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Agriculture Technologies, Energy Consumption and Agriculture Productivity: Evidence from Pakistan

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Abstract
The agriculture provides the food to human and animals. Pakistan is known as an agrarian economy. With the passage of time modernization in agriculture also happened along with other sectors of the economy. It is theoretically said that improved technology leads to increase in productivity. To check this theoretical statement, we examine the role of agriculture technologies and energy consumption on agriculture output in Pakistan. We applied time series data for the time span 1983-2019. To find the relationship between the variables ARDL model is employed. The result of the study shows that the relation between the dependent and independent variable exists in long run. It was found that the role of energy usage on agricultural output was positive and statistically significant. The effect of tractors and tube-wells on agriculture productivity is also positive and statistically significant. The impact of fertilizer was insignificant in the long run, because most of the farmers are not educated and they didn't know the proper use of fertilizer. On the base of results, this study suggests that government may subsidize the tractors and tube-wells. Government can build more agriculture universities to increase the research in agriculture sector and enhance the education of farmers.
Keywords: Agriculture technologies, energy consumption, Agriculture output, ADF and ARDL

1. Introduction

Agriculture is main source of obtaining food. The people started farming for food about 8000 B.C. At that time, farming was traditional. Farmers used manure as fertilizer and used animals instead of tractors for the preparation of land for farming (Raza & Siddiqui, 2014). With the passage of time, particularly in the last century the traditional methods were replacing by new and more effective methods such as use of tractors instead of animals for land preparation and chemical fertilizers instead of manure. However, these changes take time to occur. It was a smooth process which occurs with the passage of time (Zaman et al, 2012).

Agriculture is very important for the whole World as it provides food to the human. It also provides food to the livestock, which gives milk and meat to human as these are very important ingredients of food. It was seen that over the time the population of the World is increasing rapidly. Due to increase in the population, need of food is also increased. To meet with this increased in the food, enhancing the productivity of agriculture was required. It was also notice that the World agriculture output is doubled since 1948 (Raza & Siddique, 2014). This increase in the agriculture output was mainly driven by the agricultural technologies. Adaptation of agricultural technologies is happening rapidly and the impact of these technologies on agriculture output is also notable. The agriculturalists believe that improve seeds, water availability, improve pesticides, proper mechanization and hard work is required to increase in agriculture productivity.

Pakistan is agrarian economy. With the passage of time the share of agriculture is declining in Gross Domestic Product of Pakistan. But it remains very important sector for Pakistan because it offers employment to major part of rural labor force. It provides raw material to manufacturing sector and contribute in the earning of foreign exchange. It provides food to the population of Pakistan. The agriculture sector shows positive growth rate in 2019/20 despite the COVID-19 pandemic. The growth rate of agriculture was positive 2.67 percent despite the negative growth rate of service and manufacturing sector -0.59 and -2.67 respectively. The share of the agriculture sector in GDP was 19.31%. Agriculture sector gives employment to 18.47 million labor force (Pakistan Economic Survey, 2019/20). All these indicators are enough to support the argument that agriculture is important sector of Pakistan economy. In Pakistan, by using similar resources the productivity of the sub-sectors of agriculture remains low from other developing and developed economies. The growth of agriculture shows significant decline in Pakistan. With the passage of time agriculture shows decline in growth as it was 5.4 in 1980s, 4.4 %in 1990s and 2.7% in 2000s. The average growth rate was 2.1% in 2010s and from 2011-2018 the average growth rate was 1.7% (PES).

The two main reasons of slowing in growth are structural problems and lack of mechanization. In Pakistan, most of the major crops are affected by the weather and showed negative growth rate. It has been observed that the high and low growth rate of agriculture sector have strong relation with economic condition of the country (Ali, 2000). The part of agriculture sector in national economy is declined over the time due to structural adjustment but still it plays vital role in the national economy. That's why a higher and sustain agriculture growth is required for the economic growth and reduction in poverty as it is related with the all sectors of economy.

The argument that agricultural technologies have positive impact on agricultural productivity is supported by many studies. It was examined that fertilizers consumption have positive impact on the agriculture productivity and the increase in fertilizer consumption is caused by the price of fertilizer (Quddus et al, 2008). Chen and song (2006) investigated that the impact of technology use and technical efficiency on agriculture productivity was positive. In case of Pakistan with the passage of time the adaption of technology is increasing and the impact of these technologies is significant and positive on agricultural productivity.

The outcome of the technology depends on the response rate of technology application, price of the output and the cost of technology machinery (Demeke, 1999). Technologies with good quality is less risky and generate the greater profits, farmers adopt these technologies comfortably. The marketing system determines the price of output paid to the farmer. Improve physical infrastructure such as market sites and roads reduce the transportation costs and improve competition in markets. Production incentives are increased by the high wholesale price of output. The multiplication, processing and marketing of seed results in high price of seed.

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Price of seeds can be reduced by the competitive market and it will also reduce the cost of seed. marketing of seeds and efficiency of production can be increased by the deregulation and liberalization policies. Cost of input also influenced by the access and cost.
Energy plays vital role in increasing the agriculture output. For agriculture, energy is required for the preparation of land for farming in the form of diesel used in tractors. For irrigation energy is required to run turbines. To manufacture various inputs (for example fertilizer etc) and transportation of these inputs energy is required. Chandio et al (2018) found that the impact of energy consumption is positive by using ARDL technique for the time period of 1984-2016. Both electricity and gas consumption have positive impact of agriculture output in short and long run. It was found statistically significant that the impact of energy consumption on agriculture output was positive (Shahbaz et al 2016). Mushtaq et al (2007) explored that the impact of energy consumption on Agriculture Gross Domestic Product (AGDP) was positive. The use of energy consumption is increasing in Pakistan agriculture sector with the passage of time.
In agriculture energy demand is of two types: direct and indirect energy. Direct energy is used for preparing land, cultivating, threshing and harvesting. Indirect energy is not required in farms. Indirect energy is required for the engineering, packing and transportation of machinery, fertilizers and pesticides. Indirect energy used in production and transport agricultural inputs. Main items for indirect energy is required are seeds, fertilizers, machinery productions and pesticides. The above discussion shows significant linkage among agricultural technologies, energy consumption and agriculture productivity.
Before this study, studies are available which explore the individual effect of agriculture technologies on agriculture output and other study examined the impact of energy consumption on agriculture output. But there is no study found which examined the combine effect of agricultural technologies and energy consumption impact on agriculture output. This study is different from other studies due to following reasons, this study examined the combine impact of agriculture technologies and energy consumption on agriculture output, latest time series data has been used for analysis and most appropriate technique ARDL has been employed. Section 2 contains literature review followed by specifications of model, data and econometric methods at section 3. Findings and discussions are given at section 4 whereas section 5 consists of summary, conclusion and policy implications.

2. Literature Review

A literature review provides the complete information about the previous studies performed on specific topic. Rehman et al (2019) analyzed the relationship between the various agriculture technologies and agriculture output and they found that the impact of agricultural technologies on agriculture output is positive and significant. It was found that by improving the agriculture inputs, output of agriculture is increased (McArthur et al, 2017). Chandio et al (2016) examined the impact of various factors like water availability, credit disbursement, fertilizer off-take and area under wheat production on wheat production in Pakistan by using time series data from 1982-2011. It was found that all other variables except fertilizer off-take had positive and significant impact on agriculture output. Urges (2015) found that the variables like fertilizer consumption, land labor ratio, household size and manure are important factors of agriculture productivity.
Faridi et al (2015) investigated the impact of formal credit on agriculture output in Pakistan by using the time series data from 1975-2010. The results state that the impact of costly technologies was positive and significant. It was found that labor employed, number of tractors, number of tube-wells, water availability and improved seeds have positive and significant impact on agriculture output (Raza & Siddique, 2014). Ahmad and Hen (2012) investigated the determinants of agriculture growth in Pakistan by using time series data from 1965-2009. Results of ARDL regression analysis showed that impact of fertilizer consumption, human capital and credit disbursement was positive and significant while area under crop production was insignificant.
Saleem and Jan (2011) explored the role of credit disbursement in agriculture productivity in Dera Ismail khan a district of Punjab, Pakistan by using the data for the period of 1990-2008. It was found that credit plays vital role in increasing the agriculture output. Oaikhenan et al (2020) found that the impact of government spending and electricity consumption was positive for the period of 1981-2017 in Nigeria Economy. Raeeni et al (2018) examined the impact of cheap energy on agriculture of Iran by using time series data for the period of 1967-2015. Unidirectional causality was found between energy consumption and agriculture growth. Moghaddasi and Pour (2016) found that the role of energy usage on agriculture productivity was positive for the period of 1974-2012.

3. Methodology

3.1. Model and data

In this study we follow the model used by the Rehman et al (2019). We used agriculture output an as dependent variable following Rehman et al (2019). Fertilizer consumption is measured as Fertilizer off take (000) similar to Rehman et al (2019). Energy consumption used similar to Zaman et al (2012). The variables, number of tractors and number of tub-wells are used similar to Raza and Siddiqque (2012).

$$LAO_t = \alpha_t + \beta_1 LENC_t + \beta_2 LFC_t + \beta_3 LNT_t + B_4 LNTW_t + \in_t$$

LAOt is log of agriculture output which is measured in million rupees (similar to Rehman et al 2019). L$ENCt$ is log of energy consumption. LFCt is log of fertilizer used in the agricultural production (in 000 tones). LNTt is log of number of tractors. L$NTWt$ is log of number of tube-wells and $\in_t$ is error term. Data is used for the period of 1982/83-2018-19. Data of all variables obtain from the Pakistan Economic Survey except the energy consumption per capita. The data of energy consumption is extracted from Statistical Review of World energy (BP Statistics Review).

3.2. Econometric methods

To check the unit root in series, study employed the Augmentin-Dicky fuller test which was presented by the Dicky and fuller in 1979. The was stationary at mix order I (1) and I (0). We appied ARDL technique to explore the linkage in agricultural technologies, energy consumption and agricultural output. In econometrics, for short and long run analysis ARDL technique is most widely used. Pesaran et al (2001) presented the Autoregressive Distributed Lag technique. Unit root test results states that variables used in the study are stationary at I (0) and I (1).

$$\Delta LAO_t = \alpha_0 + \beta_1 LAO_{t-1} + \beta_2 LENC_{t-1} + \beta_3 LFC_{t-1} + \beta_4 LNT_{t-1} + B_5 LNTW_{t-1} + \sum_{i=0}^{p_1} \delta_1 \Delta LAO_{it-1} + \sum_{i=0}^{p_2} \delta_2 \Delta LENC_{it-1} + \sum_{i=0}^{p_3} \delta_3 \Delta LFC_{it-1} + \sum_{i=0}^{p_4} \delta_4 \Delta LNT_{it-1} + \sum_{i=0}^{p_5} \delta_5 \Delta LNTW_{it-1} + \in_{it}$$

Where α_0 is a constant and $\in_{it}$ is an error term. Other variables are already explained. The following hypothesis is tested through Bound test based on F-statistics to determine whether there is cointegration or not.

$H_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$ (there is no co-integration)

$H_1 = \beta_1 = \beta_2 \neq \beta_3 \neq \beta_4 \neq 0$ (there is co-integration)

The calculated value of F-statistics is compared with the critical values given by the Pesaran, Shin and Smith, (2001). The critical values of F statistics have two bounds; upper bound I (0) and lower bound I (1). If calculated value of F statistics is greater from the critical value of upper bound at 5% the cointegration exist. If calculated F statistics value is less from 5% critical value, then no cointegration while value F statistics is between lower and upper bound critical value then inconclusive results. Once long run relationship exists then parameters can be evaluated by using following equation:

$$LAO_{it} = \alpha_0 + \sum_{i=0}^{p_1} n_1 \Delta LAO_{it-1} + \sum_{i=0}^{p_2} n_2 \Delta LENC_{it-1} + \sum_{i=0}^{p_3} n_3 \Delta LFC_{it-1} + \sum_{i=0}^{p_4} n_4 \Delta LNT_{it-1} + \sum_{i=0}^{p_5} n_5 \Delta LNTW_{it-1} + \epsilon_{it}$$

After evaluating the long run parameters, short run parameters can be evaluated with following error correction model based equation.

$$\Delta LAO_{it} = \alpha_0 + \sum_{i=0}^{p_1} \gamma_1 \Delta LAO_{it-1} + \sum_{i=0}^{p_2} \gamma_2 \Delta LENC_{it-1} + \sum_{i=0}^{p_3} \gamma_3 \Delta LFC_{it-1} + \sum_{i=0}^{p_4} \gamma_4 \Delta LNT_{it-1} + \sum_{i=0}^{p_5} \gamma_5 \Delta LNTW_{it-1} + \omega \mathrm{ECM}_{t-1} + \epsilon_{it}$$

Where ECM_{t-1} is error correction term with lagged period. ECM shows the speed of adjustment in long run equilibrium after shock. The value of ECM lies between0-1. Moreover, it confirms the long run relationship.

4. Results and Discussions

Results of ADF test are given in Table 1. ADF test is used to examine the stationary of variables. Results of ADF test showed that agriculture output (LAO) is stationary at First difference. Fertilizer consumption (LFC) is stationary at first difference. Energy consumption (ENC) is stationary at first difference. Number of Tractors (LNT) is stationary at level and number of tube-well (LNTW) is stationary at first difference.

Table 1: Results of Stationarity

Variable	ADF test stat (at level)	Prob-value	ADF test stat (at 1st difference)	Prob-value	Stationary status
LAO	-0.082	0.3302	-1.032	0.000*	I(1)
LFC	0.202	0.1922	-2.089	0.000*	I(1)
LENC	-0.021	0.1040	-1.115	0.000*	I(1)
LNT	-0.222	0.0017*	-	-	I(0)
LNTW	-0.075	0.6754	-1.004	0.000*	I(1)

*indicates that variable is stationary at 1%.

Bound test is used to examine the link among energy consumption, agriculture technologies and agriculture output. The existence of association among the variables in long run is depend on the value of F-stat. If the Value of I (1) is less from F-stat value at 5% or value of F-stat is greater from the value of I (1) at 5 percent, then the long run link exists between the variables. If the value of F-stat is less than the value of I (1) at 5% the long run relationship doesn't exist among dependent and independent variables. Table 2 showed that the value of F-stat is 4.129637 and the value of I (1) at 5 percent is 3.48 which shows that long run relationship exist between the variables. K denotes the parameters which are 4 in this study.

Table 2: Bound Test Estimation

Stat	K	Value
F stat	4	4.129
	Bound Test Critical Value	
Level of Sign	I(0)	I(1)
10	1.9	3.01
5	2.26	3.48
1	3.07	4.44

Table 3 shows the results of Diagnostic tests. It shows that residuals are normally distributed, there is no Heteroskedasticity, correlation also does not exist.

Table 3: Result of Diagnostic Tests

	Test	F stat	P values
Heteroskedasticity	ARCH	0.131	0.718
Normality	Jarque-Bera	1.389188	0.49927
Serial correlation	Breusch-Godfrey Serial Correlation LM Test	0.651105	0.5312
CUSUM		Stable	
CUSUMSQ		Stable	

Results of CUSUM and CUSUMSQ states that the model is stable as values are relying under the limits. Figure 1 displays that values of CUSUM and CUSUMSQ are within the limits.

Figure 1: CUSUM

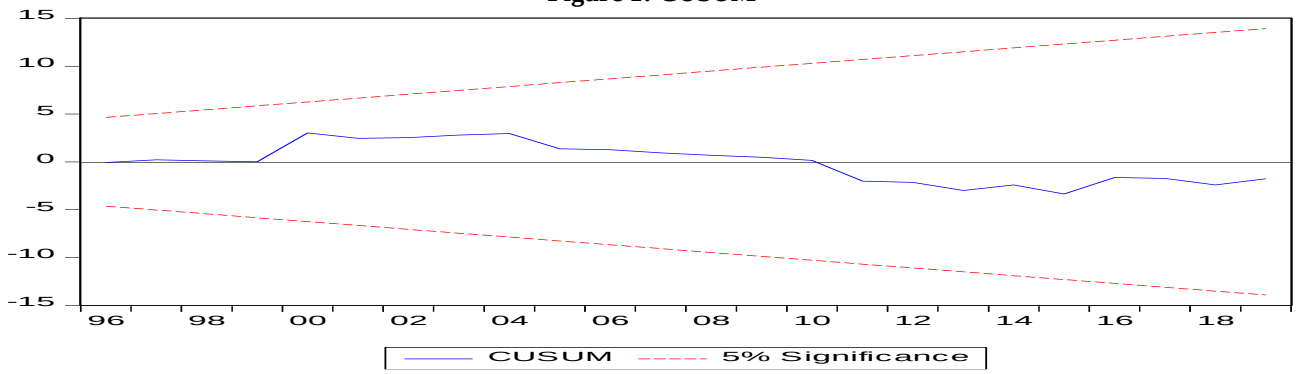
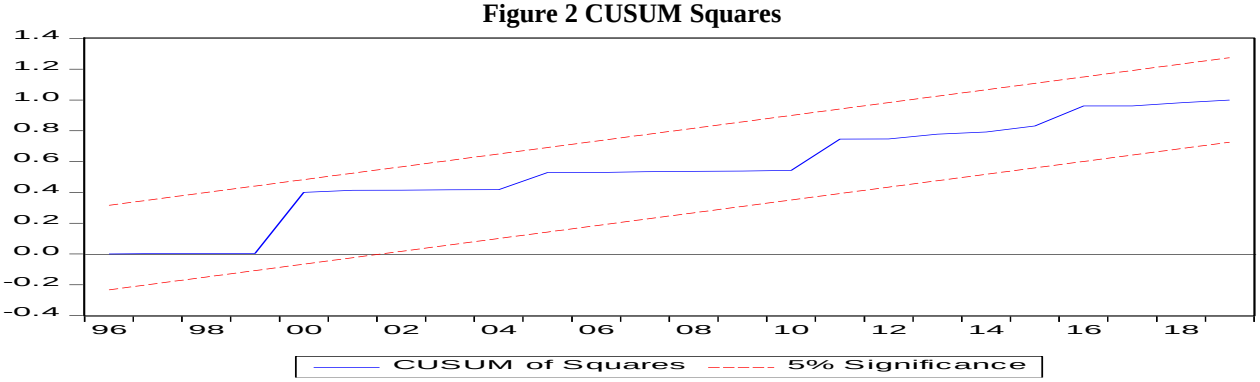


Figure 2 CUSUM Squares



Long run results are given in table 4. Energy consumption impact on agriculture output is positive and significant in long run. The coefficient value of the energy consumption is 1.858 and it is significant at 1%. The coefficient value stats that one percent increase in energy consumption leads to increase the agriculture output 1.85%. These findings of the study are similar to other studies (Mushtaq et al 2014, Raeeni et al 2019, Bakhet and Abdullah 2010). It was also found that the impact of the fertilizer consumption is insignificant. The coefficient value of the fertilizer consumption is -0.031 and insignificant. The findings that impact of fertilizer consumption on agriculture output are in line with Raza and Siddiqui (2014) and Rehman et al (2016). In Pakistan most of the farmers are uneducated and they are not fully aware about the proper use of fertilizer and suitable time of providing fertilizer to crop. The other main reason of fertilizer consumption which leads to the insignificant impact of the fertilizer consumption is the structure of the soil. Outcome showed that the impact of number of tractors is positive on agriculture output. The coefficient value of number of tractors is 1.118 which is significant at 1%. This means that one percent increase in number of tractors will increase the agriculture output 1.118 percent. It was also found that the impact of number of tube-wells is positive and significant. The coefficient value of number of tube-wells is 0.141 and it is significant at 1%. It means that increase in one percent of number of tractors will lead to increase in agriculture output 0.141 percent. These results are similar to Raza and Siddiqui (2014).

Tables 4: Long Run Results

	Dependent variable is lnAO			
Var	Coef	S.E.	t-test	Prob. Value
lnENC	1.858	0.153	12.130	0.0000
lnFC	-0.031	0.100	-0.309	0.7596
lnNT	1.118	0.091	12.294	0.0000
lnNTW	0.141	0.027	5.184	0.0000

Short run results of estimation are given in table 5. Table depicts the role of energy consumption in short is positive and significant at first difference. The elasticity of energy consumption is 2.2 which is greater from long run elasticity (1.86). It shows the diminishing returns of energy consumption in long run. Impact of tractors on agriculture output is positive and insignificant at first difference while tractors impact is significant at second difference. The elasticity of tractors in short run is 0.39 at second difference. The elasticity of short run (0.39) is less from long run elasticity (1.12). It shows that farmer become skill and learn that how to use tractors efficiently.

Table 5: Results of Short run

Dependent Variable is LAO				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LAO1(-1))	0.060760	0.027340	2.222328	0.0359
D(LENC)	2.201385	0.938976	2.344453	0.0277
D(LENC(-1))	-0.768328	0.757746	-1.013965	0.3207
D(LENC(-2))	-1.052869	0.789899	-1.332916	0.1951
D(LENC(-3))	-4.061751	0.938857	-4.326272	0.0002
D(LNT)	0.019725	0.148487	0.132843	0.8954
D(LNT(-1))	0.387378	0.164169	2.359629	0.0268
D(LNTW)	0.027773	0.030701	0.904615	0.3747
CointEq(-1)*	-0.510721	0.104057	-4.908110	0.0001

Results show the value of ECM is negative and significant so the long run linkage exists among the variables. The coefficient value of the ECM is -0.51 and it is significant. The value -0.51 states that any divergence from equilibrium will be corrected and it will converge 51% in towards the equilibrium in one.

5. Conclusion and Policy implications

It has been observed that countries in the world are showing remarkable growth in agriculture sector. The productivity of per hectare of most of the countries is much higher from Pakistan. Although it has been thought that Pakistan is an agrarian economy but in present time the agriculture sector of the Pakistan economy is behind from other sectors of the economy and the agriculture sectors of different countries. The productivity of per hectare of Pakistan agriculture is much low when it comes to compares with other countries productivity. It has been observed the adaption of modern technologies in agriculture sector of Pakistan is very low as compared it with other countries. This study tried to explore the role of various technologies in agriculture output. Study used the time series data for the period of 1982/83-2018/19 to examine the role of various technologies in agriculture productivity. To check the stationarity of data ADF unit root test was employed. The results of the ADF test showed that all the Variables are stationary at first difference only number tractors variable is stationary at level. So it was found that variables are stationary at mix order as number of tractors is stationary at I (0) and all other variables agriculture output, energy consumption, number of Tube-wells and fertilizer consumption are stationary at first difference I (1). ARDL technique was employed to find out the relationship between energy consumption, tractors, fertilizers and Tube-wells in long and short run period. To check the normality Jarque Bera test has been employed which states their residuals are normally distributed. To check the Heteroskedasticity ARCH test was used which showed that Heteroskedasticity does not exist. Results of Bresuch-Godfrey test states that serial correlation does not exist. Results of ARDL technique showed that the role of energy consumption, number of tractors and number of Tube-wells is positive on agriculture output. The use of fertilizers is found insignificant. The reason for the insignificant of fertilizer consumption is lack of education of farmers.

The findings of the study have some important policy suggestions which are:It is found that impact of energy consumption is positive and significant so the Government can make sure low cost and continuous energy supply to increase the agriculture productivity. Government may subsidize the tractors. Subsidies on tractors make it cheaper and small farmers will be able to buy it. Government can run campaigns and advertise about fertilizers and pesticide use this will make farmers to proper use the fertilizer and pesticides in agriculture. Government may play active role in the education of farmers so that they able to use agriculture inputs properly.

This study investigates the impact of agriculture technologies and energy consumption on agriculture output. This study did not cover all the agriculture technologies like water availability, improve studies, water availability, irrigation system and other technologies like harvesting due to time constraints. This study analyzes the impact of energy consumption by using energy consumption per capita, energy required for agriculture in different forms like diesel, electricity and solar energy. This study uses only agriculture technologies; it can be extended in future by using the prices of these technologies and impact of these prices on output. Moreover, cost of energy consumption impact on agriculture should have to be analyzed.

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