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Infrastructure Development and Food Security

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Abstract

Pakistan is a low-income developing nation where agriculture is its most significant sector. Reducing poverty, hunger, and food insecurity are essential features of Sustainable Development Goals (SDGs). Finding the best solutions to provide food security for Pakistan's expanding population is the foremost goal of this study. The current study examines only the supply side of food security i.e. physical availability of food (major food crops); wheat, rice and maize. The study relates the infrastructure development (transportation) to food security as supply bottlenecks arising from poor transportation networks cause food shortages. Other determinants include own price, credit availability and yield. Study uses annual time series data for Pakistan from 1980-2020 using fully modified squares (FMOLS). Findings show that infrastructure development positively contributes to food security. Findings imply improving food security by investing in infrastructure. Low-income households, farmers, and others who lack proper nutrition may find it simpler to access markets and find affordable food owing to transportation regulations and programs.

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1. INTRODUCTION

When everyone, at all times, has physical, social, and financial access to a sufficient amount of safe, nourishing food that meets their dietary needs and food choices for an active and healthy life, there is food security (Food and Agriculture Organization, 1996). Midway through the 1970s when the worldwide food crisis was beginning to take shape then the idea of food security was conceived. The availability, accessibility, and price stability of staple foods were the main concerns. The idea of food security has been developed through three generations. The first generation provided the supply side description. Sen (1980) among the others who belonged to the second generation claimed that food insecurity was caused by poor access of households. Third generation was of the view that large external shocks affect food security.

Growth in developing countries depends largely on agriculture sector which provides livelihood to poor rural inhabitants. Government in these countries mostly neglects investment in rural areas making people more exposed to internal and external shocks related to price and food insecurity. Better provision and access to food increase the earning of poor people through involvement in economic activity. The food crisis of 2008 showed drastic failure of global food markets comprising extensive trade constraints such as export prohibitions and market imperfections. Agriculture sector is the backbone of Pakistan which provides food to masses. Agriculture sector contributed to 19.41% percent of GDP in 2019-2020 and it provides employment to 37.4 percent labor[1].

One of the most urgent issues facing Pakistan- a nation with a rapidly expanding population, frequent natural disasters brought on by climate change, and entrenched economic inequality, is food security. Pakistan still faces problems with food availability, access, use, and stability despite having an agrarian economy. The condition of infrastructure is a crucial but sometimes overlooked aspect affecting food security. Any effective agricultural and food

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distribution system is built on infrastructure which includes transportation networks, irrigation systems, storage facilities, electricity, and communication services. Vulnerable communities in Pakistan are disproportionately affected by inefficient food supply chains, significant post-harvest losses, and poor market access for rural farmers due to inadequate infrastructure.
The bulk of Pakistan's agricultural activities occurs in rural areas which frequently experience inadequate storage facilities, unstable electricity, and poor road access. These shortcomings impact food costs and availability across the country by lowering farmland profitability and limiting the movement of supplies to metropolitan areas. Furthermore, droughts and floods which occur more frequently as a result of climate change are made worse by the lack of climate-resilient infrastructure. In this regard, making investments in strong infrastructure is essential to guaranteeing national food security and outstrips being a developmental objective.

Infrastructure is classified into two types: physical and nonphysical. Physical infrastructure includes roads, transportation, electricity, gas, water supply, irrigation amenities etc. Nonphysical infrastructure includes education and health provision etc. Both these infrastructures are important in order to improve food security by increasing marginal productivity of labor. Infrastructure and food security are closely linked. Many poor countries lack rural infrastructure facilities. Lack of transportation, energy and other associated infrastructure lead towards imperfect domestic markets, little integration and lower competitiveness at international level. Public sector can play its role in providing infrastructure in poor countries. In Pakistan infrastructure is the big restraint to production. The underdeveloped infrastructure impedes growth and poverty reduction goals. Lack of fiscal resources have contributed to inefficient infrastructure leading towards poor irrigation, expensive electricity, poor rural transportation and communication network which have translated into lower productivity and well-being in rural areas.

Due to higher input costs and decreased accessibility to markets for their products, poor transportation linkages reduce farmers' profit margins. Additionally, this deficiency raises the price of financial intermediation. Due to poor infrastructure there is a lack of financial institutions in rural areas making the access to credit facilities difficult. Good infrastructure is essential not only for domestic investment but to attract foreign investment. Good infrastructure plays the role of a bridge to connect deprived regions with advanced regions making gain easy. Better infrastructure of emerging economies is an important factor that has played a major role in their global integration. Through the expansion of backward and forward connections, the agriculture sector will benefit directly and indirectly from the China Pakistan Economic Corridor (CPEC), a program for infrastructural development. Access to sufficient infrastructure helps in provision of food security. It reduces the exposure to shocks, increases accessibility of food, increases the productivity and income. Thus, it ultimately improves the welfare and food security of individuals.

1.1. State of Infrastructure in Pakistan

The table below shows the comparative ranking of Pakistan according to the Global Competitive Report 2019 out of 141 countries. Relative comparison shows that relative quality of infrastructure of Pakistan is low as compared to other developing countries.

Table 1: Comparative ranking of Pakistan at Global Competitiveness Index

Country	Road connectivity	Quality of roads	Efficiency of train services	Efficiency of air transport services	Quality of electricity supply
Pakistan	52	67	47	93	99
India	72	48	30	59	108
China	10	45	24	66	18

Bangladesh	117	108	65	109	68
Iran	42	79	52	132	75
Nepal	101	120	NA	131	119
Sri Lanka	96	76	49	72	39

Source: Global Competitiveness Report (2019)

1.2. Global Food Security Index (Pakistan)

The table below shows the global food security index (GFSI) which is made up of a set of indices for 113 countries. This index measures the food security in three dimensions; affordability, availability and quality and safety. The overall goal is to access the countries that are most vulnerable through food insecurity. It considers the core issues of affordability, availability, quality and safety.

Table 2: Global Food Security Index

	Score / 100					**Rank / 113**				
	2012	**2014**	**2016**	**2018**	**2020**	**2012**	**2014**	**2016**	**2018**	**2020**
Overall Score/Rank	43.7	45.6	47.4	47.8	54.7	78	77	78	78	75
Affordability	42.9	46.4	46.4	46.3	52.6	75	73	74	74	79
Availability	44.5	45.3	49.5	50.4	63.0	85	83	75	75	39
Quality and safety	43.7	44.2	44.5	44.5	55.7	82	83	84	83	80

Source: The Economist Intelligent Unit (EIU), Score: 0-100 (best)

The purpose of this study is to investigate how much infrastructural development affects Pakistan's food security. It looks for significant gaps in infrastructure and assesses how they affect the production, distribution, and accessibility of food. The study will enhance the nation's efforts to accomplish Sustainable Development Goal 2: Zero Hunger by offering evidence-based insights that will influence strategic investment and decision. Developing long-term solutions that boost agricultural productivity and strengthen food systems' resilience nationwide requires an understanding of this link.

Significance of the Study:

Given Pakistan's continuous battle with poverty, population growth, and agricultural inefficiencies, it is important to investigate how infrastructure affects food security in the nation. Infrastructure is essential for increasing agricultural productivity, lowering post-harvest losses, and guaranteeing timely food distribution. This includes transportation networks, storage facilities, irrigation systems, and market access. In a nation like Pakistan, where a sizable section of the populace makes their living from agriculture, poor infrastructure significantly reduces the effectiveness of food supply chains which exacerbates hunger and food insecurity. Policymakers can make well-informed decisions to strategically invest in rural and urban infrastructure by knowing how infrastructure development and food security are related. This will ultimately improve access to wholesome food, increase economic stability, and advance sustainable development goals. In order to address one of Pakistan's most urgent socioeconomic issues this study is essential.

Problem Statement:

Millions of people throughout Pakistan are impacted by food insecurity which persists despite the nation's robust agricultural foundation. Lack of proper infrastructure, especially in rural and semi-urban regions is one of the fundamental but every now and then disregarded causes of this issue. Food production and distribution efficiency is severely hampered by inadequate market access, inadequate storage and refrigeration facilities, poor transportation infrastructure, and sparse irrigation coverage. In addition to increasing food waste and post-harvest losses, these infrastructure shortcomings also boost food prices and restrict supply, particularly for low-income groups. Efforts to guarantee food security will remain unfinished and ineffectual in the absence of focused infrastructure improvements. Thus, there is a crucial knowledge vacuum about how infrastructure affects food security and how wise investments could allay this rising worry in Pakistan.

To attain food security for Pakistan's expanding population, the study's major goal is to identify the best possible alternatives. The current study examines only the supply side of the food security i.e. physical availability of food regarding major food crops: wheat, rice and maize. These crops make up a large portion of Pakistan's agricultural mix, contributing 4.29 percent of the country's GDP[2]. The study relates the infrastructure development (transportation) to food security as supply bottlenecks arising from poor transportation networks cause food shortages.

There are six sections in this study. Introduction and objectives are covered in section one. Section two gives the empirical review. Section three discusses the model, variables and data. Next section discusses methodology used in the study while the last section discusses conclusion, implications and future research directions.

2. LITERATURE REVIEW

There is wide literature available on the role of infrastructure development in economic growth as well as poverty alleviation. There is a gap in literature as the effect of infrastructure development on food security has not been thoroughly investigated. This study will seek to ascertain the function of infrastructure on food security in response to this gap in research. We review the literature on infrastructure development in three broad dimensions: importance of infrastructure in promoting economic development, reducing poverty, and enhancing agricultural production and output.

Infrastructure availability is crucial for accomplishing desired economic development and growth goals as shown by credible empirical research. According to Manasan and Chatterjee (2003) improved infrastructure investment distribution across regions enables lagging regions to catch up and boost their economic potential. In a panel data set of nations where infrastructure has long-term growth benefits, Pedroni and Canning (2004) study the long-term effects of infrastructure provision on per capita. Ahmed et al. (2007) and (2013) investigated how infrastructure affects economic growth. They concluded that funding public infrastructure through taxation or foreign loans has the same effect. Tax financing limited industrial sector output, slowed down short-term economic growth, and decreased export. Infrastructure's impact on Pakistan's economic growth and TFP was estimated by Imran and Niazi (2011). Investments in telecommunications, water availability for agriculture, and electricity generation have a substantial impact on growth and TFP. The effect of communications and transportation on Pakistan's economic growth was analyzed by Faridi et al. (2011). Sahoo et al. (2010) analyzed the role of infrastructure in economic growth in China. According to Donaldson's (2010) analysis, real income levels rose as a result of the railroad infrastructure which also generated large trade profits and enhanced regional and international trade. It also decreased trade costs and interregional price differences.

Most of the empirical literature regarding infrastructure development focuses on poverty alleviation. These studies include Brockerhoff and Derose (1996), Jalan and Ravallion (2003),

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Lokshin and Yemtsov (2004, 2005), and Datt and Ravallion's (1998) work in Indian context; Van de Walle (1996) in the context of Viet Nam; Jalan and Ravallion (2003) and Jalan and Ravallion (2003) worked regarding the aspect of water supply. According to Fan, Zhang, and Zhang (2002), improving infrastructure—particularly roads and telecommunications—is crucial for alleviating rural poverty in China. In rural parts of emerging countries, Calderon and Serven (2004) show evidence of declining inequality as a result of improved infrastructure. Every microstudy examined the link between infrastructure and particular aspects of poverty, such as income, poverty, health, and other socioeconomic outcomes that are specific to an individual. Infrastructure acts as a production component on the supply side, and there are also indirect channels (improved infrastructure affects technological progress). Infrastructure in rural areas must be in good condition for agricultural productivity to rise, which is a key factor in economic growth and the eradication of poverty.

The impacts of infrastructure investment on agricultural output and productivity have been estimated by a number of econometric studies. The majority of these investigations discover a significant and favorable impact (Antle 1984; Binswanger, Khandker, and Rosenzweig 1993; Mundlak, Larson, and Butzer 2002; Fan, Hazell and Thorat 2000; Fan and Zhang 2004). Roads boost agricultural output and support the growth of the production of cereals (Khandker 1989; Gladwin et al. 2001; Rosegrant and Cline 2003; Clover 2003; Andersen and Shimokawa 2007; Manalili and Gonzales 2009). According to Fan et al., (2004), governmental expenditures on irrigation, rural education, agricultural research and development, and infrastructure (such as roads and power) in Thailand have marginally favorable effects on increasing agricultural production and lowering rural poverty. In locations with inadequate infrastructure, a supply response of 0.3–0.5% to a rise in output prices of one percent is seen in places with adequate infrastructure, the supply response is 0.7–0.9 percent, according to Chhibber (1988). To lower input costs and increase agricultural production, transportation accessibility is essential (Khandker, Bakht and Koolwal 2009; Donaldson 2010). According to the findings of Calderon, Moral-Benito, and Serven (2009) countries with relatively lesser endowments of infrastructure have greater infrastructure's marginal productivity. Infrastructure's benefits on agricultural growth and poverty reduction are significantly influenced by its quality which plays a key role in both outcomes (Fan and Chan-Kang 2005). The studies by Del Carpio et al. (2011), Dillion (2011) and Strobl and Strobl (2011) examined how irrigation affected productivity and consumption. Baek (2016) investigates whether households' likelihood of experiencing food insecurity is decreased by having access to public transportation. The dataset combines data for the years 2006 to 2009 from the National Transit Database and the Current Population Survey Food Security Supplement (CPS-FSS). Findings indicate a negative causal relationship between food insecurity and accessibility to public transit. Every additional bus-equivalent vehicle reduces the likelihood of food insecurity in families by 0.78 percentage points per 10,000 people. Leuthart et al. (2020) investigate food access in one medium-sized city in the Midwest, Bloomington, Indiana, with a particular emphasis on the public transit system. The most vulnerable households to food insecurity are probably those who depend on public transportation to get to food. In order to better serve low-income neighborhoods, policymakers and/or city planners may decide to alter existing bus routes or establish new bus routes just for food availability.

Yan, S., & Alvi, S. (2022) examined food security in South Asia caused by climate change and other macroeconomic factors. Crop yield is represented by wheat, rice and maize. Climate change is represented by growing degree days and precipitation. Other factors include gross fixed capital formation and labor force. Findings of fixed effect model show that the relationship between climate change and crop yield is non-linear and inverted u shaped. This indicates that increasing precipitation to a moderate level is beneficial; similarly growing degree days increases yields but at a decreasing rate. Gross fixed capital formation and labor force positively contribute to crop yield. The study also forecasts future cereal production. The forecast shows that the crop yields will decrease in South Asia because of climate change. It is concluded that South Asian countries will face more food security issues because they are already lagging behind developed countries in average yields and have a large population that is undernourished. Regarding the policy concerns, the findings show that provision of subsidies to farmers will increase the output, but it is not sufficient to cover the losses caused by climate change. South Asia free trade agreement (SAFTA) is not effective in compensating the climate change. Similarly, Alvi, S., Roson, R., Sartori, M., & Jamil, F. (2021) show the same findings.

Alvi, S., & Jamil, F. (2018) examine the effect of climate change and technology on cereal yield in South Asia. Cereals production includes wheat, rice and maize. Climate change is represented by temperature, precipitation, humidity and average wind speed. Technology is represented using electric and machinery in agriculture. Findings show that climate change decreases cereal yields while the technology adoption increases the cereal yields. It is recommended that South Asian countries should invest in technology to get sustainability in food production.

Hamadjoda et al., (2024) examine the effects of physical infrastructure on food security for Sub Saharan Africa. They have developed a food security index aggregate of food availability, accessibility, stability and utilization. They have used aggregate physical infrastructure index. Other measures of infrastructure are transport infrastructure index, electricity infrastructure index, internet and communication technology infrastructure index, water supply and sanitation index. Other macroeconomic variables include population growth, trade, inflation and political stability. Findings show that all types of physical infrastructure are positively associated with food security. Inflation and population growth negatively affect food security. Trade and political stability are positively associated with food security. It is suggested that there is a need to improve the quality, and access of physical infrastructure to enhance food security.

Candelise, C., Saccone, D., & Vallino, E. (2021) examine the effect of electricity access on food security. Food security is measured by the prevalence of undernourishment. Electricity is needed for agricultural production along the whole value chain: crop production; fish, livestock and forestry; post-harvest processing; food storage food transport and distribution and food preparation (FAO, 2012; Edward et al., 2020). Findings indicate that electricity access instantly impacts food availability. Findings may lead policy makers to electricity investments which may improve food security by increasing subsistence food production.

3. FORMULATION OF THE MODEL

This study is designed to examine the role of infrastructure development on the supply response/food security of major food crops in Pakistan. In this study, we concentrate on the acreage response of three crops namely wheat, rice and maize. The use of real rather than actual price as regressor reduces multicollinearity. The acreage response function included area as a dependent variable. Rao (1989) provided evidence to support this claim by stating that compared to yield or output, farmers have more control over area. Areas of land are decided upon production based on known output prices from the previous year as predicted prices. According to economic theory, crop response should be fostered when the price of a related crop rises and should be suppressed when the price of a rival crop rises. The development of infrastructure and the availability of finance are two other factors that influence supply response.

To establish if infrastructural development and credit distribution have a substantial impact on the supply of Pakistan's four primary crops, an analysis of annual time series data from 1975 to 2013 was carried out. We thus estimate the equations given below following the Nerlovian adjustment model. Nerlovian model categorizes the acreage response into price and non-price factors (supply shifters). It is based on partial adjustment and expectations for price and acreage.

$$ACR_{wt} = \alpha_0 + \alpha_1 ACR_{w(t-1)} + \alpha_2 P_{w(t-1)} + \alpha_3 Y_{w(t-1)} + \alpha_4 ID_t + \alpha_5 CD_t + u_{1t}$$

$$ACR_{rt} = \beta_0 + \beta_1 ACR_{r(t-1)} + \beta_2 P_{r(t-1)} + \beta_3 Y_{r(t-1)} + \beta_4 ID_t + \beta_5 CD_t + u_{2t}$$

$$ACR_{mt} = \delta_0 + \delta_1 ACR_{m(t-1)} + \delta_2 P_{m(t-1)} + \delta_3 Y_{m(t-1)} + \delta_4 ID_t + \delta_5 CD_t + u_{4t}$$

The description of variables is given below in the following table:

Table 3: Description and Sources of Variables

Variable	Description
ACR	Log of actual area under wheat, rice and maize cultivation in year t expressed in, 000 hectares Source: *State Bank of Pakistan (Annual Reports)*
P_{t-1}	Log of producer price of wheat, rice, potato, maize (Rs/tonne) in period t-1. Source : Agricultural Statistics of Pakistan *(various issues)*
Y_{t-1}	Log of actual yield of wheat, rice, potato, maize yield (000 tonne) in year t-1. Source: *State Bank of Pakistan (Annual Reports)*
ID	Log of infrastructure development (represented by transportation (road length in kilometers)) Source: *State Bank of Pakistan (Annual Reports)*
CD	Log of credit disbursement (Rs million) Source: *State Bank of Pakistan (Annual Reports)*

Source: Authors

4. METHODOLOGY

4.1. Unit Root Test

The augmented dickey fuller test, a more sophisticated variation of the dickey fuller test, is used to evaluate the stationarity. When integrated to order zero, a series is stationary if the null hypothesis (that it has a unit root) can be rejected. If the unit root null cannot be rejected, a series is difference stationary. Following is a description of the ADF's general structure at level and first difference:

$$\Delta Y_t = a y_{t-1} + \sum_{i=1}^{n} \beta \Delta Y_{t-1} + \delta + Y_t + \xi_t$$

$$\Delta\Delta Y = a_1 \Delta Y_{t-1} + \sum_{i=1}^{n} \beta \Delta\Delta Y_{t-1} + \delta + \gamma_t + \xi_t$$

4.2. Fully Modified Least Squares (FMOLS)

We have used the second-generation econometric technique named fully modified ordinary least square (FMOLS) developed by Philip-Hansen (1990). It's a co-integrating regression that measures the long-run supply response to price and non-price factors. Smyth and Narayan (2009) claim that co-integration regressions are reliable in the presence of endogenous regressors which are frequently present in models of production decision-making and result in asymptotically median-unbiased estimators. Additionally, it contends that co-integration regression solves the issue of measurement errors and omitted variables, reduces sample bias, adjusts for serial correlation, and also permits heterogeneity of the long-run estimators.

4.3. Why FMOLS Is Used Instead of other Techniques?

The selection of an estimation technique in time series econometrics is mostly determined by the type of data and the analysis' goal. When working with cointegrated time series data, FMOLS (Fully Modified Ordinary Least Squares) is frequently chosen over GMM, (Generalized Method of Moments) particularly in small to medium samples. By accounting for the endogeneity and serial correlation present in cointegrated regressors, FMOLS, created by Phillips and Hansen (1990) offers reliable and effective estimates of long-term connections. FMOLS adjusts the OLS estimator to take into consideration potential biases in the presence of non-stationary factors, in contrast to GMM which is better suited for dynamic panel data and might need strong instrumental variables to address endogeneity. Furthermore, when the sample size is small or when the instruments are weak or hard to recognize, FMOLS is thought to be more reliable (Pedroni, 2001). While FMOLS is specifically made for estimating long-run equilibria in cointegrated time series models, GMM estimators can be sensitive to the instruments used and may produce contradictory estimates if the moment conditions are not properly stated. Therefore, FMOLS provides a more suitable and trustworthy estimating method for a study that uses time series data to examine the long-term effects of infrastructure on food security in Pakistan.

5. RESULTS AND DISCUSSION

In this section we have presented the results of descriptive statistics, unit root test. Moreover, results of FMOLS have also been discussed.

5.1. Descriptive Statistics

Before estimation, we examine the reliability of the data. Commonly used measures of data analysis are the measure of central tendency and the measure of dispersion. The median and mode are used as the measure of central tendency. While measures of dispersion include standard deviation, quartile, deviation and mean deviation. Jarque-Bera is used to check whether the series is normally distributed. Results of the descriptive statistics are described in Table 4. Results show that mean and median of almost all the variables are same, and it also provides symmetry of the data. Results in the table show low variability because the values of the standard deviation are small. Jarque-Bera results show that we fail to reject the null hypothesis of normal distribution.

Table 4: Results of Descriptive Statistics

	Mean	**Median**	**Maximum**	**Minimum**	**Std. Dev.**	**Jarque-Bera**	**JB Probability**
ACRm	6.862	6.848	7.247	6.553	0.168	2.323	0.313
ACR_r	6.862	6.848	7.247	6.553	0.168	2.323	0.313
ACR_w	9.010	9.016	9.130	8.843	0.078	1.846	0.397
CD	11.009	10.665	14.127	7.958	1.809	2.909	0.234
ID	12.183	12.419	12.510	11.382	0.372	4.742	0.264
P_m	6.055	5.836	7.090	5.011	0.604	3.835	0.147
P_r	4.939	4.718	6.980	3.288	1.163	3.168	0.205
P_w	5.668	5.704	7.696	3.912	1.174	3.168	0.205
Y_m	7.632	7.410	8.972	6.774	0.672	4.153	0.125
Y_r	8.424	8.407	8.916	7.979	0.308	3.650	0.161
Y_w	9.798	9.836	10.191	9.293	0.286	3.142	0.208

5.2. Results of Unit Root Test

Utilizing the ADF unit root test, for further estimation, we looked at the order in which each series is integrated. The findings demonstrate that all the variables are stationary at first difference. We reject the null hypothesis of unit root at first difference whereas we have failed to reject the null at level.

Table 5: Result of ADF

variable	Level t-Statistic	Prob.	1st diff t-Statistic	Prob.	Order of integration
ACRw	-3.4680	0.0575	-7.9904	0.0000	I(1)
ACRr	-2.0540	0.2636	-5.4364	0.0001	I(1)
ACRm	-1.3282	0.6065	-6.9628	0.0000	I(1)
Pw	2.2307	0.9999	-2.6724	0.0387	I(1)
Pr	0.5280	0.9855	-5.5260	0.0000	I(1)
Pm	-1.67569	0.4341	-8.7463	0.0000	I(1)
Yw	-0.87952	0.7825	-7.7758	0.0000	I(1)
Yr	-0.87136	0.7851	-8.9750	0.0000	I(1)
Ym	-1.2524	0.9979	-5.9025	0.0000	I(1)
lD	-2.5105	0.1214	-4.1909	0.0109	I(1)
CD	-0.707	0.83	-5.036	0.0002	I(1)

5.3. Results of Fully Modified Least Squares (FMOLS)

Table 6: Dependent Variable: ACR

Variable	ACRr	ACRw	ACRm
ACR_{t-1}	0.5466***	0.0450**	-0.0690
	(4.4998)	(2.6188)	(-0.5746)
P_{t-1}	0.2678**	0.0048	0.0678
	(3.3256)	(0.2762)	(1.1307)
Y_{t-1}	2.9190**	-0.3460*	0.8989
	(2.7464)	(-1.9682)	(1.2784)
ID	1.2828**	1.2700**	1.3705*
	(3.0993)	(5.1571)	(1.7663)
CD	0.0616*	0.0208*	0.0805**
	(1.7867)	(1.8937)	(3.2467)
C	7.0940**	2.9291**	4.4430
	(3.6481)	(12.4763)	(1.7194)
R-squared	0.82485	0.81572	0.78924
Adjusted R-squared	0.80733	0.80384	0.73460
LM Statistics Prob.(F.Stat)	0.2490	0.1447	0.3790

Note: *** shows the significance at 1% while ** and * shows significance at 5 % and 10 % respectively.

The results from the estimated ARDL (1,1) model show insignificant long-run supply response to price changes. The short-run elasticities for current price (-1.19) and lagged price (1.21) are both elastic and significant; however, the elasticity for the current price is negative, a result similar to that of McKay et al. (1999) in the Tanzanian study. The explanation for this result is that price is endogenous, i.e. price is determined after supply has been observed, which results in low prices during bumper harvests and high prices when supply is low, hence the negative elasticity. This result is consistent with post-planting price announcements, which Zimbabwe tends to use. This result also implies that single equation estimations that fail to take this endogeneity into account provide inconsistent estimates. As mentioned earlier, the ARDL estimates are valid even if regressors are endogenous. Thus, in our case we have taken into account the fact that price is endogenous. The significance of the lagged price elasticity reinforces the belief that agricultural producers have adaptive price expectations, which lends support to the Nerlove price expectations model. It should be noted that the table of results for the ARDL (1,1) model has not been presented in the text as below we argue that this model suffers from specification error.

Due to the fact that production choices are typically taken in the preceding period, lagged variables are employed in the estimated equations. The lagged acreage under wheat and rice is positively associated to current acreage. This demonstrated that in the case of wheat and rice, current area is strongly dependent on lagged area. Rice acreage rises by 0.04 percent for every 1% increase in lagged wheat area, while wheat acreage increases by 0.54 percent, keeping other factors constant. The findings are in line with those of Chaudary (2000) who discovered that lagged acreage is a significant determinant of almost all current acreage of the crops under consideration. Additionally, the outcome is consistent with studies by Mahmood et al. (2007) and Kollurmath et al (2010). The coefficients of lagged yield of rice have positive and significant coefficients. Lagged yield of rice has the highest coefficient which is also statistically significant. It means that the output of rice is more responsive to food security as compared to other crops. Wheat's lagged yield is inversely correlated with its current yield since it could be replaced by other crops like barley, cotton, or maize. Ozkan et al. (2011) provide similar findings in case of Turkey.

Prices for previous wheat and maize are statistically insignificant. This demonstrates that decisions made by farmers regarding the amount of land given to these crops in the current season are unaffected by the pricing of these commodities. Chembezi (1990) suggested that because smallholder farmers have developed a mindset that considers wheat or maize as more than merely a food crop, their price risk is obviously less substantial. The lagged price of rice has positive and significant impact on food security with a value of 0.2678. The importance of lagged price elasticity supports the idea that agricultural producers have adaptive expectations about prices, which is consistent with the Nerlove price expectations model. This finding agrees with Hussain and Hussain's (2006) findings that the price of rice has a favorable impact on acreage. Additionally, this outcome is in accordance with Mahmood et al. (2007) and Abou-Talb and Mamkh (2008). In our analysis we are using transportation as a proxy of infrastructure development. Results show that infrastructure development has positive and significant impact on food security in all cases. So, we can say that infrastructure plays important role in the availability of food because first, infrastructure, such as roads, connects farmers to markets for both their products and inputs. Second, by lowering input costs and improving access to the market, effective transportation systems and public roads boost farmers' profit margins. Third, equal access to finance is improved by adequate infrastructure, particularly for small and medium-sized businesses (SMEs) and good transportation networks. Additionally, according to Fan, Hazell, and Thorat (2000) public road investment has a significant favorable impact on India's agricultural production increase. Accessibility to public transit has a demonstrable negative causal influence on food insecurity, according to Baek (2016). Every additional bus-equivalent vehicle reduces the likelihood of food insecurity in families by 0.78 percentage points per 10,000 people. Similar findings are given by Leuthart et al. (2020).

Results show that credit has positive and significant effect on food security. The reason being that essay access to credit makes farmers increase their production by buying different inputs. Credit facilities can improve the standard of small and medium enterprises. According to Asghar and Salman (2018) removing financial limitations leads to an increase in output which in turn can lower food insecurity by guaranteeing that everyone has access to food. Iftikhar and Mahmood (2017) come to the conclusion that while the agricultural economy needs a variety of resources to produce food, credit is one of the factors that aid in risk management. They discover that institutional agricultural credit makes a major contribution to the fight against food insecurity. Similar results for Bangladesh are found by Bidisha et al. (2017).

Food supply stability, cost, and accessibility are all impacted by transportation which has a significant impact on food security. Food may be transported from areas of surplus to areas of need in a timely and economical manner- thanks to good transportation networks. However, inadequate infrastructure, particularly in rural regions, can result in high transportation costs, substantial post-harvest losses, and limited access to markets for farmers, ultimately reducing the supply of food and driving up prices. For instance, a 2023 study conducted in Nigeria found that inadequate road systems made it extremely difficult to access markets which in turn contributed to a rise in food insecurity in rural areas (Ajiboye et al., 2023). Additionally, according to the World Bank (2024) up to 50% of the final retail price of food in underdeveloped nations can be attributed to transportation expenses; this means that any inefficiencies in the logistics chain are passed on to consumers-who are frequently the most susceptible. According to a study on food accessibility in San Diego, California, poor mobility might result in "food deserts," where locals find it difficult to obtain wholesome, fresh food since there are few transit choices (Rafalski and Fang, 2021). Additionally, cutting-edge technologies like drone-based food distribution are being developed to alleviate transportation-related delays in emergency or difficult-to-reach locations, enhancing supply chain responsiveness and cutting deprivation time by as much as 40% (Zambrano et al., 2023). Therefore, increasing food security, decreasing food waste, and guaranteeing equal access to nutrition all depend on bettering transportation infrastructure and logistics, especially in rural and disadvantaged areas.

6. CONCLUSION AND IMPLICATIONS

Rapid urbanization and rising incomes are two features of Pakistan's economy that have experienced significant change. Rapid expansion of the food supply is necessary due to the profound changes in economic and social structure. The Pakistani government has made increasing agricultural productivity a top priority. This study presents the findings of models that were fitted for Pakistan's main agricultural crops from 1980 to 2020 using data on acreage supply response/food security. To assess the association between agricultural supply, pricing, and infrastructure, fully modified least square (FMOLS) is used.

After conducting the preliminary data analysis, we conducted unit root test for stationarity. Next, we present the results of FMOLS. The main conclusions of this study are: first, lagged acreage of rice and wheat is significantly contributing to current acreage; second, only rice crop area allocation is responsive to price incentives; third, lagged yield of rice and wheat is significantly contributing to current yield. Last, among the non-price factor such as transportation and credit to the agriculture sector have a tremendous potential to boost crop productivity. Through looking at the sizes of the elasticities of acreage responses with regard to non-price factors, our findings show that these factors are significant to influence crop production and resource allocation. Infrastructure development is the most significant non-price factor in determining crop area.

According to our findings, Pakistan should support modernization by spending more on infrastructure. Investment in public infrastructure is also necessary to establish the ideal surroundings for a thriving capital market in rural areas. Food supply stability, cost, and accessibility are all impacted by transportation which has a significant impact on food security. Food may be transported from areas of surplus to areas of need in a timely and economical manner- thanks to good transportation networks. The construction and upkeep of rural feeder roads, perishable cold-chain logistics systems, and reasonably priced urban transit choices to food retail areas should be the top priorities for targeted investments. Public-private partnerships (PPPs) (which ensure sustainability and efficiency through shared risk and innovation) should be facilitated by governments in order to raise the significant capital needed for large infrastructure projects.

Limitations and Future Research Directions

We have limited our focus into the transportation sector, eliminating telecommunications, roads, irrigation, and electricity, as well as the social sector which includes the provision of water, sewage systems, hospitals, and educational facilities. Additionally, this study does not cover broader infrastructures including market and institutional infrastructures. Future research should focus on examining these broader effects of infrastructure development in order to evaluate which type of infrastructure is more effective.

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