 emissions as independent variables are reported in Table 4a, and those of the model with per capita arable LUSE, real GDP, and CO_2 emissions as independent variables are reported in Table 4b.

Insert Tables 4a, 4b, and 5 Here

For both models, all short and long-run estimated coefficients of the independent variables are statistically significant, except the short-run coefficient of CO_2 emissions for the model with arable LUSE. The residual diagnostic tests corresponding to each model are reported in Table 5. Accordingly there are no serial correlation, no heteroscedasticity, and residuals are normally distributed. For the model with AVA, in the long-run, a 1% increase in per capita real GDP increases per capita RE consumption by 7.29%, a 1% increase in per capita AVA increases per capita RE consumption by 4.02%, and a 1% increase in per capita CO_2 emissions decreases per capita RE consumption by 3.17%. The second model shows that a 1% increase in arable LUSE increases per capita RE consumption by 7.71%, in the long-run.

It appears clearly that economic growth boosts renewable energy production and consumption in Morocco. We can explain this by the fact that economic growth needs energy and particularly renewable energy. In addition, economic growth enables to provide the necessary investments needed for renewable energy production, distribution, and consumption. This result is similar to that established by Sadorsky (2009a) for the panel of G7 countries (Canada, France, Germany, Italy, Japan, United Kingdom, the United States of America) and that of Omri et al. (2015) concerned by a panel of 64 countries.

Agricultural production has itself a positive effect on renewable energy consumption. Indeed, the production of agricultural goods necessitates energy and more precisely renewable energy. Moreover, an increase in agricultural value added enables farmers and/or the government to acquire the necessary investments for renewable energy production and consumption. This result is opposite to that found by Ben Jebli and Ben Youssef (2016) showing that increasing agricultural value added reduces combustible renewables and waste (CRW) consumption in Brazil. They explain their result by the fact that agricultural and CRW productions are substitute activities in Brazil.

Carbon dioxide emissions reductions seem to increase renewable energy consumption. This can be explained by the substitute roles played by renewable energy and fossil energy in Morocco. Indeed, a reduction in CO_2 emissions signifies a reduction in fossil energy consumption. This finding is similar to that of Ben Jebli and Ben Youssef (2016) showing that a decrease in CO_2 emissions increases CRW consumption in Brazil. However, our result is contrary to that of Salim and Rafiq (2012) obtained for the cases of Brazil, India, China, and Indonezia, that of Sadorsky (2009a) obtained for the panel of G7 countries, and that of Omri et al. (2015) obtained for a panel of 64 countries.

Interestingly, an increase in arable land use increases also renewable energy consumption. Thus, there is not a competition between agricultural and renewable energy productions for land use in Morocco, but rather there is complementary. We can justify this result by the fact that more arable land use induces more agricultural production necessitating more renewable energy for production purposes. This constitutes a new and interesting result because this is the first research evaluating the impact of land use on renewable energy. We notice that Al Mulali et al. (2016b) study on 58 developed and developing countries showed that renewable energy production increases land inefficiency.

Insert Figures 2 and 3 Here

The estimate of the short and long-run coefficients should be examined in terms of stability because the existence of long-run cointegration between variables does not mean necessarily that the estimated coefficients are stable. The stability of the estimated coefficients is verified by using the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUM of Squares) statistical tests developed by Brown et al. (1975). When the plots of these statistics fall inside the critical bounds of 5% significance, we conclude that the estimated coefficients of a given regression are stable. These statistical tests are more powerful than any other tests (e.g. Hansen and Johansen, 1993) because they do not require the integration order to be equal to one. Fig. 2 and 3 show that the CUSUM and CUSUM of Squares of our estimated coefficients are well within the 5% critical bounds. This confirms that our computed coefficients are stable.

4.4. Granger causality tests

To investigate the short and long-run dynamic causal links between selected variables, we employ the Engle and Granger (1987)'s two steps procedure. The first step consists in the estimate of the long-run coefficients in order to recuperate the residuals. The second step estimates the parameters related to the short-run adjustment. The pairwise Granger causality test (Fisher-statistic) is considered to investigate the short-run relationships between variables, while the long-run relationships between variables are examined by using the significance of the error correction terms (t-student statistic) corresponding to each equation. The VECM representation of the long-run equations is given as follows:

$$\Delta RE_t = \phi_1 + \sum_{i=1}^{p} \phi_{11i} \Delta RE_{t-i} + \sum_{i=1}^{p} \phi_{12i} \Delta GDP_{t-i} + \sum_{i=1}^{p} \phi_{13i} \Delta CO_{2t-i} + \sum_{i=1}^{p} \phi_{14i} \Delta X_{t-i} + \tau_1 ECT_{t-1} + \zeta_{1t} \quad (3)$$

$$\Delta GDP_t = \phi_2 + \sum_{i=1}^{p} \phi_{21i} \Delta RE_{t-i} + \sum_{i=1}^{p} \phi_{22i} \Delta GDP_{t-i} + \sum_{i=1}^{p} \phi_{23i} \Delta CO_{2t-i} + \sum_{i=1}^{p} \phi_{24i} \Delta X_{t-i} + \tau_2 ECT_{t-1} + \zeta_{2t} \quad (4)$$

$$\Delta CO_{2t} = \phi_3 + \sum_{i=1}^{p} \phi_{31i} \Delta RE_{t-i} + \sum_{i=1}^{p} \phi_{32i} \Delta GDP_{t-i} + \sum_{i=1}^{p} \phi_{33i} \Delta CO_{2t-i} + \sum_{i=1}^{p} \phi_{34i} \Delta X_{t-i} + \tau_3 ECT_{t-1} + \zeta_{3t} \quad (5)$$

$$\Delta X_t = \phi_4 + \sum_{i=1}^{p} \phi_{41i} \Delta RE_{t-i} + \sum_{i=1}^{p} \phi_{42i} \Delta GDP_{t-i} + \sum_{i=1}^{p} \phi_{43i} \Delta CO_{2t-i} + \sum_{i=1}^{p} \phi_{44i} \Delta X_{t-i} + \tau_4 ECT_{t-1} + \zeta_{4t} \quad (6)$$

Where Δ represents the first difference operator; p denotes the VAR lag length; X indicates either AVA or LUSE variables; ECT_{t-1} indicates the lagged ECT corresponding to each equation; τ measures the speed of adjustment from the short to the long-run equilibrium; ζ_t denotes the residual term.

Insert Tables 6a and 6b Here

Short and long-run causal relationships are reported in Tables 6a and 6b. For the model with AVA, the lagged ECT coefficients are comprised between -1 and 0 and are statistically significant for RE consumption and AVA equations. This indicates the existence of a long-run causality running from CO_2 emissions, real GDP, and AVA to RE consumption and from RE consumption, CO_2 emissions, and real GDP to AVA. For the model with LUSE, the lagged ECT coefficients are comprised between -1 and 0 and are statistically significant for RE consumption and real GDP equations. This means that there is long-run causality running from CO_2 emissions, real GDP, and LUSE to RE consumption and from RE consumption, CO_2 emissions, and LUSE to real GDP.

For both models, there is a short-run bidirectional causality between carbon emissions and GDP and between RE consumption and GDP because fossil fuels and renewable energy are needed for economic growth. These results are in concordance with those of Apergis et al. (2010) obtained for a panel of 19 developed and developing countries. There is also a short and long-run unidirectional causality running from CO_2 emissions to RE consumption indicative of substitutability between fossil and renewable energy sources in Morocco. This finding is similar to that of Menyah and Rufael (2010) study on the United States and that of Shafiei and Salim (2014) study on OECD countries, but it differs from that of Salim and Rafiq (2012) who find a bidirectional causality between CO_2 emissions and renewable energy consumption for the cases of Brazil, India, China, and Indonezia.

For the model with AVA variable, there is short-run bidirectional causality between GDP and AVA simply because agricultural production is good for economic growth and that this latter enables to provide the necessary inputs for the former. This result is different from that of Ben Jebli and Ben Youssef (2017a) showing the existence of a short-run unidirectional causality running from GDP to AVA in Tunisia. In addition, we find a short-run unidirectional causality running from carbon emissions to AVA because fossil fuels consumption has an immediate impact on agricultural production. This result is different from that reached by Ben Jebli and Ben Youssef (2017a, 2017b) where it is proved the existence of short-run bidirectional causality between CO_2 emissions and AVA for the cases of Tunisia and of a panel of North Africa countries. We also have a short-run unidirectional causality running from AVA to RE consumption meaning that agricultural production has an immediate impact on renewable energy production and consumption in Morocco. This result is different from that reached by Ben Jebli and Ben Youssef (2017a) where it is shown no short-run causality between RE and AVA in Tunisia. Finally, we have a long-run bidirectional causality between RE consumption and AVA implying that renewable energy production has an impact on agricultural production in the long-run in Morocco.

For the model with arable LUSE variable, we show the existence of a short-run bidirectional causality between GDP and LUSE meaning that economic growth has an impact on arable lands used and vice versa. This can be explained by the fact that economic development enables to increase the productivity of arable lands and thus to decrease the per capita arable LUSE, in the short-run. We also show the existence of a short and long-run unidirectional causality running from LUSE to RE consumption. This can be explained by the fact that when more arable lands are used, agricultural production is increased necessitating more renewable energy consumption in both the short and long-run. These results are new and interesting because, to the best of our knowledge, there is no previous study on the causal relationships between land use and economic growth, or between land use and renewable energy consumption.

5. Conclusions and policy implications

This paper tries to investigate the dynamic short and long-run relationships between per capita renewable energy consumption, CO_2 emissions, real GDP, and agriculture (AVA or arable LUSE) for the case of Morocco. We use two models: the first comprises agricultural value added variable and the second comprises the arable land use variable. For each model, the dependent variable is renewable energy consumption. We employ the ARDL bounds approach and Granger causality tests by using data spanning the period 1980-2013. The Zivot and Andrews unit root test with structural break shows that variables are integrated of order 0 or 1, i.e. are I(0) or I(1). For both models, the Fisher statistics of the Wald test confirm the existence of a long-run cointegration between considered variables.

Our long-run parameters estimates prove that economic growth and agricultural production boost renewable energy production and consumption in Morocco because they need energy and especially renewable energy, and enable to provide the required investments for renewable energy production, distribution, and consumption. A diminution in carbon dioxide emissions increases renewable energy consumption meaning that renewable energy and fossil energy are substitute in Morocco. Indeed, a reduction in fossil energy consumption signifies a reduction in CO_2 emissions.

Interestingly, an increase in arable land use has a positive impact on renewable energy consumption. Therefore, there is a complementary between agricultural and renewable energy productions for land use in Morocco, and not a competition. This can be justified by the fact that more arable land use induces more agricultural production requiring more renewable energy for production purposes. This result is new and interesting because, to the best of our knowledge, this is the first econometric research evaluating the impact of land use on renewable energy.

We find a short-run unidirectional causality running from AVA to RE consumption signifying that agricultural production has an immediate impact on renewable energy production and consumption in Morocco. We also have long-run bidirectional causality between AVA and RE consumption meaning that renewable energy production has a long-run impact on agricultural production in Morocco. In addition, there is a short and long-run unidirectional causality running from LUSE to RE consumption indicating that more arable land use has an impact on renewable energy consumption even in the short-term.

In view of our empirical findings, agricultural and renewable energy productions are not in competition for land use in Morocco but rather are complementary because increasing agricultural production and/or arable land use increases renewable energy consumption in the long-run. We no longer need to worry about whether renewable energy production might discourage agricultural production, or vice versa. Morocco should continue to encourage the production and use of renewable energy because this has a beneficial impact on economic growth, agricultural production, and the environment.

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Tables

Table 1. Zivot and Andrews unit root test results

Variables	level		1st diff	
	t-stat	time break	t-stat	time break
RE	-5.493962	2005	-5.041754**	1991
CO_2	-3.338877	2004	-6.944400*	1996
GDP	-3.787503	1993	-14.05239***	1991
AVA	-4.208775	1992	-7.325703**	1991
LUSE	-2.942872**	2004	-8.561371	1994

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

Table 2a. VAR lag selection order criteria (model with AVA)

Lag	Log L	LR	FPE	AIC	SIC	HQ
0	109.8318	NA	1.58e-08	-6.614490	-6.431273	-6.553759
1	218.7270	183.7607*	4.79e-11	-12.42044	-11.50436*	-12.11678*
2	236.8358	26.03137	4.42e-11*	-12.55224*	-10.90329	-12.00566

Notes: * indicates the lag order selected by the criterion; Log L: Log Likelihood; LR: sequential modified Likelihood ratio test statistic; FPE: Final prediction error; AIC: Akaike information criterion; SIC: Schwarz information criterion; HQ: Hannan-Quinn information criterion. All statistics are tested at the 5% significance level.

Table 2b. VAR lag selection order cirteria (model with LUSE)

Lag	Log L	LR	FPE	AIC	SIC	HQ
0	105.5402	NA	2.06e-08	-6.346263	-6.163046	-6.285531
1	199.1602	157.9837*	1.63e-10	-11.19751	-10.28143*	-10.89385*
2	217.3790	26.18961	1.49e-10*	-11.33619*	-9.687236	-10.78961

Notes: * indicates the lag order selected by the criterion; Log L: Log Likelihood; LR: sequential modified Likelihood ratio test statistic; FPE: Final prediction error; AIC: Akaike information criterion; SIC: Schwarz information criterion; HQ: Hannan-Quinn information criterion. All statistics are tested at the 5% significance level.

Table 3. Fisher (F)-statistics tests for cointegration

Estimated model	Bounds testing to cointegration	Lag criteria		F-statistics	Conclusion
	optimal lag length	AIC	SIC		
F(*RE*, CO_2, *GDP*, *AVA*)	(2, 0, 0, 0)	0.564567	0.839393	3.818915*	Cointegration
F(*RE*, CO_2, *GDP*, *LUSE*)	(2, 0, 1, 0)	0.576303	0.839393	5.886110***	Cointegration

Critical values bounds

Significance	I_0 bound	I_1 bound
10%	2.72	3.77
5%	3.23	4.35
2.5%	3.69	4.89
1%	4.29	5.61

Notes: ***, * indicate statistical significance at the 1% and 10% levels, respectively. F(.) denotes the computed Fisher statistics for the autoregressive distributed lag model. All Fisher statistics are computed with unrestricted intercept. Akaike information criterion (AIC) and Schwarz information criterion (SIC) are the selected lag criteria. Critical values bounds are provided by Pesaran et al. (2001).

Table 4a. Short and long-run estimates (model with AVA)

Variables	Coefficient	Std. Error	t-Statistic	Prob.
Long-run coefficients				
GDP	7.291378	2.054882	3.548320	0.0015***
CO_2	-3.170233	1.525022	-2.078811	0.0476**
AVA	4.025160	2.288079	1.759187	0.0903*
c	-67.100267	14.119442	-4.752332	0.0001***
Short-run coefficients				
D(RE(-1))	0.274470	0.139617	1.965874	0.0601*
D(GDP)	5.572410	1.280675	4.351150	0.0002***
$D(CO_2)$	-2.422839	1.048826	-2.310049	0.0291**
D(AVA)	3.076214	1.671462	1.840433	0.0771*
CointEq.(-1)	-0.764246	0.148883	-5.133209	0.0000***

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

Table 4b. Short and long-run estimates (model with LUSE)

Variables	Coefficient	Std. Error	t-Statistic	Prob.
Long-run coefficients				
GDP	4.210314	2.054882	2.130815	0.0440**
CO_2	-2.746851	1.661934	-1.82804	0.0876*
LUSE	7.709739	4.451878	1.731795	0.0967*
C	-67.100267	14.119442	-4.752332	0.0001***
Short-run coefficients				
D(RE(-1))	0.398397	0.154104	2.585240	0.0165**
D(GDP)	5.798401	1.367082	4.241442	0.0003***
$D(CO_2)$	-2.018318	1.184762	-1.703564	0.1019
D(LUSE)	5.664925	3.126787	1.811740	0.0831*
CointEq.(-1)	-0.734775	0.148384	-4.951858	0.0001***

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

Table 5. Residual diagnostic tests results

Diagnostic tests	Model with AVA	Model with LUSE
R-squared	0.743516	0.761349
Adjusted R-squared	0.676607	0.711630
S.E. of regression	0.281899	0.266197
Durbin-Watson stat	2.101814	2.032661
Breusch-Godfrey serial correlation LM test	0.5584 (0.5804)	0.474359 (0.6285)
Heteroscedasticity test (ARCH)	0.0133 (0.9091)	0.621117 (0.6850)
Normality test (JB)	1.7931 (0.4079)	1.146125 (0.5638)

Notes: p-values are presented in parenthesis.

Table 6a. Granger causality results (model with AVA)

	Short-run				Long-run
Variables	ΔRE	ΔCO_2	ΔGDP	ΔAVA	ECT
ΔRE	-	8.74751 (0.0060)***	9.05735 (0.0053)***	3.11251 (0.0879)*	-0.843174 [-3.61991]***
ΔCO_2	0.03697 (0.9638)	-	4.84201 (0.0246)**	0.27185 (0.6059)	-0.024677 [-0.43186]
ΔGDP	3.33581 (0.0778)*	4.41601 (0.0432)**	-	23.4577 (0.0000)***	-0.023390 [-0.43311]
ΔAVA	0.07130 (0.7913)	15.2370 (0.0005)***	20.2472 (0.0001)***	-	-0.816052 [-2.81428]***

Notes: ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. T-statistics are presented in brackets and p-values are presented in parenthesis.

Table 6b. Granger causality results (model with LUSE)

	Short-run				Long-run
Variables	***ΔRE***	***ΔCO₂***	***ΔGDP***	***ΔLUSE***	**ECT**
ΔRE	-	8.74751 (0.0060)***	9.05735 (0.0053)***	8.47190 (0.0067)***	-0.740446 [-3.76747]***
ΔCO₂	0.03697 (0.9638)	-	4.84201 (0.0246)**	0.24962 (0.6210)	-0.003391 [-0.22205]
ΔGDP	3.33581 (0.0778)*	4.41601 (0.0432)**	-	8.68207 (0.0062)***	-0.238459 [-5.03026]***
ΔLUSE	0.47400 (0.4964)	2.14795 (0.1532)	3.17198 (0.0850)*	-	-0.062685 [-0.39501]

Notes: ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. T-statistics are presented in brackets and p-values are presented in parenthesis.

Figures

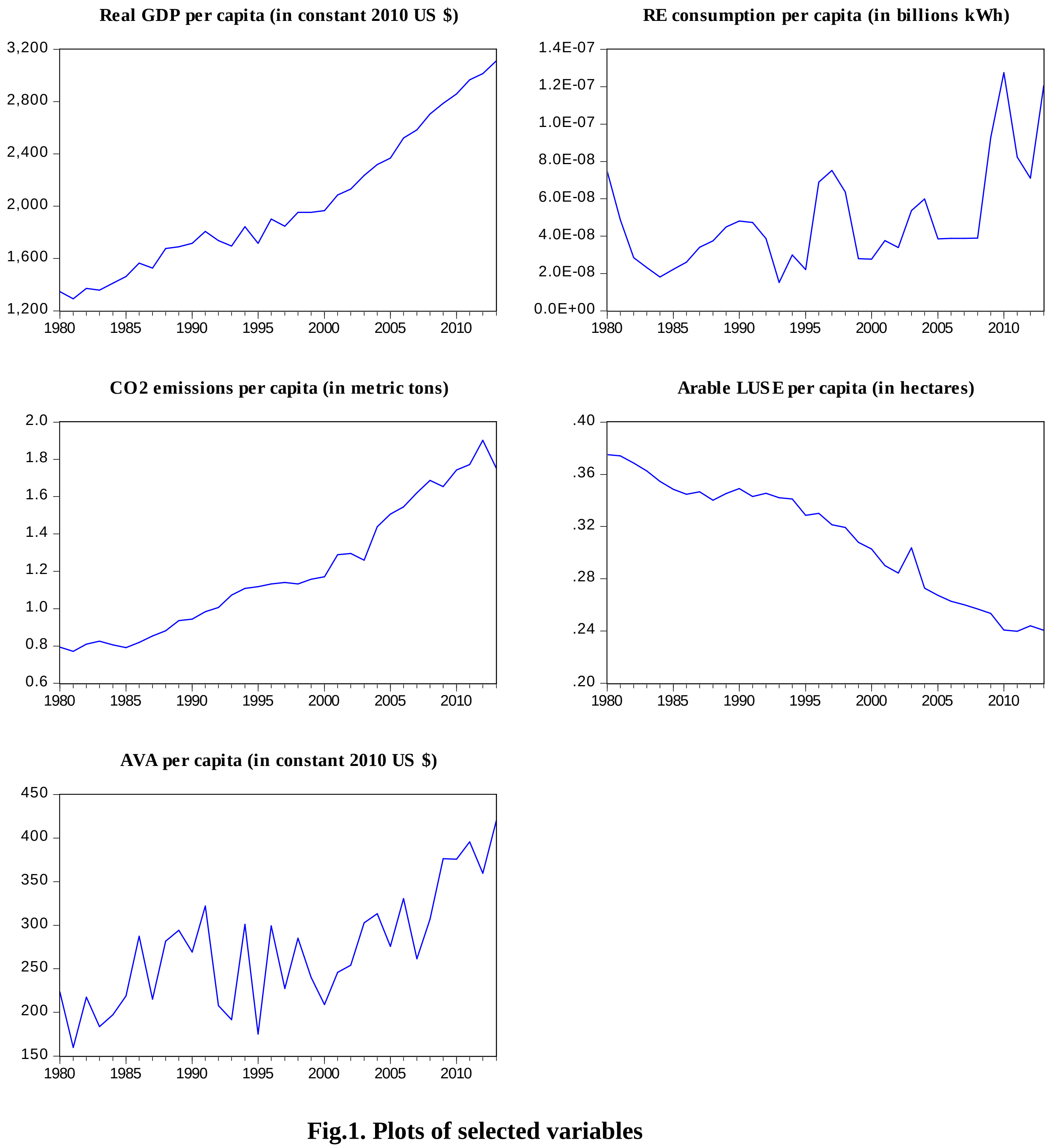

Fig.1. Plots of selected variables

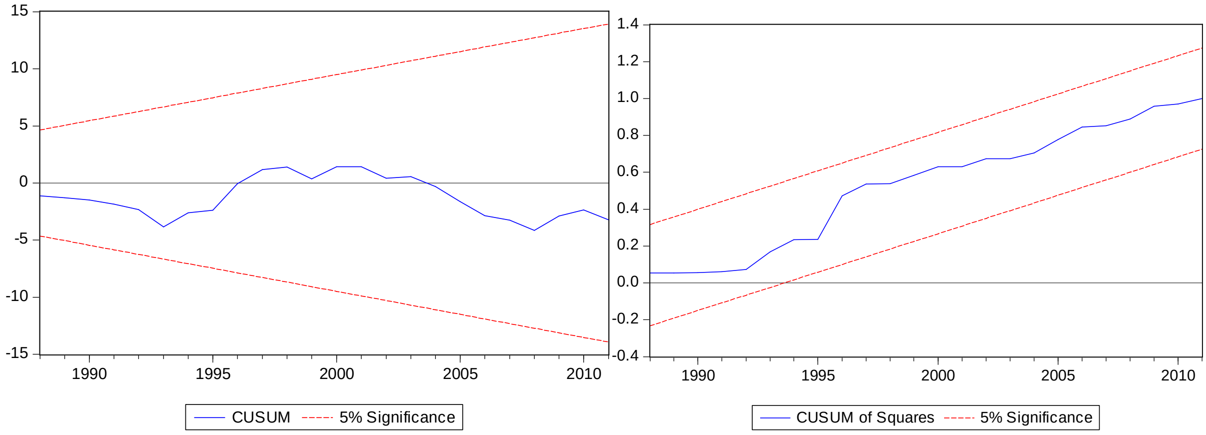

Fig.2. CUSUM and CUSUM of Squares of recursive residuals (model with AVA)

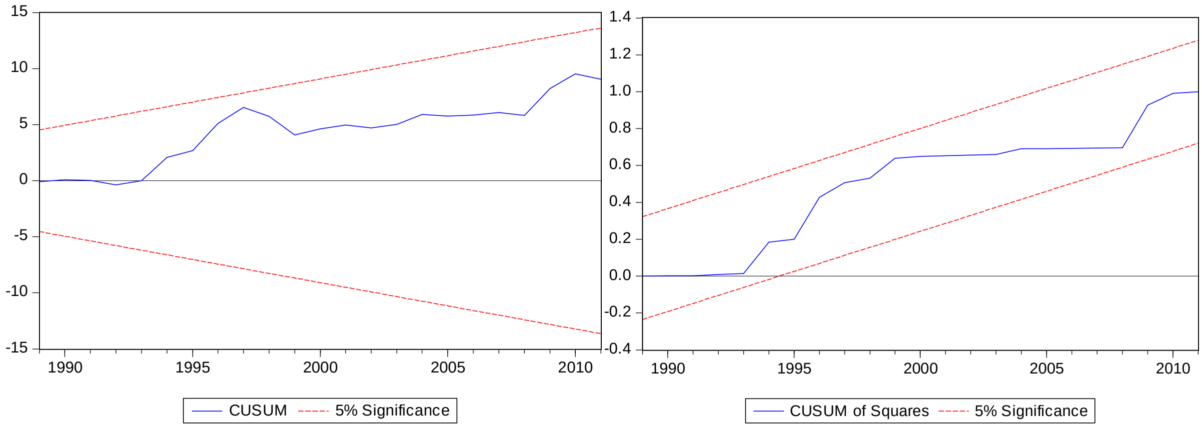

Fig.3. CUSUM and CUSUM of Squares of recursive residuals (model with LUSE)