Economic Affairs, Vol. 68, No. 03, pp. 1395-1401, September 2023
DOI: 10.46852/0424-2513.3.2023.6

AESSRA

Research Paper

Economic Analysis of Factors Affecting Sugarcane Production in Major Sugarcane Producing States of India

Neha Dwivedi*, G.K. Vani and Ashutosh Shrivastava

College of Agriculture, Jawaharlal Nehru Krishi Vishwavidyalaya Jabalpur, Madhya Pradesh, India

*Corresponding author: nehaphdsc@gmail.com (**ORCID ID:** 0000-0002-8083-3082)

Received: 14-04-2023 **Revised:** 26-08-2023 **Accepted:** 05-09-2023

ABSTRACT

Sugarcane (*Saccharum* sp.) is one of the most significant commercial crops in the world due to its strategic position, extensive uses in every nation's everyday life, and industrial uses for sustaining economic and nutritional needs. The present study, an economic analysis of factors affecting sugarcane production and policy implications in major sugarcane-producing states of India, centers on the objective to analyse the variables influencing sugarcane production. A secondary time series data for 14 states namely: Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Bihar, Gujarat, Haryana, Punjab, Andhra Pradesh, Madhya Pradesh, Uttarakhand, Telangana, Chhattisgarh, and Jharkhand, for the period 1998-99 to 2018-19 have been utilized for the present study. The variables considered in this study were area, yield, rainfall, and price (FRP). The findings imply that there was a significant linear relationship between the area and sugarcane production. The linear association of yield with production was positive but weaker than the area. Rainfall and FRP (Fair and Remunerative Prices) had a weakly positive association with production,as observed there was the insensitivity of sugarcane production to FRP and rainfall thus, efforts should be made to increase price responsiveness by reducing the sugarcane cane reservation area.

HIGHLIGHTS

- There was a significant linear relationship between the area and sugarcane production.
- The linear association of yield with production was positive but weaker than the area.

Keywords: Sugarcane, correlation, likelihood ratio test, multicollinearity

Sugarcane (*Saccharum sp.*) is one of the most important commercial crops in the world because of its strategic position and extensive uses in the daily life of any nation as well as for industrial uses aimed at nutritional and economic sustenance. Sugarcane contributes about 60 percent of the total world sugar requirement while the remaining 40 percent comes from sugar beet. In India, the sugar industry and sugarcane production are particularly important for rural development and have a sizable impact on agricultural GDP. One of the most significant agro-based sectors in India is the sugarcane-based industry, which affects the livelihoods of around 5 crore farmers and their families as well as 5 lakh people who are either directly or indirectly employed by the mills (Solomon, 2016). In 2018–19, India produced a record-breaking 400.2 million tonnes of sugarcane, an increase of 20.3 million tonnes or 5.3 percent from the previous year. With a 2.8 percent share of the gross cultivated area, sugarcane is the most important cash crop in India. In 2017–18, it contributed ₹ 68053 crores, or nearly 5.1 percent, to the value of agricultural sector output (GOI, 2019). In 2017–18, the area seeded with sugarcane expanded dramatically by 6.8%, then by another 8% in 2018–19. However, there was

How to cite this article: Dwivedi, N., Vani, G.K. and Shrivastava, A. (2023). Economic Analysis of Factors Affecting Sugarcane Production in Major Sugarcane Producing States of India. *Econ. Aff.*, **68**(03): 1395-1401.

Source of Support: None; **Conflict of Interest:** None

a dip in the area by -4.8 percent in 2019-20. As far as production was concerned,the highest increase in production was 24.1 percent recorded in 2017-18 but growth witnessed a decline during the last consecutive years in 2018-19 and 2019-20. Yield growth in sugarcane has shown large fluctuations during the 2010-11 to 2019-20 period. It has varied from – 4.8 percent in 2012-13 to 16.2 percent in 2017-18 (GOI, 2019). The amount of sugarcane produced and its costs are closely related. A sudden drop in production lowers the farmers' income and the amount of marketable surplus, which affects prices. A surplus of supply could result in a drop in prices and negatively impact farmers' revenue (Vishwajith *et al.* 2016). Although in the following years, agriculture witnessed major technological advancements, but still research studies have indicated that during the last decade growth in the production of sugarcane crops was merely a result of growth in the area under sugarcane crops. Thus, an increase in the productivity rate of sugarcane had no significant contribution to sugarcane production. Sugarcane production is governed by a combination of factors such as acreage under sugarcane, yield, state prices, climatic factors, and farm decisions. Moreover, state-wise variations exist still, and the analysis of the impact of variables such as area, production, yield, prices, and rainfall on sugarcane production in wholesome may lead to better policy implications.

Hence, to address the above-mentioned concerns, the present study was undertaken to analyze the factors affecting sugarcane production in major sugarcane-producing states of India.

Data and Methodology

The state-wise data regarding the area, production, and productivity of fourteen selected states namely: Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Bihar, Gujarat, Haryana, Punjab, Andhra Pradesh, Madhya Pradesh, Uttarakhand, Telangana, Chhattisgarh, and Jharkhand, for the period 1998-99 to 2018-19 was collected from various statistical year publications by the Directorate of Economics and Statistics and its official website (http://eands.dacnet.nic.in/).The data for FRP (Fair and Remunerative Prices) was collected from various publications of the Commission for Agricultural Costs and Prices, Ministry of Agriculture &Farmers Welfare, GOI (http://cacp.dacnet.nic.in/). The state-wise rainfall statistics were collected from various publications of the INDIA METEROLOGICAL DEPARTMENT (MINISTRY of EARTH SCIENCES) reports and data.gov.in sources. These states accounted for 98.4 percent of the production share in India during 2018-19.Among these 14 selected states, four states namely Uttarakhand, Chhattisgarh, and Jharkhand were formed in 2000 and Telangana in 2014, and as data were not readily available separately for these states after the separation of these newly formed states from parent states. Thus, the simple average was taken for area and production, while in the case of rainfall data, the weighted average was taken for these four states. After merging the data as stated above, 10 states were there in the final dataset. All analytical procedures were performed on this dataset.

Regression Model

$$Q_t = a_0 + a_1 A_{t-1} + a_2 y_{t-1} + a_3 R_t + a_4 P_{t-1} + \sum b_j D_j + e_t$$

Where,

a_0 = constant or intercept

a_i = Regression coefficient

Q_t = Sugarcane production in t year

t = Time period

A_t = Acreage of sugarcane crop in "000" ha during the t year

y_t = Productivity (kg/ha) of sugarcane crop during the *t* year

R_t = Average rainfall during the *t*, *t*–1 and *t*–2-year period (mm)

P_t = (Price ₹/QTL.) of sugarcane crop during the t year

D_j = Dummy variable for j^{th} state

b_j = Differential intercept for j^{th} state

The moving average of order three was calculated for rainfall data to account for the lagged effect of rainfall on production. Panel data was prepared by using states as subjects and year as a time factor. The panel data was well balanced on account of no missing data. It was a long panel because there were 10 states and 21 years in the panel data. To find out the extent of linear association between variables, Pearson product movement correlation between the variables was computed. Before, performing regression analysis, it was required to test the normality of production and hence Shapiro-Wilk normality test was performed over the entire panel data as well as each state series individually. The null hypothesis under the Shapiro-Wilk test was that the given variable follows the normal distribution. Box-Cox power transformation was used to find the power of the production variable to transform non-normal data to normality. Over the transformed production variable, a fixed effect least square dummy variable model was used. Residuals of the regression were tested for normality with a quantile comparison plot (Q-Q plot) and Shapiro normality test. To test for multicollinearity, Generalized Variance Inflation Factor was computed and converted to VIF for ease of interpretation. VIF values greater than 10 indicate multicollinearity among regressors. To test for heteroscedasticity, the Breusch-Pagan test was conducted by original regressors in auxiliary regression. The null hypothesis of this test was that error terms are heteroscedastic. To derive the marginal effects, the transformed production variable was differentiated concerning each independent variable, and the resulting expression was evaluated at the average values of the respective independent variable. R software for statistical computing (R Core Team, 2021) was used to carry out an analysis. Specifically, readxl (Wickham and Bryan, 2019), latest (Zeileis, Hothorn, 2002), and Rcmdr (Fox and Bouchet-Valat, 2020; Fox, 2017; Fox, 2005) packages were used to carry out correlation and regression analysis in R software.

RESULTS AND DISCUSSION

Correlation matrix between sugarcane production and the study variables

To find out the extent of linear association between variables, Pearson product movement correlation between the variables was computed. Table 1 provides the results of the correlation analysis, it was evident that production had a strong linear association with the area. The linear association of yield with production was positive but weaker than the area. Similar results were reported by Silva *et al.* (2018) in the case of the correlation between area and yield to sugarcane production and indicated that area was strongly and positively correlated with production, whereas crop yield was weakly and positively associated with production. It must be noted that the correlation coefficient between yield and area was negative as well as very low indicating no strong linear association between the two. The area had a positive but weak relationship with rainfall and FRP. Production had a weak and positive relationship with rainfall and FRP.

Table 1: Zero-order correlation matrix between various factors affecting production

Area	Production	Yield	Rainfall	FRP	
1.0000	0.9789***	-0.0057	0.1607*	0.0396	Area
	1.0000	0.1356*	0.1879*	0.0792	Production
		1.0000	-0.0544	0.1636*	Yield
			1.0000	-0.0709	Rainfall
				1.0000	FRP

*Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

Shapiro-Wilk test of normality for the production of sugarcane

To test the normality of production Shapiro-Wilk normality test was performed over the entire panel data as well as each state series individually. The null hypothesis under the Shapiro-Wilk test was that the given variable follows the normal distribution.

From Table 2, it was evident that except for erstwhile Bihar, erstwhile Madhya Pradesh, and erstwhile UP, all other states' production followed a normal distribution. Thus, the data series on production had scope for transformation towards normality.

Table 2: State-wise Results of the Shapiro-Wilk test of normality for the production of sugarcane

States	Test statistic	p-value
Erst. Andhra Pradesh	0.61541112	1.0000000
Erst. Bihar	0.00079214	0.0079214
Gujrat	0.38794562	1.0000000
Haryana	0.96089736	1.0000000
Karnataka	0.19884266	1.0000000
Maharashtra	0.16867737	1.0000000

Note: *H_0: Variable follows the normal distribution.*

Likelihood ratio test for boxCox power transformation

Box-Cox power transformation was used to find the power of the production variable to transform non-normal data to normality. Table 3 provides the output of the boxcox transformation. From the result of the boxcox transformation, it was evident that a power transformation of zero and one was rejected based on a p-value less than 0.05.

Table 3: Result of Likelihood ratio test for boxCox power transformation on the production of sugarcane across major states of India

Power	Likelihood ratio test statistic	p-value
0	2.620985	0.10546
1	319.0507	2.22e-16

From Fig. 1, it's evident that a lambda value of -0.0922 was needed to bring the data series of the production of sugarcane to normal distribution as evident from the peak log-likelihood achieved at this value of lambda.

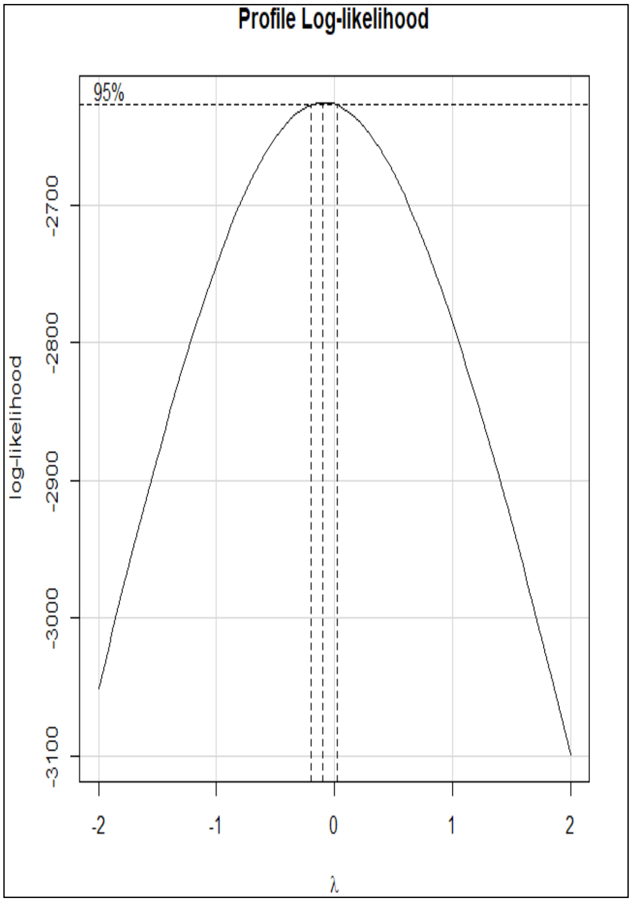

Fig. 1: Plot of log-likelihood vs lambda for power transformation of production

From Fig. 2 & 3, two quantile comparison plots (Q-Q plot), it was evident that the transformed series follows normal distribution compared to a non-transformed one.

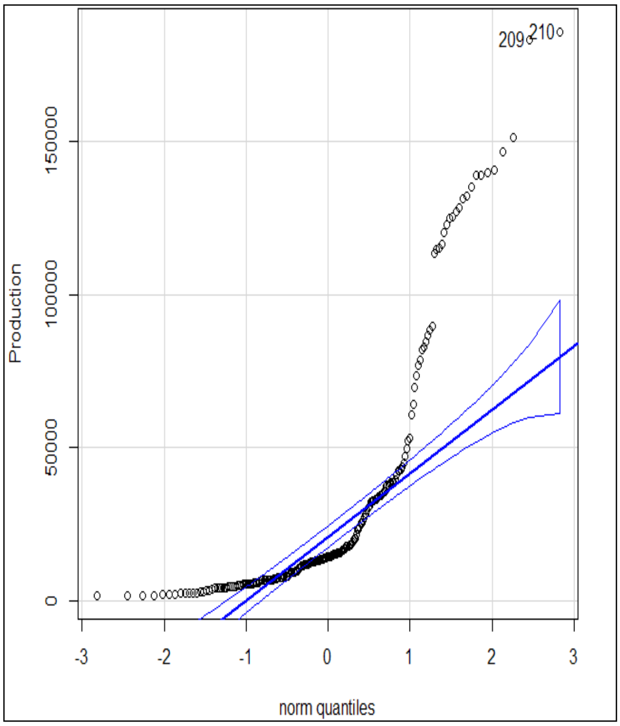

Fig. 2: Quantile comparison plot of production of sugarcane in India

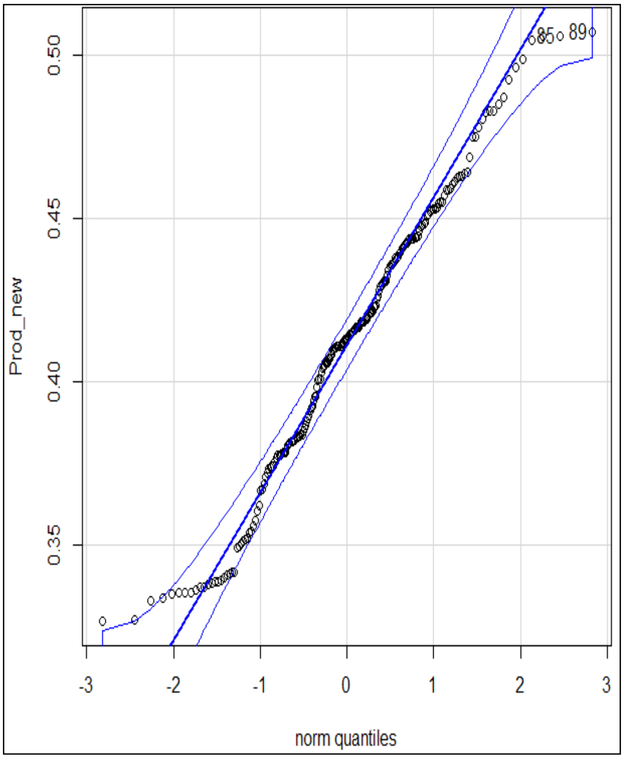

Fig. 3: Quantile comparison plot of transformed production of sugarcane in India

Panel data regression with fixed effect LSDV model

A fixed effect least square dummy variable model was used Over the transformed production variable. Residuals of the regression were tested for normality with a quantile comparison plot (Q-Q plot) and Shapiro normality test.

Table 4, provides the results of panel data regression with the fixed-effect LSDV model. The results revealed that the area had a negatively looking positive result on account of the dependent variable being production raised to the power -0.0922. Thus, the interpretation has to depend on the average value of a dependent variable and the coefficient of the explanatory variable. The succeeding discussion was in terms of marginal effects. At the average value of a dependent variable (31418 000'tonnes/ state), the effect of an increase in one thousand hectares under cultivation was 63.34 thousand tonnes. This shows that each hectare of land was worth 63.34 tonnes per hectare of additional yield to the nation. Thus, the marginal yield of 63.34 tonnes per hectare was less than the 69.86 tonnes of average yield observed in the leading ten sugarcane-producing states of India. This shows that additional thousand hectares of land under cultivation of sugarcane were not worth it. However, at the average production level of 31418 000' tonnes per state, raising productivity by one tonne per hectare would add 603 000' tonnes of additional production. Thus, raising productivity to add more production was easier. However, rainfall and fair & remunerative prices had no significant effect on production. The intercept was significant and was the reference category for erstwhile. Andhra Pradesh state. There was no significant difference among erstwhile. Bihar, erstwhile. Andhra Pradesh, Maharashtra, Gujrat, and Tamil Nadu in terms of production. The coefficient of determination was quite high at 0.9646.

It was evident from Table 4, that residuals from the regression model do not follow normal distribution since the p-value was less than a 5% level of significance. This was equally observable from the Q-Q plot of residuals (Fig. 4) where some

Table 4: Factors affecting the production of sugarcane in India

Regressors	Estimate	Std. Error	t value	Pr(>|t|)	Sig. Code
(Intercept)	4.734e-01	7.00E-03	67.6492	<2.20E-16	***
Area	-7.155e-05	6.58E-06	-10.8771	<2.20E-17	***
FRP	-1.300e-06	8.88E-06	-0.1465	0.8837	
Rainfall	6.272e-06	5.70E-06	1.1012	0.2722	
Yield	-6.814e-07	7.79E-08	-8.7509	9.74E-16	***
Dummy_erstwhile. Bihar	4.571e-03	4.00E-03	1.1431	0.2544	
Dummy_Gujrat	8.149e-04	1.73E-03	0.4717	0.6377	
Dummy_Haryana	1.597e-02	3.29E-03	4.8535	2.47E-06	***
Dummy_Karnataka	-9.097e-03	1.92E-03	-4.7294	4.30E-06	***
Dummy_Maharashtra	-5.677e-03	3.95E-03	-1.4382	0.152	
Dummy_erstwhile. MP	3.267e-02	5.23E-03	6.2483	2.53E-09	***
Dummy_Punjab	2.239e-02	2.89E-03	7.7508	4.83E-13	***
Dummy_Tamilnadu	-3.735e-04	2.39E-03	-0.1562	0.876	
Dummy_ erstwhile. UP	5.742e-02	1.40E-02	4.1157	5.68E-05	***
Multiple R-squared	0.9646				
Adjusted R-squared	0.9623				
F-statistic (13, 196 DF)	411.1			< 2.2e-16	***
Shapiro-Wilk normality test on residuals	0.98428			0.01951	
Breusch-Pagan test	41.494			1.182e-10	

Note: *Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1* observations fall outside the confidence interval. This suggests the need to check for the presence of heteroscedasticity. The Breusch -Pagan test was conducted to check heteroscedasticity and the test results presented in the table and indicates presence of heteroscedasticity. Thus, to correct this problem, robust standard errors were used in Table 4.

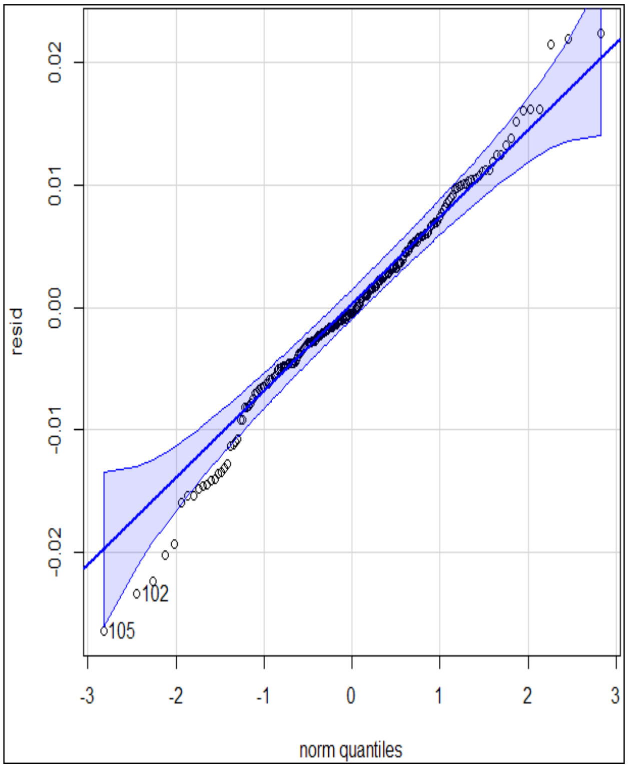

Fig. 4: Quantile comparison plot of residuals from the regression

VIF values for the regression model

To test multicollinearity, Generalized Variance Inflation factors were computed and converted to VIF for ease of interpretation. VIF values for the regression model were provided in Table 5. From the VIF values, it was evident that VIF values were all less than 10 indicating no multicollinearity problem.

Table 5: Variance Inflation Factor for different regressors in the regression model

Regressors	GVIF*	Df	GVIF^(1/(2*Df)) = VIF
Area	48.644431	1	6.974556
FRP	1.315930	1	1.147140
Rainfall	6.171374	1	2.484225
Yield	8.017466	1	2.831513
Dummy_	2165.120382	9	1.532162

Note: **Generalized Variance Inflation Factor.*

CONCLUSION

Sugarcane production had a strong linear association with the area. The linear association of yield with production was positive but weaker than the area. Production had a weak and positive relationship with rainfall and FRP. Given the insensitivity of sugarcane production to FRP and rainfall, efforts should be made to increase price responsiveness by reducing the sugarcane cane reservation area.

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