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LONG RUN VERSUS SHORT RUN ANALYSIS OF CLIMATE CHANGE IMPACTS ON AGRICULTURE

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Abstract

In this paper, we propose an original empirical investigation of the long run versus short run impacts of climate change on the Tunisian agriculture sector. We find that annual temperature decreases both cereals and date production with an exception in highland areas. In addition, annual rainfall has a positive effect on cereals but its shortages in the south negatively affect production in this region. The short run climate effect is smaller than the long run effect. Rainfall has a weak positive effect which is compensated by the threat of the brutal temperature increase during the last decades. This paper calls for the implementation of a public policy privileging and subsidizing the threatened areas.

JEL Classification: Q5

Keywords: Climate change impacts, date and cereals crop, panel co-integration, error correction model

ملخص

في هذه الورقة نقترح تحقيقا تجريبيا على المدى الطويل مقابل المدى القصير لآثار تغير المناخ على قطاع الزراعة التونسي. نجد أن درجة الحرارة تقلل سنويا من إنتاج الحبوب و التمور باستثناء المناطق المرتفعة. وبالإضافة إلى ذلك، فان الأمطار السنوية لها تأثير إيجابي على إنتاج الحبوب ولكن نقص هذه الامطار فى الجنوب تؤثر سلبا على الإنتاج في هذه المنطقة. تأثير المناخ على المدى القصير هو أقل من تأثيره على المدى الطويل. فان هطول الأمطار له أثر إيجابيا لكنه ضعيف الا ان هذا الضعف يعوض عن طريق خطر ارتفاع درجة الحرارة خلال العقود الماضية. وتدعو هذه الورقة لتنفيذ سياسة عامة لتفضيل ودعم المناطق المهددة.

1. Introduction

Climate and weather play a major role in agricultural productivity. They determine the types of crops grown by farmers and even the yield during harvesting time because of the alteration in the patterns of rainfall, temperature and radiation among other weather elements. According to Mendelsohn et al. (1994), analytical and empirical arguments maintain that climate changes lead to declining agricultural productivity. Fischer et al. (2001) predicted that 29 African countries faced an imminent aggregate loss of 35 million tons of their potential cereal production as a result of anticipated climate change. The impact of climate change on crop productivity could have multiplier effects. First, with increased temperatures and evapotranspiration, more water will be required for crop production. If this is not accompanied by an increase in precipitation, then the country is likely to experience an eminent crop failure in most parts. Second, rising temperatures have also been associated with increased disease incidence in many countries. The agriculture sector in all the MENA countries is not an exception from this disastrous situation.

In Tunisia for example, the agricultural sector represents about 20 % of employment and 12% of GDP. Therefore, understanding the impact of climate change on agricultural crops is instrumental for decision makers before deciding to subsidize the affected farmers or switching to irrigated agricultural activities. Tunisia, which belongs both to Mediterranean and sub-Saharan countries, has an attractive geographical position. Consequently, the South of Tunisia, given its Saharan nature, is affected by both its geographical position and the climate warming. However, the North of Tunisia benefits from a Mediterranean climate characterized by a hot and dry summer and a relatively rainy winter. Given this diverse climate, we will intuitively try for the moment, before confirmation by objective analysis based on empirical investigations, to explain the long-run weather and climate impacts. Indeed, temperature is expected to negatively affect cereals and date yields at least in the southern regions which are characterized by dry climate. However, rainfall and precipitations are expected to have positive impact on agricultural production. According to Fisher and Velthuizen (1996), plausible positive effects of temperature can be witnessed in mountainous areas. Otherwise, long- term lack of rainfall can affect the southern regions which suffered a real drought during the last three decades. Moreover, climate data on Tunisia, gathered during the 20th century, indicate increased heating of the climate, estimated at more than 1°C, with a pronounced trend in the past 30 years. While the country experienced one drought every 10 years at the beginning of the century, currently it suffers five or six years of drought per ten years.

The link between climate change and agricultural productivity has seen, during the last three decades, an active research in applied econometrics on environmental and agricultural economics. Most of these studies have been done in developed countries, mainly in Europe and in the United States. We will mention some for the sake of illustration: (Lang (2007), Lippert et al. (2009), Fisher et al. (2002), Schlenker et al. (2006), Adams et al. (1995), Adams et al. (1998), Rosenzweig (1993), Rosenzweig et al. (1994) Rosenberg et al. (1994)). Unfortunately there is very little research done on the MENA countries. Thanks to this intensive research many results have been reported but a lot of others are waiting more imaginations and hard work. We want to mention some of the thorniest among them here. As the use of real climate and agriculture data are more useful than data generated by experimental methods, What is the right data aggregation level to choose?, What is the right econometric tool to take care of the real specificity of climate and agriculture variables? Should we estimate static or dynamics effects of climate change on agriculture during the last century?

The main objective of this paper is to extend and improve results of the preceding work done on Europe and the United-States by the application of recent econometric techniques on the

Tunisian regional data base. This extension requires that we look for the appropriate econometric tools and explicitly take care of the deep Tunisia structural transformation. The first step of our work will be the analysis of the data and conduction of the necessary tests to see if a structural change has happened. We will then use the panel co-integration technique, which integrates explicitly the non stationary character of our panel data, to derive the estimates for the long run weather effects having the right properties and finally try to propose the appropriate policy recommendations. Section 2 will present a brief constructive literature review, and then the third section will present a description of the original climate database. The new econometric techniques, which have been extensively developed during the last period and on which we will rely, are briefly surveyed in section 4. The empirical investigation, as well as the comments and the analysis of the main results forms section 5. Finally we conclude with the policy recommendations.

2. An Overview of the Literature

It is expected that globally 20% of all damages of climate change will occur in the agricultural sector and so understanding the vulnerability of climate and weather patterns is a crucial part for estimating future climate change impacts. These changes have been considered as a major source of consensus between researchers on environmental economics during the last three decades. The long-term change in mean temperature, rainfall and precipitation has gradually been recognized as an additional factor which will have, with other conventional constraints, a significant weight on the form, scale, and spatial and temporal impact on agricultural productivity. The general consensus to emerge from the growing body of literature is that in the absence of adequate response strategies to long term climate change as well as to climate variability, diverse and region specific impacts will become more apparent. According to Rosenzweig et al. (2002), climate change is expected to result in long-term water and other resource shortages, drought and desertification, disease and pest outbreaks on crops and livestock as well as a rise in sea-levels. Consequently, vulnerable areas are expected to experience losses in agricultural productivity, primarily due to reductions in crop yields. The global welfare changes in the agriculture sector are approximated between losses of $61.2 billion and gains of $0.1 billion (Reilly et al., 1994). Under the most severe scenarios of climate change, losses are omnipresent (see studies by Rosenzweig et al. (1993), Rosenzweig and Parry (1994), Darwin et al. (1995) and Adams and Hurd (1999)). Water shortages which are accompanied by short rainy seasons are now the norm in most developing countries. Experts predict a spatial shift of crops and agricultural production, and estimation results indicate 24 percent losses in production in the developed countries and 16 percent in developing countries. Many papers have attempted during the last three decades to understand the link between climate change and agricultural production. Many of these studies were conducted in developed countries and especially in the United-States and Europe; unfortunately little work is done about developing countries which are the most affected by climate change. Change in temperature and precipitation will have varying impacts on agriculture, Fisher and Velthuizen (1996), in studying the climate change impact on Kenya, find that higher temperatures would have a positive impact in highland areas. Downing (1992) shows that in western Kenya, an increase in temperature by 2.5° C will lead to an increase of 67 percent in high potential land. Indeed, the main focus of these studies was the identification of adaptation mechanisms to climate change scenarios. But why has adaptation been successful in some instances and not in others? This is one of the major concerns of the related literature.

Several methods are used in order to understand the effects of climate change on agricultural production. Quantitative studies on impacts of climate change have mainly based on experimental and cross-sectional studies. The experimental technique which includes agro-economic simulation models was applied by Parry et al. (1988) and Adams et al. (1988). The agronomic approach was criticized by Mendelsohn et al. (1994) and Mendelsohn and Dinar (1999) who argue that the mentioned approach overestimates damage. This method (controlled experiments), which is characterized by a higher implementation costs, was primarily used to estimate impacts on grains (Adams et al. 1998). Moreover, recent studies apply the Ricardian analysis as an economic approach in focusing on efficient adaptation. These studies try to capture the effect of climatic, environmental, and economic factors on farm income and land values (see Mendelsohn et al. 1994). However, the Ricardian approach was criticized because it cannot fully control the impact of important variables that could explain the evolution of farm incomes and this can underestimate damages and overestimate benefits (Cline, 1996).

Many results are derived from several crop simulation studies. These results argue that an evolution in mean temperature or rainfall will be accompanied by an evolution in agricultural production or productivity. For instance, an increase by 2°C in minimum temperature will reduce rice yield in India at the rate of 0.71 ton per hectare while a 1°C rise in mean temperature would have no significant effect on wheat yields (Aggarawal and Sinha, 1993). Hulme et al. (1999) argue that in 100 years Africa could be on average 2-6°C warmer which will certainly affect global agricultural production. As researches improve, developing countries and particularly the poorest countries will not be able to avoid the impact of climate change which are manifested in several scenarios including higher temperatures, drought and main rainfall decrease.

The use of Ricardian approach and controlled experiments, which are criticized given their limitations, is not sufficient from an empirical point of view. However, the econometric technique, which allows for the estimation of the real relationship between climate change and agricultural production and productivity using real historical data base, has been neglected in the literature. The gain from using econometric technique is in its ability to draw a true picture of the reality by exploring real and not experimental data. In light of these findings, this article aims at expanding the existing literature in two ways. First of all, the aim of this paper is to demonstrate that the effect of long-term climate change measured by rainfall and temperature on agriculture is a real threat. The second originality of this article is to analyze variability in climate change impacts among heterogeneous 24 regions in Tunisia using disaggregated data. To our knowledge, no published paper used this recent technique in studying climate change impacts.

3. Data Description and Analysis

The empirical analysis is based on twenty four regions in Tunisia, namely Tunis, Ariana, Benarous, Manouba, Elkef, Kesrine, Béja, Seliana, Mednine, Tataouine, Kebili, Nabeul, Tozeur, Gafsa, Gabes, kairouan, Sidibouzid, Bizerte, Zaghouan, Sousse, Monastir, Mahdia, Jendouba, and Sfax. The time dimension of the panel data covers the period 1979-2011. Data on cereals production, annual rainfall and temperature are collected for the entire sample. However, data on date production are collected for a longer period beginning from 1976 and only for the south region (Gabes, Gafsa, Tataouine, Tozeur and kebeli), which naturally monopolize date production thanks to its Saharan climate. This novel and rich data base was provided by the Tunisian Ministry of Agriculture and Water Resources and the National Institute of Meteorology. The variables were converted into natural logarithmic form before the empirical analysis.

The Tunisian agricultural sector employs more than 20% of the labor force. Moreover, it represents 11.5% of the gross national product and because it is an important part of Tunisian exports it ensures a source of foreign currency. Thus, the Tunisian agriculture sector should not be neglected in the development plan and policy makers are invited to seriously protect this sector given the climate change impacts. Policy makers should correctly anticipate future climate change and hence reduce the expected negative impacts or they should improve investment decisions (e.g. irrigation, precision of early warning systems). Cereals and dates are the two important fields which represent more than 50% of the agricultural output in Tunisia. These are expected to be the most affected by climate change and weather conditions.

As we see from the descriptive statistics in table 1, the maximum value of cereals production corresponds to the maximum of rainfall in the same region (Elkef), we anticipate a positive relationship between these two variables at least in this region. However, the long run negative relationship is expected between temperature and date production because we observe a coincidence between the two maximum values of these variables in the same region (Gafsa).

During the last century, Tunisian climate variables indicate two seasons per year. As we see from the World Bank data, the average monthly rainfall and temperature are characterized by a biannual behavior. The monthly mean historical rainfall and temperature data can be mapped to show the baseline climate and seasonality by month, for specific years, and for rainfall and temperature. The chart below shows mean historical monthly temperature and rainfall for Tunisia during the time period 1960-1990.

4. Econometric Method

We begin by testing the panel unit roots then we implement the Seven tests proposed by Pedroni (1999) to obtain the long term relation between all the variables. Then, we use the full-modified OLS (FMOLS) technique to estimate the cointegration vector for heterogeneous cointegrated panels, which correct the standard OLS for the bias induced by the endogeneity and serial correlation of the regressors.

4.1. Panel unit root test

The Levin, Lin and chu test (LLC hereafter) is the founder work in nonstationary panel data literature. Like the ADF test in time series, LLC tests the null hypothesis of □$\delta = 0$□ for all i, against the alternative of $\delta < 0$ in the following equation:

$$\Delta y_{it} = \delta \mathrm{y}_{\mathrm{i,t-1}} + \sum_{l=1}^{P_i} \theta_{\mathrm{ip}} \Delta y_{i,t-1} + \alpha_{mi} d_{mt} + u_{it}$$

Where $d_{1t} = \emptyset$, $d_{2t} = \{1\}\ and\ d_{3t} = \{1, t\}$ are used to define the three ADF cases.

LLC propose a three-step procedure to implement their test. The adjusted statistic used here is:

$$\mathrm{t}_{\delta}^{*} = \frac{\mathrm{t}_{\delta} - \mathrm{N} \times \mathrm{std}(\delta) \times \mu_{\mathrm{m}\tilde{\mathrm{T}}}^{*} \times \hat{\sigma}_{\tilde{\varepsilon}}^{-2} \times \hat{\mathrm{S}}_{\mathrm{N}} \times \tilde{\mathrm{T}}}{\sigma_{\mathrm{m}\tilde{\mathrm{T}}}^{*}} \sim N(0,1)$$

With $\frac{\sqrt{N}}{T} \to 0.$

Where $\hat{\mathrm{S}}_{\mathrm{N}}$, $\mu_{\mathrm{m}\tilde{\mathrm{T}}}^{*}$ and $\sigma_{\mathrm{m}\tilde{\mathrm{T}}}^{*}$ are respectively the average standard deviation ratio calculated in the second step, the mean and standard deviation adjustments simulated by the authors for different order of m and time series dimension $\tilde{\mathrm{T}}$ (Levin and al. 2002)

The Im, Pesaran and Shin (2003) (IPS after) test is formulated by the LLC equation when m=2 and δ_i varies across individual cross-sectional units.

Thus, IPS tests the null hypothesis of $\delta_i = 0$ for all I, against the alternative of $\delta_i < 0\ for\ i = 1, \dots, N_1$ and $\delta_i = 0\ for\ i = N_1$ +1,…,N.

With $N_1 \in \left]0, N\right[$, $such\ as\ \lim_{N \to \propto}({}^{N_1}/_{N}) = \delta\ where\ 0 \leq \delta \leq 1$.

If $N_1 = 0$, we find the null hypothesis.

IPS propose to use the average of the individual ADF statistics defined as:

$$\bar{\mathbf{t}}_{\mathbf{NT}} = \frac{1}{N}\sum_{i=1}^{N} \mathbf{t}_{\mathbf{iT}}\,(\boldsymbol{P_i}, \boldsymbol{\beta_i})$$

$t_{iT} = (P_i, \beta_i)$ is the individual student statistic associate to the null hypothesis for a given lag order P_i and a vector of ADF coefficients.

$$\boldsymbol{\beta_i} = (\boldsymbol{\beta_{i,1}}, \boldsymbol{\beta_{i,2}}, \ldots, \boldsymbol{\beta_{i,p_i}})'$$

IPS (2003) use the standard normal statistic Z.

$$\bar{\boldsymbol{Z}} = \left[\sqrt{\boldsymbol{N}}\,\frac{(\bar{t}_{NT} - E(t_{iT}))}{\sqrt{var(t_{iT})}}\right] \xrightarrow[N \to \infty]{} \mathbf{N(0,1)}$$

Where the terms $E(t_{iT})$ and $var(t_{iT})$ are, respectively, the mean and variance of each statistic, and they are generated by simulations and are tabulated in IPS (1997).

4.2 Pedroni's panel cointegration test

After testing for stationarity of the variables, we turn to test for the existence of a long-run relationship among the variables. We apply the residual-based method developed by Pedroni [1999] where the cointegration rank is a priori known and equal to one. Thus, to test for the null of no cointegration in heterogeneous panels with multiple regressors, Pedroni (1999) considers the following regression;

$$y_{it} = \alpha_i + \delta_i\, t + \beta_{1i}x_{1,it} + \beta_{2i}x_{2,it} + \ldots\ldots + \beta_{Mi}\, x_{M,it} + \varepsilon_{it}$$

Where $i = 1, \ldots\ldots, N$, $t = 1, \ldots\ldots, T\ and\ m = 1, \ldots\ldots\ldots, M$.

T, N and M refer to the time series dimension, the number of cross sectional regions and the number of regression variables, respectively. Pedroni [1999] develops asymptotic and finite sample properties of testing statistics to examine the null hypothesis of non-cointegration in the panel. The tests allow for heterogeneity among individual members of the panel.

On the seven tests suggested by Pedroni, four are based on the within-dimension and three on the between-dimension. The two categories examine the null hypothesis of no cointegration in the panel. The first approach includes four statistics. They are panel m-statistic, panel q-statistic, panel PP-statistic, and panel ADF-statistic. These statistics pool the autoregressive coefficients across different members for the unit root tests on the estimated residuals. The second approach includes three statistics. They are group q-statistic, group PP-statistic, and group ADF-statistic. These statistics are based on estimators that simply average the individually estimated coefficients for each member.

Following Pedroni (1999), the heterogeneous panel and heterogeneous group mean panel cointegration statistics are calculated as follows:

Panel m-statistic:

$$T^2 N^{3/2} Z_{N,T,\hat{v}} \equiv T^2 N^{3/2}\left(\sum_{i=1}^{N}\sum_{t=1}^{T} \hat{L}_{11i}^{-2}\, \hat{\varepsilon}_{i,t-1}^{2}\right)^{-1}$$

Panel q-statistic:

$$\boldsymbol{T\, N^{1/2}\, Z_{N,T^{-1},\hat{\rho}}} \equiv \boldsymbol{T\, N^{1/2}}\left(\left(\sum_{i=1}^{N}\sum_{t=1}^{T} \hat{\boldsymbol{L}}_{\boldsymbol{11i}}^{-2}\, \hat{\boldsymbol{\varepsilon}}_{\boldsymbol{i,t-1}}^{2}\right)\right)^{-1}$$

$$\times (\sum_{i=1}^{N}\sum_{t=1}^{T} \hat{L}_{11i}^{-2} (\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{it} - \hat{\lambda}_i)$$

Panel PP-statistic:

$$Z_{tN,T} \equiv \left(\tilde{\sigma}_{N,T}^{2} \sum_{i=1}^{N}\sum_{t=1}^{T} \hat{L}_{11i}^{-2}\, \hat{\varepsilon}_{i,t-1}^{2}\right))^{-1/2}$$

$$\times (\sum_{i=1}^{N}\sum_{t=1}^{T} \hat{L}_{11i}^{-2} (\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{it} - \hat{\lambda}_i)$$

Panel ADF-statistic:

$$\tilde{Z}_{tN,T}^{*} \equiv (\left(\tilde{s}_{N,T}^{*2} \sum_{i=1}^{N}\sum_{t=1}^{T} \hat{L}_{11i}^{-2}\, \hat{\varepsilon}_{i,t-1}^{*2}\right))^{-1/2} \sum_{i=1}^{N}\sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{\varepsilon}_{i,t-1}^{*}\, \Delta\hat{\varepsilon}_{i,t}^{*}$$

group q-statistic:

$$T\, N^{1/2}\, \tilde{Z}_{N,T^{-1},\hat{\rho}} \equiv T\, N^{1/2} (\textstyle\sum_{i=1}^{N} (\sum_{t=1}^{T} \hat{\varepsilon}_{i,t-1}^{2}))^{-1} \quad \times (\sum_{t=1}^{T} (\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{it} - \hat{\lambda}_i)$$

Group PP-statistic:

$$N^{-1/2}\, \tilde{Z}_{N,T,t} \equiv N^{-1/2} \left(\sum_{i=1}^{N} (\hat{\sigma}_i^{2} \sum_{t=1}^{T} \hat{\varepsilon}_{i,t-1}^{2}\right))^{-1/2}$$

$$\times (\sum_{t=1}^{T} (\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{it} - \hat{\lambda}_i)$$

Group ADF-statistic:

$$N^{-1/2} \tilde{Z}_{tN,T}^{*} \equiv N^{-1/2} ((\textstyle\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{S}_i^{*2}\, \hat{\varepsilon}_{i,t-1}^{*2}))^{-1/2} \times (\sum_{t=1}^{T} \hat{\varepsilon}_{i,t-1}^{*}\, \Delta\hat{\varepsilon}_{i,t}^{*})$$

where $\hat{\varepsilon}_{it}$ ***is*** the estimated residual from eq.(4) and $\hat{L}_{11i}^{2}$ is the estimated long-run covariance matrix for $\Delta\hat{\varepsilon}_{i,t}^{*}$ .Similarly $\hat{\sigma}_i^{2}$ and $\hat{S}_i^{*2}$ $(\tilde{s}_{N,T}^{*2})$ are, respectively, the long-run and contemporaneous variance for individual i. The other terms are properly defined in Pedroni (1999) with the appropriate lag length determined by the Newey-West method. All seven tests are distributed as being standard normal asymptotically. This requires standardization based on the moments of the underlying Brownian motion Function. The panel m-statistic is a one-sided test where large positive values reject the null of no cointegration. The remaining statistics diverge to negative infinitely, which means that large negative values reject the null. The critical values are also tabulated by Pedroni (1999). After testing for panel cointegration and estimation of long run coefficients, we can turn to specify and estimate short run effects.

5. Empirical Estimation, Comments and Analysis of the Main Results

5.1. Unit root and panel co-integration tests

We begin by testing the presence of panel unit root for all the series. Table 2 presents the obtained results. We see from the two implemented tests the LLC (2002) and IPS (2002) that all the variables in the two sub-samples are not stationary in level. They become stationary after first difference. We conclude from this first step that all the variables are integrated in the same order. As we see from table 2, the presence of unit root is sensitive to inclusion of the trend. We obtain unit root only when trend is included. This implies that the cyclical components of these variables are deterministic rather than stochastic.

The results illustrated by Table 2, lead us to test the relationships between the cereals production (YC), the dates production (YD) and the climate variables (RL and TM) for both the first and the second subsamples. The seven tests proposed by Pedroni (1999) are implemented. We obtain without ambiguity a long term relation between all the variables for the two subsamples. All the statistics significantly reject the null hypothesis of no Co-integration. The main results are shown by Table 3.

We then conduct the individual and group FMOLS estimations. The results of climate change impacts on cereals production are summarized in table 4 while the long run estimation of climate change impacts on date production are summarized by table 5.

5.2 Climate change impacts on cereals production

As we have collected data on cereals production for all regions in Tunisia, we are able to interpret differences in long run climate effect between the heterogeneous twenty four regions. Beginning with the long-run results, our main findings can be summarized in table 4.

From the FMOLS individual results, we can conclude that the long-run impact of temperature is statistically significant for almost all the regions. In the long-run, average annual temperature decreases cereals production, in accordance with other results in the literature. However, the long-run positive effect of temperature in three mountainous regions (Kesrine, Elkef, Jendouba and Beja) was not an exception or a contradictory result. This result is in agreement with Fisher and Velthuizen (1996) who have proven, in studying the climate change impact on Kenya, that higher temperatures would have a positive impact in highland areas. The average altitude in the Beja area is of 158 meters, and its latitude and longitude is of 3644 N and 911 E, respectively. El-Kef has an altitude of 518 meters above sea level and a latitude and longitude of 3608 N and 842 E. Moreover, the most affected regions by the temperature increase during the last three decades are the south regions. For instance, in Tataouine which is located in the extreme South of Tunisia with a Saharan climate, a 1% increase in temperature decreases annual cereals production by 8.5% against only 1.29% decrease in Sfax (a coastal region). With a current average of five or six years of drought every ten years in sub-Saharan climate, it is reasonable to detect this long-run negative effect of temperature on cereals production. The average annual rainfall has a positive and statistically significant impact on annual cereals production, as we see from the panel group FMOLS estimation. Despite the poor significance of individual FMOLS long-run coefficients, we obtain a negative and statistically significant impact of rainfall in Zaghouan, Tozeur and Kébili. This is certainly due to drought and a decrease in annual precipitations in these regions.

We now turn to the short run results (table 6). They reveal that the average annual rainfall and temperature are statistically significant and have the right sign for the panel of twenty four regions. The short run impact of these two variables are smaller in magnitude than its long-run effect. This implies that over the short-run the impact of temperature and rainfall on the production of cereals is smaller, but as time goes by, they tend to have more impact and become a serious threat. Finally, the lagged error correction term is statistically significant. Its negative sign implies that after a common shock on the cereals crop and climate variables, cereals crop reverts to its equilibrium. It is crucial to note that the coefficient of 0.19 precisely means that it takes six years (1/0.19) for the cereals crop to return to its equilibrium following a shock. We interpret this as follow; after a specifically rainy period or a flood, the cereals crop increasesthen decreases automatically. This is consistent with the results of the impact of annual rainfall on cereals production. It is reasonable to accept a time difference of six years between extremely good crops and shortages. We can conversely interpret the negative effect of temperature.

5.3. Climate change impacts on date production

The south of Tunisia, which is characterized by a Saharan climate, produces the totality of dates production. The estimation of the long-run relationship between dates production and climate variables was conducted by the FMOLS method and results are reported in table 5.

From these results we detect the long-run negative effect of both temperature and rainfall on dates production. As we see from the FMOLS individual estimation, the negative impact of temperature is more important in magnitude than rainfall. In addition, as is the case of the cereals production, some regions are more influenced than others. For instance, in Gafsa, a 1% increase in annual temperature decreases dates production by 4.33% while a 1% increase in annual temperature increases dates production by 2.16 in kebili, which is located in the extreme Southeast of Tunisia. Rainfall appears to decrease dates production in the long-run and this is certainly due to increase of drought seasons during the last three decades.

The short-run results reveal that only rainfall is statistically significant for the panel of five south regions. While rainfall had an effect of 0.13 in the long run, in the short-run the effect had fallen to 0.09. This implies that over the short-run the impact of rainfall on date production is smaller but with time the impact is greater. The one period lagged error correction term sign is negative and statistically significant at the 5% level. This result implies that after a shock to date production and climate variation by any extreme natural events, date production reverts to its equilibrium. The negative coefficient (0.09) means that it takes slightly over 10 years (1/0.09) for date production to return to its equilibrium following a shock.

6. Conclusion and Policy Recommendations

The main objective of this paper was to identify the long run relationship between agriculture crops and climate variables. Using regional annual database, our contribution is twofold. In a first step, tests for panel unit root and then panel co-integration between cereals and date production and climate variables show the presence of a long run relationship between these variables. In a second step, estimation of long run coefficients reveals variability in climate change impacts between regions. The south regions, characterized by a Saharan climate, have been the most affected by temperature increases and water shortages during the last three decades. However, highland and coastal areas, located in the north, are weakly influenced by climate change.

The short run coefficients indicate that the impact of a decrease in rainfall on date production is smaller but with time they tend to have a greater impact on date production. In addition, over the short-run the impact of temperature and rainfall on cereals production is smaller, but as time goes by, they tend to have more impact and become a serious threat. Time length between extremely good crops and shortages is estimated six years for cereals and ten years for date production.

Our results show that climate and weather variability effects on agricultural production must be considered seriously in Tunisia as well as the other MENA countries. Since we estimate relatively higher negative and variable long run effect of temperature increases across regions, on cereals and date yields during the last three decades, an appropriate public policy subsidizing farmers in the most affected regions which are characterized by an arid climate will lead to a significant reduction of the negative climate change impact both on agricultural unemployment and wealth creation. However, rainfall variation has a weak positive effect which is compensated by the threat coming from the brutal temperature increase during the last decades. The best way will be to design a public policy privileging and subsidizing the threatened areas.

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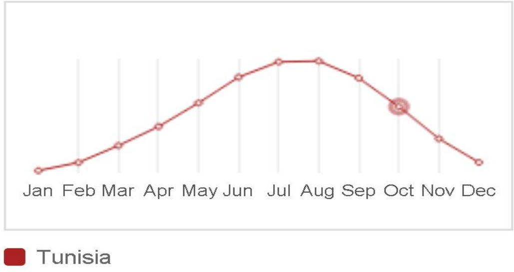
Figure 1: Average Monthly Rainfall 1901 to 2009 (mm)

Average Monthly Temperature 1901 to 2009 (C)



Source: WDI

Table 1: Descriptive Statistics of the Variables

Variable	Description	Mean	Min	Max
Rainfall in mm (RL)	Average annual level of precipitations (mm/year)	52,83	1 (Gafsa in 2005)	296 (Elkef in 2003)
Temperature (TM)	Average annual level of temperature (°C/year)	11.78	5 (Mahdia in 1981)	21 (Tozeur in 1999)
Cereals in tons (YC)	Cereals annual production by region (tons/year)	361473,3	0,5 (Gafsa in 1988)	5398880 (Elkef in 2003)
*T=33 (**1979-2011**) and n=24*				
Descriptive statistics of the second sub-sample				
Rainfall in mm (RL)	Average annual level of precipitations (mm/year)	22.7	1 (kebili in 1984)	168 (Gafsa in 1987)
Temperature (TM)	Average annual level of temperature (°C/year)	12.23	8 (Gafsa in 1978)	21 (Tozeur in 1976)
Date in tons (YD)	Date annual production by region (tons/year)	21161.26	1089 (Mednine in 2009)	91000 (Kebili in 2009)
*T= 36 (**1976-2011**) and n=5*				

Table 2: Panel Unit Root Tests

	LLC		**IPS**	
	First sub-sample : T=33, n=24			
	Trend	**no trend**	**Trend**	**no trend**
TM	-1.07	-4.51*	-1.19	-0.81
ΔTM	-10.5*	-11.2*	-17.9*	-12.8*
RL	1.61	0.59	1.66	0.71
Δ*RL*	-4.48*	-5.04*	-6.01*	-9.16*
YC	1.94	-0.49	4.17	-3.67*
ΔYC	-16.06*	-19.2*	-26.7*	-25.6*
	Second sub-sample : T=36, n=5			
TM	-1.06	-2.1*	-1.2	-4.7*
ΔTM	-1.06	-2.1*	-1.2	-4.7*
RL	-0.48	-1.04	-0.01	1.16
ΔRL	-6.7*	-7.3*	-11.9*	-13.4*
YD	-0.48	1.04	-0.01	1.16
ΔYD	-16.5*	-13.2*	-18.9*	-22.8*

Note: * indicates that we reject unit root at1%.

Table 3: Panel Cointegration Tests Results

	First sub-sample : T= 33, n=24		**Second sub-sample**	
	Trend	**no Trend**	**Trend**	**no Trend**
		Pedroni (1999) cointegration tests		
Panel-m	1,9	3,6	4,1*	5,8*
Panel-q	-14,6*	-15,9*	-21,8*	-23,6*
Panel-pp	-17,2*	-16,4*	-20,8*	-19,1*
Panel-adf	1,3	0,5	-18,8*	-15,6*
Group-q	-14,2*	-16,5*	-21,9*	-25,3*
Group-pp	-18,8*	-19,4*	-23,4*	-23,3*
Group-adf	2,3	1,4	-19,8*	-17,4*

Note: (*) Rejects the null hypothesis at the 1% significance level.

Table 4: FMOLS Estimation of Climate Change Impacts on Cereals Production

Regions	**Rainfall**	**t-stat**	**Temperature**	**t-stat**
Individual FMOLS results (within dimension)				
Tunis	0.75	(0.54)	-3.85	(-0.88)
Ariana	2.47**	(2.24)	7.62	(1.43)
Manouba	0.53	(1.03)	-3.9	(-0.72)
Benarous	0.49	(0.35)	-5.4	(-1.59)
Nabeul	0.87	(0.5)	-4.07**	(-2.82)
Bizerte	-0.08	(-0.04)	-2.66	(-0.47)
Beja	2.26	(1.37)	1.59*	(1.95)
Jendouba	0.84	(0.51)	1.89**	(2.52)
Elkef	0.05**	(2.03)	0.026**	(2.13)
Seliana	-1.01	(-0.91)	-2.56*	(-3.13)
Zaghouan	-4.39**	(-1.92)	-5.7	(-0.59)
Sousse	0.69	(0.69)	-0.40	(-1.15)
Monastir	-0.06	(-0.07)	-2.24**	(-3.5)
Mahdia	0.95	(1.50)	-7.04	(-1.77)
Kairouan	1.64	(1.35)	1.51	(0.94)
Kesrine	1.96**	(1.90)	1.09**	(2.62)
Sidibouzid	-0.68	(-0.92)	-8.79*	(-3.57)
Sfax	0.01	(0.03)	-1.29*	(-7.78)
Gafsa	0.1	(0.13)	-2.45*	(-3.57)
Gabés	-0.21	(-2.19)	-1.06**	(2.36)
Mednine	-0.36	(-0.35)	2.05	(1.39)
Tozeur	-0.28**	(-2.38)	-3.39*	(-3.61)
Kebili	-1.65**	(-2.12)	-0.63**	(-2.68)
Tataouine	-0.09	(-0.14)	-8.5*	(-3.42)
Panel Group FMOLS Results (between dimension)				
Between with trend	0.12*	(3.05)	-1.80*	(-3.15)

** and * indicate significance at 5 and 1% respectively.

Table 5: FMOLS Estimation of Climate Change Impacts on Date Production

Regions	**rainfall**	**t-statistics**	**temperature**	**t-statistics**
Gabés	0.17	(1.17)	0.83	(0.66)
Kebili	-0.21**	(-1.92)	2.16**	(1.96)
Tozeur	0.14**	(1.86)	0.65	(0.63)
Mednine	-0.01	(-0.15)	-2.12**	(-2.3)
Gafsa	0.20	(0.90)	-4.33**	(-2.65)
Between with trend	-0.13**	(-1.87)	-2.4**	(-2.74)

Note: ** and * indicate significance at 5 and 1% respectively

Table 6: Panel ECM Estimation

First sub-sample (impacts on cereals production)					
	Δlrl	Δlrl_{t-1}	Δlte	Δlte_{t-1}	ECT_{t-1}
Short-run	0,034*	0.023*	-0.93*	-0.34	-0.19*
coefficients	(1.94)	(2.31)	(3.28)	(0.39)	(-3.17)
Second sub-sample (impacts on date production)					
Short-run	-0.09**	0.001	0.22	-0.19	-0.09**
coefficients	(-2.17)	(0.03)	(0.75)	(-0.66)	(-1.97)

T-statistics are in parenthesis; *,** indicate significance at 1 and 5% respectively.