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Research Article

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Modeling the Direct Effect of Climate Change on the Cereal Production in Tunisia: A Micro-spatial Panel Cointegration Analysis

Oussama Zouabi*

University of Tunis EL Manar, Tunisia & LEAD, University of Toulon, France

Abstract

Unlike previous studies, this paper, by employing a cointegration technique on panel data, economically investigates the direct effect of climate change on the cereal production in the long-term via a new cereal disaggregated databases covering the period 1979-2012 for 24 governorates in Tunisia within a multivariate panel framework. The Pedroni panel cointegration test indicates that there is a long-run equilibrium relationship between the considered variables with elasticity's estimated positive and statistically significant in the long-run. The results generally confirm that in the long term there is a strong positive correlation between the cereal production and the direct effect of precipitation and temperature for the whole panel. At the micro-spatial level, results of the long-run equilibrium relationship show that the cereal production is extremely dependent on rainfall in most governorates of cereals producers, especially the Northwest region of Tunisia. In fact, there are several initiatives and policies that must be undertaken by Government in an attempt to improve the long term production of cereals in the most affected governorates by the phenomenon of climate change such as the development of several important and regionally-based institutions and cooperation, providing subsidies to farmers.

Keywords: Climate change; Cereal; Panel cointegration

JEL Classification: Q54; Q13; C33

Introduction

The direct and indirect effect of climate change on agricultural production cannot be generalized. In fact, the effects of this phenomenon vary from one governorate to another. It is noted that the results found in most empirical studies undertook the sustainability of growth of agricultural production in Tunisia faced with climatic uncertainties in both short-run and long-run. Although, econometric analysis in spatial panel has made efficiency argument in improving regional policy at the macro-level space in the most affected areas by this phenomenon, however this technique remains poor to detect the effect of climate change on agricultural production at micro-spatial level. Recently, several empirical studies have examined the impacts of climate change on agricultural production, but the results are different from one country to another and even between regions of the same country. For instance, In turn, Jinxia et al. [1] conducted an analysis on China. They use the Ricardian model for 8405 households randomly distributed in 28 Chinese provinces. The results detect the impact of the increase in temperature and precipitations vary by region and by type of crop. The results show an increasing of the temperature tends to increase the net income of non-irrigated production plants, which account for nearly 60% of the cultivated land. Furthermore the authors suggest that rainfall has a significant positive effect for all jurisdictions studied. However, climate change has a slightly positive effect on net income of the production of non-irrigated plants especially in the North East and North West and a beneficial effect in the South.. In this context, Kabubo and Karanga, using the VAR model for measuring the effect of climate change on agricultural production, the authors demonstrated through the case study of Kenya, that the high temperature during the winter increases the net income crop. Similar results were found by Rosenzweig et al. [2] for the case of United States. Other studies focus on the impact of climate change on certain plants. In this regard, For example, Molua uses the Cobb-Douglas production function to study the impact of temperature and rainfall on agricultural production during the period 1961-2001. The author explains the agricultural output with the following inputs: capital, labor, fertilization, precipitation, temperature and acreage. The estimation results show that agricultural production in Cameroon is very influenced by climatic variables. . However, empirical studies for the case of Tunisia are very scarce. In this context, Ali Chebil et al. [3] showed that the increase in precipitation and temperature in the governorate of Beja has a positive effect on the cereal production in the long-term. Ben Zaied and Ben Chikh [4] proved that the cereal sector in Tunisia is the most affected by climate variation. Despite the diversity of empirical studies that deal with the same issue to simulate and predict the effect of climate on agriculture in the long term, there has been almost no empirical work concerned with the co-integration method on dynamic panel data. For policy makers and in particular that of the implementation of agricultural policy, sustainable development in the agricultural areas, local politics of water resources management, forecasting the direct and indirect effects of climate change in the short and long term is essential to anticipate the risks associated with climate change on agriculture and intervene effectively in the most affected governorates. This paper will intend to develop a new original analysis which assesses the direct effect of climate change on cereal production at a micro-spatial level. Thus we must consider the spatial heterogeneity among governorates. Subsequently, we propose a new econometric approach in this area by employing the cointegration technique on dynamic panel data Preceded by the first generation unit root tests. This econometric method will be detailed at the regional level.

The remainder of this paper is structured as follows. Section 2 will present a Descriptive data and spatial analysis. Section 3 will disclose

***Corresponding author:** Oussama Zouabi, University of Tunis EL Manar, Tunisia & LEAD, University of Toulon, France, Tel: +33494142000; E-mail: oussamao77@yahoo.fr

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the panel methodology tests that will be developed in this analysis. Section 4 will expose data source and the empirical model. Section 5 will discuss the empirical results. Conclusion and Policy Implications will be reviewed in Section 6.

Methodology

Unit root test in panel

The unit root tests are crucial in any econometric treatment. Their implementation, by determining a deterministic or stochastic trend, can highlight the stationary or not of the analyzed variables. In the literature there are two generations of tests, the first generation emphasizes the heterogeneity of the variables included in the model, which considers the interdependence between individuals. The second generation of tests, developed in the early 2000s by Persaran [5], consider this interindividual interdependence. According to Hurlin and Mignon [6], it is recommended to perform the first generation of unit root test in case of micro panel data and the second generation in the case of macroeconomic panels. In this analysis, the unit root tests of Levin, Lin and Chu [7], Im, Pesaran and Shin [5], ADF-Ficher chi square and Breitung [8] are performed.

Panel cointegration test

The principal idea of the co-integration shows that the variables can have a divergent evolution in the short-run (so they are not stationary), then they will mutually evolve in the long-run. There is consequently a long-run stable relationship between the different variables. This long-run relationship is called cointegration relationship.

After the confirmation of the stationary nature of the considered variables to a given level of integration, the next is to test panel cointegration among the variables. Thus, we will compute the very popular Pedroni [9]. In fact, Pedroni [10] developed the cointegration test in panel data by exclusion the null hypothesis of no cointegration intra-interindividual for both homogeneous and heterogeneous panels [11]. Then, a new generation of cointegration tests initiated by Pedroni who derived two sets of panel cointegration tests. The first set, entitled panel cointegration tests, is based on the within dimension approach and contains four statistics: panel v-statistic (Z_v), panel rho-statistic (Z_ρ), panel PP-statistic (Z_{pp}), and panel ADF-statistic (Z_{ADF}). These statistics pool the autoregressive coefficients across different governorates for the unit root tests on the estimated residuals while taking into consideration common time factors and heterogeneity across governorates. The second set, named group mean panel cointegration tests, is based on the between dimension approach and contains three statistics: group rho-statistic (Z_ρ), group PP-statistic (Z_{pp}), and group ADF- statistic (Z_{ADF}). Generally, these statistics are based on averages of the individual autoregressive coefficients linked to the residuals' unit root tests for each governorate. Null hypothesis assumed that all seven tests specify the nonexistence of cointegration $H_0 : \beta_i=0 ; \forall_i$, while the alternative hypothesis is defined as $H_1 : \beta_i=\beta<1 ; \forall_i$ where β_i is the autoregressive term of the estimated residuals under the alternative hypothesis (H_1) and it is specified in the following equation:

$$\varsigma_{it} = \beta_i \hat{\varsigma}_{i,t-1} + \eta_{it} \quad (1)$$

Pedroni suggests that all seven statistics have a standard asymptotic distribution that is founded on the independent movements in Brownian motions when T and N→∞.

$$\left(Z-\omega\sqrt{N}\right)/\sqrt{\lambda} \xrightarrow[N,T\to\infty]{} N(0,1) \quad (2)$$

Where Z is one of the seven normalized statistics, ω and λ is tabulated in Pedroni [9].

Data and empirical model

Annual data from 1980 to 2012 were obtained from the National Institute of Statistics (INS), the Institute of Quantitative Economics (IEQ), various numbers of monthly statistical bulletins, and statistical yearbooks of Tunisia, the National Observatory of Agriculture (ONAGRI) and the National Institute of Meteorology. The twenty four governorates of Tunisia, which are included in this analysis, are Tunis, Ariana, Ben Arous, Manouba, Bizerte, Nabeul, Beja, Jendouba, El Kef, Seliana, Zaghouane, Kairouane, Bouzid, Kasserine, Sousse, Monastir, Mahdia, Sfax, Medenine, Tataouine, Kebeli, Tozeur, Gafsa and Gabes.

The econometric model is specified as follows:

$$Y_{it} = F\left(K_{it}, L_{it}, T_{it}, P_{it}\right) = K^{\alpha1}_{it} L^{\alpha2}_{it} T^{\alpha3}_{it} P^{\alpha4}_{it} \quad (3)$$

Where Y_{it}, K_{it}, L_{it}, T_{it}, P_{it} denote the agricultural production of governorate i at time t, the capital of the agricultural sector, the labor force of the agricultural sector, the average temperature and the precipitation, respectively.

The model (3) is expressed in log and specifies as follows:

$$\text{Log } Y_{it}=\alpha_1 \text{ Log } K_{it} + \alpha_2 \text{ Log } L_{it} + \alpha_3 \text{ Log } T_{it} + \alpha_4 \text{ Log } P_{it} + \varepsilon_{it} \quad (4)$$

Where α_1, α_2, α_3, α_4 denote the elasticity of agricultural production relative to capital, the elasticity of agricultural production relative to labor, the direct impact of temperature on the cereal production (α_3< 0 means that the temperature slows down the production of cereals) and the effect of rainfall on the cereal production (α_4> 0 means that precipitation is likely to improve the production of cereals), respectively.

Results and Discussion

Results from the panel unit root tests, as shown in Table 1, conclude

Tests	LLC (2002)		IPS(2003)		ADF-Ficher chisquare (2001)		Breitung (2000)	
Model	With constant and trend							
Variables	stat	Prob	stat	Prob	stat	Prob	stat	Prob
Pcer	-6.747	0.000***	-7.2	0.000***	141.87	0.000***	-3.517	0.000***
Δ Pcer	-14.742	0.000***	-20.207	0.000***	393.239	0.000***	-10.22	0.000***
K	1.074	0.858	0.749	0.000***	28.18	0.99	-2.089	0.018**
ΔK	-8.558	0.000***	-6.408	0.000***	117.47	0.000***	-5.928	0.000***
L	-2.087	0.018	-0.57	0.284	39.99	0.787	-3.77	0.000***
ΔL	-14.274	0.000***	-13.627	0.000***	251.77	0.000***	-12.846	0.000***
T	-1.652	0.049**	0.978	0.836	28.91	0.986	-2.309	0.010**
P	-10.917	0.000***	-9.555	0.000***	187.87	0.000***	-2.013	0.022**
ΔP	-17.517	0.000***	-22.003	0.000***	440.976	0.000***	-7.197	0.000***

***,**,*significance at 1%, 5% and 10% level, respectively.

Table 1: Results of unit root tests in panel, 1979-2012.

that each variable is integrated in order one. With the exception of the two variables, such as the cereal production and the rainfall are stationary in level.

Since the unit root test results showed that the considered variables are generally integrated in orders one, the next step is to test panel cointegration among the variables. The panel cointegration tests of Pedroni (1999, 2004), as shown in Table 2, generally reject the null hypothesis of no cointegration at the 1%, 5% and 10% significance level. The results present even stronger proof of cointegration. Thus, they indicate that there is a long-run equilibrium relationship between the considered variables.Then, we present the results of the long-term equilibrium relationship for not only the entire panel, but also for each governorate. So, we apply to each plant described in the model (4) two estimation methods. The FMOLS results are reported in Table 3 and show that all the coefficients are positive and statistically significant at the 5% significance level with the exception of the labor variable, which is insignificant. In addition, given that all variables are expressed in natural logarithms; the coefficients can be interpreted as elasticity estimates. The results indicate that a 1% increase in capital increases the cereal production by 0.46%; a 1% increase in temperature increases the cereal production by 0.36%; and a 1% increase in precipitation increases the cereal production by 0.16%.

Table 4 reports the results from the FMOLS in micro-spatial level, it is observed that the results are generally similar to those reported at the spatial macro level and diverge across governorates. Results show that the capital is statistically significant and has a positive effect for the 24 governorates in Tunisia. In the long term, the capital will have a greater influence on the cereal production in the northern governorates especially those in the North-west of Tunisia, which contains the most governorates of the cereal producers as Beja, Jendouba, El -Kef and Bizerte. They record the highest elasticities in the order of 1.56, 1.28, 1.28 and 1.22, respectively. However, the least producers' governorates, which lie in the south of Tunisia namely Tataouine, Kebili and Tozeur, make evidence for the lowest long-term elasticities (0.08, 0.04 and 0.08, respectively).

The labor force has a significant impact on cereal production only for Kebili. In fact, a 1% increase in the labor force reduces the cereal production by 0.14%. This result naturally interprets by the fact that the governorate of Kebili is located in the south of Tunisia, which is characterized by the palm production. The labor force in this governorate specializes on the production of their abundant crop (the palm production), which can negatively affect the cereal production. The results also show that the direct effect of climate change, measured by the rainfall level, positively and significantly impacts the cereal production for the whole panel. At the micro-spatial level, precipitation has a positive effect on all governorates except Sousse, Mahdia, Kasserine and Kebili that display negative but insignificant signs. In addition, the effect of precipitation is higher in governorates where their production of the cereal is higher. It is noted that the governorates of Beja, Jendouba and Siliana, which located in the northwest of Tunisia, represent about 40% of the cereal production in Tunisia and have long-term elasticities in the order of 0.45, 0.26 and 0.59, respectively. This result can be due to the rainy climate and socio-economic characters that characterize this region. These results are similar to those reported by Chebil et al. and Balaghi et al. [12] in their studies in which Chebil et al. confirm that the increase in precipitation during the different stages of growth positively influences the cereal production in the governorate of Beja. According to Jlibane and Balaghi, an increase or decrease in precipitation during the growth cycle of the cereal crop in Morocco is reflected by a rise or fall in production. Moreover, results derived from the middle of Tunisia show that the semi-mountainous governorates that do not belong to the littoral namely Kairouan, Kasserine and Bouzid record positive and significant elasticities, whereas they were negative but not significant in the governorates of Sahel. As for the South which represents 2% of the cereal production, the estimation results by FMOLS method show that the direct effect of climate change has a significant and positive effect on the cereal production but with very low elasticities. Besides, the temperature has a positive and significant effect on production of the cereal. This unexpected result can be explained by the fact that the temperature increase during the period of growth in long-term will be relatively constant and close to zero and does not exceed the optimum temperature for the different stages of cereal growth which comprised

Within-Dimension			Between-Dimension		
	Statistic	Prob.		Statistic	Prob.
Panel v-stat	0.34	0.366	Group rho-stat	-1.338	0.082*
Panel rho-stat	-1.51	0.065*	Group pp-stat	-7.651	0.000***
Panel pp-stat	-6.467	0.000***	Group adf-stat	-0.192	0.000***
Panel adfstat	-0.208	0.000***			

Note: Null hypothesis: No cointegration. Trend assumption: Deterministic intercept and trend. Lag selection: Automatic SIC with a max lag of 5. ***,**,*Significance at 1%, 5% and 10% level, respectively.

Table 2: Pedroni (1999, 2004) Cointegration tests, 1979-2012.

Variables	Stat.	t-Student
LK	0.46	(16.93)
LL	0.15	-1.47
LT	0.36	(5.72)
LP	0.16	(7.49)

Note: the t-statistics

Table 3: Parameter estimation using FMOLS for the entire panel, 1979-2012: Spatial Macro Effect.

Region	Variables	LK		LL		LT		LP	
North	Tunis	0.01	(3.57)	0.02	(1.39)	0.08	(4.29)	0.01	(3.86)
	Ariana	0.29	(1.93)	0.35	(0.64)	2.07	(3.69)	0.08	-0.71
	Manouba	0.28	(4.06)	0.36	(1.48)	-0.65	(2.66)	0.14	(2.71)
	B. Arous	0.14	(5.42)	0.0009	(0.17)	0.19	(1.56)	0.05	(2.56)
	Nabeul	0.51	(5.46)	0.29	(0.93)	0.11	(0.48)	0.02	(0.43)
	Bizerte	1.22	(5.30)	0.79	(0.87)	1.21	(1.63)	0.05	(0.31)
	Beja	1.56	(5.28)	0.57	(0.51)	1.41	(2.44)	0.45	(1.96)
	Jendouba	1.28	(8.57)	0.02	(0.86)	0.92	(2.07)	0.26	(2.98)
	El-Kef	1.28	(2.83)	0.45	(0.32)	0.47	(0.60)	0.24	(0.66)
	Seliana	0.8	(1.90)	0.96	(0.79)	0.61	(0.57)	0.59	(1.87)
	Zaghouan	0.41	(1.42)	0.45	(0.57)	0.14	(0.21)	0.38	(1.60)
Middle	Sousse	0.23	(3.32)	0.003	(0.21)	-0.09	(0.35)	0.02	(0.31)
	Monastir	0.01	(1.70)	0.07	(3.23)	0.03	(1.84)	-0.002	(0.53)
	Mahdia	0.18	(3.51)	0.06	(0.35)	-0.008	(0.07)	-0.02	(0.52)
	Kairouan	1.19	(5.30)	-0.03	(0.04)	1.001	(1.61)	0.54	(2.27)
	Kasserin	0.8	(3.0)	-0.01	(0.49)	-0.35	(0.41)	0.37	(1.85)
	Bouzid	0.5	(3.64)	-0.6	(1.31)	0.26	(0.62)	0.36	(2.54)
South	Sfax	0.02	(0.59)	0.07	-0.51	0.33	(1.90)	0.05	(1.13)
	Gafsa	0.11	(2.67)	-0.1	-0.71	0.11	(0.98)	0.14	(2.12)
	Gabes	0.08	(2.54)	0.001	-0.13	0.23	(1.30)	0.05	(1.45)
	Medenin	0.1	(3.72)	0.05	(0.53)	0.38	(3.82)	0.09	(2.43)
	Tozeur	0.002	(2.08)	-0.008	(1.84)	0.005	(1.22)	0.003	(1.30)
	Kebeli	0.04	(2.80)	-0.14	(2.76)	-0.01	(0.25)	0.07	(2.28)
	Tataouin	0.08	(2.22)	0.006	(0.81)	0.13	(0.87)	0.01	(0.34)

Notes: the t-statistics

Table 4: Parameter estimation using FMOLS for each Tunisian governorate, 1979-2012: spatial micro effect.

20 °C and 22°C during the month of November and the beginning of January for germination and emergence of stems that is generally done between February and the beginning of April with optimum temperature between 7°C and 8°C. An increase in temperature beyond these intervals reduces carbohydrate reserves that are available for grain filling and negatively affects the cereal production. In fact, the estimated long-term elasticities at the individual level exposed identical results to those found in macro-spatial level, with the exception of the governorate of Manouba; the estimated long-run elasticity proves that a 1% increase in temperature reduces the cereal production by 0.65%. This result is similar to those reported by Yana [13-19] and GIEC in which they confirm that the increase in temperature during the growth period entails a reduction in the duration of the grain growth which may adversely affect the productivity of the plant [20].

Conclusion and Policy Implications

This paper, by using a new method in this field namely cointegration technique on panel data, economically investigates the direct effect of climate change on the cereal production in the long-term via a new cereal disaggregated databases covering the period 1979-2012 for the 24 governorates in Tunisia [21-23].

The panel cointegration tests of Pedroni expose that there is long-run equilibrium between the considered variables [24].

The results show that in the long term there is a strong positive correlation between the cereal production and the direct effect of precipitation and temperature for the whole panel. At the micro-spatial level, results of the long-run equilibrium relationship show that the cereal production is extremely dependent on rainfall in most governorates of cereals producers, especially the Northwest region of Tunisia. However, there is a poor correlation between rainfall and cereal production in the Sahel and southern governorates [25,26]. As regards the direct effect of temperature, the results show that the temperature has a positive effect on the cereal production in the macro-spatial level. In addition, the long-term elasticities in micro-spatial level prove identical results to those found at macro level with the exception of the governorate of Manouba which displays different results.

In this regard, our results firstly lead us to conclude that the intervention of public authorities by economic policies is effective in improving the long-term production of cereals in the most affected governorates by the phenomenon of climate change and to make better support for farmers from both a logistical side as agricultural machinery, and from an organizational side (i.e. guidance, advice and training) to improve the quality of the labor force especially for rural women who represent the largest share of the workforce in agricultural production. An agricultural policy directed by the government without subsidizing the farmers in the southern region of Tunisia can cause migration to neighbouring governorates. So, it can harmfully affect the growth rate in these regions and increase the unemployment rate. In addition, the government should effectively intervene to encourage farmers to use the empty land in the littoral governorates namely Sousse, Monastir and Mahdia. These governorates benefit from socio-economic, biological and climatic factors which are favourable to produce the cereals.

In the future research, we by employing the dynamic computable general equilibrium model, will study the future impact of climate change on the macroeconomic variables via the agricultural sector.

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