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What Affects Crop Production in Pakistan: The Role of Agriculture Employment, Machinery and Fertilizer Consumption

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Abstract
Labor abundant or under developing economies normally rely on their agriculture sector. The performance of agriculture sector depends on the production of cropping, livestock, fishery, and forestry sectors. The contribution of both cropping and livestock sectors in the agriculture production is almost 96.42 percent while the cropping sector contributes almost 33.85 percent during the fiscal year 20-2021 [Pakistan Economic Survey, 2020-2021]. The focus of this study is to investigate the factors which may influence the performance of crop production in Pakistan. For this purpose, bounds testing approach for the sample period from 1976 to 2022 is considered. The empirical results reveal that employment in agriculture sector, agriculture machinery, fertilizer consumption and urban population significantly boost the pace of crop production while the role of raw material imports is witnessed to be insignificant. The above reported results proposes that utilization of latest agriculture machinery, advanced fertilizers and high employability in agriculture sector may be encouraged to uplift the share of cropping sector in agriculture production in Pakistan.
Keywords: Crop Production; Agriculture Employment, Agriculture Machinery, Fertilizer Consumption, Urban Population, ARDL

1. Introduction

The agriculture sector is considered one of the fundamental pillars of many successful economies (Mănescu et al 2016; Loizou et al 2019; Chi, 2022; Audi and Ali, 2023). To ensure food security, economic stability, and rural livelihoods the role of agricultural sector is crucial. For researchers, stakeholder, and policymakers the debate on the factors impacting crop production is of high priority. According to Pakistan Bureau of Statistics (2022) contribution of agriculture sector is 24% of GDP, it also includes half of employed labor force and foreign exchange earnings is highest through this sector. Agriculture sector employs a sizable section of labor force and significantly contributes to the Pakistan's economy, the country's agricultural downturn is a cause for increasing concern. In recent years, fall in agricultural output resulted in reduced revenues for farmers and rural communities. In modern agriculture, crops yields, and soil fertility are affected by fertilizer usage.

A decrease of 20.1% in imported supply of fertilizer has been witnessed, while on the other hand 0.3% increase is witnessed in total availability of fertilizer (Pakistan Economic Survey, 2021). Besides fertilizers, mechanization ensures productivity increase because of timely field operations (Kepner et al., 2003). The widespread use of sophisticated agricultural technology signifies a paradigm change toward automation, which may have an impact on overall productivity and operational efficiency. Production and efficiency may be affected by the presence of sophisticated agricultural equipment. The human capital required to cultivate the land is referred to as agriculture employment, whereas raw material imports demonstrate a nation's agricultural economy's reliance on outside sources. In this study, we investigate into the complex dynamics of crop production, using a comprehensive set of independent variables to examine multifaceted aspects contributing to the Crop Production Index. Moreover, the contribution of the study comes through its comprehensive examination of key determinants influencing the Crop Production Index. The study uses fertilizer consumption, agricultural machinery, agriculture raw materials imports, and employment in agriculture simultaneously which gives a whole picture and understanding of the factors shaping crop production.

The rest of paper is divided into five sections. Section 2 presents deep literature on the studied relationship. Section 3 is dedicated to methodology while section 4 shows results and interpretation, and section 5 represents conclusion and suggestions.

2. Literature Review

This section provides discussion of the past studies conducted on the topic under discussion in this study. Zhou et al. (2018) highlighted the long-run and short-run effects of farm machine use on draft animal use. The study uses pooled mean group estimator for the analysis. Combined effects of farm machine use and draft animal use has been witnessed in their study using panel production function model. The findings of the study revealed that in the long run if there is 1% increase in farm machine then draft animal use will decrease by 2.82%. However, the short-run impact was not statistically significant. Moreover, changes in output elasticity over time are also highlighted in their study. Similarly, Shockley et al. (2019) proposed a complex model for whole farm planning, this model compares different conventional and autonomous machinery for grain crop production. Their study explored various scenarios, including benefit considerations, farm size, field day risk aversion, and grain prices. The outcome revealed economic feasibility of autonomous machinery which leads to a substantial increase in net returns when accounting for input savings and a yield increase due to reduced compaction. The study contributes valuable insights into the economic viability of autonomous machinery as an alternative to conventional manned machinery in grain crop production.

Qiao (2023) examined the impact of mechanization on different crops areas using a theoretical model. The findings of the study uncover that mechanization has a positive impact on grain crops but in case of non-grain crops the impact is negative. The validation of the results are through empirical analysis considering representative provincial level panel data emphasizing potential reductions in the areas of cotton, oil, and sugar crops within a five-year time frame. The study adds depth to the understanding of mechanization's differential effects on various crop types. In a broader context, Rehman et al. (2019) empirically examined the

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impact of cropped area, water availability, credit distribution, and fertilizer consumption on Agricultural Gross Domestic Product (AGDP) for the country Pakistan. The outcome of the results uncover that fertilizer consumption, credit distribution, and improved seed distribution have a positive and significant impact on AGDP. This research contributes to understanding the intricate relationships shaping agricultural productivity in Pakistan. Cai et al. (2018) proposed the relationship between fertilizer use intensity on grain producing areas in China. Multiple cropping index, use efficiency, environmental impact weight, and safety thresholds are considered by their environmental risk assessment model. The study revealed an increasing trend in fertilizer use intensity, surpassing international safety limits. Furthermore, the research indicated regional disparities in environmental risk indexes for phosphorus and potash, offering insights into the environmental implications of fertilizer use. Akpan et al. (2022) focused on Nigeria, analyzing the consumption trend of fertilizers and its relationship with crop outputs. The study revealed significant volatility in fertilizer consumption, with the average consumption rate for composite fertilizer falling far below recommended levels. The study sheds light on the challenges and dynamics of fertilizer consumption in Nigeria, providing valuable information for policymakers and stakeholders. However, the results should be interpreted with caution as "control variables" have not been considered. In the context of rice production in Malaysia, Abidin et al. (2022) explored the impact of factors such as labor force, agricultural irrigated land, capital formation, and agricultural raw material imports. Their findings emphasized the positive and substantial influence of these factors on rice output, contributing insights into the multifaceted determinants of rice production in Malaysia. Bakari (2018) conducted an empirical study in North African countries to investigate the impact of agricultural raw materials imports on agricultural growth. The results indicated a positive long-run effect on agricultural growth in all three countries and a short-run effect in the cases of Tunisia and Egypt. This study highlighted that in agricultural sector agricultural raw materials work as a source of growth (Bakari, 2018). Pahalvi et al (2021) studied the impact of chemical fertilizers on soil health. The finding of the study highlighted that crop productivity and soil fertility are enhanced by chemical fertilizers. Martey et al (2019) investigated the impact adoption of mineral fertilizer on productivity of land and agricultural income for Ghana. The study used endogenous switching regression, propensity score matching methods, and household survey data. The study finds that land productivity and agricultural income has increases by 55% and 30% respectively by using mineral fertilizer.

After highlighting the discussion of past studies, now the data sources and methodological strategy will be presented in the next section.

3. Sources of the Data and Estimation Strategy

3.1. Sources of the Data

The historical data for the indicators such as crop production, agriculture employment, agriculture raw material imports, agriculture machinery, fertilizer consumption and urban population is fetched from World Bank (2023), World Development Indicators. The frequency of the sample period is annual which is from 1976 to 2022.

3.2. Proposed Model

The proposed model is presented as under

$$\ln CROP_t = f(\ln AE_t, \ln RIMP_t, \ln AM_t, \ln FC_t, \ln UP_t)$$

Table 1: Detail about the Variables

Variables	Composition	Sample Period
$\ln CROP_t$	Natural Log of Crop Production Index	1976-2022
$\ln AE_t$	Natural Log of Employment in Agriculture as percentage of Total Employment	1976-2022
$\ln RIMP_t$	Natural Log of Agricultural Raw Materials Imports as percentage of Merchandise Imports	1976-2022
$\ln AM_t$	Natural Log of Agricultural Machinery, Tractors Per 100 sq. km of Arable Land	1976-2022
$\ln FC_t$	Natural Log of Fertilizer Consumption as share of Fertilizer Production	1976-2022
$\ln UP_t$	Natural Log of Urban Population as share of Total Population	1976-2022

3.3. Estimation Strategy

The empirical results will be estimated by finding variance inflation factor using coefficient of correlation matrix. Later, unit root will be found by applying KPSS (1990) test for unit root. The order of integration will motivate us to apply any suitable cointegration test and preferably it will bounds test proposed by Pesaran et al. (2001). Besides cointegration test, the impact of factors of crop production on crop production will be presented for both long and short term periods. After this, the stability of the coefficients will be confirmed by considering CUSUM and CUSUM square graphs. These will confirm whether mean and variance of error terms are structurally stable or not? After this section, the empirical results and their interpretation is organized in the next section which is presented as below:

4. Results and Discussion

The results section begin from presenting basic statistics of the selected factors for this study. The probability of Jarque-Bera test for natural log of crop production, raw material imports and urban population are found to be insignificant and hence these factors are following the attributes of normal distribution. The rest factors are not following features of normal distribution due to the reason of significant probability values of Jarque-Bera test. The results are presented in the below Table 2:

Table 2: Descriptive Stats

	Mean	Std. Dev.	Jarque-Bera	Probability	Observations
$\ln CROP_t$	4.2297	0.3550	3.5275	0.1714	47
$\ln AE_t$	3.7710	0.0580	12.6711	0.0018	47
$\ln RIMP_t$	1.4501	0.1536	2.5303	0.2822	47
$\ln AM_t$	4.4520	0.5913	14.6216	0.0007	47
$\ln FC_t$	4.9381	0.1663	39.9356	0.0000	47
$\ln UP_t$	3.4768	0.0973	2.8508	0.2404	47

The results of variance inflation matrix suggest that no explanatory variable of crop production index is significantly correlated as can be witnessed from the VIF values which are less than 10. Hence it is concluded that there is no evidence found of presence of multicollinearity in this study. The Table 3 provides results:

Table 3: VIF Matrix

	$\ln AE_t$	$\ln RIMP_t$	$\ln AM_t$	$\ln FC_t$	$\ln UP_t$
$\ln AE_t$	-				
$\ln RIMP_t$	1.1136	-			
$\ln AM_t$	1.5321	1.1038	-		
$\ln FC_t$	1.1673	1.1227	1.7607	-	
$\ln UP_t$	2.8144	1.1155	6.5145	1.5885	-

After discussing VIF matrix, the results of unit root test are presented in Table 4. From the Table 4, we may find that the LM test in cases of crop production (2.3409>0.739), agriculture employment (0.9930>0.739), agriculture machinery (1.0596>0.739) and urban population (0.7822>0.739) is found to be greater than the 10 percent critical value which concludes presence of unit root at level while LM test in cases of raw material imports (0.4479<0.739) and fertilizer consumption (0.5390<0.739) is less than the 10 percent asymptotic critical value therefore, both variables are stationary at level. All these variables are found to be stationary in case when these are tested for unit root at first difference. This confirms mixed integrated order of the variables taken in this study. The results for unit root test are reported as below:

Table 4: Unit Root

	at Level			at First Difference	
Variables	LM-Test	Conclusion	Variables	LM- Test	Conclusion
$\ln CROP_t$	2.3409	Non-Stationary	$\Delta \ln CROP_t$	0.3042	Stationary
$\ln AE_t$	0.9930	Non-Stationary	$\Delta \ln AE_t$	0.1711	Stationary
$\ln RIMP_t$	0.4479	Stationary	$\Delta \ln RIMP_t$	0.0648	Stationary
$\ln AM_t$	1.0596	Non-Stationary	$\Delta \ln AM_t$	0.6775	Stationary
$\ln FC_t$	0.5390	Stationary	$\Delta \ln FC_t$	0.0780	Stationary
$\ln UP_t$	0.7822	Non-Stationary	$\Delta \ln UP_t$	0.6623	Stationary

Note: The KPSS (1992) asymptotic critical values are 0.739 at 1%, 0.463 at 5% and 0.347 at 10% percent levels of significance.

The mixed integrated order provides reason for applying bounds test to obtain cointegrating relation between crop production and its determinants. The results are provided in Table 5:

Table 5: Cointegration Test

Estimated Models	$\ln CROP_t = f(\ln AE_t, \ln RIMP_t, \ln AM_t, \ln FC_t, \ln UP_t)$
Optimal lags	(1 , 0 , 0 , 0, 0 , 0)
F – statistics	7.2807
	DIAGNOSTIC TESTS
Serial Correlation	0.5904 [0.442]
Functional Form	1.4352 [0.231]
Normality	1.9118 [0.384]
Heteroscedasticity	0.2920 [0.589]

Note: For F-Statistics; Lower Critical Bound is 2.9361 while Upper Critical Bound is 4.2274 at 5 percent significance level. Also the values within [] represents Probability Values.

The estimates of bounds test report F-stats equal to 7.2807 which is higher than 4.2274 (5 percent upper critical value) hence it confirms crop production has cointegrating relation with its factors in the long run. The insignificant probability values of serial correlation, functional form, normality and heteroskedasticity tests are suggesting absence of serial correlation, misspecification, abnormality and heteroskedasticity issues. This confirms that the proposed model is robust to all these diagnostics. Besides this, the long run impact of determinants of crop production is presented in below Table 6:

Table 6: Coefficients in Long Run

Dependent Variable: $\ln CROP_t$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
$\ln AE_t$	0.6692	0.2186	3.0611	0.0039
$\ln RIMP_t$	0.0802	0.0489	1.6406	0.1087
$\ln AM_t$	0.0747	0.0327	2.2865	0.0276
$\ln FC_t$	0.0963	0.0461	2.0896	0.0431
$\ln UP_t$	3.5703	0.2621	13.6209	0.0000
C	-11.6306	1.5919	-7.3059	0.0000

The impact of determinants of crop production for long period demonstrates that agriculture employment, agriculture machinery, fertilizer consumption and urban population are significantly enhancing crop production. The one percent increase in agriculture employment, agriculture machinery, fertilizer consumption and urban population is significantly boosting crop production by 0.6692 percent, 0.0747 percent, 0.0963 percent and 3.5703 percent respectively. The increase in agriculture employment, use of agriculture machinery and advanced fertilizers in cultivation help in stimulating crop production in Pakistan. The positive association of urban population and crop production index is difficult to interpret. The studies find that urbanization has appropriated the cropland and this puts downward pressure on the agriculture production (Andrade 2022, Bravo 2017). Nonetheless, the study highlights the contribution of agriculture employment, agriculture machinery and fertilizer consumption. Among these three, agriculture employment witnessed to improve crop production the most.

Besides throwing light on long run estimates, now we are going to discuss the impact of determinants of crop production in short run period. The results demonstrate that agriculture employment, agriculture raw material imports, agriculture machinery, fertilizer consumption and urban population are increasing crop production significantly. Moreover, one percent increase in agriculture employment, agriculture raw material imports, agriculture machinery, fertilizer consumption and urban population is increasing crop production significantly by almost 0.6485 percent, 0.077 percent, 0.0724 percent, 0.0933 percent and 3.46 percent respectively. As we concluded for long run period, it is also concluded for short run period that the urban population contributes the most in improving the performance of crop production than the rest of the order factors taken in the study. However, as discussed earlier that our focus is to demonstrate the contribution of agriculture employment, agriculture machinery and fertilizer consumption in stimulating crop production therefore, we find and conclude that among these three indicators, agriculture employment appears to be a strong determinant to elevate crop production. The findings of short term period are not different from the findings of long term period. After highlighting short run impacts of determinants of crop production, now we would like to comment on the speed of adjustment which is quite high in our case. Almost 96.91 percent error will be corrected each year in response to any external shock to economy which may result in instable long-term equilibrium. This discussion may be confirmed from the below presented Table 7:

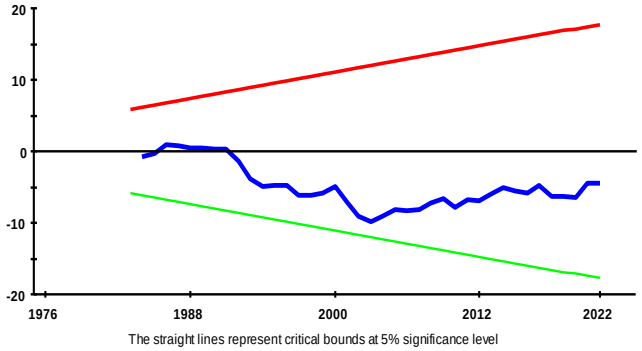
Table 7: Coefficients in Short Run

Dependent Variable: $\Delta lnCROP_t$

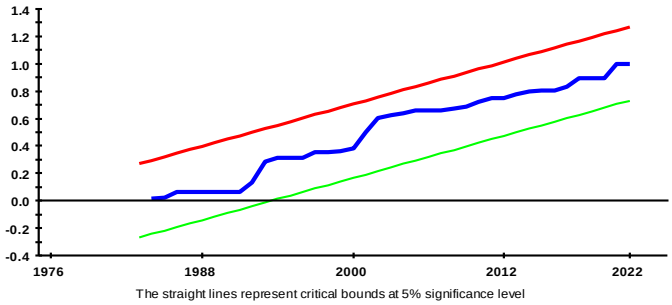
Variable	Coefficient	Std. Error	t-Statistic	Prob.
$\Delta lnAE_t$	0.6485	0.2190	2.9608	0.0051
$\Delta lnRIMP_t$	0.0777	0.0418	1.8617	0.0700
$\Delta lnAM_t$	0.0724	0.0341	2.1195	0.0403
$\Delta lnFC_t$	0.0933	0.0457	2.0439	0.0476
$\Delta lnUP_t$	3.4600	0.5836	5.9290	0.0000
ECM_{t-1}	-0.9691	0.1471	-6.5884	0.0000
	Diagnostics			
	Adjusted R-Square		0.57844	
	F-Stats [P.Value]		11.5196 [0.000]	
	DW-statistic		2.0866	
	Akaike Info. Criterion		84.9390	
	Schwarz Bayesian Criterion		78.4635	

After the short run coefficients, the CUSUM and CUSUM Square graphs provide confirmation of stability of mean and variance of error term. This helps us to safely conclude that the structural break problem is not present in our case.

CUSUM Graphs



CUSUM Square Graphs



5. Conclusion

The primary objective of this research is to investigate the impact of agriculture employment, agriculture machinery and fertilizer consumption on crop production in Pakistan. This study takes controls like agriculture raw material imports and urban population to capture their effects on crop production. To find our empirical results, this study considers bounds test by taking data series from 1976-2022 and concludes that agriculture employment, agriculture machinery and fertilizer consumption significantly

expand crop production in Pakistan. Among these three indicators, employment in agriculture sector plays pivotal role in stimulating crop production. Besides this, urban population also significantly enhances crop production. These findings are robust to all the diagnostics. This discussion allows us to propose that advanced fertilizers, modern agriculture machinery and skilled agriculture employment may accelerate the pace of crop production in Pakistan.

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