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An Economic Study for Climate Change Impact on Wheat Production in the Northern West Coast Region of Egypt

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Abstract

This paper aimed to examine the impact of climate change on wheat productivity in the five rains- fed districts: El-Negaila, Sidi Barrani, El-Daba'a, Marsa Matrouh, and EL-Alamain in the northern west coast of Egypt in which the cultivated wheat area represents about 41.4% of wheat area in Matrouh Governorate (1990-2019). The productivity is fluctuated between 1.167 to 13.38 Ardab/Fadden accompanied with the fluctuation in precipitation between 24.35 to 115.10 MM^3/Season, and fluctuation of average difference between Max. Min. temperature from 8.07 to 7 °C. Fully Modified Ordinary Least Square (FMOLS) technique was applied to investigate the relationship between wheat productivity and the independent variables (precipitation, temperature, cultivated area, labor and technology). OLS function showed that the model suffers from endogenity and heteroscedasticity. LLC and IPS statistics of panel unit root test proved that the included variables have unit root, i.e. they are non-stationary at level. Pedroni panel residual cointegration test confirmed the long run relationship between the first-order integrated variables [I (1)]. FMOLS function proved that natural climatic variables are the main determinants of wheat productivity, as a 1% increase in annual rainfall improves wheat productivity significantly by 3.3%, while temperature affects the wheat productivity negatively by 5.7%. The far west districts are the most affected by rainfall, as 1% increase of rainfall in EL-Negaila and Sidi-Barrani districts increase wheat productivity by 8.4%, 5.1% respectively. Results in all districts except EL-Negaila and Sidi Barrani showed the extent of labor intensification to enhance productivity, also all districts showed the importance of technical improvements. It is recommend adopting water policy as rain harvesting, building stone dykes and cisterns to provide: 355.5, 301.7, 287.9, 339.8, and 245.8 MM^3/Fadden in El-Negaila, Sidi Barrani, EL-Daba'a, Marsa Matrouh, and EL-Alamain districts respectively to improve wheat yield to 12 Ardab/Fadden under drought climate of north coast.

Keywords: Climate Change; Egypt; FMOLS; Pedroni test.

1 Introduction

The phenomenon of Climate change adds additional challenge to the Egyptian agricultural sector, as the high concentration of carbon dioxide in the atmosphere on one hand, and its climatic location in the dry regions which are characterized by high temperatures and fluctuation of precipitation on other hand, cause a decrease in crops productivities due to water shortage and heat stress (IPCC 2007). Several literatures attributed the phenomenon of climate change for irrational human activities and land utilizations abuse which causes the emission of greenhouses gases. The rise of greenhouses gases (expressed by carbon dioxide equivalent CO_2 e) causes a rise of oceans and atmosphere temperatures which cause a change in surface temperature see level, and rainfall seasonality (Stern 2007).

In Egypt, the phenomenon of climate change has an important consideration as CO_2 e concentration increased by 47% from 1.345 Metric Ton per capita (MT per capita) in 1990 to 2.526 MT per capita in 2016 (The World Bank Data). Rainfall and temperatures variables have also serious impacts on the Egyptian grains productivities; maize for example is highly sensitive for maximum temperature, specifically its productivity and net returns which is affected negatively in growing seasons (Amer 2012). On the contrary, technology is considered an important adaptive variable which alleviate negative impacts of climate change as the tradeoff between improved and traditional varieties of grains may improve the productivity even with an increase of temperature from 1.5°C to 3.6°C (Abou-Hadid 2006).

The northern west coast of Egypt extends along 450 km^2 of the Mediterranean Sea. This region is characterized by arid climate, influenced by the Mediterranean basin with dry hot temperatures in summer season and ranged between moderate and cold temperature during winter season. All districts of Matrouh governorate[1] except Siwa oasis are included in the northern west coast. Agriculture activity in all districts depends essentially on rainfall except for Siwa district which is irrigated by ground water and El- Hammam district which is supplementary irrigated by Nile River (The Information Note of Matrouh Governorate 1990-2019).This paper concerns mainly with rain-fed wheat production in the coastal districts: El-Negaila, Sidi Barrani, El-Daba'a, Marsa Matrouh, and EL-Alamain, as their rain-fed wheat area is 18449 Fadden represents about 41.4% of total cultivated wheat area in rain-fed and irrigated districts of Matrouh governorate which is 44517 Fadden during (1990-2019).The five districts are arranged according to their cultivated wheat area respectively: El-Negaila is 6818.2 Fadden represents about 37% , Sidi Barrani is 4248.9 Fadden represents about 23%, El-Daba'a is 3245.7 Fadden represents about 17.6%, Marsa Matrouh is 3117.5Fadden represents about 16.9%, and EL-Alamain is 1018.7 Fadden represents about 5.5% (The Information Note of Matrouh Governorate1990-2019;The Agricultural statistics1990-2019).

Rain fed agriculture system in Northern west coast of Egypt is described with primitive farming practices and inputs, as farmers are rarely adding chemical fertilizers and pesticides. Wheat is considered one of the most sensitive rain-fed crops which are affected by natural inputs (precipitation rate and average temperature). Its cultivated area is 44517 Fadden represents about 20.7% of the cultivated area in winter season of Matrouh governorate which is 214958 Fadden during 1990-2019 (The Agricultural Statistics Bulletin 1990-2019).

Figure 1 indicates the fluctuation in wheat yield between 1.167 Ardab/Fadden (0.417 Ton/ Ha) in 1996 to 13.38 Ardab/Fadden (4.87 Ton/ Ha) in 2012 (The Agricultural statistics, 1990-2019), as the precipitation amount fluctuates between 24.35 MM/Season and 115.10 MM/Season, as well as Figure 2 shows the fluctuation of wheat yield as the average difference between Max. and Min. temperature fluctuates between 8.07°C and 7°C (The Metrology Station 1990-2019). Hence, the research problem is represented in the instability of wheat productivity coincide with the variation of climate factors. The main objective of the research is to examine the impact of climate change on the wheat productivity in Matrouh governorate during (1990-2019) through:

(i) Measuring the elasticity coefficients of wheat productivity in response to the variation

[1] Matrouh Governorate Consists of Eight districts: Marsa Matrouh, El-Daba'a, Sidi Barrani, El-Negaila, EL-Alamain, El- Hammam, EL-Saloum and Siwa.

of natural climatic inputs (precipitation and temperature) relative to other economic inputs (cultivated area, labor and technology).

(ii) Comparing between districts in terms of their responses to natural and economic inputs.

The paper is structured as follows: section II resents the data resources and methodology of FMOLS approach in analyzing the panel data, section III presents the main findings and discussions, and section IV presents conclusions and recommended policy.

2 Data and Methods

The analysis relies on panel data, time series –cross sections data, to reflect the time and geographical dimensions to estimate the impact of environmental climate variables along the long period (1990-2019), focusing on difference between five rain- fed districts in Matrouh governorate, Northern West Coast of Egypt. The districts are El-Negaila, Sidi Barrani, El-Daba'a, Marsa Matrouh and EL-Alamain. Panel data estimation increases the sample size, and the degrees of freedom that increase the precision of parameters and adjust heteroscedasticity.

The time series data of wheat area and productivity are derived from the agricultural statistics bulletin, Economic Affairs Sector, Ministry of Agriculture and Land Reclamation, while the area and productivity at the districts 'level are derived from the Information Note of Matrouh Governorate, Information and Decision Making Center and Agricultural statistics, Directorate of Agriculture, Matrouh Governorate. The environmental data of precipitation and temperature are derived from the Metrology Station, Geographic Information System Unit, Sustainable Development Center of Matrouh Governorate. The statistics of agricultural labor devoted per each Fadden are extracted from the agricultural census of Matrouh Governorate. The production function model of the impact of climate change on the wheat productivity in the Northern West Coast is as follows:

$$Y_{it} = \alpha_{it} + \beta_{i1} R_{it} + \beta_{i2} M_{it} + \beta_{i3} A_{it} + \beta_{i4} L_{it} + \beta_{i5} T_{it} + \varepsilon_{it} \dots\dots\dots (1)$$

Where: i = 1, 2,…., N, and N represents the number of observations in the panel, t =1,2,….,T ,and T represents the number of observations over time, Y_{it} = wheat yield (Ardab/ Fadden), R_{it} = Average rainfall in winter season (mm^3/season), M_{it} = Average max. & min. temperature in winter season, A_{it} = Cultivated area of wheat (Fadden), L_{it} = Average number of hired and permanent Labor per Fadden, T_{it} = trend variable reflects the technology development, and ε_{it} = Error term.

This paper applied the technique of Fully Modified Ordinary Least Square (FMOLS), which is introduced by Philip and Hansen (Philips and Hansen 1990). The procedure investigates the long run relationship between the cointegrated variables and provides efficient and consistent parameters in autocorrelation and heteroscedasticity conditions. The procedure of FMOLS consists of main three steps; unit root test, Pedroni co-integration test for panel data, and FMOLS regression.

2.1. Unit Root Test

To investigate the stationary status of the involved variables in the model, unit root tests for panel data through L-L-C test and I-P-S test are applied. L-L-C test was introduced by Levin, Lin and Chu (Levin and Lin, 1992; Levin et al 2002) to check Augmented Dickey Fuller (ADF) provided that all parameters of the lagged dependent variables are homogenous between all panels groups i.e. i.e. parameters are identical for all individuals in the panel data. The test in the three cases without an intercept and a trend, with an intercept, and with an intercept and a trend are as follows:

$$\Delta Y_{it} = \rho\, Y_{it-1} + \upsilon_{it} \dots\dots\dots (2)$$

$$\Delta Y_{it} = \alpha_i + \rho\, Y_{it-1} + \upsilon_{it} \dots\dots\dots (3)$$

$$\Delta Y_{it} = \alpha_i + \beta_i t + \rho\, Y_{it-1} + \upsilon_{it} \dots\dots\dots (4)$$

Where ΔY_{it} is the first difference operator of the investigated variable with observations i=1,2,…..,N (for all cross- sections) during the period t=1,2,…..,T, while ρ is the unit root coefficient, and υ_{it} is the error term. LLC suggested the following hypotheses in the three mentioned cases respectively (i) H_0: ρ =0; H_1: ρ ≠ 0, (ii)H_0: ρ =0; α_i = 0; H_1: ρ ≠ 0; αi ϵ R, for all i=1, 2,….N, and (iii) H_0 : ρ =0; βi =0; H1: ρ ≠ 0;αi ϵ R, βi ϵ R, for all i=1,2,….N. I-P-S test is introduced by Im, Pesaran, and Shin (Im, et al 2003). The test follows the same steps of LLC test procedure, except that it imposes different coefficients ρ_i and distinct unit root values for the numbers of cross sections in the panel and thus implicitly imposes that the cross sections have the identical time length(balanced panel).

2.2. Pedroni Co-integration Test

Granger suggested the concept of co-integration which explains that although the individual time series are non-stationary, the linear combination of two or more non-stationary time series would be stationary (Gujarati 2003). However, the co-integration concept is widely applied in econometric research to refer to the long run equilibrium between non-stationary variables. Pedroni test was introduced by Pedroni (Pedroni 1999) to investigate the long run relationships between variables in the panel data. It imposes that the rank of co-integration is at almost one. Pedroni test is a residual – based test of cointegration which considers the heterogeneity condition in non-stationary panel data. The test is classified into two sets of tests: the first set consists of three statistics of group means which consider the mean of each cross section (between groups), namely; (ρ- statistic, ADF- statistic, and t- statistic), and the second set consists of four statistics of the panel which pool the statistics within the dimensions (within groups), namely, (υ-statistic, ρ- statistic, ADF- statistic, and t- statistic) (Nael 2014). For a set of observations i=1,2,…….,N in a given panel over the time t= 1,2,…,T, the cointegration technique of the regressors m=1,2,…,M, and lag length k=1,2,…,K follows the following steps (Zaied and Cheikh 2015; Nael 2014):

(i) Perform the OLS regression of y on the regressors x's in equation (8) and keep the residuals (ε_i^).

$$y_{it} = \alpha_i + \beta_{1i}x_{1it} + \beta_{2i}x_{2it} + \cdots + \beta_{mi}x_{mit} + \varepsilon_{it} \quad (5)$$

(ii) Estimate the differences of all variables in equation (8) and store the residuals (η_i^).

$$\Delta y_{it} = \sum_{m=1}^{M} \beta_{mi}\Delta x_{mit} + \eta_{it} \ldots\ldots\ldots.\ldots\ldots.(6)$$

(iii) Perform the OLS regression of $\varepsilon^{\wedge}{}_{it}$ on the $\varepsilon^{\wedge}{}_{it-1}$ in equation (8) and keep the residuals (μ_i^).

$$\varepsilon^{\wedge}{}_{it} = \gamma^{\wedge}{}_{i}\,\varepsilon^{\wedge}{}_{it-1} + \mu^{\wedge}{}_{it} \ldots\ldots\ldots\ldots\ldots\ldots..(7)$$

(iv) Perform the OLS regression of $\varepsilon^{\wedge}{}_{it}$ on$\varepsilon^{\wedge}{}_{it-1}$, and on $(\Delta\varepsilon^{\wedge}{}_{it-k})$, and keep the residuals $(\mu^{\wedge *}{}_{it})$.

$$\varepsilon^{\wedge}{}_{it} = \gamma^{\wedge}{}_{i}\,\varepsilon^{\wedge}{}_{it-1} + \sum_{k=1}^{K} \gamma^{\wedge}{}_{ik}\,\Delta\varepsilon^{\wedge}{}_{it-k} + \mu^{\wedge *}{}_{it} \ldots.\ldots.(8)$$

(v) Calculate the following variances and its normalization forms as follows:

$$S^{\wedge *2}{}_{i} = \frac{1}{T}\sum_{t=1}^{T} \mu^{\wedge *2}{}_{it}\ , S^{\sim *2}{}_{NT} = \frac{1}{N}\sum_{t=1}^{T} S^{\wedge *2}{}_{it} \ldots\ldots.(9)$$

$$♣L^{\wedge -2}{}_{11i} = \frac{1}{T}\sum_{t=1}^{T} \eta^{\wedge *2}{}_{it} + \frac{2}{T}\sum_{S=1}^{K_i}\left(1 - \frac{s}{k_i+1}\right)\sum_{t=s+1}^{T} \eta^{\wedge}{}_{it}\,\eta^{\wedge}{}_{it-S}. (10)$$

$$\lambda^{\wedge}{}_{i} = \frac{1}{T}\sum_{S=1}^{K_i}\left(1 - \frac{s}{k_i+1}\right)\sum_{t=s+1}^{T} \mu^{\wedge}{}_{it}\,\mu^{\wedge}{}_{it-S} \ldots\ldots(11)$$

♣ $L = \sum_{i=1}^{n}\left(y_i - y^{\wedge}{}_{i}\right)^2$
$L = \sum_{i=1}^{n}(y_i - \beta_1\Delta R_{it} - \beta_2\Delta M_{it} - \beta_3\Delta A_{it} - \beta_4\Delta L_{it})^2$

$L_{11} = \frac{\partial L}{\partial \beta_1}, L_{12} = \frac{\partial L}{\partial \beta_2}, L_{13} = \frac{\partial L}{\partial \beta_3}, L_{14} = \frac{\partial L}{\partial \beta_4}.$

$$S^{\wedge 2}{}_i = \frac{1}{T}\sum_{t=1}^{T}\mu^{\wedge 2}{}_{it}\ , \sigma^{\wedge 2}{}_i = S^{\wedge 2}{}_i + 2\lambda^{\wedge}{}_i\ , \sigma^{\sim 2}{}_{NT} = \frac{1}{N}\sum_{t=1}^{T}L^{\wedge -2}{}_{11i}\,\sigma^{\wedge 2}{}_{i} .. (12)$$

(vi) The seven Pedroni tests are constructed with the giving mean and variance as follow:

$$panel\ v: T^2 N^{\frac{3}{2}}\left(\sum_{i=1}^{N}\sum_{i=1}^{T}L^{\wedge -2}_{i}\ \ \varepsilon^{\wedge 2}_{it-1}\right)^{-1} \dots\dots\dots (13)$$

$$panel\ \rho: T\sqrt{N}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}L^{\wedge -2}_{i}\ \ \varepsilon^{\wedge 2}_{it-1}\right)^{-1}$$

$$\sum_{i=1}^{N}\sum_{t=1}^{T}L^{\wedge -2}_{i}\ (\varepsilon^{\wedge}{}_{it-1}\Delta\varepsilon^{\wedge}{}_{it-1} - \lambda^{\wedge}{}_i) \dots\dots\dots (14)$$

$$panel\ t: \left(\sigma^{\sim 2}_{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}L^{\wedge -2}_{i}\ \ \varepsilon^{\wedge 2}_{it-1}\right)^{\frac{-1}{2}}$$

$$\sum_{i=1}^{N}\sum_{t=1}^{T}L^{\wedge -2}_{i}\ (\varepsilon^{\wedge}{}_{it-1}\Delta\varepsilon^{\wedge}{}_{it-1} - \lambda^{\wedge}{}_i) \dots\dots\dots (15)$$

$$panel\ ADF: \left(S^{\sim *2}_{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}L_i^{\wedge -2}\ \varepsilon^{\wedge *2}{}_{it-1}\right)^{-\frac{1}{2}}$$

$$\sum_{i=1}^{N}\sum_{t=1}^{T}L^{\wedge -2}{}_i\,\varepsilon^{\wedge *2}{}_{it-1}\Delta\varepsilon^{\wedge *}{}_{it} \dots\dots\dots\dots\dots\dots (16)$$

$$group\ \rho: T\frac{1}{\sqrt{N}}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}L_i^{\wedge -2}\,\varepsilon^{\wedge 2}_{it-1}\right)^{-1}$$

$$\sum_{t=1}^{T}(\varepsilon^{\wedge}{}_{it-1}\Delta\varepsilon^{\wedge}{}_{it-1} - \lambda^{\wedge}{}_i) \dots\dots\dots\dots\dots\dots (17)$$

$$group\ t: \frac{1}{\sqrt{N}}\sum_{i=1}^{N}\left(\sigma_i^{\wedge 2}\ \sum_{t=1}^{T}\varepsilon^{\wedge 2}_{it-1}\right)^{-\frac{1}{2}}$$

$$\sum_{t=1}^{T}(\varepsilon^{\wedge}{}_{it-1}\Delta\varepsilon^{\wedge}{}_{it-1} - \lambda^{\wedge}{}_i) \dots\dots\dots\dots\dots\dots (18)$$

$$group\ ADF: \frac{1}{\sqrt{N}}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}S_i^{\wedge *2}\varepsilon^{\wedge 2}_{it-1}\right)^{-\frac{1}{2}}$$

$$\sum_{t=1}^{T}(\varepsilon^{\wedge}{}_{it-1}\Delta\varepsilon^{\wedge}{}_{it-1}) \dots\dots\dots\dots\dots\dots (19)$$

2.3. FMOLS Regression

The technique is applied to estimate the long run relationship between lagged variables to overcome the problems of nonstationary and endogeneity, which cause the serial correlation between the involved time series of the model. The technique consists of the following steps:

(i) Perform the OLS regression of y on the explanatory variables x's and arrange it in a matrix form as follows

$$y_t = \beta^T X_t + u_{1t} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (20)$$

(ii) Suppose that all explanatory variables are stationary at the first difference as follows:

$$\Delta X_{2t} = u_{2t} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (21)$$

(iii) The residuals u_t is stationary with zero mean and the covariance matrix Ω

$$\Omega = \Sigma + \Lambda + \Lambda^T = \begin{pmatrix}\sigma_{11} & \cdots & \sigma_{51}\\ \vdots & \ddots & \vdots \\ \sigma_{51} & \cdots & \sigma_{55}\end{pmatrix} + \sum_{t=1}^{\infty}E(u_0\,u^T{}_t) + \sum_{t=1}^{\infty}E(u_t\,u^T{}_0)\ .(\dots\dots 22)$$

(iv) Estimate $\beta^{\wedge}{}_{OLS}$

$$\beta^{\wedge}{}_{OLS} = (X^TX)^{-1}X^TY \dots\dots\dots\dots\dots\dots\dots (23)$$

(v) To overcome the problem of endogeneity: adjust the dependent variable y_t to be:

$$\widehat{y_t} = y_t - \hat{\theta}\,\widehat{\Omega}\,\Delta X_t \dots\dots\dots\dots\dots\dots\dots\dots (24)$$

, and adjust the error term u_t to be

$$\widehat{u_t}* = u_t - \hat{\theta}\,\widehat{\Omega}\,\Delta X_t \dots\dots\dots\dots\dots\dots\dots\dots\dots (25)$$

(vi) To overcome the problem of auto correlation: compute the parameter of autocorrelation

$$\hat{\xi} = \sum_{k=0}^{\infty}(\widehat{u_t}*\ \ u^T{}_t) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (26)$$

(vii) Estimate $\beta_{i_{FMOLS}}$ as follow:

$$\beta^{\wedge}{}_{i\,FMOLS} = \left(X_i{}^TX_i\right)^{-1}(X_i{}^TY_i^* - T\xi) \dots\dots (27)$$

3 Results and Discussion

The current section shows the empirical results of FMOLS model for investigating the impact of the climate change on the wheat productivity for the five districts: El-Negaila, Sidi Barrani, El-Daba'a, Marsa Matrouh, and EL-Alamain during (1990-2019). Firstly; the descriptive statistics of the model' variables are depicted. Furthermore; the results of OLS are presented for checking endogenity and heteroscedasticity conditions, panel unit root test and the Pedroni panel residual co-integration test are represented. Finally; the FMOLS results are shown.

3.1. Descriptive Statistics

Table 1 shows the descriptive statistics of the model's variables. The mean of wheat productivity variable (Y_{pooled}) is 1.93 Ardab/Fadden displays high discrepancies between the minimum and maximum values, from 0.082 Ardab/ Fadden in El-Daba'a district to 12 Ardab/ Fadden in EL-Alamain district while the general means range between 0.847 Ardab/ Fadden in El-Daba'a district to 3.6 Ardab/ Fadden in EL-Alamain district. The wheat productivity means accompanied with the fluctuations in the precipitation variable (R_{pooled}), as the mean of precipitation amounts 67.4mm/season, fluctuates between 14.3 mm/season as minimum amount in EL-Alamain district to 165.9 mm/season as maximum amount in El-Negaila district. The mean of difference between Maximum and Minimum temperature variable (M_{pooled}) is 8.1 ^{0}C fluctuates between 5.6 ^{0}C in El-Negaila district to 9.6^{0}C in EL- Daba'a districts.

The mean of cultivated wheat area variable (A_{pooled}) is 18449 Fadden, the minimum and maximum values range between 107.8 Fadden in EL-Alamain district to 20161.5 Fadden in El-Negaila district while the general means range between 1018.7 Fadden in EL-Alamain district to 6818.2 Fadden in El-Negaila district. The mean of cultivated wheat area variable is coincided with the mean of hired and permanent Labor per Fadden (L_{pooled}), as it accounts 12 laborers per Fadden, the minimum and maximum values range between 2-30 laborer / Fadden in Marsa Matrouh district while the general means range between 7laborer/ Fadden in Marsa Matrouh district to 17laborer/ Fadden in El-Daba'a district.

3.2. Endogeneity and Heteroscedasticity Tests

The Central Limit Theorem (CLT) imposes the exogeneity condition in OLS, which insures that independent variables are not correlated with error term; otherwise estimators are biased and inconsistent. Usually, the endogeneity problem occurs due to initial errors in data measurement. **Table 2** explains the checking process of endogeneity and heteroscedasticity status applying OLS. The results show that except trend variable, the explanatory variables (Area, Temperature, Rain, and Labor) are statistically non-significant at 5% significance level. The adjusted determination coefficient is low, that the suggested explanatory variables explain only 49% of the wheat yield change. To check the endogeneity status, the area variable (A_{pooled}) is selected to be an variable and is regressed on the other explanatory variables, because the area variable is affected by natural explanatory variables (Temperature, and Rain). The Wald test checks the null hypothesis (H_0): Variable A is endogenous, Residual A = 0 versus the alternative hypothesis (H_1): Variable A is not endogenous, Residual A $\neq$ 0. The probabilities of F-statistic and Chi-square statistics are less than 5%, i.e. variable A is endogenous. The Likelihood Ratio test checks the null hypothesis H_0: Residuals are homoscedastic versus the alternative hypothesis H_1: Residuals are heteroscedastic. The probability of LR statistic is less than 5%, i.e. the model suffers from heteroscedasticity.

3.3. Panel Unit Root Test

Table 3 shows the results of panel unit root test applying LLC and IPS statistics, as LLC and IPS statistics display all variables (Y, A, R, M, L) in the natural log form are not stationary at level or have unit root [I (0)]. On the other hand, all variables are converted to stationary or integrated of order one, [I (1)] after the first differences process.

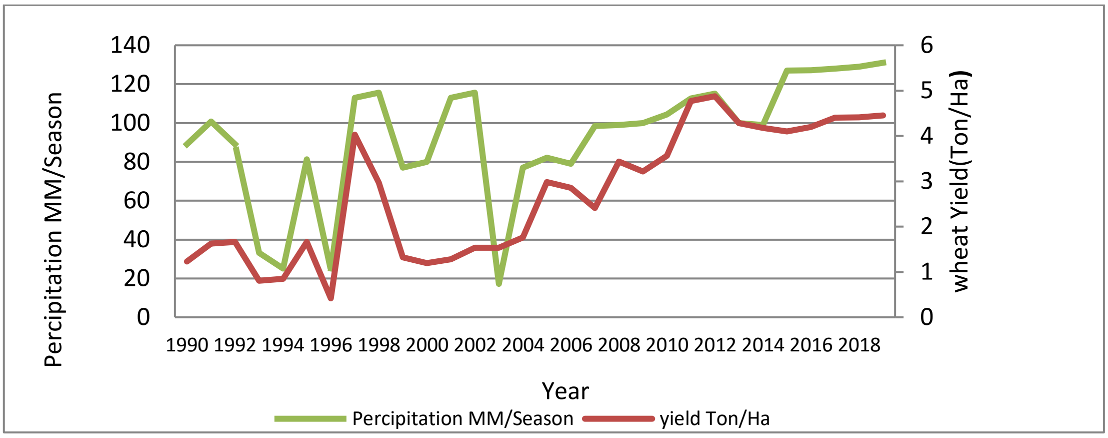

Fig 1. The trend of wheat yield with precipitation in Northern West Coast of Egypt (1990- 2019)
Source: The Agricultural Statistics Bulletin (1990-2019), Economic Affairs Sector, Ministry of Agriculture and Land Reclamation.

The Information Note of Matrouh Governorate, (1990-2019). Information and Decision Making Center, Matrouh Governorate, The Agricultural statistics, 1990-2019. Directorate of Agriculture, Matrouh Governorate.
The Metrology Station, (1990-2019). Geographic Information System Unit, Sustainable Development Center of Matrouh Governorate.

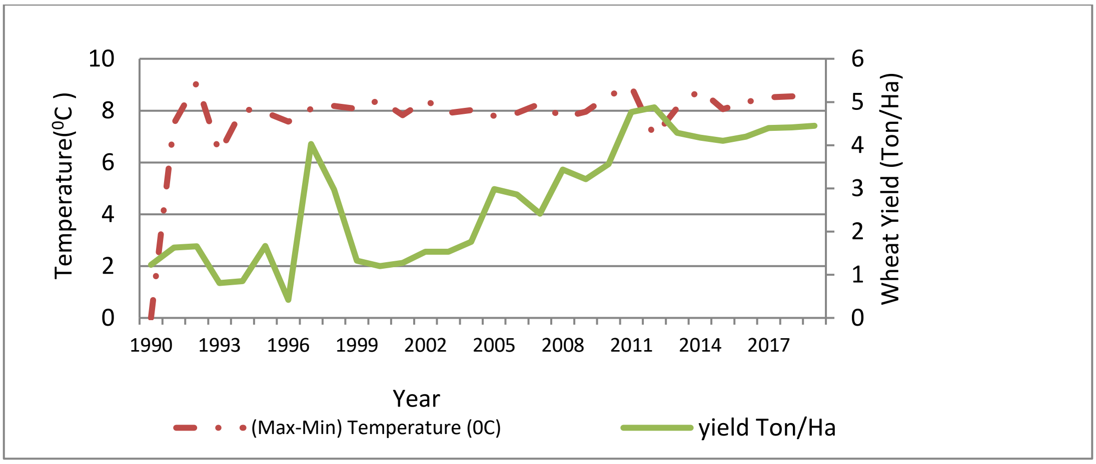

Fig 2. The trend of wheat yield and Average temperature (°C) in Northern West Coast of Egypt (1990-2019)
Source: The agricultural statistics bulletin (1990-2019) Economic Affairs sector, Ministry of Agriculture and Land Reclamation.
The Information Note of Matrouh Governorate (1990-2019)Information and Decision Making Center, Matrouh Governorate, The Agricultural statistics(1990-2019) Directorate of Agriculture, Matrouh Governorate.
The Metrology Station (1990-2019) Geographic Information System Unit, Sustainable Development Center of Matrouh Governorate.

Table 1. Descriptive statistics of wheat productivity model in Matrouh Governorate (1990-2019)

Variable	Max	Min	Mean
Y_{pooled} -wheat yield Ardab/Fadden	12	0.082	1.93
District V- EL-Negaila	6.459	0.469	2.68
District IV-Sidi Barrani	5.15	0.128	1.26
District I-EL-Daba'a	2.5	0.082	0.847
District III-Marsa Matrouh	3	0.131	1.21
District II-EL-Alamain	12	0.487	3.6
A_{pooled}-cultivated area of wheat (Fadden)	20161.5	107.8	18449
District V- EL-Negaila	20161.5	772.3	6818.2
District IV-Sidi Barrani	17305	287.4	4248.9
District I-EL-Daba'a	10080.8	386.1	3245.7
District III-Marsa Matrouh	9377.4	359.2	3117.5
District II-EL-Alamain	2813.2	107.8	1018.7
R_{pooled} Average rainfall in winter season(mm)	165.9	14.3	67.4
District V- EL-Negaila	165.9	27.7	79.4
District IV-Sidi Barrani	154.7	21.1	67.4
District I-EL-Daba'a	135	22.2	64.3
District III-Marsa Matrouh	144	19.1	75.9
District II-EL-Alamain	131.9	14.3	54.9
M_{pooled}-Average(Max-Min) Temperature in winter season ^{0}C	9.6	5.6	8.1
District V- EL-Negaila	8.2	5.6	7.2
District IV-Sidi Barrani	9.0	6.2	8.1
District I-EL-Daba'a	9.6	6.9	8.9
District III-Marsa Matrouh	9.5	6.6	8.3
District II-EL-Alamain	9.1	6.3	8.1
L_{pooled}-Hired and permanent Labor per Fadden	30	2	12
District V- EL-Negaila	12	6	9
District IV-Sidi Barrani	20	9	14
District I-EL-Daba'a	25	10	17
District III-Marsa Matrouh	30	2	7
District II-EL-Alamain	10	5	8

Source: The agricultural statistics bulletin (1990-2019) Economic Affairs sector, Ministry of Agriculture and Land Reclamation
The Information Note of Matrouh Governorate(1990-2019) Information and Decision Making Center, Matrouh Governorate.
The Agricultural statistics (1990-2019) Directorate of Agriculture, Matrouh Governorate.
The Metrology Station (1990-2019) Geographic Information System Unit, Sustainable Development Center of Matrouh Governorate.
The agricultural census of Matrouh Governorate (1990, 2000, 2010) Economic Affairs sector, Ministry of Agriculture and Land Reclamation.

Table 2. The results of OLS regression model of the impact of climate change on wheat yield in Matrouh Governorate (1990-2019)

Variable	**Coefficient**	**T-Stat.**	**Prob.**
Area(A_{pooled})	4.2E-05	0.50	0.567
Temperature (M_{pooled})	0.496	2.04	0.043
Rain (R_{pooled})	0.006	1.03	0.306
Labor (L_{pooled})	0.014	0.585	0.55
Trend(T_{pooled})	0.089	4.749	0.000
Adj.R^2 =0.49, Wald Test: Variable A is endogenous versus Variable A is non-endogenous, F Statistic= 22.9, Prob. 0.000, Chi- Square = 22.9 , Prob. 0.000, Heteroscedasticity Test Likelihood ratio =120.18, Prob. 0.000			

Source: Eviews results by the authors.

Table 3. Panel Unit Root Test

Variable	**LLC**				**IPS**			
	Level		**First difference**		**Level**		**First difference**	
	Stat.	**Prob.**	**Stat.**	**Prob.**	**Stat.**	**Prob.**	**Stat.**	**Prob.**
LnY	-0.564	0.287	-7.356	0.000	-o.675	0.249	-10.89	0.000
LnA	-1.003	0.158	-7.392	0.000	-0.606	0.272	-9.121	0.000
Ln M	-0.328	0.372	-4.350	0.000	-2.320	0.01	-14.79	0.000
LnR	-0.553	0.291	-1.746	0.040	1.553	0.939	-2.799	0.003
LnL	-1.003	0.158	-7.391	0.000	-0.606	0.272	-9.121	0.000

Source: Eviews results by the authors.

Table 4. Pedroni Panel Residual Cointegration Test

Hypothesis and tests	**Stat.**	**Prob.**
H_0:No co-integration $H_{1:}$ Common AR coefs. Within dimensions		
Panel v- Statistic	-0.0005	0.500
Panel rho -Statistic	-1.871	0.030
Panel PP-Statistic	-4.040	0.000
Panel ADF-Statistic	-1.395	0.050
H_0:No co-integration $H_{2:}$ Individual AR coefs. Between dimensions		
Group rho -Statistic	-1.131	0.129
Group PP-Statistic	-4.166	0.000
Group ADF-Statistic	-1.034	0.151

Source: Eviews results by the authors.

Table 5. The results of FM-OLS regression model of the impact of climate change on wheat yield in Matrouh Governorate (1990-2019)

Cross-Section/ districts	Rainfall Ln R	Temperature Ln M	Labor Ln L	Trend	Adj.R^2
1-EL-Negaila	8.429 (30.69)**	-1.610 (-3.060)**	0.112 (1.696)	0.487 (3.519)**	0.74
2-Sidi Barrani	5.088 (21.922)**	-1.747 (-22.071)**	0.126 (0.735)	0.718 (4.543)**	0.71
3-EL-Daba'a	3.903 (11.49)**	-6.830 (-7.998)**	0.752 (4.886)**	0.704 (5.133)**	0.53
4-Marsa Matrouh	0.211 (1.877)*	-3.474 (-13.368)**	0.494 (3.965)**	0.677 (4.893)**	0.52
5-EL-Alamain	0.629 (3.218)**	-1.498 (-2.747)**	0.578 (4.362)**	0.678 (4.052)**	0.50
Pooled series	3.262 (20.05)**	-5.687 (-10.697)**	0.525 (4.239)**	0.565 (7.265)**	0.60

*significant at 5% level of significance, **significant at 1% level of significance.
Source: Eviews results by the authors.

Table 6. Prospective and policy implications

District	Current area Fadden	Current yield Ardab/Fadden	Current water (MM^3/Fadden)	Required water (MM^3/Fadden	Total water (MM^3)
EL-Negaila	6818.2	2.68	79.4	355.5	2424023
Sidi-Barrani	4248.9	1.26	67.4	301.7	1282280
EL-Daba'a	3245.7	0.847	64.3	287.9	934470.9
Marsa Matrouh	3117.5	1.21	75.9	339.8	1059485
EL-Alamain	1018.7	3.6	54.9	245.8	250417.7
Total					5950676.6

Source: results by the authors.

3.4. Pedroni Panel Residual Cointegration Test

Table 4 shows the panel cointegration test to confirm a long run relationship between wheat productivity and rainfall, temperature, labor and technology variables. The seven statistics of Pedroni are checked, but the null hypothesis of no cointegration is rejected by four statistics, namely; Panel rho –Statistic, Panel PP –Statistic, Panel ADF –Statistic and Group PP –Statistic to prove the existence of long run relationship between the first-order integrated variables [I(1)].

3.5. The result of FM-OLS Regression Model

Table 5 shows the impact of climate change on wheat yield in Matrouh Governorate (1990-2019). After verifying the endogeneity problem, FM-OLS technique is applied to identify the long run relationship between explanatory variables (Rain, Temperature, Labor and Trend) and wheat productivity. Firstly, For cross sections (districts), the table shows that the wheat productivity in El-Negaila district is affected by natural (climatic) variables and economic variables with varying proportions under the drought conditions of northern coast, as 1% increase in rainfall variable (Ln R) increases the annual wheat productivity by about 8.4%, while 1% increase in the difference between Max-Min temperature (Ln M) decreases the annual wheat productivity by 1.6%. Furthermore, the variable of hired and permanent labor per Fadden (Ln L) doesn't show impact on wheat productivity, as the labor coefficient is non-significant contrary to the economic logic. The technology variable (T) has significant but less impact on wheat productivity rather than rainfall variable, as 1% improvement of agricultural practices and technology causes a statistical significant increase in wheat productivity by about 0.487%.

In Sidi Barrani district, 1% increase in rainfall variable (Ln R) increases the annual wheat productivity by about 5.1%, while 1% increase in the difference between Max-Min temperatures (Ln M) decreases the annual wheat productivity by about 1.7%. Furthermore, the labor variable (Ln L) is statistically non-significant contrary to the economic logic, while technology variable (T) shows that1% improvement of agricultural practices and technology causes a statistical significant increase in wheat productivity by about 0.718%.

In El-Daba'a district, 1% increase in rainfall variable (Ln R) increases the annual wheat productivity by about 3.9%, while 1% increase in the difference between Max-Min temperatures (Ln M) decreases the annual wheat productivity by about 6.8%. Furthermore, 1% increase of the variable of hired and permanent labor per Fadden (Ln L) increases the annual wheat productivity by about 0.752%, while technology variable (T) shows that1% improvement of technology causes a statistical significant increase in wheat productivity by about 0.704%.

In Marsa Matrouh district, 1% increase in rainfall variable (Ln R) increases the annual wheat productivity by about 0.21%, while 1% increase in the difference between Max-Min temperatures (Ln M) decreases the annual wheat productivity by about 3.4%. Furthermore, 1% increase of the variable of hired and permanent labor per Fadden (Ln L) increases the annual wheat productivity by about 0.494%, while technology variable (T) shows that1% improvement of technology causes a statistical significant increase in wheat productivity by about 0.677%.

In EL-Alamain district, 1% increase in rainfall variable (Ln R) increases the annual wheat productivity by about 0.63%, while 1% increase in the difference between Max-Min temperatures (Ln M) decreases the annual wheat productivity by about 1.5%. Furthermore, 1% increases of the variable of hired and permanent labor per Fadden (Ln L) increases the annual wheat productivity by about 0.578%, while technology variable (T) shows that1% improvement of technology causes a statistical significant increase in wheat productivity by about 0.678%.

Secondly; for pooled series; the results represent a significant positive long run relationship between precipitation variable (Ln R) and wheat productivity, as 1% increase in rainfall increases the wheat productivity by about 3.3%, while 1% increase in temperature variable (Ln M) decreases the annual wheat productivity by about 5.7%. Furthermore, 1% increases of the variable of hired and permanent labor per Fadden (Ln L) increases the annual wheat productivity by about 0.525%, while technology variable (T) shows that1% improvement of technology causes a statistical significant increase in wheat productivity by about 0.565%.

4 Conclusion

The key objective of this paper was to examine the impact of climate change on the wheat productivity in five rains- fed districts: El-Negaila, Sidi Barrani, El-Daba'a, Marsa Matrouh, and EL-Alamain in the northern west coast of Egypt during (1990-2019). Fully Modified Ordinary Least Square (FMOLS) technique developed by Philip and Hansen was applied to investigate the long run relationship between the cointegrated natural climatic variables (precipitation and temperature) and economic variables (cultivated area, labor and technology) for panel data under endogeneity and heteroscedasticity conditions. The results of OLS function showed that the cultivated area variable is endogenous, and the model suffers from heteroscedasticity.

The panel unit root test applying LLC (Levin, Lin and Chu) statistics and IPS (Im, Pesaran, and Shin) statistics proved that all variables are not stationary at level and integrated of order one after the first differences process. Pedroni panel residual cointegration test confirmed the existence of long run relationship between the first-order integrated variables [I (1)]. The estimated coefficients derived from the FM-OLS function proved that the natural climatic variables are the main determinants of wheat productivity in northern west coast of Egypt, as a 1% increase in annual rainfall improves wheat productivity significantly by 3.3% for the pooled series. The far west districts are the most affected regions by annual rainfall, as a 1% increase of annual rainfall in EL-Negaila and Sidi- Barrani districts increase the wheat productivity by 8.4%, 5.1% respectively. Moreover, the variable of the difference between Max-Min. temperatures affects the wheat productivity negatively by about 5.7% for the pooled series.

However, all districts except EL-Negaila and Sidi Barrani were significantly affected by hired and permanent labor force to show the extent of labor intensification. On the other side, technical improvements also are important variable in all districts which improve the low productivity of wheat under dry climate in north coast of Egypt.

The concluded results demand for implementing adaptive policies that considering the drought and water shortage such as cultivating drought tolerant wheat varieties, establishing rain harvesting program, and building cement and stone dykes and cisterns specifically in the far west districts in northern west coast (El-Negaila and Sidi Barrani districts) for enhancing the wheat productivity by 8.4%, 5.1% respectively. In the framework of the Egyptian strategy of agriculture which intends to increase the wheat productivity to 3.6 Ton/Fadden (24 Ardab/Fadden), **(Table 6)** depicts the recommend water policy for improving wheat yield to 12 Ardab/Fadden (50% of the intended wheat yield) under drought climate in northern west coast. El-Negaila district needs 355.5 MM3/Fadden, Sidi Barrani district needs 301.7 MM3/Fadden, EL-Daba'a district needs 287.9 MM3/Fadden, Marsa Matrouh district needs 339.8 MM^3/Fadden, and EL-Alamain district needs 245.8 MM^3/Fadden, and the total five rain fed area which accounts 18449 Fadden needs 5950676.6 MM^3/year.

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دراسة إقصادية لأثر التغييرات المناخية على إنتاج محصول القمح بمنطقة الساحل الشمالى الغربى لجمهورية مصر العربية

[11]

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الموجـــــز

يستهدف البحث دراسة تأثير التغيرات المناخية على إنتاجية القمح فى خمسة مراكز مطيرة بالساحل الشمالى الغربى لمصروهى: النجيلة، وسيدى برانى، والضبعة، ومرسى مطروح ،والعلمين، حيث تمثل مساحة محصول القمح بتلك المراكز 41.4% من مساحة القمح الكلية بمحافظة مطروح خلال الفترة (1990–2019). وتتمثل مشكلة البحث فى تذبذب متوسط إنتاجية القمح بتلك المراكز بين 1.167 إلى 13.38 أردب/ فدان تزامنا مع تذبذب متوسط كميات هطول الأمطار بين 24.35 إلى 115.1 ملم/ موسم، وتذبذب متوسط الفرق بين درجات الحرارة العظمى والصغرى بين 8.07 إلى 7 درجة مئوية. إستخدم البحث أسلوب المربعات الدنيا المعدلة كليا FMOLS لدراسة العلاقة بين إنتاجية القمح والمتغيرات (الأمطار، الحرارة، المساحة، العمل، والتطور التكنولوجى). أثبتت نتائج OLS وجود مشكلتى التباين الداخلى endogeneity وعدم ثبات تباين الخطأ heteroscedasticity. وقد تبين عدم إستقرار المتغيرات عند المستوى بإستخدام إحصائيتى LLC وIPS. وقد أثبت إختبار Pedroni للتكامل المشترك بين البواقى للبيانات المختلطة وجود علاقة طويلة الأجل بين المتغيرات المتكاملة من الدرجة الأولى [(1) I] . وقد أثبتت دالة FMOLS أن المتغيرات المناخية هى المحددات الرئيسية للإنتاجية ، حيث تؤدى زيادة معدلات الأمطار بنسبة 1% إلى تحسين إنتاجية القمح بنسبة 3.3 %، بينما تتسبب زيادة درجات الحرارة بنسبة 1% إلى إنخفاض الإنتاجية إلى 5.7%.وتعتبر المناطق التى تقع فى أقصى الغرب (النجيلة وبرانى) من أكثر المناطق تأثرا بالأمطار، حيث يتسبب إرتفاع معدلات الأمطار بنسبة 1% إلى زيادة الإنتاجية بحوالى 8.4% ، 5.1% بالمركزين على الترتيب،وأشارت النتائج إلى تأثرانتاجية القمح بحجم العمالة الدائمة والمستأجرة بجميع المراكز عدا مركزى النجيلة وبرانى، كما تتأثر جميع المراكزبمستوى التحسينات الفنية. ويوصى بتبنى سياسة مائية كبرامج حصاد الأمطار، وبناء السدود الاسمنتية والترابية لتوفير 355.5، 301.7، 287.9، 339.8، 245.8 م^3/فدان بمراكز النجيلة، وسيدى برانى، والضبعة، ومرسى مطروح ،والعلمين على الترتيب، لتحسين إنتاجية القمح إلى 12 أردب/فدان تحت ظروف الجفاف بالساحل الشمالى الغربى لمصر.