Efficiency of cotton production in India: Stochastic Frontier Analysis

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Abstract

This study evaluates the technical efficiency of top nine cotton producing Indian states, contributing roughly 90% to total cotton production in India, for three different time periods 2007-08, 2011-12, 2017-18 using Stochastic Frontier Analysis. It compares the change in technical efficiency of these states across these time periods. The analysis shows that technical efficiency of states fell in year 2011 and then revived in year 2017 and this variation is explained by state specific factors like credit and irrigation facilities available in the state. At the end, paper concludes that credit and irrigation facilities are one of the factors that drive the TE of top performing states and hence it suggests to focus on these factors to improve TE, which thereby will increase the total output of cotton by 8-10%.

1. Introduction

Cotton is considered as one the most important fibre and cash crop and plays a dominant role in industrial and agricultural economy of India and globe. Globally, 25 M tonnes of cotton was produced from 33 million hectare of land in the year 2019 (Amar Singh, 2020). India ranks first in global cotton production with 29 million bales in 2019-20 (Dewan, 2019). Cotton is the basic raw material for textile industry which provides direct and indirect employment to 51 million and 68 million people respectively (IBEF, 2020) signifying the importance of cotton for Indian economy. However, despite being the largest producer of cotton, productivity per hectare in India is quite low with a merely 479 kg per hectare in comparison to 771 kg/hectare at global level (Amar Singh, 2020). Indian cotton productivity level is the quite less even in comparison to the smaller countries like Myanmar, Pakistan, Syria, Uzbekistan etc. (Amar Singh, 2020). In India, 70% of cotton is produced by Maharashtra, Gujarat, and Telangana. Indian northern zone accounts for 17%, central accounts for 55%, and southern zone accounts for 26%

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of cotton production. Despite contributing 55% to India's cotton production, productivity per hectare is least in Central India (440 kg/ha) followed by Southern (514 kg/ha) and Northern India (597 kg/ha) (Amar Singh, 2020). It warrants the immediate need of identifying and resolving the major challenges in cotton production.

It is encouraging to note that over the last few years the cotton production had shown a significant increase. In 2010-11 season, it touched a record production of 325 lakh bales with an average productivity of 496 kg/ha (Cotton Corporation of India, 2010).

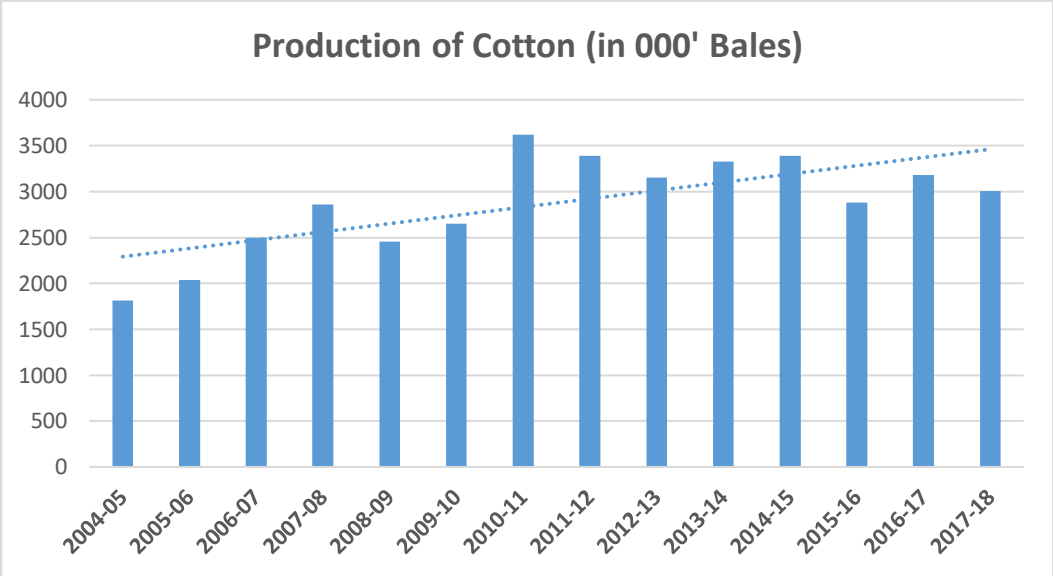

Figure 1: Production of cotton

But majority of cotton produced in India is consumed domestically and hence, export of cotton from India is only 5.5 million bales. If this increasing production trend continues in years to come, India can become a major exporter of cotton. So, this shows the importance to focus on productivity and efficiency of cotton.

There exists different types of efficiencies - Technical efficiency, allocative efficiency and economic/overall efficiency. The overall efficiency can be decomposed into technical and allocative (price) efficiency. This paper focusses on evaluating the Technical efficiency(TE). In a nutshell, TE is the proportion of a system's actual output to potential output.

Cotton production requires intensive input in form of irrigation, mechanization, fertilizers, pesticides, water resources, seeds, and human labor (Eyhorn et al., 2007;

Zulfiqar and Thapa, 2016). Higher amount of input needed for cotton production has negative implications on economy, environment, and public health (Makhdum et al., 2011). For instance, Khan et al., (2011); and Nazli, (2010) identified that farmers use excessive amount of pesticide for cotton production leading to adverse impacts on economy, farmers' health and productivity of cotton (Mancini et al., 2005; Pimentel, 2005). Additionally, cotton is water-intensive crop and scarcity of water resources and erratic weather pattern i.e., extreme and variability of monsoon and temperature conditions has negative repercussions on cotton yield (Swami et al., 2018). Excessive use of fertilizers and water resources threatens food security, lead to poor soil and land quality resulting in environmental degradation and climate change (Ali and Byerlee, 2002).These practices result in unproductive use of limited resources i.e., land and water indicating towards inefficient cotton production and management (Makhdum et al., 2011). Therefore, there should be optimal utilization of scarce resources by producing the maximum output with the given level of resources. After analyzing the problems and challenges, scientists and policymakers recommended a solution termed as Good agricultural practice (GAP) (Hobbs, 2003). GAP requires optimal utilization of agricultural inputs such as fertilizers, pesticides, irrigation, and other inorganic inputs to produce the maximum possible output which thereby lead to better productivity. In line of this, Babiker O. et al. finds that cotton farmers can improve their yield by 11% with given level of resources by improving their technical efficiency. Watto and Mugera, (2015) reported the increase in cotton productivity by 19-28% without any use of excessive input in Punjab province of Pakistan. It signifies optimization of output with given scarce resources that will further help in socio- economic, environmental sustainability, and better productivity of cotton across different regions of India and globe.

2. Literature survey

So far, number of studies have analyzed the technical efficiency for cotton productivity across India and globe. Zulfiqar et al., (2017) performed the household survey across Punjab province of Pakistan to identify the factors affecting technical and economic efficiency for better cotton production using truncated regression analysis. Imran et al., (2019) also conducted household survey to estimate and compare the technical and economic efficiency of cotton production using climate

smart method vs. conventional method with the help of truncated regression. Sharif and Bashir, (2010) surveyed Multan region of Pakistan to examine the factors affecting cotton production using Cobb-Douglas production function. The study estimated the impact of seeds, irrigation, fertilizers, cultivation, hoeing and labour cost on cotton yield and identified that scarcity of seeds, fertilizers, and irrigation limited the cotton productivity in Multan region. Yilmaz and Ozkan, (2004) examined the effect of land tenure system on cotton productivity in Turkey using Cobb-Douglas production function and revealed insignificant effect of land tenure system on cotton production.

Babiker O. et al., evaluates the technical efficiency of cotton production under Gezira scheme in Sudan and they also examine the determinants of technical efficiency. The study reveals that there is a high potential for cotton farmer to improve their yield by 11% and the study stresses on improving tenant's access to credit and extension services to improve the technical efficiency of cotton production. And it also focusses on agricultural research to improve the productivity.

Ibrahim Dari et. Al., takes the farm level data in turkey to estimate the technical efficiency and its determinants. He finds that the farm size and farmer experience positively impact the technical efficiency whereas farmer age and non farm income shows the negative relationship with the technical efficiency.

In Indian context, Mythili and Shanmugam estimated a stochastic frontier production function for 234 rice farmers in Tamil Nadu. They obtained wide variation in technical efficiency, ranging from 46.5 percent to 96.7 percent in Tamil Nadu.

Datta and Joshi, 1992 uses the data on 120 farms from the district of Aligarh in Uttar Pradesh, he documents that the technical efficiency stands at eighty-four percent and sixty-six percent for wheat and rice respectively.

M SABESH et al., shows the analysis of cotton production and productivity over the years and the Empirical evidence shows that both cotton Area and productivity played a mixed role in influencing the cotton production over the years.

K.R. Shanmugam et al.,(2006) takes the district level secondary data to evaluate the

technical efficiency of agricultural output in India using stochastic frontier analysis and it further examines the impact of factors like literacy, infant mortality rate, availability of roads and electricity on technical efficiency of agricultural production.

3. Research gaps

However, these studies identified the technical efficiency of cotton production and also the factors affecting technical efficiency but these studies were limited to only a few states. Most of the studies for Indian subcontinent were conducted for Gujarat, Punjab, Karnataka or Kerala state in isolation, and not for the whole nation or major cotton producing states. Andhra Pradesh, Tamil Nadu and Karnataka in South ; Madhya Pradesh in Centre; Punjab and Haryana in North; Gujarat, Maharashtra and Rajasthan in West are the major cotton producing states in India. But, so far, none of the studies have evaluated the efficiency of cotton for all these major cotton producing states in India.

3. Objectives

In line of this, current study is an attempt to evaluate output oriented technical efficiency of cotton production across major cotton growing states in India. Considering this, the objective of current study is to comprehensively observe the variations in rank of cotton producing states in terms of technical efficiency overtime and also assess the factors responsible for inefficiencies in states.

The study will help in optimization of factors for cotton productivity that will lead to efficient production along with socio- economic and environmentally sustainable cotton production across India. Findings of the study can be utilized by the decision makers while formulating agricultural policy for Indian subcontinent.

4. Data

The present study is based on data exclusively drawn from the Directorate of Economics and Statistics (DES), Government of India (GOI), an attached office of the Department of Agriculture and Cooperation which collects, disseminates and publishes statistics on diverse facets of agriculture and related sectors required for policy formulation by the Government. It provided us with the state wise data on

production , yield and the data for the input usage.

The following are some of the main features of the data series used.

State coverage - The study includes 9 states which are Andhra Pradesh , Gujarat , Haryana , Karnataka , Madhya Pradesh , Maharashtra , Punjab , Rajasthan , Tamil Nadu.

These are the top 9 cotton producers in India, which account for roughly 90 percent of India's cotton output.

The present paper uses the cross sectional data of above mentioned 9 states for the time periods 2007-08 , 2011-12 , 2017-18 and look into the variations in efficiency of these states in terms of cotton production across these 3 years.

I use the cotton production (in 000 bales) to represent the output of production function.

Inputs - Given the constraints on the availability of data, I could get input data only for Seed (Kg.), Fertilizer (Kg. Nutrients), Manure (Qtl.), Human Labour* (Man Hrs.) and Animal Labor (Pair Hrs.). However I have opted to consider only two input variables fertilizer and human labour due to the existence of problem of multi-collinearity among the variables.

Our basic intuition tells us that both the two inputs i.e. human labor and fertilizer are necessary for production.

Human labour is an essential input because of agriculture being labor intensive in India would imply that production would actually not happen without the presence of human labour.

Lastly, the fertilizers are also important, as they tend to increase the yield if applied judiciously.

Data on factors like irrigated area for cotton (in 000 hectares), credit to agriculture by scheduled commercial banks that can affect technical inefficiency is taken from Reserve Bank of India database.

5. Methodology

<u>Conceptual framework</u>

In standard microeconomics theory, firms are assumed to behave rationally but in analyzing efficiency it has been recognized that firms can operate inefficiently. In order to study technical efficiency of a firm, a benchmark production functions has to be constructed which is called as the frontier. Figure 2 (Brian Mazorodze, 2019)

illustrates the concept of technical efficiency where output y is produced by using combination of inputs x.

Technically, there are two types of technical efficiencies:-

1. Input oriented technical efficiency (IO in figure 2) – Point C is said to be input oriented technical efficient in comparison to point B because y level of output can be produced by reducing inputs from N to M.
2. Output oriented technical efficient (OO in figure 2) – It is the case where output can be increased by keeping the same level of inputs. Point B represents the output oriented technical efficient point in comparison to the point A.

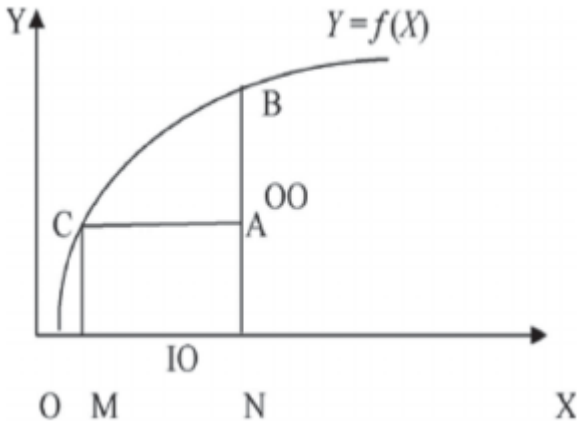

Figure 2: Input and Output oriented technical efficiency

This paper focusses on the output oriented technical efficiency.There exist two main types of approaches that can be applied to estimate efficiency:-

1. Data Envelopment Analysis (DEA)
2. Stochastic Frontier Analysis (SFA)

DEA is the Non Parametric approach that makes no assumption about the form of production function and it incorporates noise as part of the efficiency score. On the contrary, SFA is the parametric approach where form of production function is assumed to be known. The most important potential advantage of SFA is that it can separate noise in data from variations in efficiency. Given the inherent variability of agricultural production (due to demand shocks, supply shocks or other unobservable), assumption that all deviations from the frontier are associated with inefficiency (as assumed in DEA approach) is difficult to accept in this sector.

Given the benefits, the paper uses SFA which uses maximum likelihood method to calculate the frontier model based on Cobb Douglas production function.

Following Battese and Coelli (1996a), stochastic production frontier for cross sectional data can be written as:

$\ln Y = \beta 0 + \beta 1 \ln X1 + \beta 2 \ln X2 + (Vi\text{-}Ui)$

where ,

Y = Cotton production of state i (in 000 bales)

X1= fertilizers used for cotton production by state i (in kg nutrients)

X2= human labour employed for cotton production by state i (in man hours)

Ui = one sided disturbance, representing inefficiency and it is assumed to be independently distributed, such that Ui is obtained by truncation (at zero) of the normal distribution.

Vi = It depicts a symmetric and normally distributed error term which represents those factors that cannot be controlled by farmers and left out explanatory variables, and is assumed to be independently distributed of Ui.

To determine the determinants of technical inefficiency, Ui is assumed to be a function of explanatory variables. The model can be defined as:-

$Ui = \delta 1\ Zi + \delta 2\ Ti + Wi$

Where,

Zi = Irrigated area (in 000 hectares)

Ti = Credit to agriculture by scheduled commercial banks

δ = efficiency parameters to be estimated

Wi = error term that follows a truncated normal distribution

<u>SFA diagnostic checks :-</u>

1. Gamma parameter (γ) = $\sigma 2u$ / ($\sigma 2u + \sigma 2v$)

   Where, $\sigma 2u$ = variance of U and $\sigma 2v$ = variance of V

   This statistic measures the variation in output due to technical inefficiency. If it is close to 1 then much variation is explained by technical inefficiency and therefore give justification to use SFA.

2. Likelihood ratio test – This test confirms whether it is better to use SFA or the OLS model. The null hypothesis for the test is constructed based on the log likelihood values of the OLS (restricted) and the SF (unrestricted) model.

   LR test statistic = $-2[L(H0) - L(H1)]$

   Where $L(H0)$ and $L(H1)$ are log-likelihood values of the restricted model (OLS) and the unrestricted model (SF), respectively and the degree of freedom equals the number of restrictions in the test. The critical values of the mixed distribution for

hypothesis testing are tabulated in Table 1 of Kodde and Palm (1986).

critical values of the mixed chi-square distribution

	significance level						
dof	0.25	0.1	0.05	0.025	0.01	0.005	0.001
1	0.455	1.642	2.705	3.841	5.412	6.635	9.500

source: Table 1, Kodde and Palm (1986, Econometrica).

If the computed value is greater than the values in the table for a particular level of significance, in that case we reject the null of no technical inefficiency, indicating that there is technical inefficiency.

6. Results

Descriptive Analysis

The graph below shows the state wise production and area of cotton, on an average for the time period 2004-05 to 2017-18.

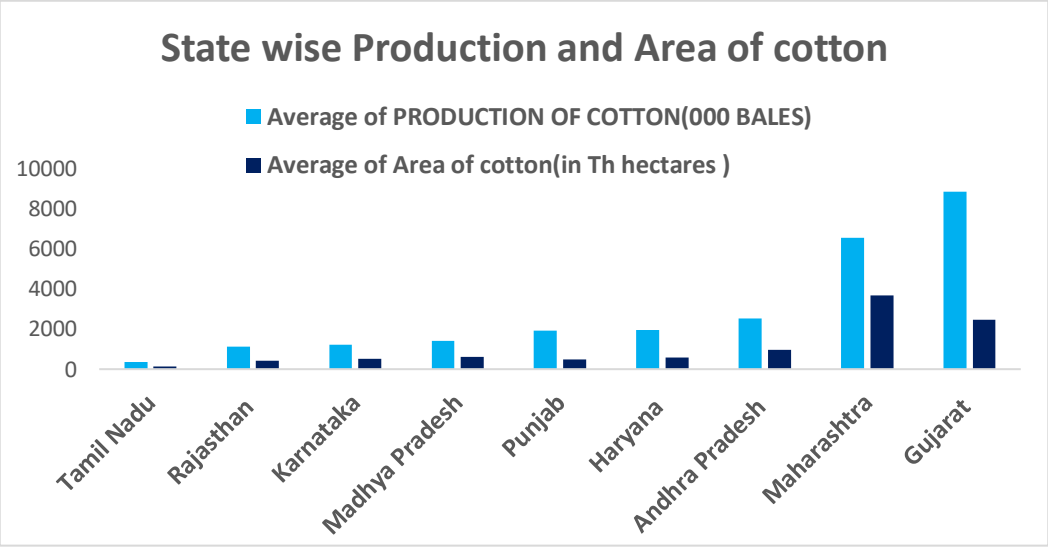

Figure 3: State wise Production and Area of cotton

From the above graph, we can observe that Maharashtra has the largest cotton sown area but its production is lower than that of Gujarat, which has lower cotton sown area than the former. The cotton sown area is lowest in Tamil Nadu and hence its production.

The graph below shows the state wise, on an average, yield of cotton per hectare for the time period 2004-05 to 2017-18.

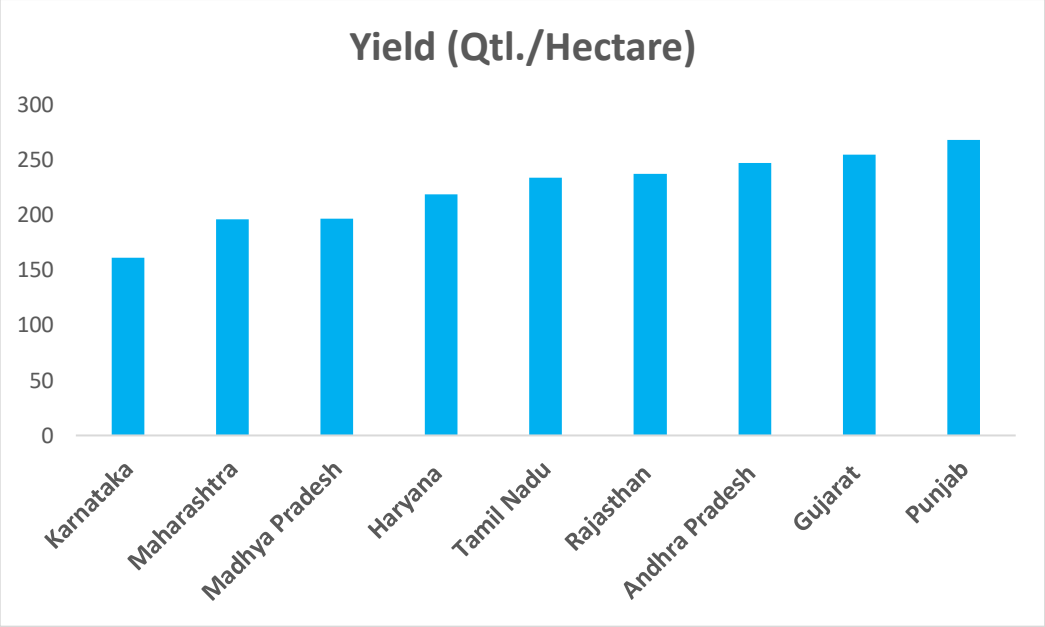

Figure 4

From the graph above, we can observe that the yield per hectare is highest in Punjab and Gujarat. And the yield of cotton per hectare is second lowest in Maharashtra which has the largest area to produce cotton.

The two graphs below show the state wise usage of fertilizer (kg nutrients per hectare) and human labour (Man hours per hectare) for the time period 2004-05 to 2017-18.

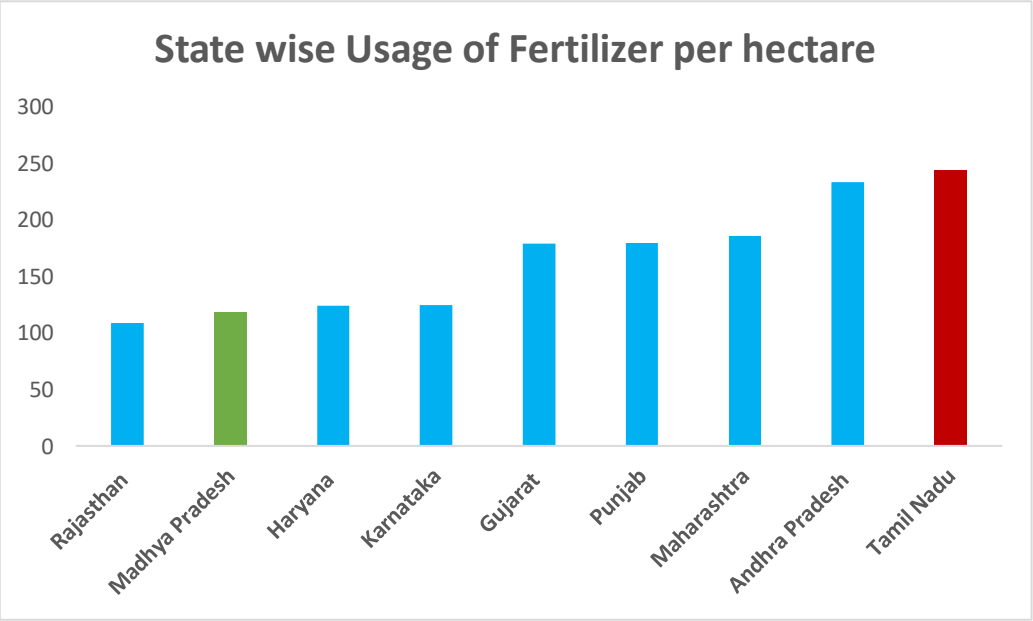

Figure 5

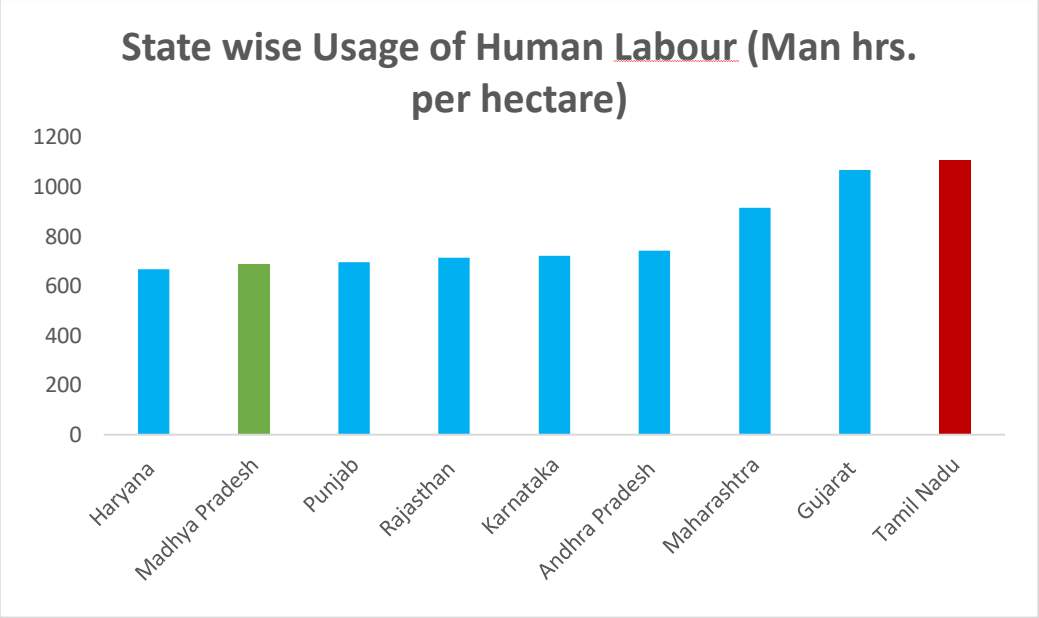

Figure 6

From the graphs above, we can observe that Yield per hectare of Tamil Nadu is lowest than that of Haryana, Madhya Pradesh , Maharashtra, Karnataka but fertilizer per hectare and human labour per hectare is highest among all the states. Other thing to note is that Maharashtra which has largest cotton sown area but the yield per hectare is second lowest, is using fertilizers (kg nutrients per hectare) and human labour (man hours per hectare) more than that of Punjab, Madhya Pradesh, Haryana etc.

The confounding fact to note is that Madhya Pradesh whose yield per hectare is higher than that of Maharashtra is using inputs per hectare lower than that of states like Maharashtra, Gujarat.

Empirical Analysis

The idea of an inefficiency stochastic frontier production function discussed in methodology section was then applied to 9 major cotton producing states for the time periods 2007-08 , 2011-12 and 2017-18 by taking cotton production in thousand bales as output. Fertilizer and human labour are taken as inputs used to produce output in the production function.

States can then be thought of as operating on the frontier or below it. The distance between the observed output and the corresponding value on the frontier reflects the level of inefficiency of a state in a certain moment in time. Over time, the state

can increase or decrease its level of inefficiency and "catch-up" to the frontier. To explain the inter state differences in technical efficiency, two factors are considered which are cotton Irrigated area (in '000 hectares) and credit to agriculture by scheduled commercial banks.

Results for year 2007 :-

ML Estimates	Time period – 2007-08	Log-Likelihood 17.2153	Prob > chi2 = 0.0000
log(cotton production)	Coefficient	P-value	standard error
Constant	-1.108564	0.000	0.0000137
Log(labour.hrs)	0.6851075	0.000	5.45E-06
log(fertilizerkgnutrients)	0.1178489	0.000	6.73E-06
Usigma	-4.898162	0.000	0.6257413
Technical Inefficiency	Coefficient	P-value	standard error
logIrrigatedAreaIn000Hect	-1.085885	0.001	0.3354037
logCREDITTOAGRIBYSCB	-2.351827	0.009	0.9020709
Constant	12.42236	0.005	4.454656

Diagnostic test results to use SFA:-

The value of likelihood ratio test came to be 24.6 which is greater than critical chi square value (given by kodde and palm, 1986) , therefore it rejects the null hypothesis and justifies to use SFA.

The result of stochastic frontier analysis for year 2007 shows that labour and capital impact output positively and are highly significant. If fertilizers increase by one percent, output increase by 0.11% . Similarly if labour increases by one percent then output increases by 0.68%. Also, we can observe that elasticity of output with respect to labour is greater than with respect to fertilizer.

After obtaining the frontier, the technical efficiency of each state for year 2007 was calculated and summary statistics for the same is presented below.

Variable	Obs	Mean	Std. Dev.	Min	Max
te_tn2007	9	.8606624	.154415	.6091665	1

From above table, we observe that the technical efficiency of states

varies between 60% to 100% with the mean technical efficiency as 86%. The graph below shows the technical efficiency for each state for the period 2007.

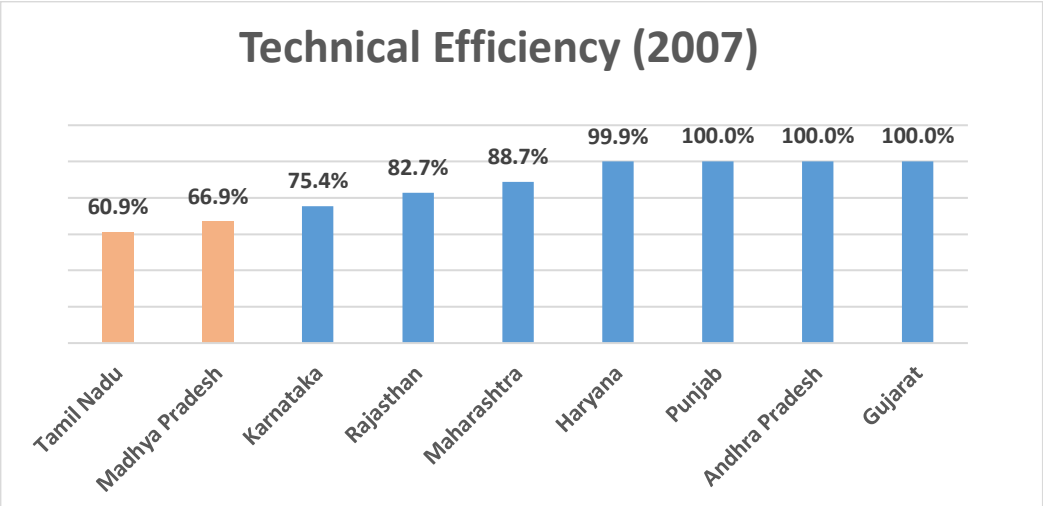

Figure 7 : Technical Efficiency of states for period 2007

From the graph, we can see that states like Andhra Pradesh, Gujarat and Punjab are the best performers in terms of efficiency in cotton production whereas for states like Tamil Nadu, Madhya Pradesh, there is scope to increase the output by 35% to 40% by using the same levels of inputs.

To explain these inter state differences, technical efficiency model is applied which includes two important state specific characteristics - cotton Irrigated area (in 000 hectares) and credit to agriculture by scheduled commercial banks that affects technical inefficiency in each state.

The results of this model are presented below.

Technical Inefficiency	Coefficient	P-value	standard error
logIrrigatedAreaIn000Hect	-1.085885	0.001	0.3354037
logCREDITTOAGRIBYSCB	-2.351827	0.009	0.9020709
Constant	12.42236	0.005	4.454656

The results of the model shows that the coefficients of these two factors are negative and significant, which means that if there is percentage increase in credit to agriculture or irrigated area for cotton then technical inefficiency score for that state falls which implies rise in technical efficiency.

<u>Results for year 2011</u> :-

ML Estimates	Time period 2011-12	Log-Likelihood 16.905	Prob > chi2 = 0.0000
log(cotton production)	Coefficient	P-value	standard error
Constant	-0.1210578	0.711	0.3271463
Log(labour man hrs)	0.0938054	0.619	1.89E-01
log(fertilizerkgnutrients)	0.6184752	0.000	1.72E-01
Usigma	-6.357804	0.000	0.5031725
Technical Inefficiency	Coefficient	P-value	standard error
logIrrigatedAreaIn000Hect	-0.2008406	0.00	0.050428
logCREDITTOAGRIBYSCB	0.5726231	0.00	0.1626552
Constant	-1.837139	0.022	0.8029288

Diagnostic test results to use SFA:-

The value of likelihood ratio test came to be 23.64 which is greater than critical chi square value (given by kodde and palm, 1986), therefore it rejects the null hypothesis and justifies to use SFA.

The model estimated by the maximum likelihood method is highly significant as shown by the large likelihood values. Both fertilizer and human labour have been found to be having a positive impact on frontier output , but the coefficient of labour is found to be statistically insignificant.

But here, we can observe that elasticity of output with respect to fertilizer is greater than with respect to human labour, which was other way around for year 2007.

After obtaining the frontier, the technical efficiency of each state for year 2011 was calculated and summary statistics for the same is presented below.

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sum te_tn2011
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Variable	Obs	Mean	Std. Dev.	Min	Max
te_tn2011	9	.7950525	.1441784	.5868992	.9999997

From above table, we observe that the technical efficiency of states varies between 58% to 100%. Also, we can observe that the mean technical efficiency of states has reduced from 86% in 2007 to 79% in 2011. The graph below shows the technical efficiency for each state for the period 2011 and 2007.

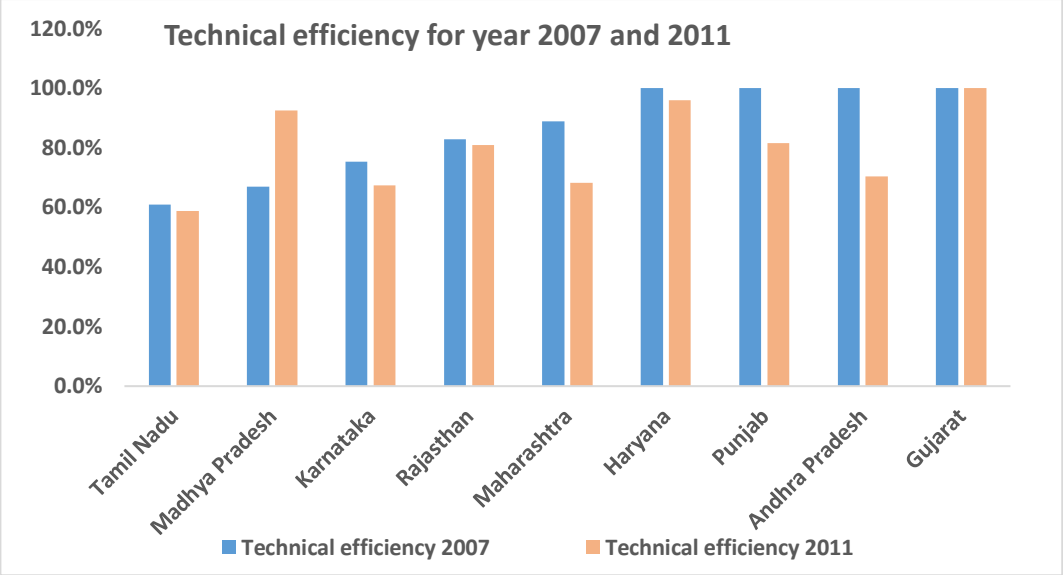

Figure 8 : Comparison of Technical Efficiency of states for period 2007 and 2011

From the graph, we can see that for the year 2011 states like Gujarat, Haryana and Madhya Pradesh are the best performers in terms of efficiency in cotton production whereas for states like Tamil Nadu, Karnataka, there is scope to increase the output by 35% to 40% by using the same levels of inputs.

Gujarat is the one state that has maintained its efficiency at 100% in year 2007 and also in year 2011. One thing to note is that Madhya Pradesh has improved its technical efficiency and also its ranking among other states by a greater extent in year 2011 as compared to year 2007. It is the only state whose technical efficiency has increased in year 2011 when compared to year 2007, otherwise it has either remained same or reduced for other states.

Other confounding thing to note is the change in efficiency score of Andhra Pradesh. Andhra Pradesh which had the second highest technical efficiency among 9 cotton producing states in year 2007, lost its position and its technical efficiency reduced to 70% in 2011 from 100% in 2007.

The efficiency score of Tamil Nadu which was the lowest in year 2007 has decreased even further to 58% in year 2011 from 61% in 2007.

Results for year 2017 :-

ML Estimates	Time period – 2017-18	Log-Likelihood 9.2647	Prob > chi2 = 0.0000
log(cotton production)	Coefficient	P-value	standard error
Constant	-0.5032041	0.267	0.4536037

Log(labour man hrs)	0.4377522	0.051	2.24E-01
log(fertilizerkgnutrients)	0.2725525	0.245	2.34E-01
usigma	-5.873162	0.006	2.156628
Technical Inefficiency	Coefficient	P-value	standard error
logIrrigatedAreaIn000Hect	1.171226	0.46	1.593255
logCREDITTOAGRIBYSCB	8.65785	0.30	8.259658
Constant	-45.46593	0.307	44.55207

Diagnostic test results to use SFA:-

The value of likelihood ratio test came to be 12.1, which is greater than critical chi square value (given by kodde and palm, 1986), therefore it rejects the null hypothesis and justifies to use SFA.

In this model, both the inputs fertilizer and human labour have been found to be having a positive impact on frontier output, but the coefficient of fertilizer is found to be statistically insignificant.

We can also observe that elasticity of output with respect to human labour is greater than with respect to fertilizer.

After obtaining the frontier, the technical efficiency of each state for year 2017 was calculated and summary statistics for the same is presented below.

Variable	Obs	Mean	Std. Dev.	Min	Max
te_tn2017	9	.9227574	.1305274	.6127672	.9985741

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From above table, we observe that the technical efficiency of states varies between 61% to 99%. Also, we can observe that the mean technical efficiency of states has increased from 86% in 2007-08 to 92% in 2017-18. The graph below shows and compares the technical efficiency for each state for the period 2007, 2011 and 2017.

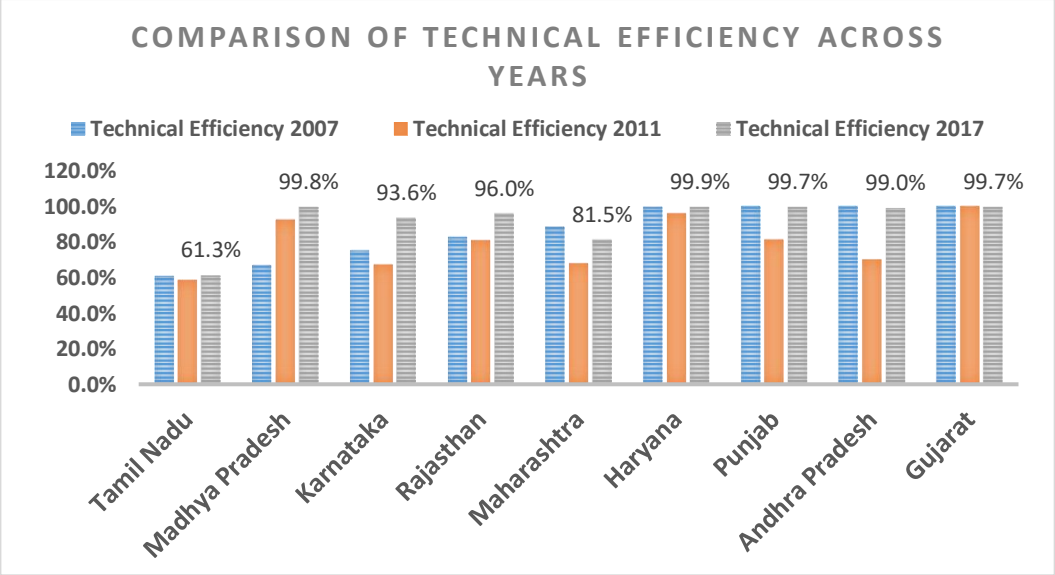

Figure 9 : Comparison of Technical Efficiency of states for period 2007, 2011 and 2017

From the above graph, we can observe that technical efficiency of each state has improved in 2017 when compared to year 2011 i.e., most of the states are approaching frontier over the time which is thereby a positive sign.

The startling fact that can be observed from the graph is that the Gujarat has maintained its efficiency at 100% across all the three years. The reason behind this can be the increasing trend in productivity of cotton overtime. The graph below shows the productivity of cotton for the state Gujarat for three time periods.

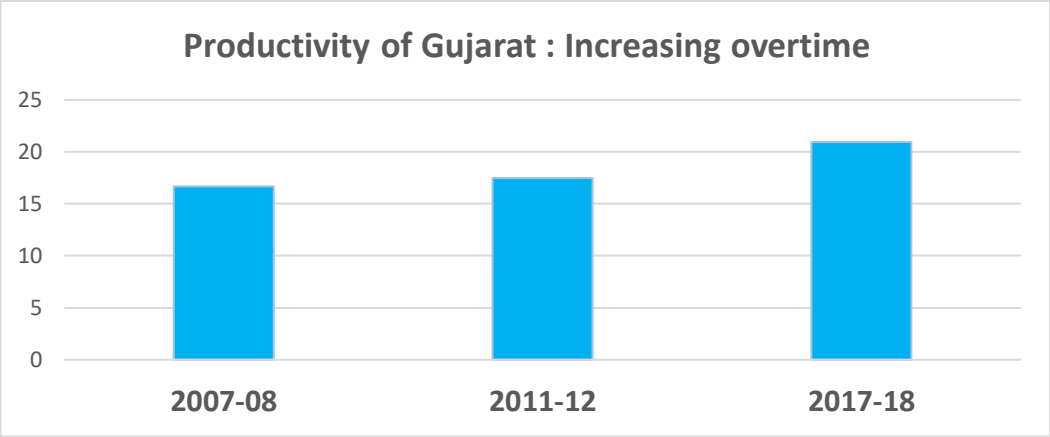

Figure 10

And other states like Haryana, Punjab, Andhra Pradesh have also attained the 100 percentage efficiency level in year 2017.

The performance of Madhya Pradesh is worth noting because of its consistent improvement in technical efficiency overtime. It has reached to efficiency level of

99% in year 2017 from 67% in year 2007.

Our technical efficiency model for time period 2007-08 showed that the state specific characteristics like irrigated area for cotton , credit facilities given to agriculture are the factors that significantly affect the technical inefficiency of cotton production across states. That is, if there is rise in provision of such factors then technical inefficiency of cotton production in particular state falls , i.e., technical efficiency rises.

The figure below has two panels in which upper panel shows the average cotton area as % of total agricultural area and lower panel shows the irrigated area as % of cotton sown area for all the nine states.

From this, we can observe that Tamil Nadu whose technical efficiency was lower among all states across all the time periods, the irrigated area for cotton as % of total cotton area is also falling down overtime for Tamil Nadu.

Secondly, we can observe that Madhya Pradesh whose technical efficiency was increasing overtime, the irrigation facilities are also improving over the time period.

Thirdly, the share of irrigated land in Maharashtra is lower comparatively.

Fourthly, the states like Punjab, Haryana whose production is closer to the frontier ,i.e., states that are relatively more technical efficient are having more irrigated area as % of cotton sown area.

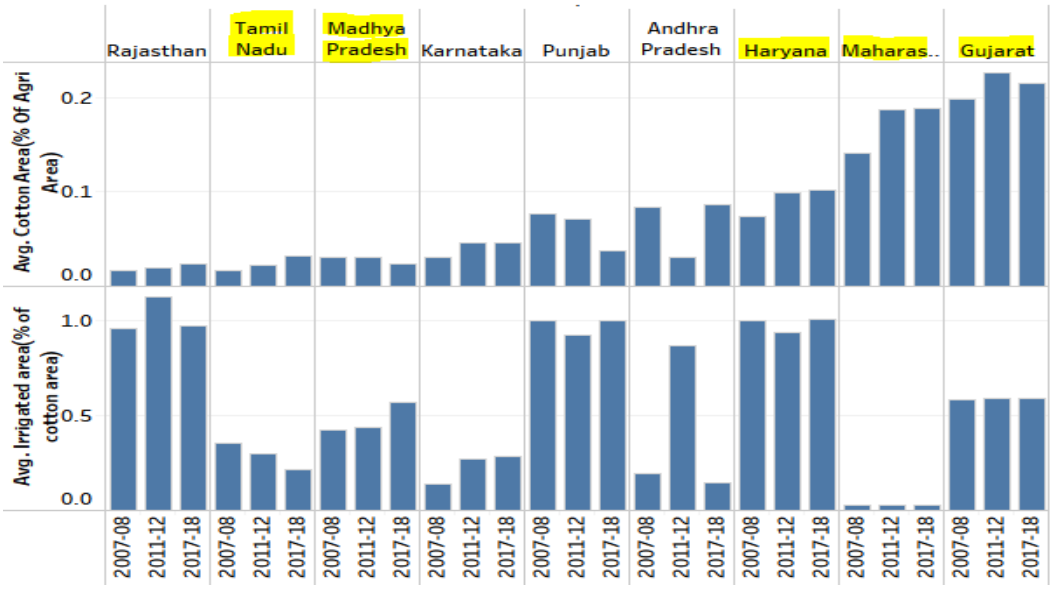

Figure 11: Irrigated Area as % of cotton sown area in Indian states

The graph below shows the trends of credit given to agriculture by scheduled

commercial banks as % of total credit given.

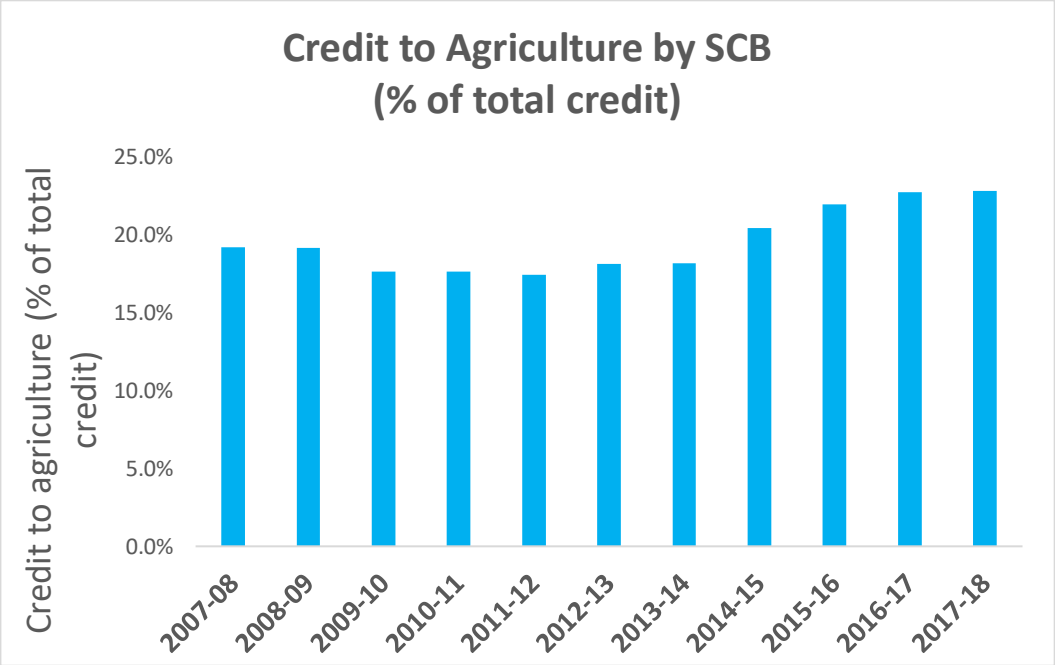

Figure 12: Credit given to agriculture by scheduled commercial banks

From above figure, we can see that the credit given to agriculture by scheduled commercial banks fell down in year 2011-12, which justifies the fall in technical efficiency for almost all the states in year 2011-12.

The graph below shows the credit to agriculture given by scheduled commercial banks as % of total credit given for 9 cotton producing Indian states.

The graph below shows the percentage of credit given to agriculture across three different time periods for all the nine states.

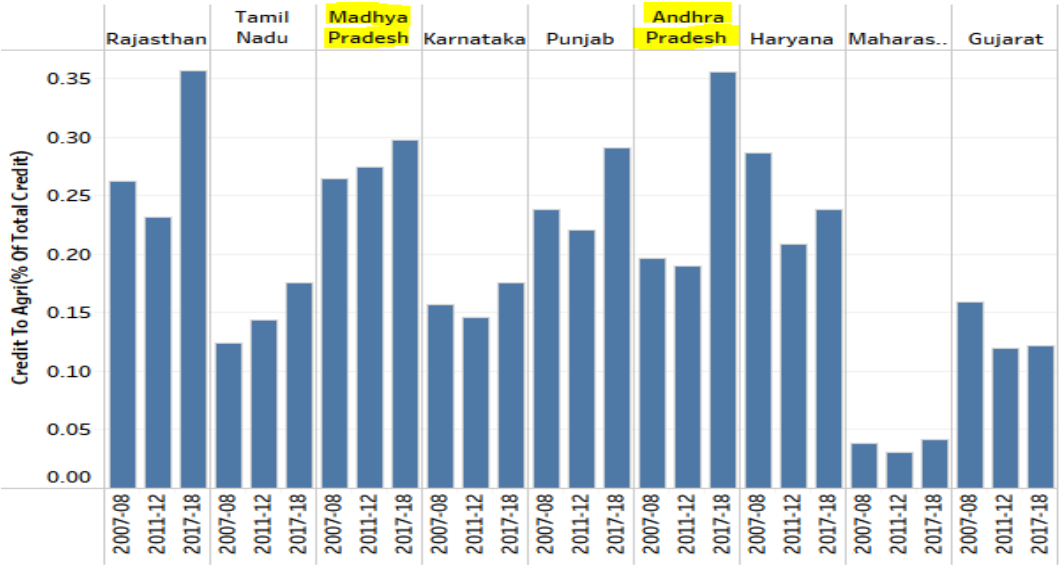

Figure 13: credit to agriculture by scheduled commercial banks as % of total credit given

From the above figure, we can observe that Madhya Pradesh whose technical efficiency was improving over time, the credit facilities are also improving in the state overtime.

The technical efficiency of Andhra Pradesh fell down in time period 2011-12 which can be related to fall in credit availability to agriculture in Andhra Pradesh for the same time period.

There are multiple factors like farmer's education, climatic conditions, extension services for cotton production, farmer's experience, family size etc (Babiker O. Mahgoub1*, Mutasim Mekki M.Elrasheed2 and Hag Hamad Abdelaziz3) that can affect efficiency of cotton production but due to lack of availability of secondary data on such factors, the study in this paper is limited to few factors only.

7. Conclusion

In this study, we have analysed state level technical efficiency and its determinants for the periods 2007, 2011 and 2017.

The study shows a fall in technical efficiency of cotton production across all states in time period 2011-12 when compared to 2007-08.

But during this time period, only Madhya Pradesh is the state that shows the rise in its technical efficiency from 66% in 2007 to 92% in year 2011. Madhya Pradesh experienced rise in technical efficiency in all three time periods, the reason for this can be improvement in credit and irrigation facilities in Madhya Pradesh overtime.

Other thing to note is that the technical efficiency of all states has increased in year 2017 when compared to year 2007 except the Maharashtra.

The technical efficiency of Maharashtra has decreased overtime, the reason for this can be poor credit and irrigation facilities available in the state.

The results of our inefficiency model give the evidence for supporting the importance of irrigation and credit facilities for agricultural production in India.

Therefore, at the end, paper concludes that credit and irrigation facilities are one of the factors that drive the TE of top performing states and hence it suggests to focus on these factors to improve TE, which thereby will increase the total output of cotton by 8-10%.

Finally, there is scope to extend the study further by including factors like farmer's education, climatic conditions, extension services for cotton production, farmer's

experience, family size etc. in the technical inefficiency model and then assessing their impact on technical efficiency.

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