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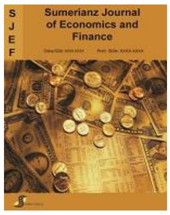

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Economies of the Factors Affecting Crop Production in India: Analysis Based on Cobb-Douglas Production Function

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Abstract

The Cobb-Douglas Production Function which has the advantage of permitting hypothesis testing and calculation of confidence intervals to test the reliability of the estimation has been applied in this study of the agricultural production process using several production factors within the broad terms of land, labor, & capital. Agricultural production has been considered as the dependent variable, whereas, area coverage for agricultural production, labor employed in agriculture, agricultural household expenditure, fertilizer applied, and irrigation coverage have been considered as independent variables. Agricultural productivity has been examined from a different perspective such as the productivity of land, labor, and capital. The factors of production estimated through the regression analysis demonstrated that the growth of crop production significantly depends on the application of fertilizer. Besides, irrigation and household consumption also have a positive impact on production. The use of seeds, types of machinery, and expenditures for sowing and harvesting are considered responsible for the increase in consumption for rural households, so their use may have some positive impact on production, but the effect of these factors is not much significant. Land and labor have a negative correlation with crop production. Overall crop production shows decreasing returns to scale due to a decrease in land productivity, use of traditional plow methods, land degradation, decrease in soil fertility, and increase in soil salinity. The increasing crop production is the result of the application of fertilizer and improved seeds. Land and labor were negatively correlated with crop production, whereas, fertilizer was positively correlated but excessive use of inorganic fertilizer may further aggravate soil fertility. This study also measures the marginal contribution of each input to aggregate agricultural output.

Keywords: Agricultural productivity; Cobb-douglas production function; Decreasing return to scale; Fertilizer Irrigation; Land degradation; Soil fertility.

1. Introduction

In recent years, agricultural production increasingly depends on science & technology advances, farm infrastructures, fertilizers & pesticide use, planting structures for crops, water management, and policy for agriculture development, all aimed at enhancing productivity. All these input factors have different influences on agricultural production and researchers turned the attention of government and practitioners toward agricultural technologies and practices concerns, and then, diverse mathematical models (such as the Cobb-Douglas production function, and Solow remaining value model), have been used to measure their contribution to agricultural production in the short and long terms.

India is home to 1.3 billion people, and globally ranks second in terms of agricultural output. The agriculture, forestry, and fishing sector accounted for 16.4% of the gross value added (GVA) in 2021. In contrast, the sector is serving as a primary source of livelihood for more than 50% of the country's population. Low and stagnant income across these sectors remains a focal point of policy debate in India. These sectors account for the majority of the poor in the country. Recent estimates show that about 220 million people are poor in India. One of the most prominent pathways to enhance farmers' income is the adoption of improved agricultural technologies for enhancing productivity. The literature reveals that the adoption of improved technologies is the key to increasing agricultural -

productivity and farmers' income (Duflo *et al.*, 2011; Kumar and Pal, 2020; Mason and Smale, 2013; Matuschke *et al.*, 2007; Subramanian and Quim, 2009). Despite a very strong impact on the well-being of farmers, the adoption of improved technologies is low, especially in the context of developing regions. Both demand and supply side factors play a crucial role in the adoption and diffusion of improved agricultural technologies. Demand side factors include - awareness and knowledge about technology, access to credit and relevant inputs, risk implications, and marginal returns (Barrett *et al.*, 2010; Besley and Case, 1993; Duflo *et al.*, 2011; Feder *et al.*, 1985; Varshney *et al.*, 2019). Supply-side factors include policy support, investment in agricultural research and extension system, availability of infrastructure, and institutional arrangements for the delivery and benefit sharing of technologies. A perfect blending of demand and supply side factors accelerates the penetration rate of improved technologies for achieving desired outcomes.

The Indian agricultural economy has performed erratically during the past several decades. Indian agricultural output, especially that of paddy and wheat in irrigated areas, recorded a quantum jump in growth during the 1970s and 1980s in response to the widespread adoption of new seed and fertilizer-based technologies. This was accompanied by substantial growth in rural infrastructure mainly through public investment. The growth stimulus spread into rain-fed agricultural production beginning in the 1980s. With the rapid adoption of high-yielding coarse cereals, oilseeds, pulses, and cotton. Rising yield growth and cropping intensities greatly contributed to buoyant agricultural growth, despite frequent instability due to weather events and natural disasters. But, India suffered slower agricultural growth beginning with the 1990s and its gap with the growth in the non-agricultural sector is widening along with continued and increased pressure of the dependent agricultural population. The widening gap has seriously jeopardized the natural goal of inclusive economic growth, as two-thirds of India's population still depends on Agriculture & Allied Sectors for gainful employment and secure livelihood. The difficulty of improving agricultural productivity on a sustainable basis is further compounded by increasing pressure on natural resources and the environment, the vulnerability of agriculture to shocks like climate change, and the fragmentation of farms. Agricultural growth in India needs to increasingly rely on sustainable and improving productivity growth through continued technological and institutional innovation within the structural constraints and given natural resources in India (Sinha, 2019; Sinha and Sinha, 2022; Sinha, 2022a). It is important to note that some positive development on these fronts has helped maintain agricultural growth at a reasonable level and have insulated the country from the food crisis. However, the share of agriculture to GDP was 20.2% in 2020-21 while the share of industry and service sector was 25.92% and 53.89% respectively. Nevertheless, the agriculture sector is crucial for India as it employs almost two-thirds of the labor force and economy of most of the rural people who roll with agriculture. This sector is also the primary source of inputs for the industry sector. Improved and extensive farming requires more labor in a sense but mechanization gradually reduces the demand for labor in agriculture. The landless poor find jobs in industrial and service sectors and obtains higher real wages. Many additional off-farm jobs are also linked with the expansion of farming creating options for higher income. An increase in agricultural productivity allows labor and capital to be diverted to expand the non-agricultural sectors. Over time, although, the share of agriculture in GDP has significantly declined in India, the contribution of agriculture to non-agricultural growth has maintained an upward trend and it remains an irreplaceable driving force for the economic growth of the country. A highly dense population imposes a challenge to feed its people. The country also suffers from one of the lowest land–man ratios (0.12 ha per person) of the world and climate vulnerabilities which further aggravate the challenge of food security. India lost about 4.4 million ha of productive arable land from 1970 to 2021 and the process of contraction of arable land is still going on. Rapid urbanization and increasing use of land for infrastructural development cause a 1% annual loss of agricultural land in India.

There is no alternative to increasing crop productivity since India is an agrarian country with a high population density and low land-man ratio. Improving productivity and efficiency are fundamental strategies to develop a country's economy. Crop productivity should be as high as in the developed country. India has achieved tremendous success in food production in the last few decades amidst challenges of land degradation, land use changes, and climate effect. But there remain some challenges to meeting the growing needs due to the increase in population and loss of land to development activities. This study will help to identify the push factors of agricultural production and provide insights to increase the productivity of crops. This may be helpful for planners and policymakers to bring about the desired adjustment in resources and consequently in formulating strategies for the production of agriculture. Therefore, improvement in agricultural productivity and efficiency remains a top priority for India to ensure food security for its population and industrial growth to meet the demand to become a middle-income country. It can be outlined that the econometric model could be applied in the study of agricultural production using several productive factors within the board in terms of land, labor, and capital. The effects of land and labor are not significant, but capital in the form of fertilizer application, irrigation coverage, and expenditure for agricultural material as well as technology plays the most effective role in crop production.

This study has attempted to analyze the contributory effects of production factors for crop production in India so that policy measures can be taken to increase crop productivity. The production function approach has been applied in several studies to identify the effects of factors. But no attempts were made to study the effects of factors of crop production using the Cobb-Douglas production function in India. This study has considered the Cobb-Douglas production function for the time series data of five important factors of crop production, namely land, labor, fertilizer, irrigation, mechanization allocation, and household expenditure in India.

2. Objectives

In addition to the common factors of production (capital stock, labor force, land area), the range of agricultural technologies considered in this article includes, mechanization, chemical technology, management practices, and policies relating to cropping, as well as other agricultural infrastructures. This study depends on the econometric analysis model based on Cobb-Douglas (C-D) production function to determine the influence of agricultural technologies on the growth of agricultural value-added in India over the period 1990-2021. Then, an analysis is made on the response of agricultural value-added growth over time further to technological innovations or shocks, and the corresponding suggestions are put forward. The main issue investigated is how are agricultural technologies linked to agricultural production growth; and what association of agricultural technologies should be deployed for sustaining the growth of the agricultural gross domestic product.

The specific objectives of this study are :

- to estimate the elasticity of basic inputs or factors in crop production in India,
- to find the Marginal Productivity of factors or inputs,
- analyzing the response of agricultural value-added growth over time further to technological innovations or shocks, and
- To put forward the policy suggestions to increase crop production.

3. Productivity of Inputs

The productivity of agriculture has been examined in the literature from the perspective of the factors of production such as land, labor, and capital. The land is fixed and permanent and its productivity is explained by the yield per unit of land. Some of the developing countries have attempted to increase land productivity by adopting the methods practiced by the developed countries. The productivity of labor is more competitive than the productivity of land and commonly measured by total agricultural output per unit of labor, which could be enhanced through training, demonstrations, and an increase in wages. Capital is used to purchase land; reclamation of land; drainage; irrigation process; livestock purchase; feeds; seeds; fertilizer; chemicals; agricultural implements; and machinery. Capital is used to enhance the efficiency of land through the qualities of various inputs and their combinations.

4. Review of Literature on Productivity Measurement

Several parameters have been used in literature to measure agricultural productivity (Kendall, 1939); Stamp (1958); Sapre and Deshpande (1964); Enyedi (1964); Khushro (1964); Bhatia (1967); Shafi (1984); Singh (1972); Valoon *et al.* (2005). Prominently, three approaches of economic models have been used to measure agricultural productivity: i) Growth Accounting technique; ii) Econometric Estimation of Production relationships; and iii) Non-Parametric Models. Each of these approaches is used to measure aggregate agricultural output and are suitable for addressing different questions with varying data requirement and have related strength and weakness.

Growth Accounting Technique (GAT) involves compiling detailed accounts of input and output, aggregating them into input and output indices to calculate a Total Factor Productivity (TFP) index. The use of GAT imposes several strong assumptions about technology. However, it has a disadvantage in that the statistical methods cannot be applied to evaluate their reliability. Goksel and Ozden (2007), have applied the TFP with Cobb-Douglas production function in agriculture to analyze the agricultural productivity in Turkey.

Non-parametric models use linear programming techniques to calculate the Total Factor Productivity (TFP). This approach has the advantage that it does not impose any restrictive assumption on the production technology. However, the major disadvantage of this approach is that the model used is not statistical and so cannot be tested or verified statistically.

The econometric estimation of the production relationship is based on either the ‘production function’ or ‘cost function’. This approach has the advantage that it permits quantifying the marginal contribution of each input to aggregate production, e.g., one can determine the impact of the one-percent increase in fertilizer use on overall agricultural production, holding all other inputs constant. If the functional form is more flexible, a further advantage is that fewer restrictive assumptions about the technology are imposed Besides, the econometric models have the advantages that this approach permits hypothesis testing and calculation of confidence interval to test the reliability of the estimation. However, the econometric models require more data than the other approaches.

Cobb-Douglas introduced the production function in 1928 to describe the distribution of national income. Jorgenson *et al.* (1987), used a cost function approach for each major sector of the U.S. economy to estimate rates of sectoral productivity growth and concluded that productivity growth has been more rapid than in other sectors. Lewis *et al.* (1988), used a production function approach to calculate productivity growth rates for agriculture and the rest of the Australian economy (industry and service) and concluded that the rate of productivity growth in agriculture had been higher than for the remainder of the economy. Wang and Yu (2013), mentioned that production functions specify the output of a firm, an industry, or an entire economy for all combinations of inputs. Felipe and Adams (2005), opined that the Cobb-Douglas production function is still the most ubiquitous form in analyses of growth and productivity. (Olsson and Carl-Axel, 1971) opined that Cobb and Douglas concentrated on the industrial sector, but Swedish economist Wicksell used production functions for the production process in agriculture. Cobb-Douglas ignored the land, whereas, Wicksell added the factor ‘land’ to discuss the production process in agriculture. Even if the production function assumes earlier to be constant returns to scale, (Olsson and Carl-Axel, 1971) opined, referring to Wicksell, that it can also be thought of as increasing or decreasing return to scale for the agricultural sector. Armagan and Ozden (2007), also expressed that Cobb-Douglas-type production function equations were appropriate for the functional analysis intended for agricultural activities. It was preferred since it provides easy calculation, and the ability to test production flexibilities statistically. It introduces a different point of view on the product concept and determines the input use efficiency putting forth the function of the outputs obtained based on the inputs used. Cobb Douglas production function has also been used by Renting (2013) where they have used four independent variables such as agricultural machinery, capital, land, and labor investment to investigate the contribution rate of mechanization to agricultural production. Capital investment as shown by agricultural material consumption in their study was the largest contributor to agriculture production in the Shaanxi province of China. According to Echeverria (1998), agriculture is less labor-intensive than both services and industry in Canada, but the capital intensity is similar in the three sectors. In his case, labor must hurt agricultural production. On the other hand, transformations and technological developments that occurred in the agricultural sector over time have affected productivity Armagan and Ozden (2007). Rahman and Lovely (2009), have shown, using linear and exponential growth models for time series data, that rice production was highly correlated with the irrigated area. They have suggested the expansion of the irrigated area to increase rice production. Merge and Jema (2019) has reviewed various existing research findings and identified the most common factors impeding crop production such as lack of more recently introduced improved seeds, initial capital for investment, loss of cropland, labor, pesticides, farm storage techniques, methods of small scale irrigation, and religious and cultural challenges. Their study led to the understanding that capital for investment, improved seeds, cropland, labor, and irrigation are important factors of crop production. Khatun and Sadia (2016), have also applied the Cobb-Douglas production function to identify the relation of GDP with labor and capital for some selected Asian countries. They have used ordinary least squares for model estimation using time series data. Cobb-Douglas production function has also been used by Yuan (2011) to analyze the relationship between agricultural output and input factors in Hebei province. Cultivated areas, agricultural manpower, effective irrigation area, chemical fertilizer usage, agricultural machinery usage, and electricity consumption have been taken as input. They have found that cultivated area and manpower causes less effect on the output while the effectiveness of irrigation area, chemical fertilizer, machinery, and electricity usage has a greater influence on the agricultural output. Dharamsiri and Datye (2011), have also used the Cobb-Douglas production function to analyze the agricultural production process in Sri Lanka that measures the marginal contribution of each input to aggregate agricultural output. (Kamat *et al.*, 2007) employed the Cobb Douglas Production Function using the OLS specification to investigate the determinants of agricultural gross domestic product for the period 1970-71 to 2002-03, during pre and post-economic reforms. Our empirical findings reveal that the Indian agriculture sector has witnessed Decreasing Returns to Scale after the introduction of economic reforms, indicating that the input availability is under strain during the same period. Jefferson (2021) measures the contribution rate of agricultural production factors, introducing the Cobb- Douglas production function and calculating the contribution rate of technological progress, labor input contribution rate, and the capital input contribution rate of China's agricultural development, and analysis of deficiencies in agriculture. Finally, based on the results of empirical analysis, reliable suggestions were made for the future development of China's agriculture. China's agriculture has a high position in the economy and is one of China's pillar industries. China's agricultural labor market is saturated, and the increase in labor hurts China's agricultural development; technological progress has a significant role in boosting China's agricultural economy. Olena (2021), using the Cobb-Douglas production function has shown that economic growth in agriculture is associated with improved quantitative and qualitative characteristics of labor potential, growing capital investment, and reducing pollutant emissions. The elasticity coefficients of the constructed Cobb-Douglas function (the sum exceeds 1) justified that the economic development of agriculture mainly contains the features of a large-scale economy, and the modern level of science and technology provides advantageous expanding production to increase output. The constructed models allowed to forecast assessment of the development of the agricultural sector components and can be used to develop the basic directions of the state agricultural policy to manage the formation and use of resource potential.

This study has applied the Cobb-Douglas production function of crop production using the relevant production factors within the broad terms of land, labor, and capital. Effects of land and labor are not prominent in crop production. Capital in the form of fertilizer application, irrigation coverage, and expenditure for agricultural material consumption as well as technology plays the most effective role in crop production.

5. Methodology

5.1. Nature of Data

The secondary data have been used for this study. Data on factors of production have been selected based on earlier exposure so that they can be appropriate for this study. Data on crop production have been considered as dependent variables, whereas, land area coverage for agricultural production, labor employed in agriculture, agricultural household expenditure, fertilizer applied, and irrigation coverage have been considered as independent variables. For all the variables, time-series data have been collected for 32 years from 1990 to 2021.

5.2. Data Sources

The data used were collected from various reliable sources for different variables.

- Crop production: This represents the overall yearly crop production for the entire of India. The data under this variable are measured in physical quantities, i.e., in lac metric tons. The data was collected from the Government of India.
- Area coverage under cultivation: The area (in lac hectares) under which all the crops are cultivated is considered the land area coverage under cultivation. The data was derived from the Government of India sources. The land

is, somewhat, treated as fixed capital and therefore Cobb Douglas's function equates only two factors representing labor and capital (Olsson and Carl-Axel, 1971). But for the food supply for the growing population, the nations adopt extension agriculture. The land area for extension agriculture increases historically to produce more crops. But due to population pressure in India, the area of land has started decreasing to accommodate housing and growth centers. From this point of view, land has been taken as a variable input rather than fixed input.

- Labor: The percentage of employees engaged in agriculture concerning the total population in lac has been considered as agricultural labor. The data was derived from the Government of India sources.
- Household expenditure: Household expenditure has been taken as a proxy for capital input. The use of seeds, types of machinery, and expenditures for sowing and harvesting are considered responsible for the increase in consumption for rural households. In this sense, household expenditure causes an effect on crop production. This data has been taken from the Government of India sources.
- Fertilizer: The data provides the number of fertilizers used per hectare of land (kg/hectare). Though the quantity of fertilizer to be put in a unit of land for a particular crop is fixed, the farmers mostly cannot put it in optimum level due to the high cost of fertilizer. Therefore it has been taken as a variable input for crop production. The data was derived from the Government of India sources.
- Irrigation: This data provides information about the proportion of the total cultivated area under irrigation. It was derived from the Government of India sources.

5.3. Model Specification

The production function is a mathematical equation determining the relationship between the factors and quantity of input (resources) for production and the number of goods it produces most efficiently. It answers the queries related to marginal productivity, level of production, and cheapest mode of production of goods. The agricultural output is the result of investment in land, labor, and capital. The crop production in lac metric tons has been treated as agricultural output. The total area used for crop production has been considered as land and the number (in lac) of agricultural labor has been considered as labor. Agricultural household consumption, fertilizer used in cropland, and proportion of irrigation coverage have been considered for capital inputs. Although types of machinery, fertilizer, irrigation, seeds, water, and training are valuable capital inputs for crop production, fertilizer, irrigation, and household consumption have been taken as proxies for capital input for data constraints. The use of seeds and types of machinery for sowing and harvesting are considered responsible for the increase in consumption for rural households. The equation of the Cobb-Douglas production function is

$$Y = A.L^{\beta 1}K^{\beta 2} \ldots\ldots (1)$$

where, Y = crop production (output) ; A = factor productivity ; L = labor input ;
K = capital input; β1 = share of labor for output; β2 = share of capital for output.

Since household consumption, irrigation, and fertilizer have been taken as proxies for capital, the function stands as

$$Y = A.L^{\beta 1}.D^{\beta 2}.C^{\beta 3}.F^{\beta 4}.I^{\beta 5} \ldots\ldots (2)$$

where Y= crop production (output); A = factor productivity;
L = area of cultivated land as input; D = labor input; C = household consumption input ;
F = fertilizer ; I = Irrigation; β1= share of land for output; β2= share of labor for output;
β3 = share of household consumption for output ; β4 = share of fertilizer for output ; β5 = share of irrigation for output.

Equation 2 is non-linear as the derivatives of Y concerning the parameters are dependent on the parameters themselves. So non-linear least squares approach should be used to estimate this equation. But Ordinary Least Squares (OLS) can be applied to estimate the model after linearizing the equation by taking natural logarithms for both sides. By linearizing, equation 2 becomes,

$$\ln Y = \ln A + \beta 1 \ln L + \beta 2 \ln D + \beta 3 \ln C + \beta 4 \ln F + \beta 5 \ln I + \ldots\ldots (3)$$

The β values represent the elasticity of production concerning the corresponding input. The summation of β values represents the degree of returns to scale. It may be noted that the summation of β values is: i) One under constant returns to scale; ii) >1 under decreasing returns to scale; and iii)<1 under increasing returns to scale. It was discussed earlier that the Cobb-Douglas production function could be thought of as increasing, decreasing, or constant returns to scale for the agricultural sector. Marginal productivity determines the net rewards for the factors of production when one-factor input increases. In other words, it is the change in output with the change in addition units of input, other factors remaining constant. It helps to find the prices of the factors like labor, land, capital, and entrepreneurship of the farmers. Marginal productivity is measured by the ratio of change in output to change in input and expressed by the equation:

$$MP = \Delta Y / \Delta I \ldots\ldots (4)$$

Where MP = marginal productivity; ΔY = Change in output; Δ I = Change in input.

6. Results and Discussion

6.1. Descriptive Statistics

Table 1 describes variables (in logarithm) in terms of central tendency and dispersion. Throughout the study, the average value-added is about 13.22 million, almost identical to the average value of net capital stocks. The discrepancy between the maximum and minimum values of each variable is likely to be insignificant except for fertilizer as it is shown in Table 1. The statistics show that except for irrigation of which the mean values are greater than the median values, all other variables are negatively skewed. In addition, it is found that all variables show a leptokurtic tendency given that their kurtosis coefficients are positive. The statistics also inform about a normal distribution regarding all variables except *fertilizer*.

Table-1. Descriptive statistics of variables*

	L land	L labor	L irrigation	L fertilizer	Lhousehold Exp.
Mean	7.856	7.368	8.507	2.713	9.196
Median	7.943	7.564	8.208	2.317	9.691
Standard Deviation	0.512	0.625	0.092	0.371	1.889
Skewness	-0.838	-0.764	0.119	0.098	-1.667
Kurtosis	2.422	3.654	1.871	1.501	0.473
Jarque-Bera	3.508	2.732	1.184	3.755	0.153
Probability	0.467	0.158	0.480	15.773	0.0004
Sum square deviation	0.213	0.427	0.211	3.581	92.838
No.of Observation	32	32	32	32	32

Source: Author's calculation
*indicates the logarithm of the variables.

6.2. Estimation of OLS Parameters

Based on equation (3), the growth of agricultural output is estimated by running the relevant econometric model containing an autoregressive component. The regression model performs well, predicting 95% of the specified equation correctly. The causality between the growth of agricultural value-added and its determinant factors is established through F-statistic. All the diagnostic tests on residuals coming from the long-run model estimation (serial correlation, heteroscedasticity, normality) are desirable. The parameters of equation (3) were estimated by the Ordinary Least Squares (OLS) using Stata. Results are presented in Table 2.

Table-2. Estimates for the parameters, coefficient & standard errors

Factors	Parameter	Coefficient	Standard Error
Intercept	lnA	9.8103	4.2304
ln land	β1	-1.5432*	0.8246
ln labor	β2	- 0.1101	0.4024
ln household expenditure	β3	0.0881	0.0862
ln fertilizer	β4	0.5208**	0.1631
ln irrigation	β5	0.0682	0.1579

Source: Author's Calculation. * and ** indicate significance at 5% and 1% respectively.
No. of Observation: 32 F (5, 26) = 105.1824
Prob>F = 0.0000 R^2 = 0.9528
Adj R^2 = 0.9438 Root MSE = 0.0701
Durbin Watson d –statistic (6, 32) = 1.0459

Durbin-Watson test shows that d-Watson (1.0459) is greater than R^2 (0.9529). Santamaria (2009) and Baumohl and Stefan (2009) have observed much higher values of adjusted R^2 and much lower values of Durbin-Watson statistics for spurious regression. The higher value of the Durbin-Watson statistic than R^2 in this study tells that the time series is stationary and confirms that the OLS estimation is not spurious. The coefficient of determination (R^2) indicates that 95% of data are explained in this model. The p-value associated with the F value is very small (0.0000) which concludes that the independent variables predict the dependent variable. P>|t| value for land and fertilizer indicates the coefficients of these two variables are statistically significant. The coefficients of labor, expenditure and irrigation are less significant. The coefficient of land indicates that a 1% increase in the cultivated area causes 1.54% less production and the coefficient of fertilizer indicates that a 1% increase in fertilizer causes a 0.52% increase in production. Labor is negatively correlated whereas consumption and irrigation are positively correlated with crop production. An inverse correlation of land with crop productivity was also found by Msangi (2017) and Ansoms (2008). It can be described in two ways. The area of land increases due to an increase in individual farm size. Large farmers may not be interested in plowing all their land with the same efficiency, whereas small farmers, having no alternative for livelihood, plow with full efficiency. The efficient use of fertilizer causes an increase in crop production. Since the fertilizer is subsidized, small farmers can avail of fertilizer at less cost. Another explanation of less ΔY, ΔI productivity is the inclusion of fallow land to an extension of crop production to feed its large population. Char lands and coastal saline lands are included for the area of cultivation to be increased. However, crop production cannot be at its optimum level because of the unfavorable condition of the soil.

6.3. Decreasing Returns to Scale

Decreasing returns to scale is also known as increasing costs. It is a situation where a portion of the production process increases the factors of production, such as labor and capital. However, the output does not increase by the same or a higher proportion. Diminishing returns to scale occur in the long run. The sum of the coefficients of independent variables is less than unity, it shows decreasing return to scale. It was found that β1 + β2 + β3 + β4 + β5 = - 0.977, is less than one, and shows decreasing returns to scale. It implies that if land, labor, fertilizer, irrigation, and household consumption increase by some proportion, crop production decreases less than proportionately over time. Soil fertility has decreased over time due to extensive cultivation as the new technology was not adopted. It causes decreasing returns to scale.

6.4. Marginal Productivity

Marginal productivity refers to the extra output, return, or profit yielded per unit by advantages from production inputs. It is the change in output resulting from employing one more unit of a particular input, assuming that the quantities of other inputs are kept constant. Diminishing marginal productivity means that using an increasing amount of inputs during the production period while holding other inputs constant will eventually lead to decreasing productivity. Diminishing marginal productivity is a natural phenomenon that cannot be avoided or eliminated. Estimates for the marginal productivity of the factors, viz., land, labor, household consumption, fertilizer, and irrigation derived from the analysis are presented in Table 3.

Table-3. Marginal Productivity of the Factors

Factors	Marginal productivity
Land	-1.544
Labor	-0.110
Household expenditure	0.088
Fertilizer	0 .521
Irrigation	0.068

Source: Author's calculation.

The marginal productivity of land implies that crop production will be 1.54 metric tons less due to an increase in one more hectare of land. Similarly, crop production will be 0.11 metric tons less due to an increase in one more labor. But if one more kg of fertilizer is applied per hectare 0.52 lac metric tons more crops will be produced and 0.07 metric tons more crops will be produced due to an increase in one more hectare of irrigation coverage. Besides, one unit of expenditure for agricultural material as well as technology plays the most effective role by enhancing 0.09 metric tons in crop production.

7. Conclusion

The elasticity and marginal productivity of factors for crop production or basic inputs, viz., land, labor, fertilizer, irrigation, and household expenditure for agricultural material & technology have been estimated through the application of the Cobb-Douglas production function model. The factors of production estimated through the regression analysis demonstrated that the growth of crop production significantly depends on the application of fertilizer. Besides, irrigation and household expenditure on agricultural input materials & technology also have a positive impact on production. The use of seeds, types of machinery, and expenditures for sowing and harvesting are considered responsible for the increase in consumption for rural households, so their use may have some positive impact on production, but the effect of these factors is not much significant. Land and labor have a negative correlation with crop production. Overall crop production shows decreasing returns to scale due to a decrease in land productivity, use of traditional plow methods, land degradation, decrease in soil fertility, and increase in soil salinity in the coastal region. The increasing crop production is the result of the application of fertilizer and improved seeds. The excess use of inorganic fertilizer may further aggravate soil fertility. Recommendations and policy strategies to increase agricultural production in India based on the findings of this study and related facts are mentioned in the Section to follow.

Recommendations & Policy Strategies

The findings of this study and the derived results lead to the following recommendations and formulation of policy strategies:

- Increasing land productivity is essential to meet the food crisis as India has a low land-man ratio and every year arable land is being lost due to urbanization and several developmental activities.
- The goal of sustainable agriculture should consider a systematic approach associating technologies and practices that impulse positively the growth rate of agricultural value-added in the long term.
- Farmers should be provided with proper technical knowledge of farming and replace traditional sowing and harvesting methods.
- Investment is key for the growth and prosperity of the agricultural sector. The Government should formulate strategies for increased investment in agriculture, both by the public and private sectors.
- The marginal returns to public investment in agricultural R&D, roads, energy, and irrigation need to be worked out for fund utilization in the agricultural sector.
- Proper management of production practices and inputs is necessary.
- Research on transformative and technological development should also be given priority.

- There are significant and certain benefits to draw economically from the utilization of a system of technological innovations including mechanization, renewed capital stocks, and sustainable farming practices involving temporary cropping & permanent cropping.
- Farming practices like agroforestry and multi-cropping are recommended for the sake of ecological concern.
- Soil health is essential to enhance productivity. It could be rejuvenated rapidly through the crop rotation technique.
- Sectoral development policies & strategies as well as natural phenomena are significant determinants of agricultural production growth.

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References

Ansoms, A. (2008). *The inverse relationship between farm size and productivity in rural Rwanda.* Institute oF Development Policy and Management, University of Antwerp.

Armagan, G. and Ozden, A. (2007). Determinations of Total Factor Productivity with Cobb-Douglas Production Function in Agriculture: The Case of Aydin-Turkey. *Journal of Applied Sciences,* 7(4): 499-502.

Barrett, C. B., Caster, M. R. and Timmer, C. P. (2010). A century long perspective o agricultural development. *American Journal of Agricultural Economics,* 92(2): 447-68.

Baumohl, E. and Stefan, L. (2009). Stationarity of time series and the problem of spurious regression, mpra paper no. 27926.

Besley, T. and Case, A. (1993). Modeling technology adoption in developing countries. *American Economic Review,* 83(2): 396-402.

Bhatia, S. S. (1967). A new approach to measure agricultural efficiency in Uttar Pradesh. *Economic Geography,* 43: 224-60.

Dharamsiri, L. M. and Datye, V. S. (2011). Application of cobb-douglas production function for analyzing the process of agricultural production: A case study of Sri Lanka. *Trans. Inst. Indian Geographers,* 33(2): 251-63.

Duflo, E., Kremer, M. and Robinson, J. (2011). Nudging farmers to use fertiliser: Theory and experimental evidence from Kenya. *American Economic Review,* 101(6): 2350-90.

Echeverria, R. G. (1998). Agricultural research policy issues in latin america: An overview, elsevier. *World Development,* 26(6): 1103-11.

Enyedi, G. Y. (1964). Geographical types of agriculture. Applied geography in hungary, n/p budapest.

Feder, G., Just, R. E. and Zilberman, D. (1985). Adoption of agricultural innovation in developing countries: A survey. *Economic Development and Cultural Change,* 33(2): 255-98.

Felipe, J. and Adams, F. G. (2005). A theory of production" the estimation of the cobb-douglas function: A retrospective view. *Eastern Economic Journal,* 31(3): 427-45.

Goksel, A. and Ozden, A. (2007). Determination of total factor productivity with cobb-douglass production function in agriculture: The case of aydin- Turkey. *Journal of Applied Science,* 7(4): 499-502.

Jefferson, Q., 2021. "Econometrics research on factors affecting the output value of China's agricultural output level: Empirical analysis based on the cobb-douglas production function model." In *12th International Conference on E-Education, E-Business, E-Management, and E-LearningJanuary 2021.* pp. 287–95.

Jorgenson, D. W., Gollop, F. M. and Fraumani, B. M. (1987). *Productivity and U.S. economic growth.* Harvard University Press: Cambridge.

Kamat, M., Tupe, S. and Kamat, M. (2007). Indian agriculture in the new economic regime, 1971-2003: Empirics based on the cobb douglas production function. Available: https://mpra.ub.uni-muenchen.de/id/eprint/6150

Kendall, M. G. (1939). The geographical distribution of crop production in England. *Journal of the Royal Statistical Society,* 162: 24-28.

Khatun, T. and Sadia, A. (2016). Relationship between real gdp and labour & capital by applying the cobb-douglas production function: A comparative analysis among selected asian countries. *Journal of Business Studies,* XXXVII(1).

Khushro, A. M. (1964). Return to scale in Indian agriculture. *Indian Journal Agricultural Economics,* 19: 52-53.

Kumar, S. and Pal, S. (2020). *Economic impact of ICAR research: Some recent evidence.* ICAR-NIAEPR: New Delhi.

Lewis, P. E. T., Martin, W. J. and Savage, C. R. (1988). Capital and investment in the agricultural economy. *Quarterly Review of Agricultural Economics,* 10: 45-52.

Mason, N. M. and Smale, M. (2013). impact of subsidised hybrid seeds on indicators of well-being among smallholder maize growers in Zambia. *Agricultural Economics,* 44(6): 659-70.

Matuschke, I., Mishra, R. R. and Timmer, C. P. (2007). Adoption and impact of hybrid wheat in India. *World Development,* 35(8): 1422-35.

Merge, B. and Jema, H., 2019. "Factors impeding effective crop production in ethiopia, journal of agricultural science; vol. 11, no. 10; 2019 mohajon, h., 2013: Food, agriculture and economic situation in Bangladesh." Proceedings of 2nd International Conference on Global Sustainable Development, 2013, Office of Research, Innovation, and Commercialization, Khadim Ali Shah Bukhari Institute of Technology.

Msangi, H. A. (2017). *Examining the inverse relationship between farm size and efficiency in Tanzanian agriculture, unpublished MSc thesis.* Sokoine University of Agriculture: Tanzania.

Olena, V. (2021). Assessment of factors of sustainable development of agricultural sector using the cobb-douglas production function. *Baltic Journal of Economic Studies,* 7(2).

Olsson and Carl-Axel (1971). The cobb-douglas or the wicksell function? *Economy and History,* 14(1): 64-69.

Rahman, M. W. and Lovely, P. (2009). Impact of irrigation on food security in bangladesh for the past three decades. *Journal of Water Resource and Protection,* 3(1).

Renting, H. (2013). Investigation of the contribution rate of agricultural mechanization to agricultural production using cobb douglas model. *Information Technology Journal*, 12(8): 1607-13.

Santamaria, V. (2009). Spurious regression. *Journal of Probability and Statistics*: 27.

Sapre, S. G. and Deshpande, V. D. (1964). The inter-district variation in efficiencies in maharastra state. *Indian Journal of Agricultural Economics,* 19: 242-52.

Shafi, M. (1984). *Agricultural productivity and regional imbalance.* Concept Publishing Company: New Delhi.

Singh, J. (1972). A new technique for measuring agricultural productivity in haryana (India). *The Geographer*, 19: 15-33.

Sinha, J. K. (2019). Influence of technologies on the growth rate of GDP from Agriculture: A case study of sustaining economic growth of agriculture sector in Bihar. *Statistical Journal of IAOS,* 35: 277-87.

Sinha, J. K. (2022a). Public expenditure for agricultural development & economic growth of bihar (1981-2019). *Asian Journal of Economics and Finance,* 4(4): 414-24.

Sinha, J. K. and Sinha, A. K. (2022). Syndrome of declining economic importance of agriculture in bihar(1960 – 2018). *Journal of Humanities, Arts and Social Science*: 1.

Stamp, L. D. (1958). The measurement of land resources. *The Geographical Review,* 48(1): 110-16.

Subramanian, A. and Quim, M. (2009). Village-wide effects of agricultural biotechnology; the case of bt cotton in India. *World Development,* 37(1): 256-67.

Valoon, G. V., Patil, S. G. and Huger, L. B. (2005). *Strategies for assessment.* SAGE Publication: New Delhi.

Varshney, D., Joshi, P. K. and Devesh, R. (2019). *Identifying innovators and early adaptors of agricultural technology: A case of wheat varieties in rajasthan, India, IFPRI discussion paper 1808.* International Food Policy Research Institute: Washington, D.C.:

Wang, X. and Yu, F. (2013). Some characterizations of the cobb-douglas and CES production functions in microeconomics. *Abstract, and Applied Analysis*: 6.

Yuan, Z. (2011). Analysis of agricultural input-output based on cobb–douglas production function in hebei province, North China. *African Journal of Microbiology Research,* 5(32): 5916-22.