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Studying the Effects of Climate Change of Precipitation and Temperature on Yield of Iran's Irrigated Wheat using the Dynamic Panel Method

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ABSTRACT: Today, climate change is the most important environmental problems in the world and its importance in the agricultural sector is more than others and since the country's agricultural production system is less flexible towards changes in technology and investment, therefore the sensitivity of this sector to climate changes is more vulnerable. Regarding this issue, the effects of climate variables including average annual temperature and total annual rainfall with variables of fertilizer, seed, machinery and labor on wheat, an important strategic product of Iran, was evaluated in this study. In this study, the dynamic panel, a new econometric method, and DOLS pattern were used to estimate the model. Data used in this study was obtained from 20 years and 11 provinces of the country. The results showed that the climate variable of temperature had a positive effect on yield of irrigated wheat before the maximum annual temperature of 17.77 °C and then had a negative effect, in addition, the climate variable of precipitation had a positive effect on yield of irrigated wheat before the maximum total annual rainfall of 577.8 mm and then had a negative effect. Given these results, it is recommended to prevent human interference in nature in order to prevent temperature increasing and to deal with raising in temperature it is suggested to use temperature resistant varieties.

Keywords: Temperature, climate change, precipitation, dynamic ordinary least squares, irrigated wheat.

INTRODUCTION

In recent years, climate changes had affected all regions around the world and its effects had been observed in many parts of the world in recent decades and are expected to be intensified in the coming decades. In fact, climate change is one of the phenomena that the current world is experiencing it (Gafari *et al.,* 2014). Climate or in other words the weather conditions prevailing at a given time and area is an important environmental element affecting the life on Earth (Carson, 1999). But in the meantime, human activities with the burning of fossil fuels are the major source of global climate change. In fact, with the rise of human activities, the concentrations of greenhouse gases would be increased, which would cause global warming, and eventually would lead to extensive changes in the global climate. These changes may have positive, neutral and negative effects depending on each region (Janjua *et al.,* 2014). Such activities would lead to the accumulation of long-term sustainable greenhouse gases in the atmosphere (carbon dioxide, methane, nitrous oxide and halocarbons), and for this reason, the issue of climate change due to global warming has become a major concern throughout the world in recent years. Scientists introduce the greenhouse gases, such as carbon dioxide (CO_2) as the main cause of global warming.

Unlike other pollutants, such as sulfur dioxide (SO_2) that mostly has local impact, CO_2 emissions would cause global-scale problems (Lau *et al.,* 2014). Although climate change in some regions of the world, especially in northern latitudes up to 55 degrees would have positive effects on agricultural production (Ewert *et al.,* 2005), the negative effects of climate change would be most severe in hot and dry areas (Gregory *et al.,* 2005).

The known consequences of climate change are changes in rainfall, wind direction, increasing in droughts, increasing in desertification and changes in the level of groundwater and surface water resources (Angel, 2008). Although the different economic sectors such as agriculture, forestry, water, industry, tourism, energy and even financial and insurance markets are affected by climate changes, the agriculture is the most sensitive sector to these changes (Hosseini *et al.,* 2013). Due to the close relation to natural resources and weather conditions, agriculture sector is more influenced by changes in temperature and precipitation and thus available water to farmers. Agriculture and natural resources are extremely dependent on weather and hence climate variability and changes, both in short -term (during the growing season) and long- term have a decisive role in its production and sustainability (Gafari *et al.,* 2014).

Agriculture sector is economically and physically vulnerable to changes in climate factors such as temperature and precipitation. In addition, the semi-arid nature of some countries with the rise of agriculture on marginal land, frequent droughts, scarce water resources and frequent fluctuations in rainfall would intensify this damage (Benhin, 2008). So according to what was said, changes in climate variables such as temperature and precipitation have an important role in agricultural productivity and rising in temperature and reducing in rainfall are the main variables in the phenomenon of climate change, which Changes in the pattern of these two variables can reduce yield during harvest time (Ben Zaied, 2013). Therefore, it is expected that climate change could influence the food production, food prices and potentially food security (Jayatilleke and Yiyong 2014).

Many studies have been done inside and outside the country about agricultural science, economic development and agricultural economy in the context of climate change and its dangers on agricultural production, which some examples of these studies are mentioned here.

Koochaki and Nasiri (2008) examined the impact of climate change with increasing in CO_2 concentration on wheat yield in Iran and concluded that although CO_2 concentration moderated negative impact of temperature rising in to some extent, but the yield of irrigated wheat in different regions declined between 14 to 21 percent according to the climate condition of the target year. Aligani *et al* (2011) in a study evaluated the effect of temperature and rainfall on yield of Iran's irrigated wheat based on combined time-series data from 1991 to 2006 and 14 provinces with high yield, and the results showed that for each provinces, physical variables (inputs) of model except the used pesticide had a significant positive effect on wheat yield and rainfall and temperature had positive and negative effects on wheat yield, respectively. Zarekani *et al* (2014) studied the effects of climate change on the economy of irrigated wheat in North Khorasan, Iran. Their results showed that climate change had been occurred in the last 30 years in this province and a significant relationship was observed between the logarithm of the parameters of minimum temperature, maximum temperature and annual precipitation with the yield of irrigated wheat. Mohammadi *et al* (2014) studied the effects of climate change on wheat cultivation time and growth period length in Sararood, Kermanshah, Iran. Results showed that in the coming period, the average temperature in all months of the year would increase from 1.7 to 2.5°C and continue until the end of 2039, and under conditions of climate change in the future, 25 days would be detracted from the growing period and the appropriate period for wheat cultivation would be reduced between 9-20 days.

Nicholas (1997) examined the effects of climate change on wheat yield in Australia and concluded that by increasing one degree in temperature, wheat yield increased as much as 3-5 percent. Sultana *et al* (2009) by studying the vulnerability and adaptation of wheat production to the climate change in four climatic regions of Pakistan concluded that increasing in temperature would reduce the crop yield in arid, semi-arid and semi-humid areas, but in the wet area with a gradual increase in temperature of 4 °C compared to the current situation, wheat yield would have an increasing trend. Luo *et al* (2009) by investigating the potential effects of climate change on wheat yield in area located in the southern part of Australia, suggested that the antedating of cultivation time is the most effective strategy for adaption to this phenomenon. Ben Zaied (2013) examined the effects of climate change of annual precipitation and temperature on agricultural sector in Tunisia using the dynamic panel method and fully modified ordinary least squares (FMOLS). The results showed that the annual temperature and precipitation had negative and positive impact, respectively on crop production and total agricultural production in Tunisia. The effect of climate in the short-term was also estimated smaller than long-term. Janjua *et al.* (2014) in a study titled "climate change and wheat production in Pakistan" examined the effects of climate change on wheat production using the autoregressive distributed lag model (ARDL) during 1960-2009. The results showed that climate change did not affect wheat production in Pakistan and only variables of fertilizer and cultivation land had a significant effect on wheat production in a short-term. Aditya *et al* (2014) studied the effect of climate change hazard on harvest intensity using the dynamic panel and dynamic ordinary least squares (DOLS) for 42 years. Their results showed that the effect of climate change hazard was negative on harvest intensity in a short-term in rural area in India, while this effect was positive in long-term.

Agricultural sector is an important sector in Iran, hence studying the two important parameters of climate, temperature and precipitation (which influence other climate parameters) on the yield of strategic crops, Iran's irrigated wheat is very important, because wheat is one of the main agricultural crops and most needed food supply in Iran and provides about 47% of calories consumed per capita in the country (Hosseini *et al.*, 2013). Additionally, studying these two parameters on crops yield over a period of time could help farmers to learn about climate change processes on wheat production and adopt the necessary decisions. In the present study, the irrigated wheat products had been selected due to its strategic essence as well as its large contribution in production.

MATERIALS AND METHODS

Production function shows the relationship between used inputs and produced outputs in different levels of consumption.

The general shape of the production function is as following (equation 1) (Mosanejad and Naggarzadeh 1997):

Equation 1

$$Y = f(X_1, X_2, ..., X_n)$$

where *Y* is production amount; *X* is production factors (in order of a wide variety of labor, investment and materials). Now, if in the production of a product, in addition to the managed production factors, the unmanaged production factors are considered, then the production function will be (equation 2):

Equation 2

$$Y = f(X^1, X^2, X^3)$$

where X1 is a vector of managed production inputs such as cultivation area, fertilizer, seed and other physical inputs, X2 is a vector of unmanaged production inputs such as climatic factors (temperature, precipitation, etc.), and X3 is the used technology. In this study, equation 2 is affirmed as equation 3 (Janjua *et al.*, 2014), so the yield function of irrigated cotton will be as following:

Equation 3

$$Ly_{it} = F(Lrain_{it}, Lrain^2_{it}, Ltem_{it}, Ltem^2_{it}, Lkood_{it}, Lbazr_{it}, Llaber_{it}, Lmachin_{it})$$

where

ly_{it}: is the natural logarithm of irrigated cotton yield,

$lrain_{it}$: is the natural logarithm of the total annual rainfall,

$lrain2_{it}$: is squared natural logarithm of total annual rainfall,

$ltem_{it}$: is natural logarithm of average annual rainfall,

$ltem2_{it}$: is squared natural logarithm of average annual rainfall,

$lkood_{it}$: is the natural logarithm of total used fertilizer per hectare,

$lbazr_{it}$: is the natural logarithm of used seed per hectare,

$llaber_{it}$: is the natural logarithm of labor per hectare,

$lmachin_{it}$: is the natural logarithm of the average using percentage of machines per hectare.

It should be noted that in the function of irrigated cotton, according to equation (3) to show the relationship between climate variables of temperature and precipitation with irrigated cotton yield, the square of these variables was used, in order to not only estimate a linear relationship but also to achieve a more accurate estimate. To investigate the long-term the relationship of irrigated cotton yield function DOLS method was used

The DOLS method is a way to estimate long-term relationship which was represented by Stock and Watson (1993) that by applying some adjustments to the ordinary least squares method, the response of a dependent variables towards changes in independent variable is evaluated (Alizadeh and Golkhandan 2014). The main advantages of this method compared with other estimators of cointegration vectors is that this one can also be used in small samples and can avoid simultaneously bias and has normal asymptotic distribution (Fetres *et al.,* 2011). In this method to estimate long-term coefficients the equation 4 will be used:

Equation 4

$$Y_{it} = \alpha_i + \beta X_{it} + \sum_{j=1}^{p} \gamma_j \Delta X_{i,t-j} + \sum_{j=1}^{p} \delta_j \Delta X_{i,t+j} + u_{it}$$

where, P is the past and future trends (primacy or recency, lag and lead), $\Delta X_{i,t-j}$ is the difference between an explanatory variable interval with lag, $\Delta X_{i,t+j}$ is difference between explanatory variable and future trends, γ_j is lag coefficients or past trends, δ_j is future trends coefficients, u_{it} is error of estimated long-term dynamic relationship and Y_{it} is dependent variable (Feghehmajidi and Ebrahimi 2014).

In this study, the annual data of production Ministry of Agriculture Jihad was used for variables of yield, seed, fertilizer, machines and labor from 1991-1992 to 2001-2002 and climate variables data of annual precipitation and temperature for each provinces were provided by Iran Meteorological Organization. This study included 11 provinces including Fars, Khorasan, Khuzestan, Isfahan, Tehran, West Azerbaijan, Hamedan, Qazvin, Kermanshah, Ardebil and East Azerbaijan, because more than 70% of irrigated wheat is produced in these provinces (Ministry of Agriculture Jihad, 1991-2011), And finally, to assess estimates the Eviews8 software was used.

RESULTS

Before analyzing the relationships between variables, the stationarity of the study series should be evaluated by unit root test. Usual econometric models in experimental work are based on durability assumptions of studied variables, because the possibility of the false estimate with nonstationary variables is expected and reliance on the results of such estimates would lead to misleading results (Baltagi, 2005). Therefore, in this study, two popular unit root tests in panel patterns including Levin, Lin. and CF (1993) and Im, Pesaran and Shin (2003) are used. The null hypothesis in these tests is based on presence of one unit root. A summary of these two tests results is shown in Table 1 and 2 which separately show the results of unit root tests for the logarithm of studied variables on the level and after the first difference, given the assumption of existence of trend and intercept variables.

Table 1: Results of the unit root test of variables on the level.

With intercept and trend				With intercept				Variable
Im, Pesaran and Shin test		Levin, Lin. and CF test		Im, Pesaran and Shin test		Levin, Lin. and CF test		
probability value	T-statistic	probability value	T-statistic	probability value	T-statistic	probability value	T-statistic	
0/71	-0/89	0/48	-0/39	0/07	-1/5*	0/052	-1/9*	LY
0/58	-0/78	0/15	-1/00	0/78	-0/38	0/44	-0/14	LRAIN
0/1	-1/05	0/34	-0/40	0/09	-1/43*	0/47	-0/08	LRAIN2
0/07	-1/7*	0/05	-2/04**	0/07	-1/5*	0/06	-1/83*	LTEM
0/06	-1/8*	0/04	-2/02**	0/078	-1/56*	0/068	-1/78*	LTEM2
0/37	-0/31*	0/92	1/40*	0/1	-1/27	0/07	-1/8*	LKOOD
0/10	-1/30	1/00	8/37	0/09	-1/3*	0/12	-1/13	LBAZR
0/075	-1/8*	0/09	-1/24*	0/075	-1/47*	1/00	8/71	LLABER
0/072	-1/66*	0/08	-1/60*	0/63	0/35	0/399	-0/25	LMACHIN

Reference: research findings (*, ** and *** respectively significant at 10, 5 and 1% level)

Table 2: Results of variable unit root test in the first difference.

With intercept and trend				With intercept				Variable
Im, Pesaran and Shin test		Levin, Lin. and CF test		Im, Pesaran and Shin test		Levin, Lin. and CF test		
probability value	T-statistic	probability value	T-statistic	probability value	T-statistic	probability value	T-statistic	
0/000	-6/82***	0/000	-4/12***	0/000	-8/29***	0/000	-6/05***	dLY
0/000	-7/86***	0/000	-3/06***	0/000	-9/44***	0/000	-4/77***	dLRAIN
0/000	-6/39***	0/000	-3/56***	0/000	-9/48***	0/000	-5/18***	dLRAIN2
0/000	-7/78***	0/000	-4/38***	0/000	-9/86***	0/000	-4/00***	dLTEM
0/000	-7/64***	0/000	-4/63***	0/000	-9/75***	0/000	-3/65***	dLTEM2
0/000	-5/20***	0/000	-4/48***	0/000	-7/26***	0/042	-1/97**	dLKOOD
0/000	-9/53***	0/000	-6/77***	0/000	-11/44***	0/000	-8/75***	dLBAZR
0/000	-8/90***	0/000	-4/66***	0/000	-10/42***	0/000	-7/12***	dLLABER
0/000	-6/62***	0/000	-6/50***	0/000	-8/31***	0/000	-8/12***	dLMACHIN

Reference: research findings (*, ** and *** respectively significant at 10, 5 and 1% level)

According to the results of the unit root tests in Tables (1) and (2), briefly all the variables in the model at 1% confidence level were non-stationary and had one unit root, so that their first difference at 1% level were stationary or I(0). Model estimates with stationary variables would lead to a false regression model, which difference methods and cointegration test are there to avoid reliance on a false regression. But using difference between variables in estimating pattern coefficients, valuable information about the variables level would be lost; therefore using this method is not suitable to prevent false regression, which cointegration tests can be used to solve this problem (Alizadeh and Golkhandan 2014). The cointegration concept evokes a long-term equilibrium relationship that economic system moving towards it over time (Noferesti, 1999). Hence, despite existence of non-stationary variables in the model, a cointegration was established between them, and then the results of the model estimation would be reliable. Cointegration tests in panel data have greater authority and reliability than cointegration tests for each level individually and these tests can even be used when the time period is short and the sample size is also short (Baltagi, 2005).

In this paper, the method proposed by Kao (1999) was used to evaluate the cointegration tests in the model. The null hypothesis in this test was the lack of cointegration or long-term relationship. The results of t-statistic in Kao test was not significant at 1% confidence level (t = 3.51). Thus, according to the results of this test, the existence of long-run relationship between the yield of irrigated wheat and other variables was approved. In other words, the null hypothesis based on the lack of cointegration or long-term relationship was rejected.

After proving the existence of cointegration in the model using Kao cointegration test, estimating of long-term relationship would be examined. There are many ways to estimate the long-term pattern, which was previously mentioned in this study. According to the literature of cointegration, a combination of DOLS based on the fixed effects model was used (Khaliliaraghi *et al.,* 2012). It should be noted that the Kao suggests that this estimation method is more efficient and provides valid statistical inference (Kao, 2000). The results of DOLS model is shown in Table 3.

Table 3: Results of estimation model using DOLS.

T-statistic and probability value	Coefficient amount	Variable
2/15 (0/03)	2/03**	$lrain_{it}$
-1/82 (0/07)	-0/16*	$lrain2_{it}$
2/70 (0/007)	9/49***	$ltem_{it}$
-2/48 (0/014)	-1/68**	$ltem2_{it}$
4/37 (0/000)	0/46***	$lkood_{it}$
0/99 (0/321)	0/16	$lbazr_{it}$
0/06 (0/95)	0/002	$llaber_{it}$
3/07 (0/002)	0/13***	$lmachin_{it}$

Reference: research findings (*, ** and *** respectively significant at 10, 5 and 1% level)

According to Table 3 which shows the results of model estimation using DOLS, suggest that all variables except physical variables of seed and labor were significant in long-term. In addition, there was a significant relationship between the climate variables of temperature and precipitation and yield of irrigated wheat. However, the maximum temperature could be calculated according to the results and first and second coefficients of the climate variables, which in logarithmic pattern, this point of return threshold or maximum temperature is determined by equation 6 (Hoseyninasab and Paykari 2012.):

Equation 6

$$T = \exp\left(\frac{-\alpha_1}{2\alpha_2}\right)$$

where, T is maximum temperature or return threshold; α_1 is the first power of is climate variables; and α_2 is the square of climate variables. Considering the results and having the coefficients of first and second power of climate variables, the maximum temperature and maximum precipitation could be obtained.

According to calculations, the maximum temperature, which after it the yield of irrigated wheat decreases, was 16.77; this means that before 16.77, increasing in temperature led to an increase in wheat yield but after that the yield decreased. In addition, the maximum rainfall was obtained 566.8, which before this maximum rainfall, increasing in annual rainfall led to an increase and after that led to a decrease in wheat yield.

In the case of non-climatic variables, fertilizer and machinery which are directly related to the yield, it can be expressed that one percent increase in these two variables would increase the wheat yield of 0.46 and 0.13, respectively.

DISCUSSION AND CONCLUSION

Today, climate change is the most important environmental problem of human societies. The agricultural sector is one of the most vulnerable sectors affected by climate change. Since the country's agricultural production systems are less flexible towards changes in technology and investments, therefore the sensitivity of this sector to climate change is more vulnerable. Hence, the necessary preparation and knowledge to deal with the effects of this phenomenon can have an effective role in reducing the probable damage. Considering this issue, in this study, two important climate factors including temperature and precipitation as well as physical factors of fertilizer, seed, labor and machinery was investigates on the yield of the strategic crop, Iran's irrigated wheat. The results of DOLS indicated that both climate of variables average annual temperature and total annual precipitation influenced the yield of irrigated wheat in long term, which the effect of temperature was positive until maximum temperature of 16.77°C and then it was negative; and the effect of total annual precipitation was positive until 566.8 mm and then it was negative. In addition, the results of physical variables were consistent with the theory. In general and according to the findings, temperature increases can lead to yield losses in irrigated wheat and since human activity is a major source of rising temperatures, therefore it is recommended to make a policy to prevent the destruction of natural resources by humans, and since, climate change and global warming can lead to huge risks of reduction in yield and then production in the future and of course will reduce the incentive to produce, and this in turn may have indirect effects on the pattern of trade, development and food security.

Thus, according to the weather conditions and the type of cultivation in each region, it is suggested that the effects of climate change on function of strategic products and different regions or provinces should be examined separately to obtain the best cultivation pattern for vulnerable areas. Additionally, the use of resistant cultivars to temperature or cultivating varieties that have completed the sensitive period to heat stress before the start of warm period, can also be useful to counter the phenomenon of climate change. Furthermore, farmers should use new irrigation systems due to the water scarcity in the country, which the water requirement of crops could be eliminated by using minimum amount of water.

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