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MAXIMIZING CEREAL YIELDS IN SOUTH ASIA: THE IMPACT OF AGRICULTURAL INPUTS

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ABSTRACT

Food security is a top priority of developing countries. Most of these countries are highly populated and face issues of low agricultural productivity and food poverty. In these nations, being self-sufficient in food supplies is a highly desired objective. This study aimed to determine the comparative impact of different inputs on the production of cereals in South Asia. The data used for the study is taken from the World Development Indicators (WDI), which spans the years 1990 to 2021. Owing to the nature of the data, the panel data model was used for analysis. All three-panel model techniques of pooled OLS, fixed effect, and random effects are employed for analysis. Nonetheless, fertilizer consumption, agricultural machinery in the form of tractors, and annual freshwater withdrawal are found to have a positive and significant impact on the output of cereal crops in the sample countries according to a large number of the model results. However, the results for the labor force and land are significant and inversely related to those for cereal crop production in the sample countries, which may be due to the predominance of capital-intensive agriculture. The results of this study will assist South Asian nations in addressing concerns about food supply and self-sufficiency more effectively. A lot of research has looked at how inputs affect agricultural productivity at the national or subnational level. In this study, the effects of several closely related agricultural inputs on "cereal production for entire South Asia" were examined. By changing investment, policy, market behavior, and overall agricultural productivity, the study will have a major economic impact on economies.

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INTRODUCTION

The world has experienced an increase in food insecurity in recent years. Worldwide, food insecurity affected more than 10% of the population in 2017 (Berge et al., 2019). Undernourishment affects 13% of the population in developing countries (Pawlak and Kołodziejczak, 2020), and it is particularly prevalent in developing economies (Pollard and Booth, 2019). According to Mittal and Sethi (2009), the majority of the world's hungry people live in South Asian countries, which have the highest rate of undernutrition worldwide. In 2020, 9.9% of people worldwide and 15.8% of South Asians were determined to be undernourished. 1 Poverty and food insecurity are correlated phenomena. According to Islam et al. (2021), 33.4% of the world's severely poor reside in South Asia alone. It is important to recognize the problem of food insecurity, particularly in light of the 2030 Sustainable Development Goals (SDGs). Additionally, to address this problem, production must be increased to its maximum potential, and everyone must have access to food (Mârza et al., 2015).

Except for India and Pakistan, most South Asian countries are experiencing a decline in per capita food production and supply. Furthermore, South Asian countries are expected to face a severe food crisis by 2050, and food security will be a critical issue in the years ahead (Ahmad et al., 2021). Food security is directly dependent on agricultural production (Mârza et al., 2015). However, this process is indirectly dependent on other factors that support agricultural production, including inputs such as seeds, fertilizers, and other equipment (Mârza et al., 2015).

The majority of people's diets, whether in developed or developing nations, consist mostly of cereals and their products, which provide them with a significant amount of energy (Laskowski et al., 2019). Sorghum, maize, oats, wheat, and rice are some of the primary grains. These plants are cultivated across an area of almost 700 million hectares in enormous quantities. The fact that cereals account for approximately half of the global caloric intake illustrates their significance (Singer et al., 2019). Fibers from cereals and whole grains must be consumed for a balanced diet. It is believed that eating these items can lower the risk of developing several ailments, including type II diabetes, cancer, and heart-related conditions (Haung et al., 2015). It is well known that cereals are the main source of carbohydrates and energy in the human diet. Furthermore, it is regarded as the most significant protein in the world (Poutanen et al., 2022).

South Asian people rely heavily on cereal crops to meet their caloric needs. Sugarcane, rice, and wheat production in 2017 were estimated to be 394, 238, and 146 million tonnes, respectively. In 2018, South Asia produced more than 15% of the global cereal

[1] South Asia: share of the population who are undernourished 2020 | Statista

production; however, this region's share of global production is still far lower than its share of the global population (Mughal and Fontan, 2020). Additionally, South Asian countries include Bangladesh, India, Afghanistan, and others, which rely heavily on agriculture for economic growth.

Nobody can deny farmers access to modern agricultural inputs and its significance. Inputs such as fertilizer, labor, land, water withdrawal, and tractors, on the other hand, have direct impacts on cereal crop production. Improved inputs and modern machinery are well known to be important determinants of agricultural output. However, the relationship must be qualified. As a result, the purpose of this research was to determine the impact of inputs on cereal crop production in South Asia. The empirical findings of this study are expected to be useful for providing useful information to policymakers and planners responsible for the development of the agricultural sector. The study's findings will also assist policymakers in developing future development policies.

The purpose of this study was to investigate how the output of cereal crops in South Asia was affected over 32 years, from 1990 to 2021, by several factors, such as fertilizer usage, irrigated land, agricultural machinery, employment in agriculture, and freshwater withdrawal. The research era is determined by the accessibility of the data. South Asian countries contain the highest number of undernourished people worldwide, accounting for approximately 40% of the world's hunger (Mittal and Sethi, 2009). Furthermore, poverty in this region is also very high. This region is home to 33.4% of the world's extremely poor people (Islam et al., 2021). Therefore, food insecurity and the high poverty level are the reasons why South Asia is selected for this research. Another reason for choosing this continent over any other continent is that Pakistan is also located in South Asia.

There are numerous studies at the country or sub-country level that have discussed the impact of inputs on agricultural production. However, this study has been performed to see the impact of inputs on "cereal production for entire South Asia". Therefore, the contribution of the present study is that it determines the relative impact of inputs such as total consumption of fertilizer per hectare of arable land, irrigated land, total number of tractors per 100 km2 of arable land, number of workers employed in agriculture, and annual water withdrawal on the overall production of “cereal crops” in entire South Asia.

Several academic studies have looked at the relationship between inputs and agricultural output both nationally and globally. Much of the relevant literature has produced findings that are similar to each other and have almost similar outcomes. We will briefly discuss the results of a few research that examine the relationship between inputs and outcomes in this field.

In agriculture, as in any other industry, knowledge and skills play a crucial role. Hasan et al. (2011) explored the factors that are important for determining the variation in the yield of wheat in the three major wheat-producing areas of Dinajpur, Jamalpur, and Rajshahi in Bangladesh by using cross-sectional farm-level data. The results of the aggregate production function revealed that factors such as gypsum, the cost of irrigation, land and soil type, the date of sowing, animal power, and farm yard manure (FYM) significantly influenced the variation in wheat yield.

Obilor (2013) investigated the impact of commercial bank credit on Nigeria's agricultural sector from 1984 to 2007. The study's empirical findings show that agricultural credit guarantee schemes and government fund allocation have a positive and significant impact on Nigeria's agricultural productivity. However, variables such as agricultural product prices and commercial bank credit have significant but negative impacts on Nigerian agricultural productivity.

Suleman and Adjei (2015) investigated the impact of microfinance on agricultural production in the Pru district in Ghana. The data for this study were obtained through well-structured surveys in the study area. The results of the study revealed that microfinance has a positive impact on agricultural production in the study area and plays a significant role in increasing production. The authors of the study recommended that proper education be provided to farmers related to the process of loan acquisition.

Chandio et al. (2018) examined the impact of inputs on the production of grain crops in Pakistan using time series data for a period of 38 years, i.e., from 1978 to 2016, to estimate the data obtained by the ARDL approach to cointegration. The study's findings show that factors, such as the area under cultivation, higher quality seeds, fertilizer consumption, and water availability, have a positive and significant impact on grain crop production. However, the impacts of other inputs, such as tractors, tube wells, and insecticides, are negative. The farmers in the study area were found to be uneducated about the use of fertilizers and chemicals.

Udokang (2020) used time series data from the years 2002–2003 to 2006–2007 to investigate the factors that affect crop output in Nigeria. The author employed the stepwise regression method to evaluate the data. The study's findings indicate that Nigeria's soil and climate are both favorable; thus, adding fertilizer to increase agricultural yields is not necessary. The Nigerian farming sector has an adequate labor force to alter crop output, thanks in part to new technology.

In a different study, Zaman (2021) used time series data spanning 32 years, or from 1985–2016, to examine the contribution rates of factors affecting crop output in Bangladesh. The author employed the Cobb–Douglas production function to analyze the data. The study's findings indicate a negative correlation between labor and land and agricultural productivity. Conversely, there are positive correlations between agricultural productivity and household spending, irrigation, and fertilizer consumption. There was a statistically significant difference between the land and fertilizer coefficients. Thus, there is generally a declining return to scale in crop production, which calls for immediate technological advancement and improved agricultural management.

Using a two-step Meta frontier model, Kumar et al. (2022), compare the technical efficiencies and technological gap ratios of chickpea farming in three key locations of Ethiopia that produce chickpeas. It displays regional variations in the technological efficiencies, technological gap ratios, and meta-technical efficiencies (MTEs) based on data from 681 farm households that cultivate chickpeas in the three regions. The study looked at the factors influencing these various production levels and found strategies for raising chickpea yields while reducing yield disparities. Harnessing the full potential of improved chickpea cultivars in Ethiopia would require increasing farmers' access to improved seeds, providing them with need-based and gender-responsive extension support, encouraging their participation in technology development programs, and implementing appropriate rainwater management.

The study conducted by Djurle et al. (2022) focuses on strategies for anticipating and reducing the impact of biohazards on livestock and crop primary production. These biohazards, which can be the result of unintentional or deliberate pathogen introductions, have the potential to seriously harm farmers, the agriculture sector, society, and global trade economically. The threat of agro terrorism in Europe exists, despite the fact that few incidents of it are reported. The swift progress in biotechnology and developing technologies gives rise to fresh worries regarding potential hazards. The potential impacts of unintentional or intentional biohazards on agricultural production were reviewed, along with strategies for mitigating them, using the FORSA analytical framework for risk and vulnerability analysis. Enhanced farm biosecurity, more capacity for monitoring and laboratory testing, better interagency communication, and more efficient use of resources all contribute to greater readiness and event management capabilities. This review focuses on Europe, but the lessons learned are applicable globally.

At the county level, Yin et al. (2024) conducted a quantitative analysis of changes in the harvested acreage and yields of China's four most popular crops—rice, wheat, maize, and soybeans—between 1980 and 2011. To measure the factors influencing the observed variations in harvested area and yields for the primary cultivation region of each of the four crops, the authors employed spatial panel regressions. The findings demonstrated a positive correlation between harvested areas and increases in the gross domestic product, population, and urbanization. The yields of the three cereal crops rose with the increased use of technology and fertilizer inputs, but the harvested area of soybeans fell, especially after China joined the WTO.

The conclusions drawn from the literature demonstrate that increasing the quality and quantity of inputs leads to an increase in agricultural output. Achieving food self-sufficiency requires an understanding of the link between these inputs and production. The majority of related research shows that inputs, including water availability, fertilizer usage, credit to farmers, machinery (tractors), and cultivable areas, have a positive and significant impact on crop yield. Any deviation from the expected results for standard inputs with limited research could be attributed to the quality of these inputs and random factors. Determining the relative effect of inputs on the production of cereal crops across the whole South Asian region is the aim of this study.

METHODOLOGY

Theoretical Background

According to Ruttan and Hayami (1972), agrarian development theory should provide insight into the dynamics of agricultural growth in economies ranging from those where output is growing at an annual rate of 1.0% or less to those where output is growing at an annual rate of 4.0% or more. The five categories of theories of agricultural development are as follows: 1) the frontier model; 2) the conservation model; 3) the urban-industrial impact model; 4) the diffusion model; and 5) the high-payoff input model (Ruttan, 1977).

The 18C English Agricultural Revolution led to the creation of the conservation model. To make better use of land and water resources, this model suggests modifying cropping systems that are more complicated and labor intensive, using organic manures, and capital creation in the form of physical infrastructure. In many places worldwide, agricultural development within the parameters of the conservation model was able to maintain a sustainable rate of growth in agricultural production.

The location variations in agricultural development were primarily related to differences in environmental factors according to the conservation model. Additionally, it contrasts sharply with models that associate geographic differences in the level and rate of economic development, primarily with urban-industrial development. Von Thünen (1996) initially developed the urban-industrial impact model to explain geographical variations in farming intensity and labor productivity in an industrialized society. T.W. Schultz later extended this model to explain the more effective performance of the factor and product markets connecting the agricultural and nonagricultural sectors in regions with rapid urban-industrial development. This model has been extensively tested in a few states but has received little attention in the developing world.

The diffusion model suggests that in agriculture, the diffusion of improved husbandry practices, including crop and livestock practices, has been a significant source of productivity. According to this viewpoint, agricultural development can progress through more effective dissemination of technical knowledge and the narrowing of productivity gaps between farmers and regions. The strength of this model is that since the emergence of agricultural economics as a separate sub discipline linking agricultural sciences and economics in the late nineteenth century, the diffusion model has served as the major intellectual foundation for much of the research and extension effort in farm management and production economics. Limitations of this model include the fact that neither rapid modernization of traditional farms nor rapid growth in agricultural output has been achieved.

Three categories were created by the author to group the new high-payoff inputs. The ability of research institutes in the public and commercial sectors to produce new technical knowledge, the industrial sector's ability to develop and produce new technological inputs and market them, and, finally, farmers' ability to pick up new skills and use new inputs efficiently. The model does suggest that the availability and cost of high-yield, contemporary inputs are critical to the economic prosperity of a developing nation's agricultural industry. The model seems capable of generating a sufficiently high rate of agricultural growth to provide a foundation for overall economic development. However, as a theory of agricultural development, the model is still incomplete. The model does not fully incorporate the mechanism through which resources are allocated among education, research, and other alternative public and private sector economic activities.

In summary, according to the frontier model, increasing cultivated land and labor capacity will result in increased agricultural output. The next conservation model suggested ways to improve the production and use of manure, labor- and land-intensive farming techniques, and capital formation to maximize the use of water and land resources. The third model, the location model, asserts that agricultural areas located closer to urban areas have greater product prices, property prices, and land use returns. This model also implies that access to urban industrial centers is related to machinery investment per hectare as well as per man but has a minor impact on other factors. The fourth model is the diffusion model, which suggests that the rapid spread of improved husbandry practices, crops, and livestock has been an important contributor to productivity. According to this perspective, agricultural development can progress through closing the productivity gaps between farmers and the region and increasing the efficiency with which technical knowledge is disseminated. The last model, the high pay-off input model, suggests that the cost and accessibility of contemporary, high-payoff inputs determine how quickly an impoverished nation's economy may expand. Agricultural investment turns a profit when these agricultural inputs are successfully provided at a reduced cost. We can infer from the prior discussion that the frontier model and the high pay-off input model are the theories pertinent to this study.

Sources of the Data

In this study, secondary sources of data were used to examine the relative effects of agricultural inputs, namely, fertilizer consumption, agricultural employment, irrigated land, and annual fresh water with drawl on cereal production in South Asia; these included Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. The secondary data covering a period of 32 years, ranging from 1990 to 2021 are presented in the given Table 1. The data are obtained from the World Development Indicators (WDI).

Empirical Model

To analyze the relative effectiveness of agricultural inputs on cereal production, panel data are used for estimation purposes. Panel data has many advantages. First, it can detect and measure effects that are not easily visible in cross-sectional or time series data. Second, panel data consists of large datasets because there is less collinearity and more variability among variables than cross-sectional or time series data. Third, it allows the investigation of more complex behavioral models (Gujarati, 2022). A panel dataset is a cross-sectional time-series dataset in which the behavior of entities is observed over time. Panel data can be estimated using three different models: the random effect model, the fixed effect model, and the pooled OLS model (also called the common effect model).

For this research, cereal production was chosen as the dependent variable, whereas agricultural machinery (tractors), fertilizer consumption, irrigated land, employment, and annual freshwater withdrawal were the explanatory variables. These variables are selected from the literature. The functional form of their relationship can be written as follows:

$$Q_{it} = f\ (L_{it}, K_{it}, LD_{it}, FC_{it},\ WT_{it}) \quad (1)$$

where *i* = 1..,5 (South Asian countries).

t = the considered period. i.e., 1990…….2021.

(Q_{it}) represents cereal production.

(L_{it}) represents agricultural employment.

(K_{it}) is the total agricultural machinery (tractors).

(LD_{it}) represents irrigated land.

(FC_{it}) is the total fertilizer consumption,

(WT_{it}) represents the annual freshwater withdrawal.

The specific form (Cobb–Douglas) of this general equation can be written as follows (Cobb and Douglas, 1928):

$$Q_{it} = A\ L_{it}^{\alpha_1}\ K_{it}^{\alpha_2}\ LD_{it}^{\alpha_3}\ FC_{it}^{\alpha_4} WT_{it}^{\alpha_5}\ e^{u_{it}} \quad (2)$$

where A is a positive constant that represents total factor productivity and u_{it} is a random error term.

The above equation is linearized for computational convenience and better interpretation of estimated coefficients using log transformation.

$$ln\ Q_{it} = lnA + \alpha_1 lnL_{it} + \alpha_2 lnK_{it} + \alpha_3 lnLD_{it} + \alpha_4 lnFC_{it} + \alpha_5 lnWT_{it} + u_{it} \quad (3)$$

Furthermore, $\alpha_1, \alpha_2, \alpha_3, \alpha_4, and\ \alpha_5$ are the coefficients for the respective variables. Because both the dependent and independent variables are in log form, the coefficients are represented as elastic.

The strategy for the static panel data model is that we start with the pooled OLS model. One of the main assumptions of pooled OLS is that it ignores heterogeneity among cross-sections. The pooled OLS for this study can be written as follows:

$$lnQ_{it} = \alpha_0 + \alpha_1\ lnL_{it} + \alpha_2 lnK_{it} + \alpha_3 lnLD_{it} + \alpha_4 lnFC_{it} + \alpha_5 lnWT_{it} + u_{it} \quad (4)$$

* Here, α_0 is assumed to be the same or common for all countries.

In the second step, we estimate the fixed effect model. The main assumptions of the fixed effect model include that it takes into account heterogeneity explicitly; furthermore, it assumes strict homogeneity of X_{it} conditional on the unobserved effect. In this model, we simply add a dummy variable (D_j) for each country except one (considered as a reference category) to equation (4) to avoid omitted variable bias. We added four dummies (j=4) to equation (4) to obtain equation (5) since there are five selected countries. This can be written as:

$$lnQ_{it} = \alpha_0 + \alpha_1 lnL_{it} + \alpha_2 lnK_{it} + \alpha_3 lnLD_{it} + \alpha_4 lnFC_{it} + \alpha_5 lnWT_{it} + \sum_{j=1}^{4} \beta_j\ D_j + u_{it} \quad (5)$$

Next, we estimate the random effect model. In this step, the error term in equation (4) changes to w_{it}; furthermore, we add one more error term to the equation, i.e., v_i. This new error term reflects the randomness of sample selection. This can be written as:

$$lnQ_{it} = \alpha_0 + \alpha_1 lnL_{it} + \alpha_2 lnK_{it} + \alpha_3 lnLD_{it} + \alpha_4 lnFC_{it} + \alpha_5 lnWT_{it} + v_i + w_{it} \quad (6)$$

All of the models are estimated through OLS/GLS. The pooled OLS model and fixed effect model are estimated through OLS regression. The random effect model was estimated through GLS. Furthermore, models (4) and (5) are selected through the F test. Selection between models (5) and (6) is performed through the Hausman test, and selection between models (6) and (4) is performed through the LM test.

Table 1. Description of variables with a unit of measurement and data source.

Independent variables	Description	Unit	Data source
Cereal production	This variable includes only data related to the crops harvesting for dry grain, including wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains.	Cereal yield, kg per hectare	WDI (World Development Indicator)
Fertilizer consumption	Fertilizer consumption is the amount of plant nutrients consumed per unit of arable land.	Kilograms per hectare of arable land	WDI
Agriculture Irrigated land	Includes areas that have been purposefully provided with water, including land that is irrigated through controlled flooding	% of total agricultural land	WDI
Agriculture machinery	The number of tractors that are used in the agriculture sector at the end of the calendar year specified or during the first quarter of the following year is referred to as agriculture machinery.	Per 100 KM2 of arable land	WDI
Employment, agriculture	engage persons to carry out activities for producing goods or to provide services for pay or profit	% of total employment	WDI
Annual freshwater withdrawal, agriculture	Agriculture withdrawals include total withdrawals for watering irrigated lands and for livestock production	% of total freshwater withdrawal	WDI

RESULTS AND DISCUSSION

To assess the impact of inputs on cereal yield, static panel modeling was employed. Since the output of one period's crop is independent of the previous crop, which was harvested before the new crop, the dynamic model is meaningless in the context of agricultural production. The following are the interpretations of the expected outcomes:

Pooled OLS (Model 1)

The estimated impact of different variables on cereal production through the pooled OLS model is shown in Table 2. The results show that all of the inputs have positive and significant impacts on the dependent variable, i.e., cereal production.

The value of the return to scale is 6.312, which we obtained by adding all of the variables' coefficient values. The value of the return to scale indicates that cereal production in South Asia was in stage one, indicating that inputs were underutilized by cereal producers. This implies that cereal producers could benefit from economies of scale associated with increasing returns. Furthermore, production could be increased by using more production resources at this stage, i.e., stage one.

Fixed effects (Model 2)

The results of the estimates obtained by the fixed effects model are given in the Table 3. The coefficients of fertilizer, labor employed, irrigated land and tractor had significant impacts on the production of cereal crops, but the variable water withdrawal had an insignificant impact on cereal crop production.

In this model, the first variable, fertilizer, is highly significant, with a p-value of 0.0000. Moreover, climate change has a positive impact on cereal crop production. The labor employed is also significant with a coefficient value (-0.7339348), which means that other things remaining constant 1 percent increase in the variable labor employed will lead to a 0.73 percent decrease in the production of cereal crops on average. The labor force may not have the required skills or maybe over-employed, which is a phenomenon of labor-abundant countries. Irrigated land is also significant and has an inverse relationship with cereal production. This also indicates an inefficient utilization of land for agricultural cereal production. The remaining two variables of agricultural machinery (tractor) and water are significantly and positively correlated with cereal production, with a coefficient value of 0.3925955.

The value of the return to scale is -1.1098032, which we obtained by adding all of the variable coefficient values. The value of the return to scale indicates that cereal production in South Asia was at stage three, indicating that inputs were overused by cereal producers. This finding implied that cereal producers have diseconomies of scale associated with decreasing returns. Furthermore, production could be decreased by using more production resources at this stage, i.e., stage three.

Random Effects (Model 3)

The estimated results of the third model are given in Table 4. This model also estimates that labor employed, fertilizer consumption, water withdrawal, and tractor have a significant impact on the production of cereal crops but that variable land has an insignificant impact on cereal crop production.

Here, fertilizer is highly significant, with a p-value of 0.0000 indicating a direct impact on cereal crop production. The variable labor employed is also significant and has a coefficient value (of 0.7718262), which can be interpreted as another factor remaining constant: a 1 percent change in the variable labor employed will lead to a 0.772 percent change in the production of cereal crops on average. The variable input of irrigated land is nonsignificant but has a positive impact on cereal production, with a coefficient of 0.4574175. The variables of tractor and water withdrawal are both significant and directly associated with the objective variable of cereal production.

The value of the return to scale is 2.47, which we obtained by adding all of the variable coefficient values. The value of the return to scale indicates that cereal production in South Asia was in stage one, indicating that inputs were underutilized by cereal producers. This finding implied that cereal producers could benefit from economies of scale associated with increasing returns. Furthermore, production could be increased by using more production resources at this stage, i.e., stage one.

Selection between Three Models

F Test

Now, to compare the pooled OLS and fixed effect models to determine which model is better, we use the F test. Here, the F test examines the null hypothesis that all individual-specific effects are zero.

H_0: β_j = 0; Or H_0: $\beta_{1=}$ $\beta_{2=}$ $\beta_{3\,=}$ $\beta_{3\,=}$ 0; H_1: $\beta_j \neq 0$; F test for which all u_i=0: F(4, 120)=23.36; Prob > F =0.0000.

Therefore, above, we have an F test value, and its probability value is 0.0000; therefore, based on the fixed effect model and F test value, we reject the null hypothesis. This means that there are individual-specific effects. This test yielded a significant result that was in favor of the fixed effect model. Based on this test, we can say that the fixed effect model is better than the pooled OLS model.

Hausman test

The fixed effect model and random effect model were selected to determine which model was better. We use the Hausman test. Therefore, for our null hypothesis, the random effect model is better, whereas for the alternative hypothesis, the fixed effect model is better. The results of the Hausman test are given Table 5.

Table 2. Results of the Pooled OLS model.

lncerealproduction	Coef.	Std. Err.	t	P>|t|	[95% conf. Interval]	
lnfertilizer	0.547	0.062	8.81	0.000	0.424	0.669
Lnlabor	2.059	0.282	7.30	0.000	1.501	2.617
Lnland	1.828	0.750	2.44	0.016	0.343	3.312
lntractor	0.909	0.125	7.29	0.000	0.662	1.155
lnwater	0.969	0.036	26.45	0.000	0.897	1.041
_cons	-28.145	2.676	10.52	0.000	-33.443	-22.848

Table 3. Results of fixed effects model.

lncerealproduction	Coef.	Std. Err.	t	P>|t|	[95% Conf. Intervel]	
lnfertilizer	0.481	0.0771256	6.23	0.000	0.3280758	0.6334823
lnlabor	-0.734	0.4127767	-1.78	0.078	-1.551204	0.0833344
Lnland	-1.397	0.6827858	-2.05	0.043	-2.748555	-.0448187
lntractor	0.393	0.1373522	2.86	0.005	0.1206477	0.6645432
Lnwater	0.147	0.5527237	0.27	0.790	-.9469104	1,241799
_cons	14.53247	12.59767	1.15	0.251	-10.41004	39.47498

Table 4. Results of random effects model.

Lncereal production	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
lnfertilizer	0.4731784	0.0781895	6.05	0.000	0.319929	0.626427
Lnlabor	0.7718262	0.3796343	2.03	0.042	0.0277566	1.515896
Lnland	0.4574175	0.7451641	0.61	0.539	-1.003077	1.917912
lntractor	0.6541171	0.1254444	5.21	0.000	0.4082505	0.8999837
Lnwater	1.113236	0.0499833	22.27	0.000	1.01527	1.211201
_cons	-20.68281	2.93518	-7.05	0.000	-26.43566	-14.92997

Table 5. Results of the Hausman test.

variables	Coefficients		Difference (b-B)	S.E.
	Fixed (b)	Random (b)		
lnfertilizer	0.480779	.4731784	.0076006	.
lnlabor	-.7339348	.7718262	-1.505761	.1620568
lnland	-1.396687	.4574175	-1.854104	.
lntractor	.3925955	.6541171	-.2615216	.0559403
lnwater	.1474441	1.113236	-.9657914	.5504591

b= consistent under Ho and Ha; B = inconsistent under Ha, efficient under Ho; Test: Ho differences in coefficients not systematic; Chi2(5) = (b-B)'[(V b-V B)^(-1)](b-B) = 60.8; Prob>chi2 = 0.0000.

Breusch Pagan LM test

Here, the null hypothesis is that the pooled OLS is better, and the alternative hypothesis is that the random effect model is better.
Breusch and Pagan Lagrangian multiplier test for random effects
Lncerealproduction[count,t] = Xb + u[count] + e[count,t]
Estimated results are given in Table 6.

Table 6. Results of Breusch Pagan LM test.

Breusch Pagan LM test	Var	Sd = sqrt(Var)
Lncerealproduction	26.99163	5.195347
E	.1035069	.3217248
U	.0146988	.1212384

Test: Var(u) = 0; chibar2(01) = 6.61; Prob > chibar2 = 0.0051.

The results of the Breush Pagan Lagrangian multiplier show the value of the chi-square is 6.61, and the probability value is 0.0051, so we reject the null hypothesis in favor of the random model. That is, the random effect model is better than the pooled OLS model. Therefore, both the F test and LM test conclude that the fixed effect model and random effect model are better than the pooled OLS model. Therefore, if both the fixed effect model and random effect model are significant, then we must determine which one of the two is more significant and which one is better than the other. Therefore, we use the Hausman specification test. Here, the chi-square value is 60.80, and its probability is 0.0000, which is less than 0.05, which means that this test is significant. Based on this test, we reject the null hypothesis. We conclude that the fixed effect model is appropriate.

However, our results are inconclusive. The main theoretical reason for our inconclusive results is that a larger number of time series data and a smaller amount of cross-sectional data are associated with a greater likelihood of differences in the values of parameters estimated by the fixed effect model and the random effect model. As a result, the fixed effect model is preferable due to its ease of computation. Furthermore, the F and Hausman test both favor the fixed effect model (Gujarati, 2022).

CONCLUSIONS AND RECOMMENDATIONS

The main objective of this research was to ascertain the proportional influence of various inputs, including labor, water withdrawal, tractors, irrigated land, and fertilizer, on the production of cereal crops in South Asia between 1992 and 2021. We employed a static panel data model that comprised three different types of models, a pooled OLS model, a fixed effect model, and a random effect model, to empirically evaluate the study's hypothesis on whether these inputs affect cereal crop production. Additionally, these models are selected using the Hausman, LM, and F tests. The study's findings show that fertilizer use and water extraction have significant positive effects on the production of grain crops in South Asia. Previous studies on comparable topics, including those by Ahmad (2011), Hussain (2012), Ahmad et al. (2021), and Chandio et al. (2018), provide support for these results. Additionally, data estimation indicated that tractors have a favorable and significant impact on South Asian cereal output, which is consistent with findings from earlier research, such as that of Gillani et al. (2021). This suggests that the production of cereal crops in South Asia is significantly influenced by three inputs: fertilizer, water withdrawal, and tractors. The empirical results show that the labor force and irrigated land have a negative but significant impact on South Asia's grain crop productivity. Zaman (2021) and Msangi (2017), among other studies, also discovered an inverse relationship between crop output and these two inputs. This indicates that the production of cereal crops in South Asia is not dependent on either labor or land. Advanced inputs are generally accepted as important factors influencing crop output. However, according to the findings of this research, the most important determinants of cereal crop production in South Asia are inputs such as machinery (tractors), fertilizer consumption, and water withdrawal.

Based on the results of the present research, the following recommendations are made: Fertilizer is an important factor in the production of cereal crops in selected South Asian countries. Therefore, to achieve a higher and maximum yield of cereals, the required doses of fertilizer must be applied at the appropriate time. In this study, labor was negatively related to cereal crop production. This could be due to a lack of necessary training/skills required for agricultural work. As a result, the focus should be more on organizing sessions at the village level to prepare laborers for practical and technical agricultural skills. Irrigated land is an important factor in cereal crop production. Therefore, proper field preparation is required before harvesting crops in select countries of South Asia. Furthermore, proper irrigation system maintenance and the use of modernized irrigation techniques are needed. Another important factor influencing agricultural production is water withdrawal. Adequate and timely availability of water can boost agricultural output. To increase water availability, the government should improve canal and watercourse systems. In terms of the relative importance of inputs, this study revealed that fertilizer, water withdrawal, and tractors are the most important inputs for cereal crop production in South Asia. All of these factors significantly influence cereal production in a positive way. The irrigated land and labor employed, on the other hand, are the least important inputs for South Asian cereal production. These two variables were inversely related to the dependent variable. To increase agricultural production in the study area, the input mechanism must be revitalized. Thus, the quantity and quality of the input used in the field heavily influence production. Furthermore, the quantity and quality of outputs are directly proportional to the quality and quantity of inputs.

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