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Effects of wheat yield and area under wheat crop on agricultural GDP in Pakistan: An econometric analysis

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A B S T R A C T

This study investigates and explores the relationship between wheat crop yield, area under wheat crop, and agricultural gross domestic product (GDP) in Pakistan. Times series data from 1970–2015 were used in this study. The Phillips-Perron unit root test was used to check the stationarity of the data. The Johansen cointegration test was performed to evaluate the long-term relationships between the dependent and independent variables. An econometric ordinary least square method was applied to estimate the relationship between wheat crop yield, area under wheat crop, and agricultural GDP. The results of the Johansen cointegration test revealed a long-term relationship between the variables. The regression results indicate that wheat crop yield has a positive and significant relationship with agricultural GDP, while the area under wheat crop has a negative relationship with agricultural GDP.

1. Introduction

Wheat is an important cereal crop for many countries where it is consumed as a staple food. Two aspects of crop production that have gained increasing importance are sustainability and reliability. For wheat production, water and energy supply are significant requirements and will continue to be essential in the future in order to ensure the sustainability and reliability of production. However, water and energy conservation are two key issues for researchers who have sought to decrease the use and the cost of these two commodities in such a way that production would not be hampered. In the 1980s, Pakistan experienced a golden era of water management: a canal irrigation system was constructed during this time. However, the effects of subsequent drought have stressed irrigation systems. The country experienced difficulty in recovering from the shock following a period of water scarcity that lasted nearly three years from 1999 to 2002. This scarcity in water caused the over-use of ground water though the pumping of ground water and use of wells, which consumed a huge amount of available energy despite the country experiencing problems in the provision of this commodity as well (GOP, 2008).

Furthermore, the availability of water for agriculture is expected to decrease from 72% to 62% from 1995 to 2020. Globally, this availability has been estimated to decrease from 87% to 73% in developing countries (Khan et al., 2006). Pakistan is largely an agricultural country, and water scarcity will thus have disadvantageous impacts on its economy. In addition, Pakistan directly subsidizes several agriculturally related activities, and more than 40% of labor is directly or indirectly engaged with the agricultural sector (GOP, 2008). In Pakistan, traditional crops, such as wheat, are planted in a flat basin and flooded with water for irrigation. However, huge water losses occur with this type of irrigation. Losses due to evaporation and deep percolation exacerbate severe water shortages, thereby encouraging further groundwater overexploitation. Alternative methods and technologies for crop irrigation are necessary to explore, such as raised bed (RB) technology, for example.

Agriculturists are facing an enormous challenge in order to meet the food requirements of nine billion people by the middle of the 21st century (FAO, 2009). Producing more food from less water in arid and semi-arid areas is one particular challenge for today's agriculture (Shideed, 2011). Water

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shortage and scarcity result in the degradation of land under rainfed agriculture and also lower food production, particularly in the agricultural and semi-agricultural zones of Africa (De Fraiture et al., 2010). About 80% of the world's agriculture comprises of rainfed land, which produces 80% of global food (Falkenmark et al., 2001; Valipour, 2013; Rehman et al., 2015).

In North Africa and West Asia, 95% agricultural land is rainfed, while in Uzbekistan, about 40% of agricultural land is rainfed and has been adversely affected by water shortages (Shaumarov and Birner, 2013; Zakaria et al., 2013). In particular, wheat is an important crop in Pakistan due to its wide consumption (Hussain et al., 2006). In Pakistan, 6.35 million hectares of land are irrigated with channel water and 12.53 million hectares are cultivated using water from wells and for the remaining 3.59 million hectares, no water is available (GOP, 2012). Limited water causes a reduction in wheat biomass, thereby reducing the overall yield of wheat crops (Oweis and Hachum, 2006; Tavakkoli and Oweis, 2004; Xie et al., 2005). The poor and sparsely distributed rainfall in arid regions of Pakistan further aggravates the situation. Small to complete crop losses have occurred under conditions of severe water stress and have been well documented for wheat crops (Oweis, 1997; Rehman et al., 2016a). To combat this issue, the harvesting and utilization of rain water have been successfully applied in many arid regions, wherein runoff water from catchment areas is collected and then direction to crop acreage (Qiang et al., 2006; Short and Lantzke, 2006). Rain water efficiency can be improved with appropriate water harvesting techniques, such as those with a focus on micro-watershed management (Concepcion et al., 2006; Zakaria et al., 2012). Such techniques can increase the capacity of water per unit crop area and also increase productivity (Oweis and Hachum, 2003; Ramotra and Giakwad, 2012; Rehman et al., 2016b).

The effects of irrigation on crop production are usually quantified through the use of crop water production functions, which have examined crop yields under a large variation and number of water applications (English and Raja, 1996).

In many cases, moderate irrigation can significantly increase production yield (Huang et al., 2002). However, as stated by Jin et al. (1999), extreme irrigation results in reduced efficiency in water use by crops, whereas effective water use efficiency leads to higher yields. Similarly, Olesen et al. (2000) showed that the impacts of irrigation on wheat crops are almost entirely due to increased transpiration, while water use efficiency and the harvest index remain unaffected.

Significant differences have been found between soil water content and irrigation rate under different irrigation conditions, crop yield and water use efficiency were found to significantly vary under distinct conditions (Kang et al., 2002). In particular, the effects of limited irrigation and soil water stress on crop yield and water use efficiency can be dependent on the particular growth stage of a crop (Singh et al., 1991).

2. Production and area used for wheat crop

Area under wheat crop in hectares and wheat crop yield in kg/hectares in Pakistan are presented in Fig. 1 and Fig. 2**,** respectively.

3. Materials and methods

Data were collected from a secondary source known as the Pakistan Statistical Year Book (various issues) for the 1970–2015 periods. Three variables were included in the model: wheat crop yield, area under wheat crop, and agricultural gross domestic product (GDP) of Pakistan. To check the stationarity of each variable, a Phillips and Perron (1988) unit root test was applied, including the trend and the intercept, which is appropriate for a finite sample (FAO, 2001). After checking the stationarity of the series, a Johansen cointegration test (Johansen and Juselius, 1990) was applied to examine the long-term relationships between the dependent and independent variables. To this end, the trace statistic and the Max-Eigen statistic were used.

To show the relationship between wheat crop yield, area under wheat crop, and agricultural GDP, an econometric OLS method was applied, and the following model was estimated (Eq. 1):

$$Y = AX_1^{\beta 1}X_2^{\beta 2} \quad (1)$$

Taking the natural logarithm of Eq. 1 and considering two explanatory variables, Eq. 1 was converted to the following form (Eq. 2):

$$LnY = \beta_0 + \beta_1 LnX_1 + \beta_2 LnX_2 + \mu \quad (2)$$

where

β_0 = Natural logarithm of A (intercept)

lnY = Natural logarithm of the agricultural GDP per year (in millions of rupees)

lnX_1 = Natural logarithm of wheat yield (in thousand tons)

lnX_2 = Natural logarithm of area under wheat crop (in thousand hectares)

μ = error term

So, Eq. 2 can also be written as follows (Eq. 3):

$$\ln(\text{agricultural GDP}) = \beta_0 + \beta_1 \ln(\text{wheat crop yield}) + \beta_2 \ln(\text{wheat crop area}) + \mu \quad (3)$$

4. Results and discussion

4.1. Phillips-Perron unit root test

The results of the Phillips-Perron unit root test are presented in Table 1. The stationary of the data was reviewed, including the data trend and the intercept. According to Table 1, agricultural GDP and area under wheat crop are non-stationary, while wheat crop yield is stationary. To transform agricultural GDP and area under wheat crop to stationary data, we took their first difference and then once again evaluated their stationarity to confirm the results.

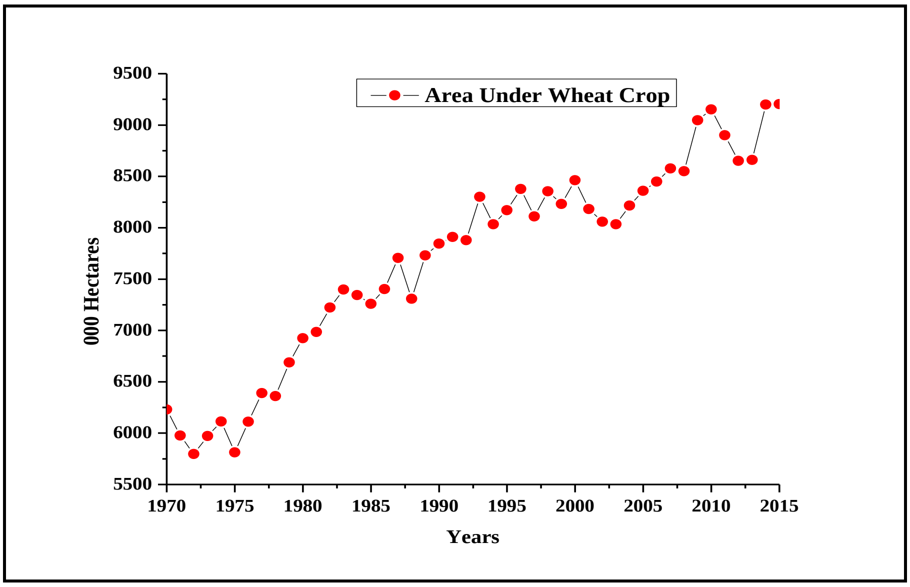

Fig. 1: Area under wheat crop in Pakistan, 1970–2015

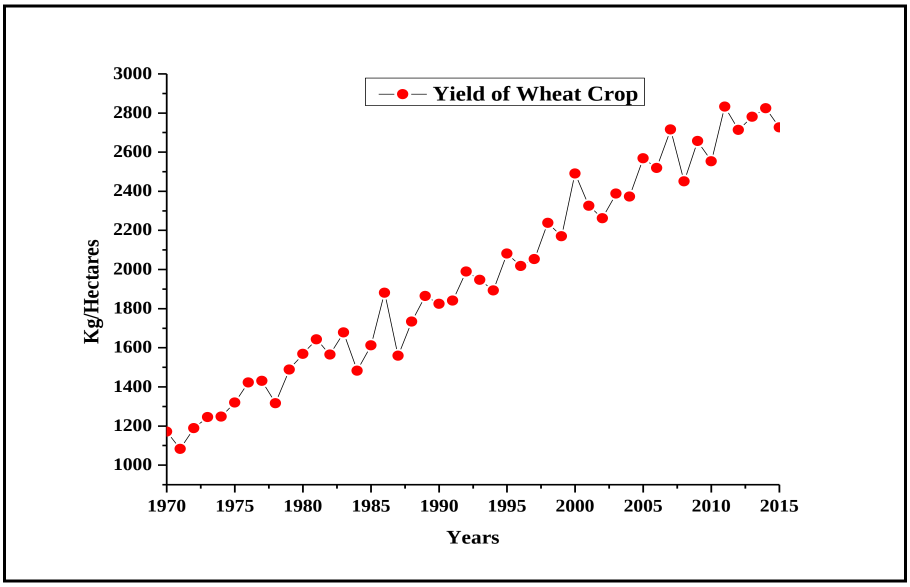

Fig. 2: Yield of wheat crop in kg/hectares in Pakistan, 1970–2015

Table 1: Phillips-Perron unit root test including the trend and the intercept

Variables	At level		First Difference	
	Adjusted t-statistic	Critical values	Adjusted t-statistic	Critical values
Agricultural GDP	-2.098322 (0.5327)	1% -4.175640 5% -3.513075 10% -3.186854	-7.036702* (0.0000)	1% -4.180911 5% -3.515523 10% -3.188259
Wheat crop yield	-4.039289* (0.0142)	1% -4.175640 5% -3.513075 10% -3.186854	-19.25221* (0.0000)	1% -4.180911 5% -3.515523 10% -3.188259
Wheat crop area	-2.241455 (0.4560)	1% -4.175640 5% -3.513075 10% -3.186854	-8.338973* (0.0000)	1% -4.180911 5% -3.515523 10% -3.188259

Note: *, **, and *** indicate significance levels of 1%, 5%, and 10%, respectively.

Moreover, the regression results may be spurious due to the lack of cointegration between the study variables. For this purpose, a cointegration technique including the trace statistic and the Max-Eigen statistic was used to estimate the long-term relationships between the variables of wheat crop yield, area under wheat crop, and agricultural GDP of Pakistan for the period of 1970–2015. The results of this cointegration analysis are presented in Tables 2 and 3 and reveal the existence of long-term relationships among the variables. The null hypothesis that cointegration does not exist may be rejected. Because the values of the trace statistic and the Max-Eigen statistic are larger than their relevant critical values, one cointegrating equation was able to determine at a 5% probability level.

Table 2: Johansen cointegration test using the trace statistic

Eigenvalue	Trace Statistic	5% Critical Value	Prob.**	Hypothesized No. of CE(s)
0.422556	34.67865	29.79707	0.0127	None *
0.230473	12.16377	15.49471	0.1492	At most 1
0.034103	1.422613	3.841466	0.2330	At most 2

Trace test shows 1 co-integrating equation at the 0.05 level; * denotes rejection of the hypothesis at the 0.05 level; ** denotes that values are accurate

Table 3: Johansen cointegration test using the Max-Eigen statistic

Eigenvalue	Max-Eigen Statistic	5% Critical Value	Prob.**	Hypothesized No. of CE(s)
0.422556	22.51488	21.13162	0.0318	None *
0.230473	10.74116	14.26460	0.1677	At most 1
0.034103	1.422613	3.841466	0.2330	At most 2

The Max-Eigen test shows one co-integrating equation at the 0.05 level; *denotes rejection of the hypothesis at the 0.05 level

4.2. Results of regression analysis

To show the relationship between wheat crop yield, area under wheat crop, and agricultural GDP in Pakistan over the period of 1970–2015, an econometric ordinary least square (OLS) method was applied.

The regression results are presented in Table 4. The results showed that the coefficient of wheat crop yield is highly significant at both 1% and 5% significance levels, indicating a positive and significant relationship between agricultural GDP and wheat crop yield.

For a 1% increase in wheat crop yield, agricultural GDP increases by 7.01%. The results of this study contradict the results of Anyanwu (2010), who used the correlation method and found a negative relationship between wheat crop yield and agricultural GDP in Nigeria. Moreover, the results showed a negative relationship between area under wheat crop and agricultural GDP.

Presently, in Pakistan, wheat production is very low in comparison to developed countries as a result of water shortage and low water availability.

The value of R^2 is high (0.84), demonstrating that about 0.84% of total variation in agricultural GDP is explained by the two considered explanatory variables (wheat crop yield and area under wheat crop). The calculated value for the F-statistic was 114.1596, with a probability value of 0.000000, suggesting that the overall fitness of model is good.

Table 4: Regression analysis

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	56.51845	16.70161	3.384013	0.0015
Ln (wheat crop yield)	7.017328	0.938460	7.477491	0.0000
Ln (wheat crop area)	-12.46102	2.836394	-4.393263	0.0001
R-squared: 0.841515; Adjusted R-squared: 0.834144				
F-statistic: 114.1596; Prob(F-statistic): 0.000000				
Durbin-Watson statistic: 0.863118				

5. Conclusion and recommendations

This empirical study examined the relationship between wheat crop yield, area under wheat crop, and agricultural GDP in Pakistan for the 1970–2015 periods. Time series data were collected from the Pakistan Statistical Year Book (various issues). To check the stationarity of the data series, Phillips-Perron (PP) unit root tests were applied. The Johansen cointegration test was used to examine the long-term relationships between the dependent and independent variables. An econometric ordinary least square (OLS) method was applied to investigate the relationship among wheat crop yield, area under wheat crop, and agricultural GDP. The results of the Johansen cointegration test revealed a long-term relationship exists among these variables in Pakistan. The results of the regression analysis showed that the coefficient of wheat crop yield was highly significant at both the 1% and 5% significance levels with respect to agricultural GDP, indicating a strongly positive and significant relationship between these variables. A 1% increase in wheat crop yield therefore led to an increase of 7.01% in agricultural GDP. Finally, the results indicated the presence of a negative relationship between area under wheat crop and agricultural GDP.

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