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Research Article

Technical Performance of Agriculture Farming Decision Making Entities in Telangana State: A New Integrated Evaluation Using Data Envelopment Analysis (DEA) Approach

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Abstract. The present research paper, we evaluate technical performance of agriculture farming decision making entities Optimality Analytics by CCR and BCC techniques through Data Envelopment Analysis approach for the Telangana state and see that the optimal empirical performances of farming entities with respective to all the districts of the state of Telangana. The district wise agriculture farming decision making entities performances is evaluated by considering the Technical/Pure Technical Efficiency of one district over rest of the districts under various permutations by computing the Efficiency scores, Scale Efficiency (SE), CRS, VRS, References and Peers of the DMUs, and also assign a rank of decision-making units based on the reference sets. Integrated analytical techniques were used to improve the inputs and outputs values of the inefficient DMUs. A new integrated CCR and BCC theoretical models are used to evaluate the performance of the districts for the data are presented in this research paper.

Keywords. CCR, BCC, DEA, Technical efficiency, Pure technical efficiency, CRS, Most productive scale size, Reference set, Rank of DMU, Peers, Potential improvement

Mathematics Subject Classification (2020). 90C32, 62C05, 90C06

1. Introduction

Initiation of agriculture farming was a revolutionary step in human history. Agriculture farming, which is in progress during the Neolithic period of man's survival on earth was initially for subsistence only, but with the increase in population, grew man's need for sufficient agricultural farming. Therefore, the necessity in bringing more land under farming in turns necessitated the use of animal power in agriculture field. The emerging trends in agricultural are implementations and new technology, varieties of seeds and some new crops were introduced. Farmers was benefitted, to some extent, with the expansion of trade and commerce, improved irrigation facilities, transport and communication sector. India implemented substantial policy reforms aimed at achieving food grain self-sufficiency and increasing production through greater farming expertise.

The "best practice" is a comparative method and which is most important attribute in data envelopment analysis. The main aim of this "best practice" is an action and link between an action and outcomes or goals. Rutter and Maughan [9] used DEA optimal techniques and their efforts extending towards the "best practice" in the field of science and technology. This technique direct to the lot of improvement in the production field. Kwimbere [4] applied different analytical techniques for their research study. Nellutla *et al*. [5] evaluated performance of universities in Telangana state. Nellutla *et al*. [7] find efficiency scores of different types schools in AP state by CCR Model. In this current research article, we consider agriculture farming dataset for Telangana state and asses and analyze which district technically perform well for agricultural farming data collected for the financial years 2018-19 and 2019-20 by a new integrated CCR, BCC Model in Data Envelopment Analysis, which help the government authorities and formers to plan well for the future years to come for a better efficient cultivation and profits to the farmers.

2. Data Envelopment Analysis

In the present situation, the DEA has emerged into a better diversity of applications in many sectors. The data envelopment analysis signifies a great progression for data analysis, which finds extensive uses in industry, education, society even in agriculture sector. Data envelopment analysis techniques find the best performance of entities. Data Envelopment Analysis is data oriented and mathematical approach. Data Envelopment Analysis (DEA) measuring the performance of decision-making entities or utility factors. Rede and Bhattacharyya [8] assessed efficiency of Pomegranate Growers, Ye [11] perform an Analysis on Technical Efficiency of Paddy Production in China, and Nellutla *et al*. [6, 10] using different models in DEA for their data analysis. Donthula *et al*. [3] Assessed the performance of Agriculture forming in Telangana State for the financial years 2018-19 and 2019-20. The most important and widely used new integrated technique in Data Envelopment Analysis is CCR and BCC models.

3. CCR and BCC Models in Data Envelopment Analysis

3.1 Efficiency Analysis

This is a most important factor in Data Envelopment Analysis. Efficiency Analysis is computed and asses the best and optimal performance of the entities. The efficiency of single input and single output is computed as follows:

$$\text{Efficency} = \frac{\text{Output}}{\text{Input}}. \tag{1}$$

The best practice in efficiency analysis is by comparing input and output units entities, which transforms inputs into outputs. This type production process can occur in agriculture farming sector also. In agriculture farming sector utilization of proper harvesting, human resources and Technology as inputs which helps in computing the farming outputs in this process as shown in below:

Agriculture Farming Inputs → Agriculture Farming Process → Agriculture Farming Outputs

Figure 1. Transformation process of Inputs/Outputs variables

Suppose there are n number of DMUs, i.e., $\text{DMU}_1, \text{DMU}_2, \text{DMU}_3, \dots, \text{DMU}_N$. These DMUs have common inputs and outputs items and for all $j = 1, 2, 3, \dots, n$.

The selection of DMUs is chosen based on the following conditions:

(1) Data set are available for each one of input and output variables,

(2) The numerical data set of DMUs is positive.

(3) The inputs and outputs variables should reflect in the components that will enter into the relative efficiency evaluation of the Decision Making Units.

(4) In this analysis, smaller amount of input and larger amount output are also preferable, so that the efficiency scores should be reflects in DEA.

(5) The measurement units of input and outputs variable data set need not to be congruent.

Suppose n inputs and s outputs are chosen with properties noted 1, 2 and 3. Let the input variables DMU_j be $(x_{1j}, x_{2j}, x_{3j}, \dots, x_{nj})$ and output variables DMU_j be $(y_{1j}, y_{2j}, y_{3j}, \dots, y_{sj})$.

The input variable matrix and output variable matrix X and Y are represented as follows:

$$X = \text{Inputs} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nn} \end{bmatrix}, \tag{2}$$

$$Y = \text{Outputs} = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ y_{s1} & y_{s2} & \cdots & y_{sn} \end{bmatrix}. \tag{3}$$

Here X is an $(n \times n)$ matrix and Y is an $(s \times n)$ matrix.

3.2 The CCR Model

Banker *et al*. [1] and Charnes *et al*. [2] explained properties and evaluation process of CCR model in Data Envelopment Analysis. The basic assumption of CCR model is Constant Return to Scale. This returns scale shows the relationship between Inputs and Outputs variables. Researchers Charnes, Cooper and Rhodes (CCR) were introduced this model and using this model calculates *Overall Efficiency* (OE) scores of the DMUs. The DEA Primal CCR model is explained in the following section.

3.3 Basic Notations and Terminologies in DEA

The decision making units or utilization factors are represented by $\text{DMU}_1, \text{DMU}_2, \text{DMU}_3, \dots,$ DMU_n. These DMUs are containing inputs and outputs variables.

x_{ij} : The ith input of the jth DMUs $x_{1j}, x_{2j}, x_{3j}, \dots, x_{mj}$

y_{ij} : The jth output of the jth DMUs $y_{1j}, y_{2j}, y_{3j}, \dots, y_{sj}$

v_i : The weights of the ith input, $i = 1,2,3,\dots,m$

u_R : The weights of the jth output, $r = 1,2,3,\dots,s$

Therefore, the Fractional Programming Problem (FPP) is given by

$$\text{Max}\, R = \frac{u_1 y_{1k} + u_2 y_{2k} + u_3 y_{3k} \cdots + u_s y_{sk}}{v_1 x_{1k} + v_2 x_{2k} + v_3 x_{3k} \cdots + v_m x_{mk}}, \quad k = 1,2,3,\dots,n \tag{4}$$

$$\text{Subject to constraints} : \frac{u_1 y_{1j} + u_2 y_{2j} + \cdots + u_s y_{sj}}{v_1 x_{1j} + v_2 x_{2j} + \cdots + v_m x_{mj}} = 1, \quad j = 1,2,3,\dots,n \tag{5}$$

$$\text{Non-negativity } u_1, u_2, u_3, \dots, u_s = 0 \text{ and } v_1, v_2, v_3, \dots v_m = 0 \tag{6}$$

The input and output ratio of decision making units not exceed one. The objective of the model is to maximize the decision making units. The optimal value of the model R^* is one. Mathematically, eq. (6) is not sufficient for the fractional terms in (5) and is to have a positive value. Assuming that all the outputs have been non zero's. This leads to the reflected in weights u_R and v_i being assign positive values. The following Linear Programming Problem (LPP) was converted into the Factional Program problem.

$$\text{Max } R(u,v) = u_1 y_{1k} + u_2 y_{2k} + u_3 y_{3k} + \ldots + u_s y_{sk} \tag{7}$$

$$\text{Subject to} : v_1 x_{1j} + v_2 x_{2j} + v_3 x_{3j} + \ldots + v_m x_{mj} = 1 \tag{8}$$

$$u_1 y_{1j} + u_2 y_{2j} + u_3 y_{3k} + \ldots + u_s y_{sj} \le v_1 x_{1j} + v_2 x_{2j} + v_3 x_{3j} + \ldots + v_m x_{mj} \tag{9}$$

$$u_1, u_2, u_3, \dots, u_s = 0, \quad v_1, v_2, v_3, \dots v_m = 0 \tag{10}$$

Therefore, Optimal Solution (v^*, u^*, R^*).

By the primal problem, ratio scale is evaluated, and the primal problem becomes

$$\text{Max} R^*(v^*, u^*) = \frac{\sum_{r=1}^{s} u_R^* y_{rk}}{\sum_{i=1}^{m} v_i^* x_{ij}} \tag{11}$$

$$R^*(v^*, u^*) = \sum_{r=1}^{s} u_R^* y_{rj} \quad \text{(from (4))} \tag{12}$$

$$\text{Subject to constraints} : \sum_{r=1}^{s} u_R^* y_{rj} - \sum_{i=1}^{m} v_i^* x_{ij} \le 0, \quad j = 1,2,3,\dots,n \tag{13}$$

$$\sum_{i=1}^{m} v_i x_{ik} = 1 \tag{14}$$

$$\text{Non-negativity} : u_R = 0, \quad v_i = 0 \tag{15}$$

The above mentioned LPP yields the Optimal Solution (OS) R^*, where R^* score is called CCR Efficiency score or Technical Efficiency (TE) of the particular DMU_js. The efficiency scores of all DMUs are calculated by repeating the process of each decision making units DMU_j, $\forall$ $j = 1,2,3,\dots,n$.

The optimal efficiency scores of the DMUs are always less than or equal to one i.e., $R^* \leq 1$. If DMUs score $R^* < 1$ is known as relatively inefficient decision making unit and $R^* = 1$ is known as relatively or technically efficient.

3.4 The BCC Model

This is the next model in data envelopment analysis and the model CCR extended by Banker *et al*. [1] and Charnes *et al*. [2]. This Model can be used in efficiency analysis under the assumption of a variable return to scale. In this assumption input and output variables and constraints equal to one is adjoined. This model is called "BCC Model". In this model added constraint as an additional variable into the multiplier problem. This extra variable makes it possible to affect the VRS evaluation process. These scales are known as CRS or IRS or DRS. The composite units of similar scale size units are evaluated in this model formulation.

The Production Possibility Set is defined as below:

$$P(BCC) = \{(x,y)/x \geq x\lambda, y \leq y\lambda, e\lambda = 1, \quad \lambda \geq 0\} \tag{16}$$

The input-oriented model calculates the entities relative efficiency scores by solving envelopment form of linear programming problem:

$$\text{Objective function Min } (\theta_B, \lambda) : \theta_B \tag{17}$$

$$\text{Subject to}: \ \theta_B x_0 - x\lambda = 0 \tag{18}$$

$$y\lambda = y_0 \tag{19}$$

$$e\lambda = 1 \tag{20}$$

$$\lambda = 0 \tag{21}$$

Here θ_B is scalar.

Dual multiplier form of the LPP BCC$_R$ is as follows:

$$\text{Objective function} : \text{Maximize } (v, u, x_0)R = uy_0 - u_0 \tag{22}$$

$$\text{Subject to constraints: } vx_0 = 1 \tag{23}$$

$$-vX + uY - u_0 e = 0 \tag{24}$$

$$u = 0, \quad v = 0$$

Here u_0 is free in sign, where v and u are vectors and θ and u_0 are scalars.

The corresponding BCC Fractional Programming is found from the dual problem as follows:

$$\text{Objective function} : \text{Maximize } \frac{uy_0 - u_0}{vx_0} \tag{25}$$

$$\text{Subject to constraints} : \frac{uy_j - u_0}{vx_j} = 1, \quad j = 1, 2, 3, \dots, n \tag{26}$$

$v = 0$, $u = 0$, u_0 is free in sign.

The difference between DEA models of CCR and BCC Model is presented in the free variable u_0. This dual variable is associated with the constraints $e\lambda = 1$ in the envelopment model.

The BCC model optimal solution is represented by notations $(\theta_B^*, \lambda^*, s^{-*}, s^{+*})$.

Here θ_B^* : maximal PTE, λ^* : peer weights, s^{-*} : input excesses and s^{+*} : output short.

3.5 Peer Group (PG)

Peer Group is a collection of great units that comprises those that are efficient when compared to the optimal weights of inefficient units. Peer group another name is reference set.

3.6 The Reference Set (RS)

When we observed the DMU has efficiency score $R^* < 1$ then there must be one constraint produce equality between the left-handand right-hand side of the equation (7) other wise, R^* could be enlarged. Let $j \in (1,2,3,\dots,n\}$ and

$$e'_k = \left\{ j : \sum_{r=1}^{s} u_R^* y_{rj} = \sum_{i=1}^{m} v_i^* x_{ij},\ j = 1,2,3,\dots,n \right\}. \tag{27}$$

The subset of E_k and E'_k, composed of the efficient DMUs, is known as Reference Set (RS) to the $\text{DMU}_1, \text{DMU}_2, \text{DMU}_3, \dots, \text{DMU}_{k-1}$.

3.7 Potential Improvement (PI)

This information can be used to develop objectives that will help to the inefficient DMUS of input or output variables bring in to the better performers.

3.8 Reference Comparison (RC)

As a first step in data envelopment analysis is setting targets, the inefficient units compare with the units in its reference set.

3.9 Returns to Scales (RTS)

The optimal performance evaluation process depends on the Returns to Scale. In DEA, basically two types of scaling techniques are used. First one is Constant Returns to Scale and second one is Variable Returns to Scale.

3.10 Constant Returns to Scale (CRS)

In this scaling mode out puts directly reflects the input results.

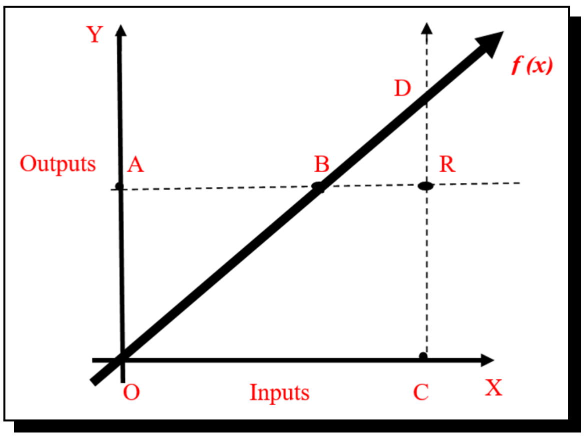

Figure 2. Constant Returns to Scale

From Figure 2 we noticed that $f(x)$ is represented by straight line and have a single slope. Graphically R projected onto the frontier line and also the points B and D is projected on the frontier line.

3.11 Variable Returns to Scale

Under this scaling mode, there are two types of returns to scales in Data Envelopment Analysis. Those are increasing and decreasing returns to scales.

3.12 Increasing Returns to Scale (IRS)

Each unit increases in input results, the output results increases more than proportionate quantity displaying. This scale is known as decreasing returns to scale (DRS).

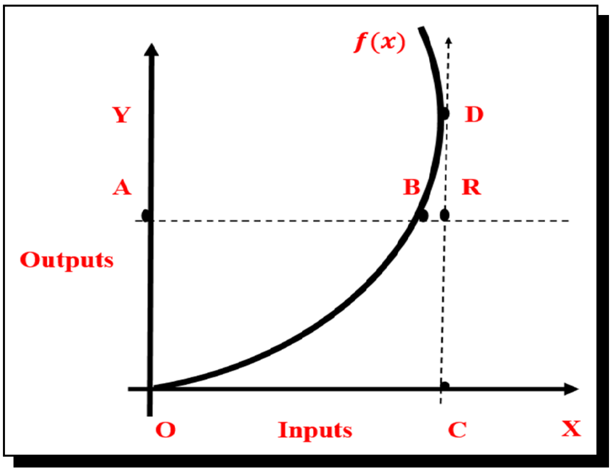

Figure 3. Increasing returns to scale

From the above figure, we noticed that $f(x)$ with an increasing slope. Here R is lies above the efficient frontier hence its known as increasing returns to scale (IRS).

3.13 Decreasing Returns to Scale

Each unit decreases in input results and the output results decreases by less than proportionate quantity displaying; hence this scale is known as decreasing returns to scale (DRS).

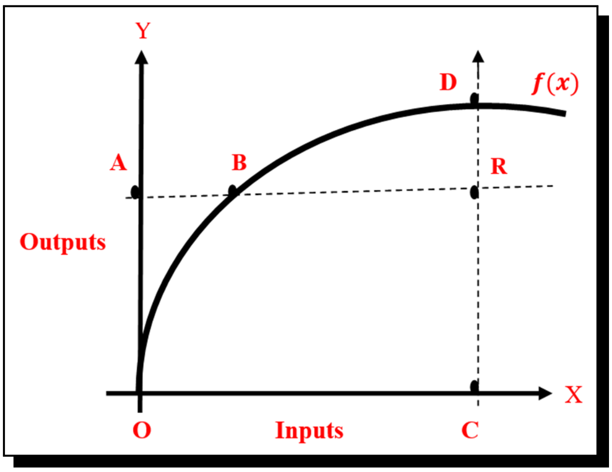

Figure 4. Decreasing returns to scale

From Figure 4, we noticed that $f(x)$ has a decreasing slope. R is lies below the efficient status, where B and D points are projected on the frontier line.

3.14 Rank of DMUs

Identify the reference sets of the DMUs using CCR and BCC Models and assign a rank of a DMUs.

3.15 Most Productive Scale Size (MPSS)

The Most Productive Scale Size is the one of the important applications in DEA. The CCR and BCC techniques are used found out the best DMU is under Most Productive Scale Size (MPSS). In Data Envelopment Analysis a DMU found to be efficient in CCR model will also found efficient DMU in BCC model and CRS prevails.

3.16 Decomposition of Technical Efficiency (TE)

In general, the CCR technical efficiency scores are called Global Technical Efficiency (GTE) and the BBC technique in Data envelopment Analysis assumes that convex combinations of observed farming data from production possibility set (PPS) and BCC model scores is called Local Pure Technical Efficiency (LPTE). In Data Envelopment Analysis, any DMU is fully efficient in CCR and BCC new integrated techniques, it is operating in the Most Productive Scale Size (MPSS). If any DMU has fully efficient in BCC model techniques and low efficiency score in CCR Model, then this DMU is locally efficient but not global due to the scale size of the Decision Making Units. For this reason, the Scale Efficiency is play vital role in this analysis.

The Scale Efficiency (SE) is obtained as follows:

$$\text{Scale Efficiency (SE)} = \frac{\theta^*_{CCR}}{\theta^*_{BCC}}, \tag{28}$$

where θ^*_{CCR}: The CCR model optimal scores of the DMUs,

θ^*_{BCC}: The BCC model optimal scores of the DMUs.

For BCC efficient Decision Making Units with constant to scale (CRTS), which DMU is in MPSS, and its Scale Efficiency score is one. The CCR Model score is called the Technical Efficiency (Global). The BCC model expresses the Pure Technical Efficiency (Local) under variable returns to scale (VRTS).

4. Data Consideration and Analysis

The CCR Model efficiency scores for the financial year 2018-19 is reported in Table 1.

Table 1 shows the variation of Technical Efficiency (TE) for the 32 districts has recorded between $0.470 \le R^* \le 1.000$. Also, seven districts in efficient frontier namely Jagtial, Karimnagar, Khammam, CCR Technical efficiency scores cause input losses in Nizamabad, Vikarabad, Warangal rural, Warangal urban, and other 25 districts. In order to improve agricultural output performance in both the Rabi and Kharif seasons, potential improvement is required.

Table 1 show that In comparison to the 32 districts, Jagtial, Karimnagar, Khammam, Nizamabad, Vikarabad, Warangal rural, and Warangal urban are technically (CCR) efficient. The peers with all other districts appear to be Jagtial, Karimnagar, Khammam, Nizamabad, Vikarabad, Warangal rural, Warangal urban, and Khammam district, with Khammam district maintaining the highest references. When compared to the other districts, this district has a higher peer contribution. Every effective DMU, according to the DEA approach, is a role model DMU. Jagtial, Karimnagar, Khammam, Nizamabad, Vikarabad, Warangal rural, and Warangal urban, for example, are technically efficient DMUs in and of themselves.

Table 1. Technical Efficiency (TE) scores per district for the 2018-19 financial year

S. No.	Districts	Technical efficiency R^*	Number of references	Number of peers	Rank of DMUs in CCR	List of the peers
1	Adilabad	0.837	0	3	20	Khammam, Vikarabad, Warangal Rural
2	Bhadradri	0.698	0	2	20	Khammam, Vikarabad
3	Jagtial	1.000	8	0	7	Jagtial
4	Jangaon	0.882	0	2	20	Jagtial, Khammam
5	Jayashankar	0.965	0	3	20	Khammam, Vikarabad, Warangal Rural
6	Jogulamba	0.734	0	3	20	Khammam, Vikarabad, Warangal Rural
7	Kamareddy	0.766	0	3	20	Jagtial, Karimnagar, Khammam
8	Karimnagar	1.000	2	0	6	Karimnagar
9	Khammam	1.000	22	0	1	Khammam
10	KomaramBheem	0.966	0	2	20	Vikarabad, Warangal Rural
11	Mahabubabad	0.882	0	3	20	Khammam, Vikarabad, Warangal Rural
12	Mahabubnagar	0.957	0	2	20	Vikarabad, Warangal Rural
13	Mancherial	0.848	0	3	20	Khammam, Vikarabad, Warangal Rural
14	Medak	0.853	0	3	20	Khammam, Vikarabad, Warangal Rural
15	MedchalMalkajgiri	0.470	0	2	20	Jagtial, Khammam
16	Mulugu	0.926	0	3	20	Khammam, Nizamabad, Warangal Rural
17	Nagarkurnool	0.833	0	2	20	Vikarabad, Warangal Rural
18	Nalgonda	0.586	0	2	20	Jagtial, Khammam
19	Narayanpet	0.915	0	2	20	Vikarabad, Warangal Rural
20	Nirmal	0.953	0	3	20	Khammam, Nizamabad, Warangal Rural
21	Nizamabad	1.000	6	0	5	Nizamabad
22	Peddapalli	0.940	0	3	20	Jagtial, Khammam, Nizamabad
23	Rajanna	0.899	0	3	20	Khammam, Nizamabad, Warangal Rural
24	Rangareddy	0.816	0	2	20	Khammam, Vikarabad
25	Sangareddy	0.970	0	3	20	Khammam, Vikarabad, Warangal Rural
26	Siddipet	0.733	0	2	20	Khammam, Vikarabad
27	Suryapet	0.698	0	2	20	Jagtial, Khammam
28	Vikarabad	1.000	15	0	3	Vikarabad
29	Wanaparthy	0.911	0	3	20	Khammam, Nizamabad, Warangal Rural
30	Warangal Rural	1.000	16	0	2	Warangal Rural
31	Warangal Urban	1.000	1	0	7	Warangal Urban
32	Yadadri	0.525	0	2	20	Jagtial, Khammam

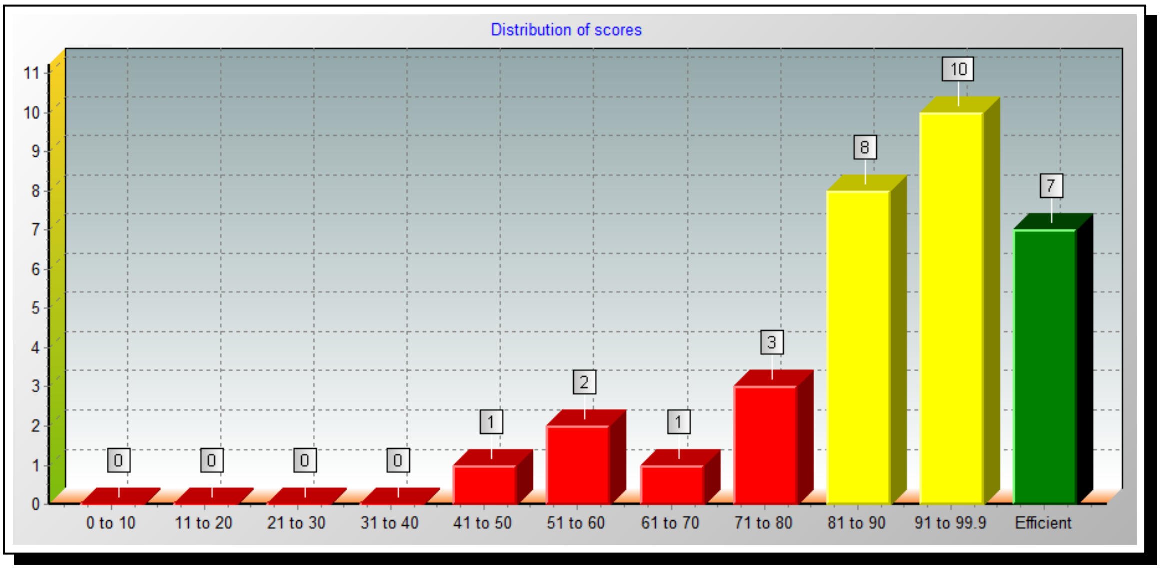

Figure 5. The graph depicting the CCR model's score distribution for the financial year 2018-19

The score limit 41-50 is just 1 DMU, 51-60 is 2 DMUs, 61-70 is 1 DMU, 71-80 is 3 DMUs, 81-90 is 8 DMUs, and 91-99 is 9 DMUs, according to the CCR Model distribution of score graph for the financial year 2018-19. 10 DMUs are on the inefficient frontier, whereas 7 DMUs are on the efficient frontier.

From Table 2, the BCC Model technique Pure Technical Efficiency (PTE) differences for 32 districts has the following limits $0.547 \le R^* \le 1.000$. Also, eleven districts inefficient status namely Jagtial, Jayashankar, Karimnagar, Khammam, KomaramBheem, Mahabubnagar, MedchalMalkajgiri, Nizamabad, Vikarabad, Warangal Rural, Warangal Urban and the remaining 21 districts inputs losses as per BCC Pure Technical efficiency scores in this analysis. From this analysis, we proposed that in order to increase their performance in terms of agricultural output in unproductive districts, they need to boost their potential.

From Table 2, it is clear that Jagtial, Jayashankar, Karimnagar, KomaramBheem, Mahabubnagar, MedchalMalkajgiri, Nizamabad, Vikarabad, Khammam, Warangal Rural, Warangal Urban districts are Technically (BCC) Efficient as compared to the 32 districts. It is observed that the Peers with all other districts seems to be Jagtial, Jayashankar, Karimnagar, Khammam, KomaramBheem, Mahabubnagar, Medchalmalkajgiri, Nizamabad, Vikarabad, Warangal Rural. Warangal Urbandistricts is having highest references. Peer contribution of this district is more comparable to other districts. For Example, Jagtial, Jayashankar, Karimnagar, Khammam, KomaramBheem, Mahabubnagar, Medchalmalkajgiri, Nizamabad, Vikarabad, Warangal rural, Warangal urban are performed well. These are BCC districts. Technically efficient districts are role models in and of themselves. The PTE of the Yadadri district is clearly 0.547. As a result, the Yadadri district is a border that is technically inefficient. When it comes to returns to scale, VRS is the way to go. It could have produced 0.547, or 54.70 percent, of the present outputs. As a result, all inefficiencies are eliminated by reducing all inputs by 0.453, or roughly 45 percent of their current values. In reality, by comparing with the reference set and peer weights, we can express the input and output values required to get Yadagiri district into efficient state. Similarly, we compare the performance of remaining inefficient areas in order to enhance crop yields in both the Rabi and Kharif seasons.

Table 2. The Pure Technical Efficiency scores of the districts for the financial year 2018-1

S. No.	District (DMU)	BCC technical efficiency	Number of references	Rank of DMUs	Number of peers	List of the peers
1	Adilabad	0.853	0	22	4	Khammam, KomaramBheem, Warangal Rural, Medchalmalkajgiri
2	Bhadradri	0.994	0	22	3	Khammam, Vikarabad, Medchalmalkajgiri
3	Jagtial	1.000	5	7	0	Jagtial
4	Jangaon	0.916	0	22	3	Medchalmalkajgiri, Warangal Urban, Khammam
5	Jayashankar	1.000	3	8.5	0	Jayashankar
6	Jogulamba	0.771	0	22	4	KomaramBheem, Warangal Rural, Medchalmalkajgiri, Khammam
7	Kamareddy	0.769	0	22	3	Warangal Urban, Khammam, Karimnagar
8	Karimnagar	1.000	2	10	0	Karimnagar
9	Khammam	1.000	21	1	0	Khammam
10	KomaramBheem	1.000	8	4	0	KomaramBheem
11	Mahabubabad	0.900	0	22	4	KomaramBheem, Warangal Rural, Medchalmalkajgiri, Khammam
12	Mabubnagar	1.000	1	11	0	Mabubnagar
13	Mancherial	0.887	0	22	4	KomaramBheem, Warangal Rural, Medchalmalkajgiri, Khammam
14	Medak	0.915	0	22	4	KomaramBheem, WarangalRural, Medchalmalkajgiri, Khammam
15	Medchalmalkajgiri	1.000	17	2	0	Medchalmalkajgiri
16	Mulugu	0.972	0	22	4	Warangal Rural, Warangal Urban, Medchalmalkajgiri, Khammam
17	Nagarkurnool	0.834	0	22	3	Warangal Rural, Vikarabad, Khammam
18	Nalgonda	0.588	0	22	3	Jagtial, Medchalmalkajgiri, Khammam
19	Narayanpet	0.929	0	22	4	KomaramBheem, Jayashankar, Warangal Rural, Vikarabad
20	Nirmal	0.965	0	22	4	Nizamabad, Warangal Rural, Warangal Urban, Khammam
21	Nizamabad	1.000	3	8.5	0	Nizamabad
22	Peddapalli	0.958	0	22	4	Nizamabad, Jagtial, MedchalMalkajgiri, Khammam
23	Rajanna	0.952	0	22	4	Warangal Rural, Warangal Urban, Medchalmalkajgiri, Khammam
24	Rangareddy	0.840	0	22	4	KomaramBheem, MedchalMalkajgiri, Vikarabad, Khammam
25	Sangareddy	0.971	0	22	4	Jayashankar, Warangal Rural, Vikarabad, Khammam
26	Siddipet	0.742	0	22	3	Vikarabad, Medchalmalkajgiri, Khammam
27	Suryapet	0.703	0	22	3	Jagtial, Medchalmalkajgiri, Khammam
28	Vikarabad	1.000	7	5.5	0	Vikarabad
29	Wanaparthy	0.926	0	22	4	Warangal Rural, Warangal Urban, Medchalmalkajgiri, Khammam
30	Warangal Rural	1.000	13	3	0	Warangal Rural
31	Warangal Urban	1.000	7	5.5	0	Warangal Urban
32	Yadadri	0.547	0	22	3	Jagtial, Medchalmalkajgiri, Khammam

The BCC Model distribution of the scores graph for the financial year 2018-19 is shows below:

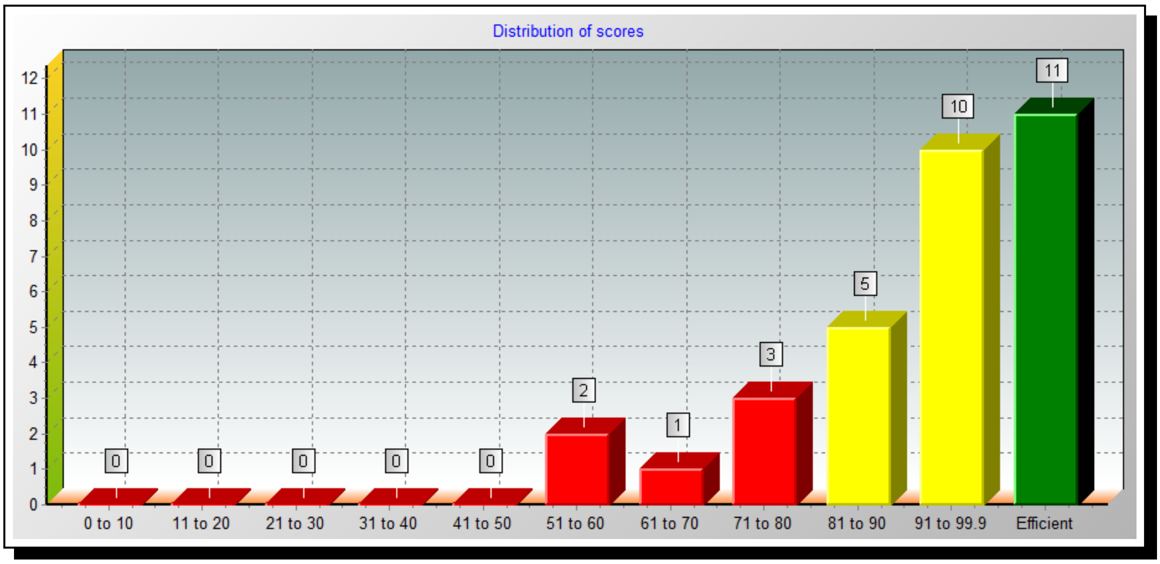

Figure 6. For the 2018-19 finacial year, the BCC Model Score Distribution Graph is constructed

From Figure 6, we observe that the score limits are 51-60 is 2 DMUs, 61-70 is no' DMU, 71-80 is 4 DMUs, 81-90 score is 5 DMUs, 91-99.9 score limit 10 DMUs. These DMUs are under inefficient frontier and 11 DMUs are in efficient status.

Table 3 shows that the efficiency scores variation for the 32 districts has the following boundary i.e., $0.778 = R^* = 1.000$. Also, nine districts are under efficient frontier and 23 districts inputs loses as per CCR Technical efficiency. These districts Potential improvements are required in order to improve the performance with regards to yield of crops in both rabi and kharif seasons.

From Table 3 it is clear that Bhadradri, Khammam, Mahbubnagar, Medak, Mulugu, Nirmal, Suryapet, Vikarabad, Warangal Rural are "Technically (CCR) Efficient" when compared to the 32 districts. It is observed that Bhadradri, Khammam, Mahabubnagar, Medak, Mulugu, Nirmal, Suryapet, Vikarabad, Warangal Rural are peers of the inefficient districts. We observe that Warangal Rural district is having highest references in this analysis and peer contribution of this district is more compare to other districts. Bhadradri, Khammam, Mahabubnagar, Medak, Mulugu, Nirmal, Suryapet, Vikarabad, Warangal Rural are Technically (CCR) Efficient and itself is a role model districts.

The district of KomaramBheem has a Technical Efficiency (TE) of 0.778, as seen in Table 3. As a result, the KomaramBheem district is technically inefficient. If the scaling mode is constant, the present outputs may have been 0.772, or 77.20 percent of the inputs. As a result, all inefficiencies are eliminated by reducing all inputs by 0.228, or roughly 23% of their current values. In reality, we may use the reference set and peer weight, as well as the input and output values, to bring the system up to speed. In a similar vein, we examine the remaining inefficient districts in order to enhance their performance in terms of agricultural yield.

Table 3. The Technical Efficiency scores of the districts for the Financial Year 2019-20

S. No.	Districts	Technical efficiency R^*	Number of references	Rank of DMUs	Number of peers	List of the peers
1	Adilabad	0.986	0	21	3	Medak, Vikarabad, Warangal Rural
2	Bhadradri	1.000	2	9	0	Bhadradri
3	Jagtial	0.887	0	21	3	Medak, Suryapet, Warangal Rural
4	Jangaon	0.962	0	21	2	Khammam, Mulugu
5	Jayashankar	0.942	0	21	2	Khammam, Mulugu
6	Jogulamba	0.879	0	21	3	Mahabubnagar, Medak, Warangal Rural
7	Kamareddy	0.946	0	21	3	Medak, Suryapet, Warangal Rural
8	Karimnagar	0.868	0	21	3	Khammam, Nirmal, Warangal Rural
9	Khammam	1.000	10	2	0	Khammam
10	KomaramBheem	0.778	0	21	1	Vikarabad
11	Mahabubabad	0.882	0	21	3	Khammam, Mahabubnagar, Warangal Rural
12	Mahabubnagar	1.000	8	4.5	0	Mahabubnagar
13	Mancherial	0.912	0	21	2	Mulugu, Vikarabad,
14	Medak	1.000	9	3	0	Medak
15	Medchalmalkajgiri	0.910	0	21	2	Vikarabad, Warangal Rural
16	Mulugu	1.000	4	8	0	Mulugu
17	Nagarkurnool	0.970	0	21	3	Khammam, Mahabubnagar, Warangal Rural
18	Nalgonda	0.888	0	21	3	Khammam, Vikarabad, Warangal Rural
19	Narayanpet	0.964	0	21	2	Bhadradri, Mahabubnagar
20	Nirmal	1.000	5	7	0	Nirmal
21	Nizamabad	0.928	0	21	3	Medak, Suryapet, Warangal Rural
22	Peddapalli	0.868	0	21	2	Khammam, Nirmal
23	Rajanna	0.959	0	21	3	Medak,Suryapet, Warangal Rural
24	Rangareddy	0.928	0	21	2	Mahabubnagar, Vikarabad
25	Sangareddy	0.855	0	21	2	Mahabubnagar, Vikarabad
26	Siddipet	0.966	0	21	3	Medak, Suryapet, Warangal Rural
27	Suryapet	1.000	6	6	0	Suryapet
28	Vikarabad	1.000	8	4.5	0	Vikarabad
29	Wanaparthy	0.889	0	21	3	Mahabubnagar, Medak, Warangal Rural
30	Warangal Rural	1.000	15	1	0	Warangal Rural
31	Warangal Urban	0.996	0	21	2	Khammam, Nirmal
32	Yadadri	0.930	0	21	3	Khammam, Nirmal, Warangal Rural

The CCR Model distribution of scores graph for the financial year 2019-20 is show below:

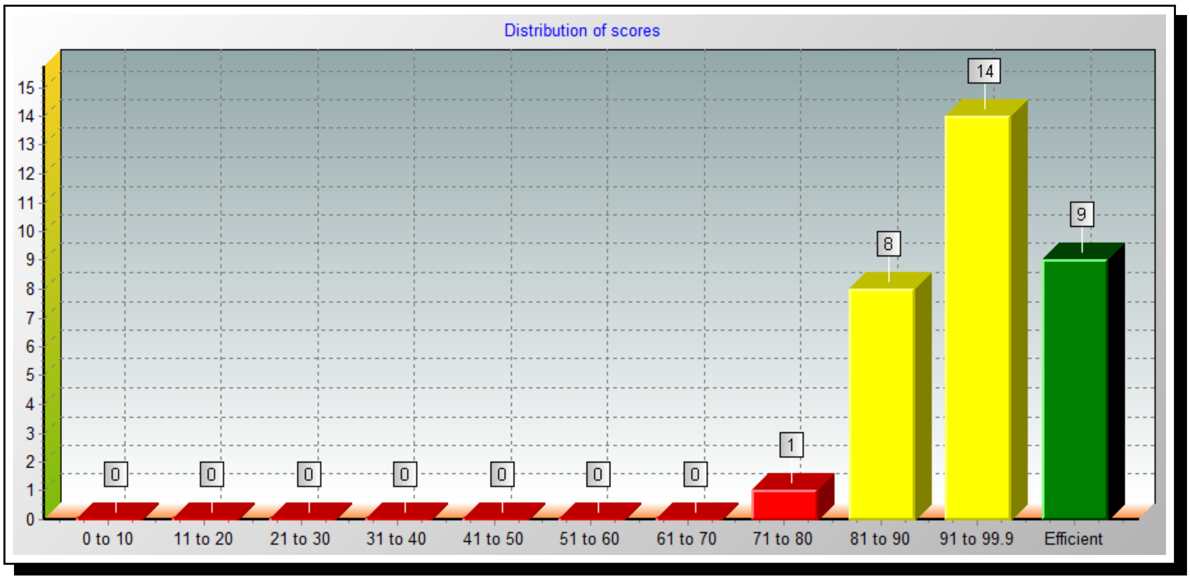

Figure 7. The graph depicting the CCR model's score distribution for the fiscal year 2019-20

From the above distribution (Figure 7) of scores graph, we observe that the score limit 71-80 is one DMU, 81-90 score 8 DMUs and 91-99.9 score limit 14 DMUs are technically under inefficient status and nine DMUs are in efficient status.

From Table 4, the pure technical efficiency variation for the 32 districts has the following bounds $0.823 \le R^* \le 1.000$. Also, 14 districts have been appearing in efficient status, 18 districts appear inefficient status and input loses as per BCC Pure Technical efficiency. These in efficient districts potential improvements are required in order to improve the performance with regards to yield of crops in both rabi and kharif seasons.

From Table 4 it is clear that Bhadradri, Khammam, Mahabubnagar, Medak, MedchalMalkajgiri, Mulugu, Nalgonda, Nirmal, Nizamabad, Siddipet, Suryapet, Vikarabad, Warangal Rural, Warangal Urban are Pure Technically (BCC) Efficient when compared to the 32 districts. It is observed that the peers to all other districts seems to be Bhadradri, Khammam, Mahabubnagar, Medak, MedchalMalkajgiri, Mulugu, Nalgoda, Nirmal, Nizamabad, Siddipet, Suryapet,Vikarabad, Warangal Rural, Warangal Urban, Warangal Rural district is having the highest references. The peer contribution of this district is high while compare to remaining districts in this data analysis.

The following DMUs Bhadradri, Khammam, Mahabubnagar, Medak, MedchalMalkajgiri, Mulugu, Nalgonda, Nirmal, Nizamabad, Siddipet, Suryapet, Vikarabad, Warangal Rural, Warangal Urban are Technically (BCC) in efficient status and these are role model districts.

Table 4. The Pure Technical Efficiency (PTE) scores of the districts for the financial year 2019-20

S. No.	Districts	Pure Technical Efficiency	Number of References	Rank of DMUs	Number of Peers	List of the Peers
1	Adilabad	0.985	0	22.5	4	Medak, Vikarabad, Warangal Rural, Medchalmalkajgiri
2	Bhadradri	1.000	3	12.5	0	Bhadradri
3	Jagtial	0.911	0	22.5	5	Nizamabad, Medak, Vikarabad, Warangal Rural, Siddipet
4	Jangaon	0.966	0	22.5	3	Khammam, Mulugu, Warangal Rural
5	Jayashankar	0.945	0	22.5	3	Khammam, Mulugu, Warangal Rural
6	Jogulamba	0.883	0	22.5	4	Mahabubnagar, Medak, Warangalrural, Medchalmalkajgiri
7	Kamareddy	0.988	0	22.5	4	Siddipet, Suryapet, Warangal Rural, Nizamabad
8	Karimnagar	0.869	0	22.5	4	Nirmal, Warangal Rural, Warangal Urban, Khammam
9	Khammam	1.000	9	1.5	0	Khammam
10	KomaramBheem	0.823	0	22.5	3	Vikarabad, Mahabubnagar, Medchalmalkajgiri
11	Mahabubabad	0.884	0	22.5	4	Khammam, Mahabubnagar, Warangal Rural, Medchalmalkajgiri
12	Mahabubnagar	1.000	7	5	0	Mahabubnagar
13	Mancherial	0.924	0	22.5	3	Mulugu, Vikarabad, Khammam
14	Medak	1.000	5	7.5	0	Medak
15	Medchalmalkajgiri	1.000	8	4	0	Medchalmalkajgiri
16	Mulugu	1.000	4	10	0	Mulugu
17	Nagarkurnool	0.983	0	22.5	4	Khammam, Nizamabad, Warangal Rural, Vikarabad,
18	Nalgonda	1.000	1	14	0	Nalgonda
19	Narayanpet	0.968	0	22.5	4	Bhadradri, Warangal Rural, Vikarabad, Suryapet
20	Nirmal	1.000	4	10	0	Nirmal
21	Nizamabad	1.000	4	10	0	Nizamabad
22	Peddapalli	0.869	0	22.5	3	Khammam, Nirmal, Warangal Urban
23	Rajanna	0.969	0	22.5	4	Medak, Suryapet, Warangal Rural, Medchalmalkajgiri
24	Rangareddy	0.928	0	22.5	3	Mahabubnagar, Vikarabad
25	Sangareddy	0.856	0	22.5	3	Mahabubnagar, Vikarabad, Bhadradri
26	Siddipet	1.000	3	12.5	0	Siddipet
27	Suryapet	1.000	5	7.5	0	Suryapet
28	Vikarabad	1.000	9	1.5	0	Vikarabad
29	Wanaparthy	0.892	0	22.5	4	Mahabubnagar, Medak, Warangal Rural, Medchalmalkajgiri
30	Warangal Rural	1.000	12	1	0	Warangal Rural
31	Warangal Urban	1.000	6	6	0	Warangal Urban
32	Yadadri	0.931	0	22.5	4	Warangal Rural, Warangal Urban, Nirmal, Khammam

The BCC Model distribution of the scores graph for the financial year 2019-20 is presented below:

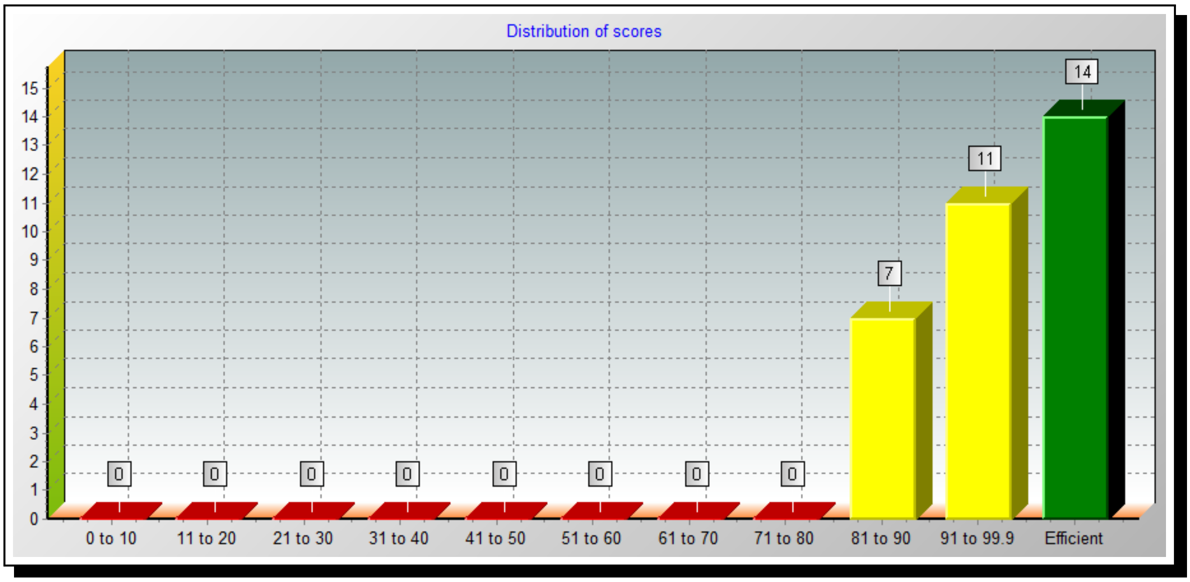

Figure 8. The BCC Model Distribution of Scores Graph for the financial year 2019-20

From Figure 8, Scores Graph for the financial year 2019-20; the score limit 81-90 7 DMUs and 91-99.9 score limit 11 DMUs. These DMUs are follow under inefficient status and nine DMUs are in efficient status in this financial year.

From Table 5 we observe that thirteen out of 32 districts for the financial year 2018-19 and fifteen out of 32 districts in 2019-20 are below average as per CCR model efficiency scores.

As per BCC model efficiency scores, eleven out of 32 districts in 2018-19 and twelve out of 32 districts in 2019-20 are in below average.

As per BCC model analysis 11 districts are under efficient status in addition to that 7 districts are under efficient as per CCR Model efficiency scores, which retain its previous efficient frontier in the financial year 2018-19 and 14 districts are efficient frontier in addition to that eight districts in efficient as per CCR Model scores, which retain its previous efficient frontier for the financial year 2019-20.

Under the Scale Efficiency 5 out of 32 districts in 2018-19 and 5 out of 32 districts in the financial year 2019-20 were below average.

From Table 5, it noticed that for the financial year 2018-19 Jagitial, Karimnagar, Khammam, Nizamabad, Vikarabad, Warangal Rural, Warangal Urban Districts efficient in CCR as well as BCC model.These seven districts are under MPSS status, while Adilabad, Jangaon, Jogulamba, Kamareddy, Mahabuabad, Mancherial, Medak, Mulugu, Nagar Kurnool, Nalgonda, Naryanpet, Nirmal, Rangareddy, Sangareddy, Siddipet, Suryapet, Wanaparthy, Yadadri districts shows increasing returns to scale and Bhadradri, Jayashankar, Komarambheem, Mahabubnagar, MedchalMalkajgiri, Peddapalli, Rajanna districts shows decreasing returns to scale.

Table 5. Summary of Data Envelopment Analysis efficiency scores for the financial years 2018-19 and 2019-2020

S. No.	District (DMU)	2018-19				2019-2020			
		TE	PTE	SE	RTS	TE	PTE	SE	RTS
1	Adilabad	0.837	0.853	0.981	IRS	0.986	0.985	1.000	IRS
2	Bhadradri	0.698	0.994	0.702	DRS	1.000	1.000	1.000	CRS
3	Jagtial	1.000	1.000	1.000	CRS	0.887	0.911	0.975	IRS
4	Jangaon	0.882	0.916	0.963	IRS	0.962	0.966	0.995	IRS
5	Jayashankar	0.965	1.000	0.965	DRS	0.942	0.945	0.997	IRS
6	Jogulamba	0.734	0.771	0.952	IRS	0.879	0.883	0.995	IRS
7	Kamareddy	0.766	0.769	0.996	IRS	0.946	0.988	0.957	DRS
8	Karimnagar	1.000	1.000	1.000	CRS	0.868	0.869	0.999	IRS
9	Khammam	1.000	1.000	1.000	CRS	1.000	1.000	1.000	CRS
10	Komarambheem	0.966	1.000	0.966	DRS	0.778	0.823	0.945	IRS
11	Mahabubabad	0.882	0.900	0.98	IRS	0.882	0.884	0.998	IRS
12	Mahabubnagar	0.957	1.000	0.957	DRS	1.000	1.000	1.000	CRS
13	Mancherial	0.848	0.887	0.956	IRS	0.912	0.924	0.987	IRS
14	Medak	0.853	0.915	0.932	IRS	1.000	1.000	1.000	CRS
15	MedchalMalkajgiri	0.470	1.000	0.47	DRS	0.910	1.000	0.91	DRS
16	Mulugu	0.926	0.972	0.955	IRS	1.000	1.000	1.000	CRS
17	Nagarkurnool	0.833	0.834	0.999	IRS	0.970	0.983	0.987	DRS
18	Nalgonda	0.586	0.588	0.996	IRS	0.888	1.000	0.888	DRS
19	Narayanpet	0.915	0.929	0.985	IRS	0.964	0.968	0.996	IRS
20	Nirmal	0.953	0.965	0.987	IRS	1.000	1.000	1.000	CRS
21	Nizamabad	1.000	1.000	1.000	CRS	0.928	1.000	0.928	DRS
22	Peddapalli	0.94	0.958	0.981	DRS	0.868	0.869	0.999	IRS
23	Rajanna	0.899	0.952	0.944	DRS	0.959	0.969	0.990	IRS
24	Rangareddy	0.816	0.840	0.971	IRS	0.928	0.928	1.000	IRS
25	Sangareddy	0.97	0.971	0.999	IRS	0.855	0.856	0.999	IRS
26	Siddipet	0.733	0.742	0.988	IRS	0.966	1.000	0.966	DRS
27	Suryapet	0.698	0.703	0.993	IRS	1.000	1.000	1.000	CRS
28	Vikarabad	1.000	1.000	1.000	CRS	1.000	1.000	1.000	CRS
29	Wanaparthy	0.911	0.926	0.984	IRS	0.889	0.892	0.997	IRS
30	Warangal Rural	1.000	1.000	1.000	CRS	1.000	1.000	1.000	CRS
31	Warangal Urban	1.000	1.000	1.000	CRS	0.996	1.000	0.996	DRS
32	Yadadri	0.525	0.547	0.960	IRS	0.930	0.931	0.999	DRS
	Average	0.861	0.904	0.955		0.940	0.955	0.985	

For the financial year 2019-20, Bhadradri, Khammam, MahabuNagar, Medak, Medchal, Mulugu, Nirmal, Suryapet, Vikarabad, Warangal Rural districts are efficient in both models. These 10 districts are under Most Productive Scale Size status. Adilabad, Jagitial, Jangaon, Jogulamba, Karimnagar, Kommarambheem, Mahabuabad, Mancherial, Naryanpet, Peddapalli, Rajanna, Rangareddy, Sangareddy, Wanaparthy districts shows increasing returns to scale and

Kamareddy, Kamareddy, Nagar Kurnool, Nalgonda, Nizamabad, Siddipet, Warangal Urban, Yadadri districts shows decreasing returns to scale.

The CCR Model TE and BCC Model PTE efficiency score summary for the financial years 2018-19 and 2019-20 is presented below for the clarity of data analysis.

Table 6. Efficiency scores summary for the financial years 2018-19 and 2019-20

	2018-19		2019-20	
	TE of CCR Model	TE of BCC Model	TE of CCR Model	TE of BCC Model
Average Efficiency	0.8613	0.9041	0.940	0.9554
SD of Efficiency	0.1442	0.1232	0.0573	0 .0545
CV of Efficiency	16.74%	13.6%	6.10%	5.7%
Efficiency-Minimum	0.470	0.547	0.778	0.823
Efficiency-Maximum	1.000	1.000	1.000	1.000
Number of Efficient DMUs (districts)	8	11	9	15
Total number of DMUs (districts)	32	32	32	32

From Table 6 we observe that for the financial year 2018-19 the average agriculture Technical Efficiency is 0.8613, the standard deviation is 0.1442 and CV is 16.74%. The maximum and minimum technical efficiency is 1 and 0.470 respectively. In 2019-20 the average agriculture technical efficiency in 32 districts is 0.940, the standard deviation is 0.0573 and 6.10%. The maximum and minimum technical efficiency is 1 and 0.778 respectively.

For the financial year 2018-19 the average agriculture Pure Technical Efficiency in 32 districts is 0.9041, the standard deviation is 0.1232 and CV is 13.6%. The maximum and minimum Pure technical efficiency is 1 and 0.547 respectively. In 2019-20 the average agriculture technical efficiency in 32 districts is 0.9554; the standard deviation is 0 .0545and 5.7%. The maximum and minimum pure technical efficiency is 1 and 0.823 respectively.

5. Conclusion

From this Study, For the finacial year 2018-19, we discovered Jagtial, Karimnagar, Khammam, Nizamabad, Vikarabad, Warangal rural, Warangal urban district farmers performs well as per CCR Technical Efficiency. Jagtial, Jayashankar, Karimnagar, Khammam, Komaram Bheem, Mahabubnagar, Medchal Malkajgiri, Nizamabad, Vikarabad, Warangal Rural, Warangal Urban district farmers performs well as per BCC Pure Technically Efficiency when compared to the 32 districts.

For the financial year 2019-20 Bhadradri, Khammam, Mahabubnagar, Medak, Mulugu, Nirmal, Suryapet, Vikarabad, Warangal Rural farmers performs well as per CCR Technical Efficiency. Bhadradri, Khammam, Mahabubnagar, Medak, Medchal Malkajgiri, Mulugu, Nalgonda, Nirmal, Nizamabad, Siddipet, Suryapet, Vikarabad, Warangal Rural, Warangal Urban district farmers performs well as per BCC Pure Technically Efficiency when compared to the 32 districts. From the new integrated model evaluation, we found that that Khammam, Vikarabad, Warangal rural districts farmers performs well for the both the financial years.

Potential Improvement is essential for improving in their performance with regards to yield of crops for the remainig ineffieient ditricts. Thus, removal of all inefficiencies is achieved by reducing all inputs by % of their observed values and need to bring every districts into efficient status. The Nation is motivated to find ways and continue its increase rapidly population effectively fed. In such a scenario, leveraging the available natural resources and existing sources is the only way to generate the ends to meet.

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

References

[1] R. D. Banker, A. Charnes and W. W. Cooper, Some models for estimating technical and scale inefficiencies in data envelopment analysis, *Management Science* **30**(9) (1984), 1078 – 1092, URL: http://www.jstor.org/stable/2631725.

[2] A. Charnes, W. W. Cooper and E. Rhodes, Measuring the efficiency of decision making units, *European Journal of Operational Research* **2**(6) (1978), 429 – 444, DOI: 10.1016/0377-2217(78)90138-8.

[3] P. K. Donthula, R. Nellutla and V. V. Haragopal, Measuring the technical efficiency in agriculture farming through CCR model by data envelopment analysis, *IOSR Journal of Mathematics* **17**(4) (2021), 1-8, URL: https://www.iosrjournals.org/iosr-jm/papers/Vol17-issue4/Ser-2/A1704020108.pdf.

[4] F. J. Kwimbere, *Measuring Efficiency in Not-for-Profit Organizations: An Attempt to Evaluate Efficiency in Selected UK University Departments*, Thesis, School of Management, University of Bath (1987).

[5] R. Nellutla, R. Ashok, M. Ramesh and V. V. Haragopal, Technical efficiency of universities in telangana state through data envelopment analysis (DEA) approach, *EJ-MATH European Journal of Mathematics and Statistics* **2**(6) (2021), 30 – 39, DOI: 10.24018/ejmath.2021.2.6.62.

[6] R. Nellutla, M. Goverdhan and V. V. Haragopal, Measuring the technical efficiency of decision making units by CCR model in data envelopment analysis, *International Journal of Scientific Research in Mathematical and Statistical Sciences* **5**(4) (2018), 54 – 60, DOI: 10.26438/ijsrmss/v5i4.5460.

[7] R. Nellutla, V. V. Haragopal and D. Vijayalaxmi, Technical efficiency of management wise schools in secondary school examinations of Andhra Pradesh by CCR model, *IOSR Journal of Mathematics* **13**(1) (2017), 1 – 8, DOI: 10.9790/5728-1301020108.

[8] G. D. Rede and K. Bhattacharyya, Efficiency of pomegranate growers: A data envelopment analysis, *Economic Affairs* **65**(2) (2020), 161 – 166, DOI: 10.46852/0424-2513.2.2020.4.

[9] M. Rutter and B. Maughan, School effectiveness findings 1979–2002, *Journal of School Psychology* **40**(6) (2002), 451 – 475, DOI: 10.1016/S0022-4405(02)00124-3.

[10] B. Vittal, R. Nellutla and M. K. Reddy, Selection and analysis of input-output variables using data envelopment analysis of decision making units – Indian private sector banks, *International Journal of Engineering and Advanced Technology* **10**(5) (2021), 119 – 126, DOI: 10.35940/ijeat.E2674.0610521.

[11] S. Ye, Appraisal of agriculture production efficiency in Shandong province based on data envelopment analysis, *International Journal of Managerial Studies and Research* **3**(1) (2015), 12 – 17, URL: https://www.arcjournals.org/pdfs/ijmsr/v3-i1/3.pdf.