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Environmental efficiency analysis of India's regional industry: a data envelopment analysis (DEA) based approach

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ABSTRACT
The economy of India is the sixth-largest in the world measured by nominal GDP and the third-largest by purchasing power parity (PPP). The country is classified as a newly industrialized country, and one of the G-20 major economies, with an average growth rate of approximately 7% over the last two decades. In this paper, we aim to make environmental efficiency analysis of India's regional industry. there is a growth rate of approximately 13% in pollution over the last 4 years. Data envelopment analysis (DEA) method is a constant return to scale measure (CRS) model considering undesirable outputs is introduced to measure the environmental efficiency of different regions. Big data is introduced in the collection and selection of the input and output data of the states and regions of India. Further, we evaluate the environmental efficiencies of India's industry using data from 2015 to 2019. The results show that apart from several developed provinces, the environmental efficiencies of India's industry are generally low. And the environmental efficiencies of the regions did not show any increasing trend through the past 4 years. Moreover, lager differences exist in environmental efficiencies between the regions in India. Finally, we suggest the Indian government to focus on the low environmental efficiencies and the unbalanced development of its regional industry

KEYWORDS *Environmental efficiency India's regional industry Data envelopment analysis Big data*

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I. INTRODUCTION

The economy of India is the sixth-largest in the world measured by nominal GDP and the third-largest by purchasing power parity (PPP). The country is classified as a newly industrialized country, and one of the G-20 major economies, with an average growth rate of approximately 7% over the last two decades. India's economy will be larger than the UK's, for the first time in more than 100 years. This dramatic shift has been driven by India's rapid economic growth over the past 25 years.

India has made fruitful achievements with accelerating its export product. For example, Jewellery--41.2 billion dollars, Machinery--13.6 billion dollars, Cereals--10.1 billion dollars, and many more. There is no doubt that industrial growth makes a significant contribution to India's economic development. However, along with there is a huge and serious environmental pollution, India's industrial production has features of high energy consumption and high emissions. One typical environmental problem is greenhouse gas emissions.

The Indian government also attaches great importance to environmental problems in recent years, several environmental laws and regulations has been enacted to restrict high polluting enterprises.

Environmental laws

In the Constitution of India, it is clearly stated that it is the duty of the state to 'protect and improve the environment and to safeguard the forests and wildlife of the country'. It imposes a duty on every citizen 'to protect and improve the natural environment including forests, lakes, rivers, and wildlife'. Reference to the environment has also been made in the Directive Principles of State Policy as well as the Fundamental Rights. The Department of Environment was established in India in 1980 to ensure a healthy environment for the country. This later became the Ministry of Environment and Forests in 1985.

The constitutional provisions are backed by several laws – acts, rules, and notifications. The EPA (Environment Protection Act), 1986 came into force soon after the Bhopal Gas Tragedy and is considered an umbrella legislation as it fills many gaps in the existing laws. Thereafter many laws came into existence as the problems began arising, for example, Handling and Management of Hazardous waste rule in 1989.

Environmental performance evaluation has been the focus of study in the past several decades. Environmental performance index (EPI) plays an important role in assessing environmental efficiency. The Environmental Performance Index (EPI) is a method of quantifying and numerically marking the environmental performance of a state's policies. This index was developed from the Pilot Environmental Performance Index, first published in 2002,and designed to supplement the environmental targets set forth in the United Nations Millennium Development Goals. The Environmental Performance Index (EPI) ranks countries' performance on high-priority environmental issues in two areas: protection of human health and protection of ecosystems.

There are two main methods on environmental efficiency evaluation. The first one is stochastic frontier analysis method, which is parametric approach. The second one is a nonparametric method, which is known as data envelopment analysis (DEA). Stochastic Frontier approach is generally applicable to a single output scenario, but need to estimate the specific functional form. Incorrect functional form may lead to get incorrect results. Data envelopment analysis, as a nonparametric method was first proposed by Charnesat(1978). It can be used to evaluate the relative efficiency of a set ofhomogeneous decision-making units. In addition, it does not require a specific form of the production function and is especially suitable for multi-input and multi-output scenarios. For the effectiveness in identifying the best-practice frontier and ranking the DMUs of DEA method, it has been popularly used in benchmarking and efficiency evaluation of schools, hospitals, bank branches and so on. As the industrial production always use energy resources and labor to produce desirable outputs, such profits and GDP. We choose DEA as our analysis approach for the India's industry evaluation in this paper.

As we know, environmental factors are always considered as undesirable outputs. In order to use DEA method to evaluate the environmental efficiency of India's industry, we have to deal with undesirable outputs in the model. Recently, modeling of undesirable outputs (such as pollution, waste) has attracted considerable attention in the DEA literature. The literature in this area may be classified into three categories.

a) The first category is taking the undesirable outputs as inputs for processing. This approach only needs the information on whether the data should be minimized or maximized, but it cannot reflect the real production process.
b) The second category is conducting data transformation to undesirable outputs first, and then evaluating the environmental efficiency by using the DEA model based on the transformed data.
c) The third one is a direct approach. It based on Fare et al. (1989) which replace strong unnecessary of outputs which are assumed weakly useless. The work in this direction has been extensively developed

However, the data are huge and indicators are numerous for different regions in India, which has made the data-collection, data storage, data selection, and data analysis very difficult in the evaluation. Therefore, DEA is used to managing and selecting the data to evaluate the environment efficiency of India.

DATA ENVELOPMENT ANALYSIS (DEA)

William W. Cooper (1978): “Data envelopment analysis is a method for evaluating decision making units within an organization, by using imputed shadow prices. These prices are computed using a fractional program that is solved by reducing it to a linear program.”

- Data envelopment analysis (DEA) is a nonparametric method in operations research and economics for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision making units (or DMUs).
- Data Envelopment Analysis (DEA) measures the relative efficiencies of organizations with multiple inputs and multiple outputs. The organizations are called the decision-making units, or DMUs.
- DEA is a mathematical programming approach to provide a relative efficiency assessment (called DEA efficient) for a group of decision making units (DMU) with multiple number of inputs and outputs.
- DEA assigns weights to the inputs and outputs of a DMU that give it the best possible efficiency. It thus arrives at a weighting of the relative importance of the input and output variables that reflects the emphasis that appears to have been placed on them for that DMU.
- It concerned with evaluations of performance and it is especially concerned with evaluating the activities of organizations such as business firms, government agencies, hospitals, educational institutions

DEA has been used for both production and cost data. Utilizing the selected variables, such as unit cost and output, DEA software searches for the points with the lowest unit cost for any given output, connecting those points to form the efficiency frontier. Any company not on the frontier is considered inefficient. A numerical coefficient is given to each firm, defining its relative efficiency. Different variables that could be used to establish the efficiency frontier are: number of employees, service quality, environmental safety, and fuel consumption. An early survey of studies of electricity distribution companies identified more than thirty DEA analyses—indicating widespread application of this technique to that network industry. A number of studies using this technique have been published for water utilities. The main advantage to this method is its ability to accommodate a multiplicity of inputs and outputs. It is also useful because it takes into consideration returns to scale in calculating efficiency, allowing for the concept of increasing or decreasing efficiency based on size and output levels. A drawback of this technique is that model specification and inclusion/exclusion of variables can affect the results."

Under general DEA benchmarking, for example, "if one benchmarks the performance of computers, it is natural to consider different features (screen size and resolution, memory size, process speed, hard disk size, and others). One would then have to classify these features into “inputs” and “outputs” in order to apply a proper DEA analysis. However, these features may not actually represent inputs and outputs at all, in the standard notion of production. In fact, if one examines the benchmarking literature, other terms, such as “indicators”, “outcomes”, and “metrics”, are used. The issue now becomes one of how to classify these performance measures into inputs and outputs, for use in DEA.

APPLICATIONS

- It is most useful when a comparison is sought against "best practices" where the analyst doesn't want the frequency of poorly run operations to affect the analysis. DEA has been applied in many situations such as: health care (hospitals, doctors), education (schools, universities), banks, manufacturing, benchmarking, management evaluation, fast food restaurants, and retail stores.
- The analyzed data sets vary in size. Some analysts work on problems with as few as 15 or 20 DMUs while others are tackling problems with over 10,00 DMUs.

STRENGTHS OF DEA

DEA can be a powerful tool when used wisely. A few of the characteristics that make it powerful are:

- The main advantage to this method is its ability to accommodate a multiplicity of inputs and outputs.
- It doesn't require an assumption of a functional form relating inputs to outputs.
- DMUs are directly compared against a peer or combination of peers.
- Inputs and outputs can have very different units. For example, X1 could be in units of lives saved and X2 could be in units of lives saved and X2 could be in units of dollars without requiring an a priori tradeoff between the two.

DRAWBACK

- A drawback of this technique is that model specification and inclusion/exclusion of variables can affect the results

II. METHOD AND MODELS

Before introducing the method and the models that will be used in this paper, we first define the symbols that will be used.

Data

K = inputs

M = outputs
N = Number of DMU’s
i = 1, 2……, K: index for inputs
X = input matrix
Y = output matrix
x_i = *the i-th input of DMU*
y_i = *the i-th output of DMU*
u’ = vector of output weights
v’ = vector of input weights
θ = scalar constant λ = vector constants

We shall begin by defining some notation. Assume there is data on K inputs and M outputs on each of N firms or DMU's as they tend to be called in the DEA literature. For the i-th DMU these are represented by the vectors xi and yi, respectively. The KxN input matrix, X, and the MxN output matrix, Y, represent the data of all N DMU's. The purpose of DEA is to construct a non-parametric envelopment frontier over the data points such that all observed points lie on or below the production frontier. For the simple example of an industry where one output is produced using two inputs, it can be visualized as a number of intersecting planes forming a tight-fitting cover over a scatter of points in three-dimensional space. Given the CRS assumption, this can also be represented by a unit isoquant in input/input space.

The best way to introduce DEA is via the *ratio* form. For each DMU we would like to obtain a measure of the ratio of all outputs over all inputs, such as u'yi/v'xi, where u is an Mx1 vector of output weights and v is a Kx1 vector of input weights. To select optimal weights, we specify the mathematical programming problem:

$\max_{u,v} (u'y_i/v'x_i)$,

$u'y_j/v'x_j \leq 1, j=1,2,...,N$,

$u', v' \geq 0$.

This involves finding values for u and v, such that the efficiency measure of the i-th DMU is maximized, subject to the constraint that all efficiency measures must be less than or equal to one. One problem with this ratio formulation is that it has an infinite number of solutions. To avoid this one can impose the constraint v'xi = 1, which provides:

$\max_{\mu,\nu} (\mu' y_i)$,

$\nu' x_i = 1$,

$\mu' y_i - \nu' x_i \leq 0, i=1,2,...,N$,

$\mu, \nu \geq 0$,

where the notation change from u and v to μ and ν reflects the transformation. This form is known as the *multiplier* form of the linear programming problem.

Using the duality in linear programming, one can derive an equivalent *envelopment* form of this problem:

$\min_{\theta,\lambda} \theta$,

$-y_i + Y\lambda \geq 0$,

$\theta x_i - X\lambda \geq 0$,

$\lambda \geq 0$,

where θ is a scalar and λ is a Nx1 vector of constants? This envelopment form involves fewer constraints than the multiplier form (K+M < N+1), and hence is generally the preferred form to solve. The value of θ obtained will be the efficiency score for the i-th DMU. It will satisfy θ≤ 1, with a value of 1 indicating a point on the frontier and hence a technically efficient DMU, according to the Farrell (1957) definition. Note that the linear programming problem must be solved N times, once for each DMU in the sample. A value of θ is then obtained for each DMU.

The input and output indicators and the data

- The input and output indicators

In order to use the proposed model to make environmental efficiency evaluation for the DMUs (regions in India), we need firstly give the input and output indicator of each DMU. To avoid the situation in which many DMUs are evaluated as DEA efficient, we accept the principle of DEA theory that the number of the DMUs should be not less than five times the total number of the input and output indicators. In addition, with the consideration of the input and output indicators in Wu et al. (2014), and Song and Guan (2014). And since we make environmental efficiency evaluation of 27 DMUs in India, in this paper we use three inputs and three outputs in the evaluation. The input and output indicator for the DMUs are listed as below.

Input

X1: Total number of employees of industry (NE 10,000)

X2: Total energy consumption (EC 10,000 tce)

X3: Total investment in fixed cost of industry (FC 100 million Rs)

Desirable output

Y1: Gross domestic product in the region (GDP 100 million Rs)

Undesirable outputs

Y1: Total emissions of carbon dioxide (E $CO_2$10,000 tons)

Y2: Industrial solid waste (ISW 10,000 tons)

As can be seen from these indicators, the outputs are distinguished into desirable output (GDP) and undesirable outputs (E CO_2 and ISW).

We then collected the corresponding data (2016 to 2019) from India Annual Survey ofIndustries. A simple descriptive statistical analysis of the data is given in various tables.

Environmental efficiency analysis of India's regional industry

In this section, we make the environmental efficiency analysis of India's regional industry using our proposed approach. We mainly concern to analyze the regional environmental efficiency for each DMU.

Environmental efficiency of the states of INDIA from 2015 to 2019

Table 1

Statistical data of 2015-16

STATES	NE	FC	EC	GDP	E CO2	ISW
Maharashtra	188.0606	26096.562	70853.8	209954.8	12.256	570233.2
Gujarat	138.3773	31274.639	356813.5	60456.3	10.023	5668158.25
Tamil Nadu	194.0819	16145.171	244944.6	66531.2	7.259	816655.8
Karnataka	90.6473	13192.146	101265.9	45521.2	7.212	489412.408
Uttar Pradesh	86.4346	9064.742	160697	68900.7	11.951	434932.87
Haryana	58.2372	5385.588	65973.9	30195.9	7.285	433839.4
Uttarakhand	34.2385	5066.863	40874.7	9769.6	7.952	54381.648
Rajasthan	47.4883	5301.625	104052.2	40342.2	9.395	403179.24
Telangana	58.2372	0	98456.2	0	0	0
Andhra Pradesh	136.2788	25393.903	187134.8	66259.2	9.885	358024.4
West Bengal	65.4276	7169.937	108421.6	53820.9	9.615	815772.64
Himachal Pradesh	16.344	4449.031	31766.6	6495.7	8.086	224694.14
Madhya Pradesh	31.4838	4990.615	86477	31167	6.215	329059.2
Jharkhand	19.6793	6742.579	137473.2	14389.1	6.278	1544692.01
Punjab	60.0041	3734.551	105703.9	25643	7.589	215958.72
Odisha	28.4637	16080.526	103936.8	21458.3	4.268	166150.38
Chattisgarh	18.5985	5063.239	77544.1	13287.2	5.298	14346.4
Kerala	39.3425	1546.086	50291.6	30790.6	5.528	517107.824
Goa	6.5974	860.627	13731.2	3602.5	2.515	21895.65
Assam	18.0531	1515.746	20330.8	12582	5.389	17978.8
Jammu & Kashmir	6.3704	440.142	5404	6575.9	2.984	10585.98
Sikkim	0.8906	113.924	783.3	861.6	1.142	2713.104
Bihar	12.6592	754.715	24953.8	24731.8	6.248	153361.2
Meghalaya	1.1005	281.066	5656.4	1641.2	2.287	21481.464
Tripura	0.2521	35.095	1263.4	2098.2	2.018	25060.5
Nagaland	0.2521	12.731	58.7	1320.3	2.134	13440.257
Manipur	0.5303	5.826	5.3	1050.4	1.975	8335.44

Table 2

Environmental efficiency of the states in 2015-16

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Maharashtra	1.00000
2	Gujarat	1.00000
3	Tamil Nadu	0.43947
4	Karnataka	0.66360
5	Uttar Pradesh	0.90856
6	Haryana	0.73702
7	Uttarakhand	0.73830

8	Rajasthan	0.9716 7
9	Telangana	0.0000 0
10	Andhra Pradesh	0.6107 9
11	West Bengal	0.9863 9
12	Himachal Pradesh	1.0000 0
13	Madhya Pradesh	1.0000 0
14	Jharkhand	1.0000 0
15	Punjab	0.5764 7
16	Odisha	0.7615 5
17	Chattisgarh	0.9268 2
18	Kerala	1.0000 0
19	Goa	1.0000 0
20	Assam	1.0000 0
21	Jammu & Kashmir	0.1832 0
22	Sikkim	0.1710 8
23	Bihar	0.3517 3
24	Meghalaya	0.2526 4
25	Tripura	1.0000 0
26	Nagaland	1.0000 0
27	Manipur	1.0000 0

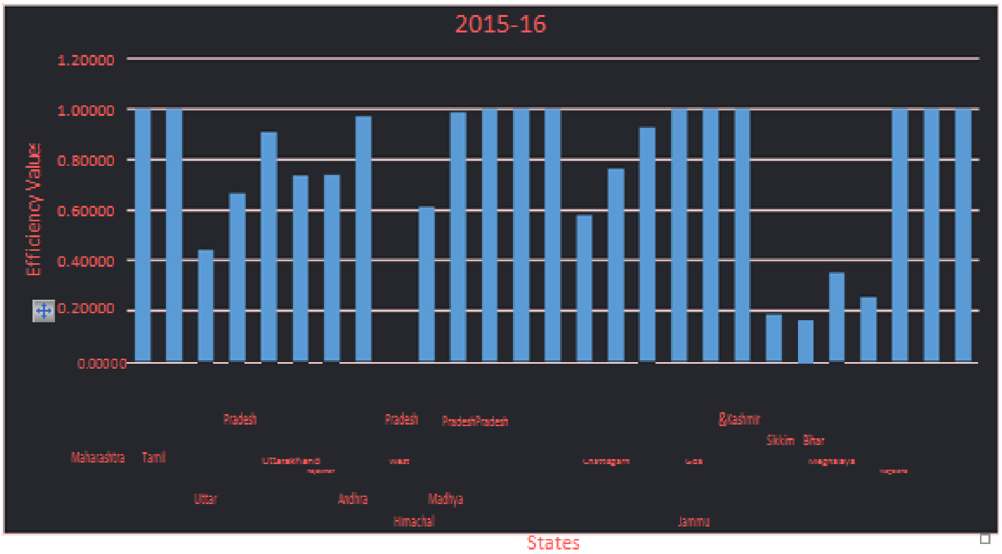

Figure 1._Environmental efficiency of the states_

Table 3

Statistical data of 2016-17

STATES	NE	FC	EC	GDP	E CO2	ISW
Maharashtra	178.4909	34492.959	348804.8	144846.6	12.208	689989.2
Gujarat	136.3628	32612.528	379193.9	71212.3	12.042	6152658.23
Tamil Nadu	196.502	18724.233	264031.8	85148.5	8.883	965615.8
Karnataka	86.2203	14515.109	102879.6	69001.5	9.026	511204.85
Uttar Pradesh	82.5537	10271.141	176760.2	81221	13.285	486688.513
Haryana	56.6595	7839.623	80052.4	35040.7	9.986	532389.45
Uttarakhand	33.53	5299.803	50862.1	13291.9	10.685	60919.86
Rajasthan	44.3027	6142.162	127599.9	49400.4	10.385	411078.61
Telangana	70.111	5847.297	102441.9	0	0	0
Andhra Pradesh	50.3615	13081.848	130552.2	81506.6	10.643	393164.2
West Bengal	65.6123	8206.693	121038.5	61350.2	10.804	1060932.642
Himachal Pradesh	18.4833	4009.16	40592.9	8229.4	10.09	312294.87
Madhya Pradesh	30.2209	13657.975	96526.5	36382.6	8.062	3808015.2
Jharkhand	18.8046	6728.469	146074.4	17472.4	8.615	1641790.54
Punjab	58.352	3906.929	117355.6	29773.4	9.826	240365.76
Odisha	26.3651	16377.525	117528.3	25527.3	5.457	187942.38
Chattisgarh	17.3076	6030.773	87955.5	17883.9	6.624	17070.4
Kerala	38.0498	1870.369	55491.1	41231.3	7.542	593652.45
Goa	5.5831	827.836	13776.2	3864.7	3.895	22990.25
Assam	16.7835	1310.951	21124.3	15740.6	6.279	21610.4
Jammu & Kashmir	6.0658	524.823	7491.9	8653.7	3.873	12048.57
Sikkim	1.0278	144.075	591	1233.8	2.086	3257.904
Bihar	11.6396	646.737	27686.9	28216.8	8.549	156993.2

Meghalaya	1.1986	349.006	7627.1	2159.7	2.878	24477.94
Tripura	2.8526	33.927	1299.1	2166.3	3.578	29419.2
Nagaland	0.3039	17.412	68	1361.9	4.287	15891.817
Manipur	0.6084	7.561	320.5	1323.8	4.189	9697.44

Table 4
Environmental efficiency of the states in 2016-17

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Maharashtra	0.61596
2	Gujarat	0.66664
3	Tamil Nadu	0.43374
4	Karnataka	0.90129
5	Uttar Pradesh	0.77537
6	Haryana	0.63129
7	Uttarakhand	0.72420
8	Rajasthan	0.90068
9	Telangana	0.00000
10	Andhra Pradesh	1.00000
11	West Bengal	0.77397
12	Himachal Pradesh	0.98546
13	Madhya Pradesh	1.00000
14	Jharkhand	1.00000
15	Punjab	0.55288
16	Odisha	0.67716
17	Chattisgarh	0.87199
18	Kerala	1.00000
19	Goa	1.00000
20	Assam	1.00000
21	Jammu & Kashmir	0.31835
22	Sikkim	0.26787
23	Bihar	0.55191
24	Meghalaya	0.40207
25	Tripura	0.69751
26	Nagaland	1.00000
27	Manipur	1.00000

Figure 2.*Environmental efficiency of the states*

Table 5
Statistical data of 2017-18

STATES	NE	FC	EC	GDP	E CO2	ISW
Maharashtra	188.6025	32636.16	435530.3	164750.6	14.455	826189.2
Gujarat	137.2669	38265.385	397992.3	80674.5	14.619	6544158.45
Tamil Nadu	204.6553	27081.648	301664.3	98646.1	12.098	1135363.2
Karnataka	92.7392	16731.05	130489.8	79775	11.078	590200.908
Uttar Pradesh	91.2206	10243.627	194275.3	94650.8	14.008	541168.834
Haryana	61.2419	7065.108	186632	39574.8	11.089	587139.64
Uttarakhand	38.6654	5479.327	49926.4	14803.5	10.995	68274.36
Rajasthan	47.0078	7149.502	131482.4	54970.1	10.562	457386.84
Telangana	74.7062	5694.436	96163	0	0	0
Andhra Pradesh	52.2057	14862.643	144157.7	92866.6	13.256	397340.8
West Bengal	64.5738	8094.66	122701.4	69411.3	11.606	1140176.507
Himachal Pradesh	19.4608	4769.133	39983.7	9258.9	11.82	333098.42
Madhya Pradesh	32.2833	8608.707	98783.3	40137.2	9.485	408600
Jharkhand	18.7877	7134.878	142522.5	19401.3	8.845	1872450.58
Punjab	60.2818	3935.562	121891	33471.4	10.448	253658.88
Odisha	26.0771	21086.599	111821.1	27727.1	6.18	203303.016
Chattisgarh	16.6236	6408.052	89012.9	19733	9.825	18160
Kerala	35.1662	232.965	56306.9	46291.6	9.419	757092.216
Goa	5.6684	793.409	13348.8	4224.3	4.032	23481.67
Assam	18.6483	1444.632	33361.8	17488.4	7.285	25878.45
Jammu & Kashmir	6.6829	517.712	7606.3	9740	4.318	13140.54
Sikkim	1.2749	173.938	721	1386.2	2.398	3639.264
Bihar	11.3594	803.738	9337.5	32947.5	8.898	165165.2

Meghalaya	1.3434	362.758	8139.2	2369.7	3.088	25839.86
Tripura	2.9121	27.221	1501.7	2559.3	3.925	32688.451
Nagaland	0.3746	17.872	89.7	1605.9	4.464	16981.416
Manipur	0.5879	9.793	359.4	1544.1	4.508	10242.24

Table 6
Environmental efficiency of the states in 2017-18

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Maharashtra	0.54830
2	Gujarat	1.00000
3	Tamil Nadu	0.39775
4	Karnataka	0.74362
5	Uttar Pradesh	0.69539
6	Haryana	0.49961
7	Uttarakhand	0.77447
8	Rajasthan	0.77588
9	Telangana	0.00000
10	Andhra Pradesh	1.00000
11	West Bengal	0.79161
12	Himachal Pradesh	1.00000
13	Madhya Pradesh	0.82369
14	Jharkhand	1.00000
15	Punjab	0.45760
16	Odisha	0.67175
17	Chattisgarh	1.00000
18	Kerala	1.00000
19	Goa	1.00000
20	Assam	0.92671
21	Jammu & Kashmir	0.33997
22	Sikkim	0.25363
23	Bihar	0.67658
24	Meghalaya	0.42431
25	Tripura	1.00000
26	Nagaland	1.00000
27	Manipur	1.00000

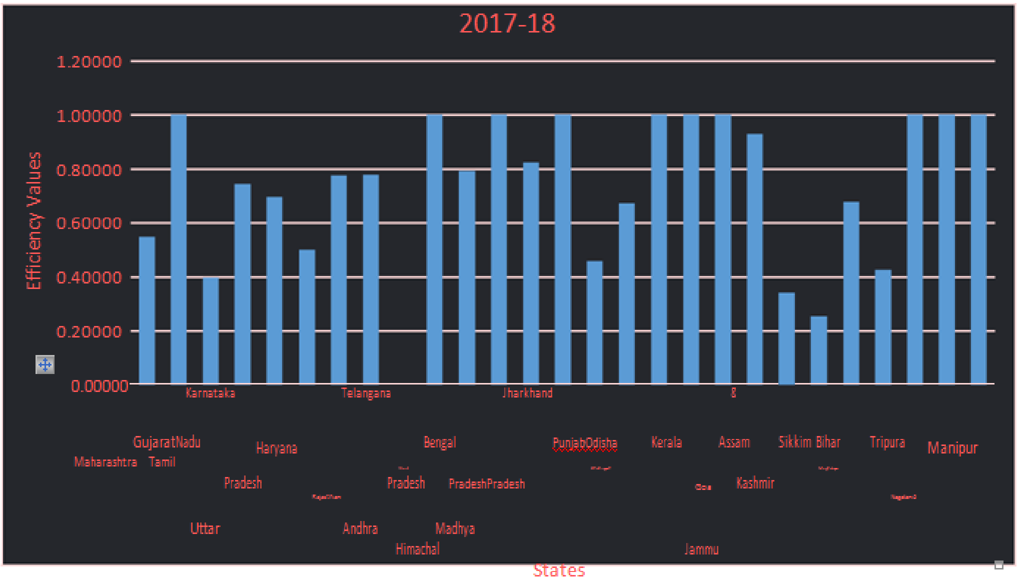

Figure 3.*Environmental efficiency of the states*

Table 7

Statistical data of 2018-19

STATES	NE	FC	EC	GDP	E CO2	ISW
Maharashtra	188.3675	33714.366	380923.8	179212.2	14.565	1032736.5
Gujarat	146.2206	43770.158	455632.1	89520.2	13.398	8180198.06 3
Tamil Nadu	212.7703	22131.634	294418.9	112062	12.387	1419204
Karnataka	97.4022	16902.324	131977.8	90783.9	11.134	737751.135
Uttar Pradesh	74.4026	10896.835	218790	104199.7	14.228	676461.042 5
Haryana	88.3331	8794.812	108153	44186.4	10.975	733924.55
Uttarakhand	37.4861	8794.812	54622	16493.1	10.845	85342.95
Rajasthan	48.752	7654.382	152960.6	61219.4	10.354	571733.55
Telangana	20.8781	5739.296	84601.3	52200.1	8.459	548931.48
Andhra Pradesh	69.2301	14824.439	151641.6	53292.2	12.052	496676
West Bengal	52.8417	8626.799	129975.2	72900	10.419	1425220.63 4
Himachal Pradesh	34.4031	4875.483	43841.9	10110.8	11.384	416373.025
Madhya Pradesh	18.2085	9729.658	116332.8	45134.8	9.598	510750
Jharkhand	58.3316	7566.533	102662.2	22072.9	8.989	2340563.22 5
Punjab	63.247	4114.017	116895.4	36801.1	10.557	317073.6
Odisha	17.9324	22947.886	147344.9	30980.7	6.207	254128.77
Chattisgarh	6.561	7793.471	111651.9	22299	8.243	22700
Kerala	38.4058	2934.983	52393.6	51989.6	9.515	946365.27
Goa	19.5567	887.143	12308.9	4554.8	4.058	29352.0875
Assam	9.7156	1616.94	26855.4	19514.5	7.342	32348.0625
Jammu & Kashmir	6.5022	577.918	5966.1	10268.1	4.506	16425.675
Sikkim	1.3675	176.248	877.1	1520.9	2.579	4549.08

Bihar	1.0594	994.456	12441.9	41086.2	8.918	206456.5
Meghalaya	1.4339	350.312	9175	2517.2	2.464	32299.825
Tripura	0.3684	32.428	1468.4	2966.7	4.048	40860.5637 5
Nagaland	0.5519	20.029	121.7	1772.7	4.537	21226.77
Manipur	0.7591	11.374	678	1804.2	4.576	12802.8

Table 8
Environmental efficiency of the states in 2018-19

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Maharashtra	0.57261
2	Gujarat	1.00000
3	Tamil Nadu	0.38646
4	Karnataka	0.69322
5	Uttar Pradesh	0.76133
6	Haryana	0.47801
7	Uttarakhand	0.69612
8	Rajasthan	0.67246
9	Telangana	1.00000
10	Andhra Pradesh	0.44506
11	West Bengal	0.89872
12	Himachal Pradesh	1.00000
13	Madhya Pradesh	1.00000
14	Jharkhand	1.00000
15	Punjab	0.63194
16	Odisha	0.64190
17	Chattisgarh	1.00000
18	Kerala	1.00000
19	Goa	1.00000
20	Assam	1.00000
21	Jammu & Kashmir	0.29751
22	Sikkim	0.24654
23	Bihar	1.00000
24	Meghalaya	0.17830
25	Tripura	1.00000
26	Nagaland	1.00000
27	Manipur	1.00000

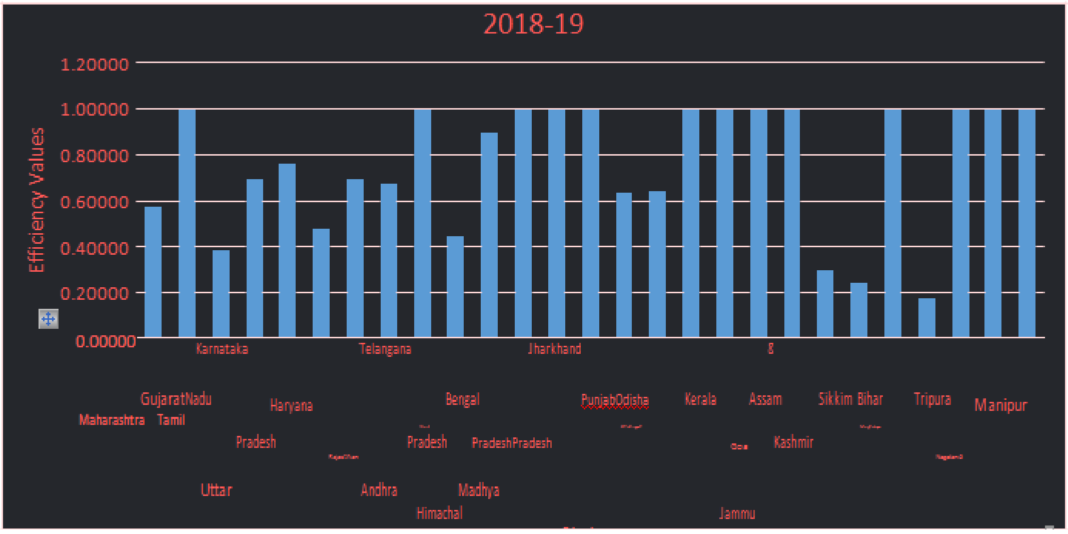

***Figure 4.**Environmental efficiency of the states*

Table 9
Average Environmental efficiency of the states of INDIA from 2015 to 2019

STATES	2011-12	2012-13	2013-14	2014-15	AVERAGE
Maharashtra	1.00000	0.61596	0.54830	0.57261	0.68422
Gujarat	1.00000	0.66664	1.00000	1.00000	0.91666
Tamil Nadu	0.43947	0.43374	0.39775	0.38646	0.41436
Karnataka	0.66360	0.90129	0.74362	0.69322	0.75043
Uttar Pradesh	0.90856	0.77537	0.69539	0.76133	0.78516
Haryana	0.73702	0.63129	0.49961	0.47801	0.58648
Uttarakhand	0.73830	0.72420	0.77447	0.69612	0.73327
Rajasthan	0.97167	0.90068	0.77588	0.67246	0.83017
Telangana	0.00000	0.00000	0.00000	1.00000	0.25000
Andhra Pradesh	0.61079	1.00000	1.00000	0.44506	0.76396
West Bengal	0.98639	0.77397	0.79161	0.89872	0.86267
Himachal Pradesh	1.00000	0.98546	1.00000	1.00000	0.99637
Madhya Pradesh	1.00000	1.00000	0.82369	1.00000	0.95592
Jharkhand	1.00000	1.00000	1.00000	1.00000	1.00000
Punjab	0.57647	0.55288	0.45760	0.63194	0.55472
Odisha	0.76155	0.67716	0.67175	0.64190	0.68809
Chattisgarh	0.92682	0.87199	1.00000	1.00000	0.94970
Kerala	1.00000	1.00000	1.00000	1.00000	1.00000
Goa	1.00000	1.00000	1.00000	1.00000	1.00000
Assam	1.00000	1.00000	0.92671	1.00000	0.98168
Jammu & Kashmir	0.18320	0.31835	0.33997	0.29751	0.28476
Sikkim	0.17108	0.26787	0.25363	0.24654	0.23478
Bihar	0.35173	0.55191	0.67658	1.00000	0.64505
Meghalaya	0.25264	0.40207	0.42431	0.17830	0.31433
Tripura	1.00000	0.69751	1.00000	1.00000	0.92438
Nagaland	1.00000	1.00000	1.00000	1.00000	1.00000
Manipur	1.00000	1.00000	1.00000	1.00000	1.00000

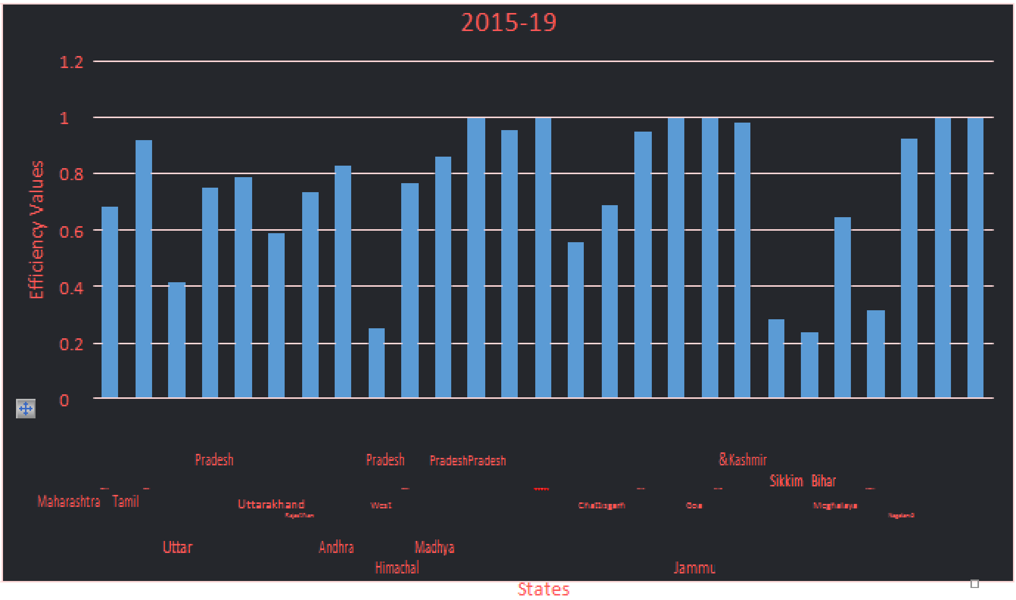

Figure 5.*Average Environmental efficiency of the states*

Environmental efficiency analysis of states

It should be noted here that the higher the environmental efficiency is the more efficient the region is. From Table 9 and Fig. 5, the following conclusions can be drawn. Firstly, Jharkhand, Kerala, Goa, Nagaland and Manipur performed well from 2011 to 2015. Their environmental efficiencies are all equal to 1, i.e. they are all efficient in these 4 years. Secondly, Sikkim performs the worst, its average efficiency is 0.23487 which is the smallest among all the DMUs. Thirdly, most of the states in India did not perform well in the four years. five states generate average environmental efficiencies that have not exceeded 0.5. Taken Uttar Pradesh as an example its environmental efficiency in the 2011-2015 are 0.90856, 0.77537, 0.69539 and 0.76133 respectively. And its average environmental efficiency is 0.78516. Fourthly, the environmental efficiency trend of regions is not promising since the environmental efficiencies of most the DMUs did not show any obvious increasing trend during the four years. Also, take Uttar Pradesh as an example, its environmental efficiency had reduced from 0.90856 to 0.77537 (2011-2013) and from 0.77537 to 0.69537 (2012-2014). Finally, we find that the very few states generally performed better than the other states. Notably, all the efficient regions are same regions. These results show us that the environmental efficiencies of the regional industries in India are not optimistic and more actions need to be taken, by both the industries and the government, into practice to handle with the undesirable outputs of the industrial enterprises.

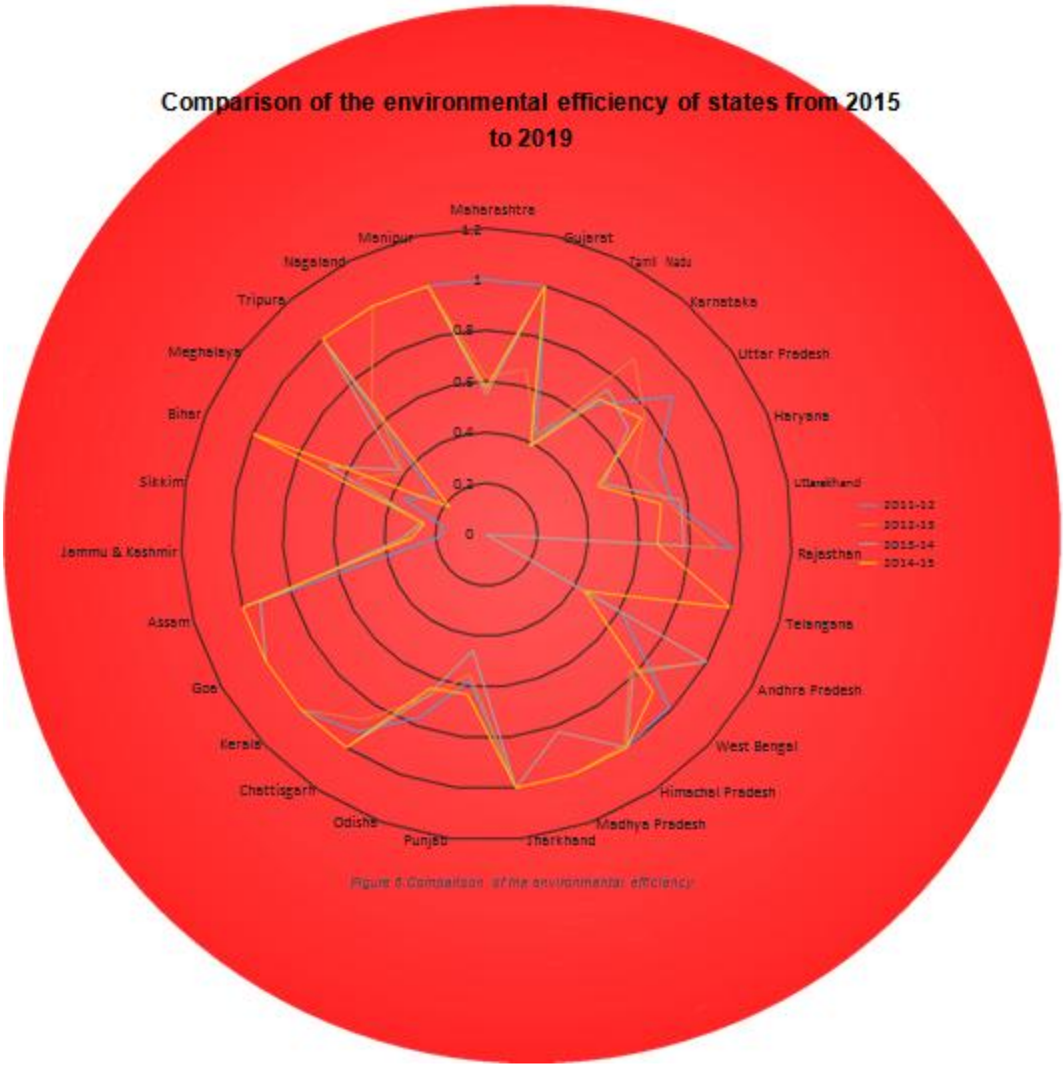

Figure 6.*Comparison of the environmental efficiency*

Environmental efficiency of large regions of INDIA from 2015 to 2019

Table 10

Statistical data of Central Zone 2015-16

STATES	NE	FC	EC	GDP	E CO2	ISW
Madhya Pradesh	31.4838	4990.615	86477	31167	6.215	329059.2
Chhattisgarh	18.5985	5063.239	77544.1	13287.2	5.298	14346.4

Table 11

Environmental efficiency of the Central Zone 2015-16

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Madhya Pradesh	1.00000
2	Chhattisgarh	1.00000

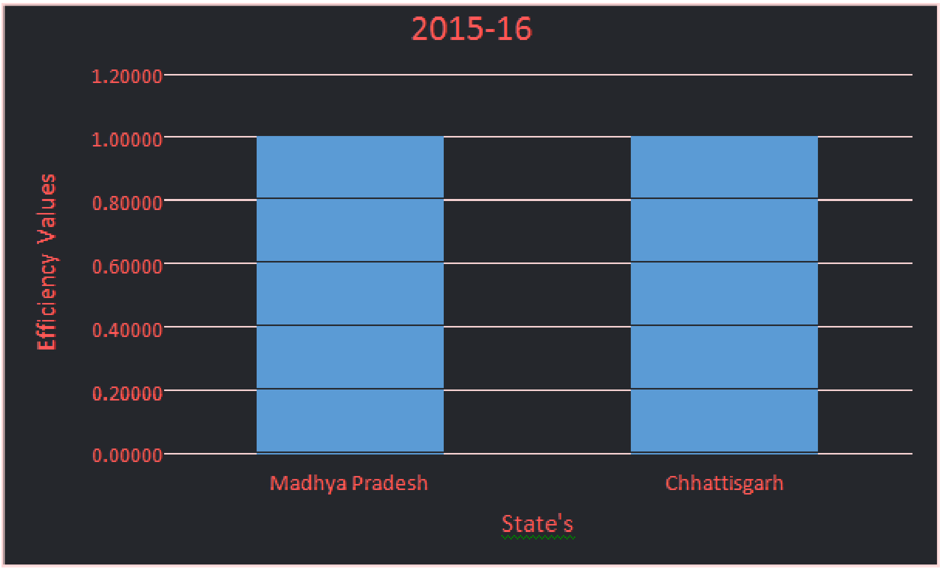

Figure 7.*Environmental efficiency of the Central Zone*

Table 12

Statistical data of Central Zone 2016-17

STATES	NE	FC	EC	GDP	E CO2	ISW
Madhya Pradesh	30.2209	13657.975	96526.5	36382.6	8.062	3808015.2
Chhattisgarh	17.3076	6030.773	87955.5	17883.9	6.624	17070.4

Table 13

Environmental efficiency of the Central Zone 2016-17

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Madhya Pradesh	1.00000
2	Chhattisgarh	1.00000

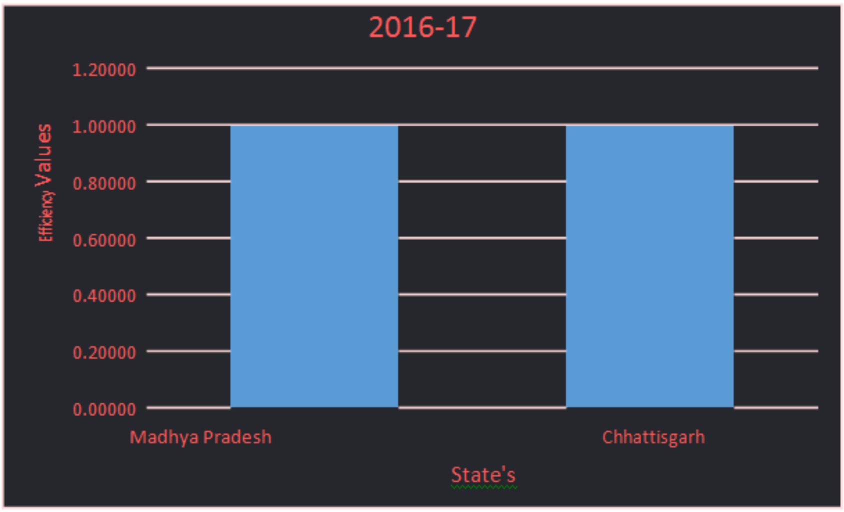

Figure 8.Environmental efficiency of the Central Zone

Table 14

Statistical data of Central Zone 2017-18

STATES	NE	FC	EC	GDP	E CO2	ISW
Madhya Pradesh	32.2833	8608.707	98783.3	40137.2	9.485	408600
Chhattisgarh	16.6236	6408.052	89012.9	19733	9.825	18160

Table 15

Environmental efficiency of the Central Zone 2017-18

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Madhya Pradesh	1.00000
2	Chhattisgarh	1.00000

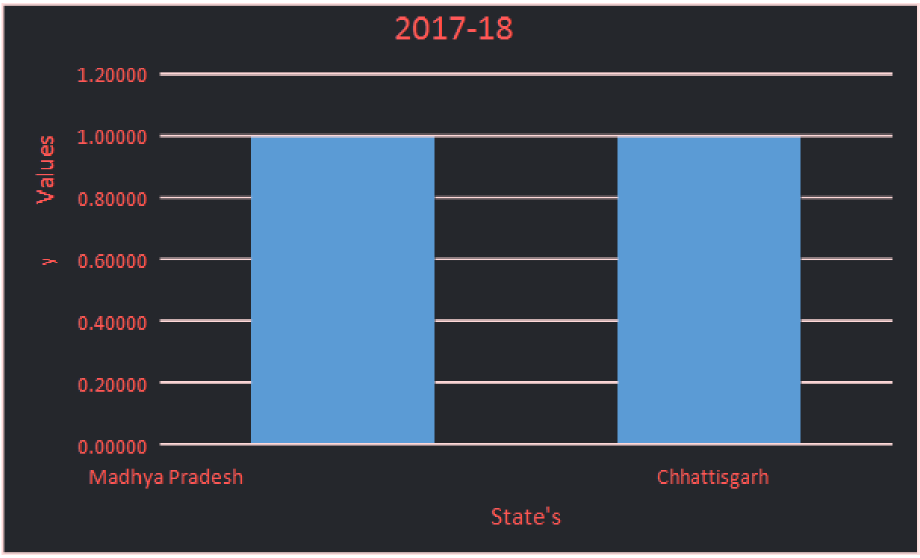

Figure 9.Environmental efficiency of the Central Zone

Table 16

Statistical data of Central Zone 2018-19

STATES	NE	FC	EC	GDP	E CO2	ISW
Madhya Pradesh	18.2085	9729.658	116332.8	45134.8	9.598	510750
Chhattisgarh	6.561	7793.471	111651.9	22299	8.243	22700

Table 17

Environmental efficiency of the Central Zone 2018-19

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Madhya Pradesh	1.00000
2	Chhattisgarh	1.00000

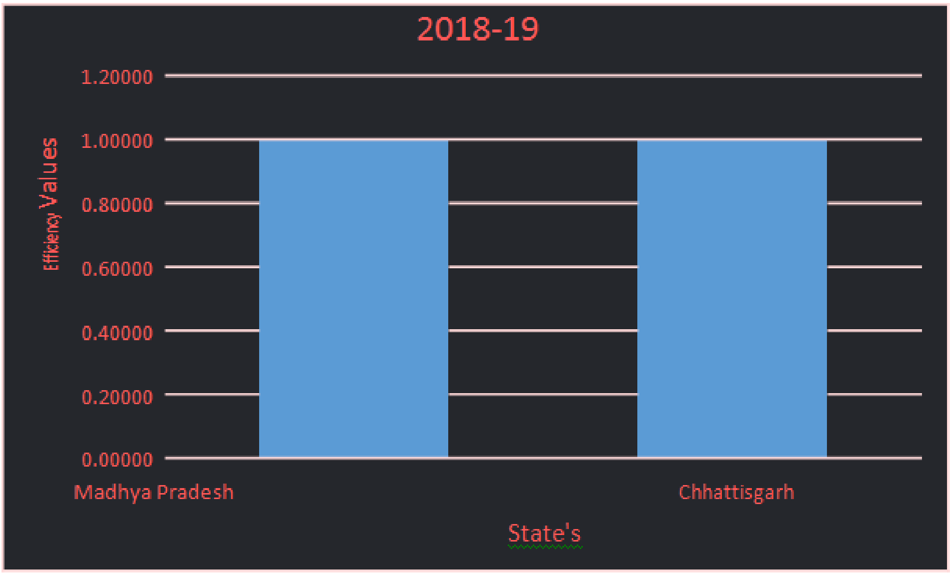

Figure 10.*Environmental efficiency of the Central Zone*

Table 18

Statistical data of East Zone 2015-16

STATES	NE	FC	EC	GDP	E CO2	ISW
Bihar	12.6592	754.715	24953.8	24731.8	6.248	153361.
Orissa	28.4637	16080.526	103936.8	21458.3	4.268	166150.3
Jharkhand	19.6793	6742.579	137473.2	14389.1	6.278	1544692.
West Bengal	65.4276	7169.937	108421.6	53820.9	9.615	815772.6

Table 19

Environmental efficiency of the East Zone 2015-16

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Bihar	1.00000
2	Orissa	0.39572
3	Jharkhand	1.00000
4	West Bengal	0.87644

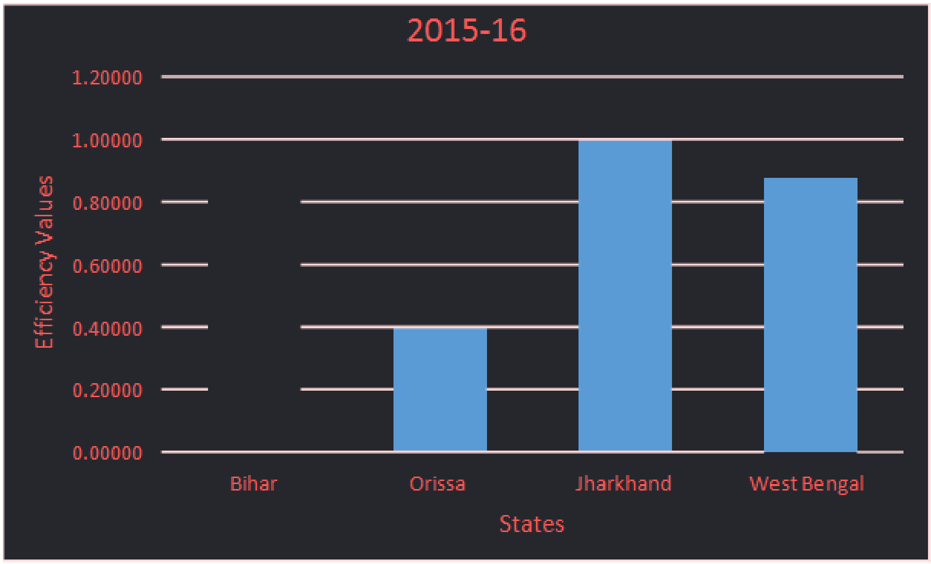

Figure 11. *Environmental efficiency of the East Zone*

Table 20
Statistical data of East Zone 2016-17

STATES	NE	FC	EC	GDP	E CO2	ISW
Bihar	11.6396	646.737	27686.9	28216.8	8.549	156993.2
Orissa	26.3651	16377.525	117528.3	25527.3	5.457	187942.38
Jharkhand	18.8046	6728.469	146074.4	17472.4	8.615	1641790.54
West Bengal	65.6123	8206.693	121038.5	61350.2	10.804	1060932.642

Table 21
Environmental efficiency of the East Zone 2016-17

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Bihar	1.00000
2	Orissa	0.41247
3	Jharkhand	1.00000
4	West Bengal	0.99360

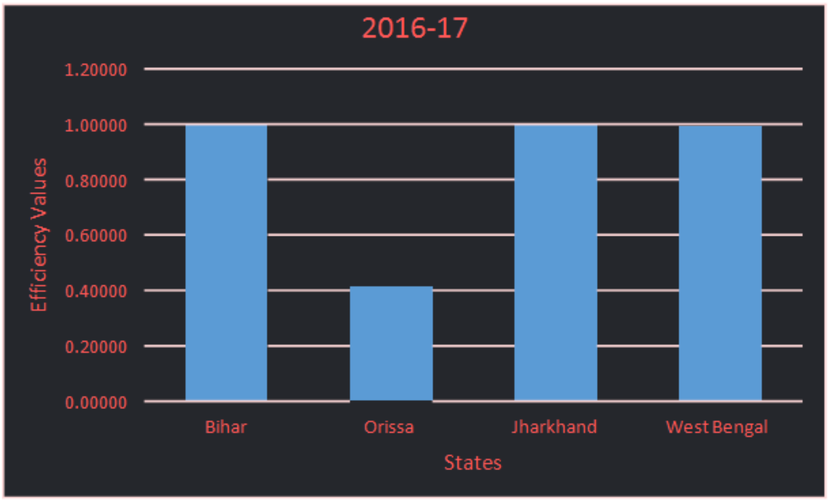

Figure 12. *Environmental efficiency of East Zone*

Table 22
Statistical data of East Zone 2017-18

STATES	NE	FC	EC	GDP	E CO2	ISW
Bihar	11.3594	803.738	9337.5	32947.5	8.898	165165.2
Orissa	26.0771	21086.599	111821.1	27727.1	6.18	203303.016
Jharkhand	18.7877	7134.878	142522.5	19401.3	8.845	1872450.58
West Bengal	64.5738	8094.66	122701.4	69411.3	11.606	1140176.507

Table 23
Environmental efficiency of the East Zone 2017-18

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Bihar	1.00000
2	Orissa	0.38340
3	Jharkhand	1.00000
4	West Bengal	0.62817

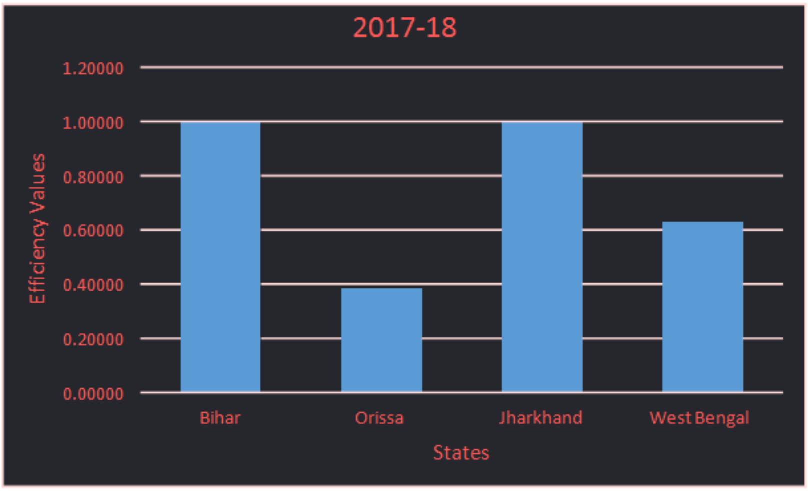

Figure 13. *Environmental efficiency of East Zone*

Table 24

Statistical data of East Zone 2018-19

STATES	NE	FC	EC	GDP	E CO2	ISW
Bihar	1.0594	994.456	12441.9	41086.2	8.918	206456.5
Orissa	17.9324	22947.886	147344.9	30980.7	6.207	254128.77
Jharkhand	58.3316	7566.533	102662.2	22072.9	8.989	2340563.225
West Bengal	52.8417	8626.799	129975.2	72900	10.419	1425220.634

Table 25

Environmental efficiency of the East Zone 2018-19

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Bihar	1.00000
2	Orissa	0.10108
3	Jharkhand	1.00000
4	West Bengal	0.59167

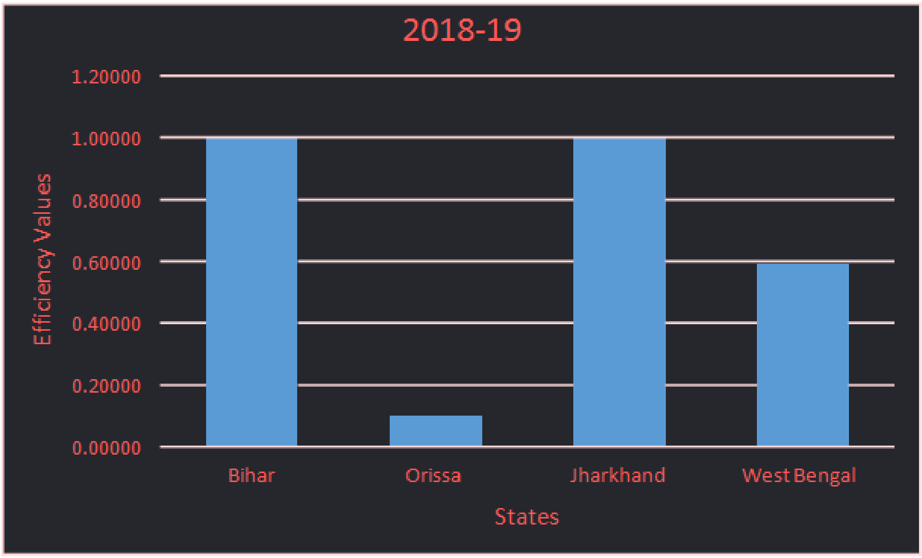

Figure 14. *Environmental efficiency of East Zone*

Table 26

Statistical data of North Zone 2015-16

STATES	NE	FC	EC	GDP	E CO2	ISW
Jammu and Kashmir	6.3704	440.142	5404	6575.9	2.984	10585.98
Himachal Pradesh	16.344	4449.031	31766.6	6495.7	8.086	224694.14
Punjab	60.0041	3734.551	105703.9	25643	7.589	215958.72
Uttarakhand	34.2385	5066.863	40874.7	9769.6	7.952	54381.648
Uttar Pradesh	86.4346	9064.742	160697	67900.7	10.951	434932.87
Haryana	58.2372	5385.588	65973.9	30195.9	7.285	433839.4

Table 27
Environmental efficiency of the North Zone 2015-16

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Jammu and Kashmir	1.00000
2	Himachal Pradesh	1.00000
3	Punjab	0.86810
4	Uttarakhand	0.48719
5	Uttar Pradesh	0.99196
6	Haryana	1.00000

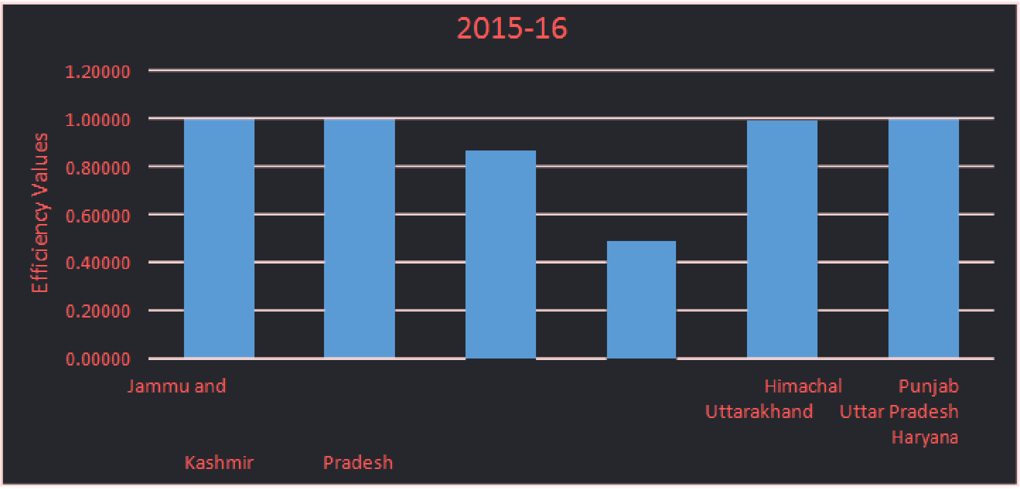

Figure 15. *Environmental efficiency of North Zone*

Table 28
Statistical data of North Zone 2016-17

STATES	NE	FC	EC	GDP	E CO2	ISW
Jammu and Kashmir	6.0658	524.823	7491.9	8653.7	3.873	12048.57
imachal Pradesh	18.4833	4009.16	40592.9	8229.4	10.09	312294.87
Punjab	58.352	3906.929	117355.6	29773.4	9.826	240365.76
Uttarakhand	33.53	5299.803	50862.1	13291.9	10.685	60919.86
Uttar Pradesh	82.5537	10271.141	176760.2	81221	13.285	486688.513
Haryana	56.6595	7839.623	80052.4	35040.7	9.986	532389.45

Table 29
Environmental efficiency of the North Zone 2016-17

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Jammu and Kashmir	1.00000

2	Himachal Pradesh	1.00000
3	Punjab	1.00000
4	Uttarakhand	0.50697
5	Uttar Pradesh	0.90266
6	Haryana	1.00000

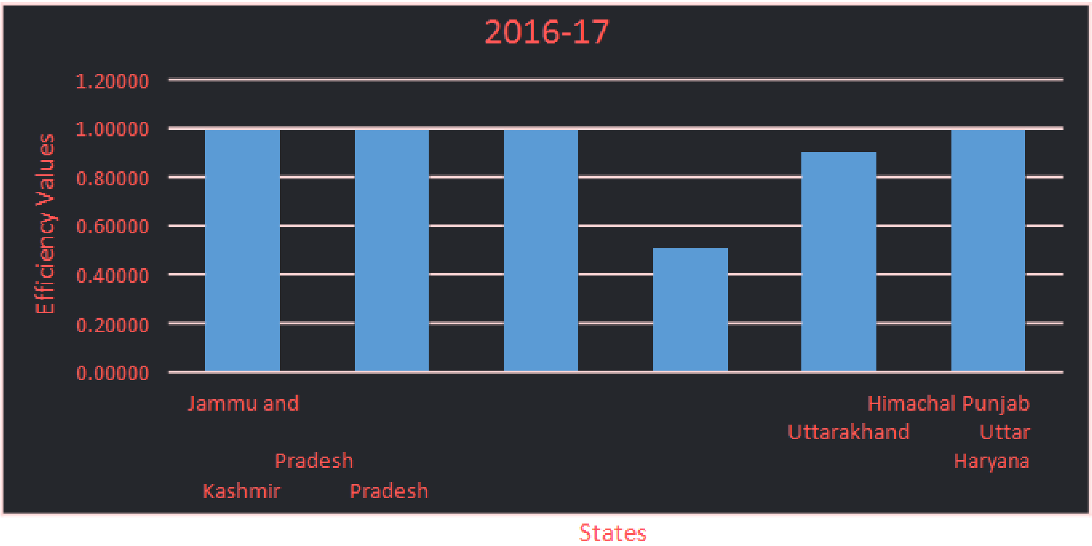

Figure 16. *Environmental efficiency of North Zone*

Table 30
Statistical data of North Zone 2017-18

STATES	NE	FC	EC	GDP	E CO2	ISW
Jammu and Kashmir	6.6829	517.712	7606.3	9740	4.318	13140.54
Himachal Pradesh	19.4608	4769.133	39983.7	9258.9	11.82	333098.42
Punjab	60.2818	3935.562	121891	33471.4	10.448	253658.88
Uttarakhand	38.6654	5479.327	49926.4	14803.5	10.995	68274.36
Uttar Pradesh	91.2206	10243.627	194275.3	94650.8	14.008	541168.834
Haryana	61.2419	7065.108	186632	39574.8	11.089	587139.64

Table 31
Environmental efficiency of the North Zone 2017-18

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Jammu and Kashmir	1.00000
2	Himachal Pradesh	1.00000
3	Punjab	0.94454
4	Uttarakhand	0.44364
5	Uttar Pradesh	0.94880
6	Haryana	1.00000

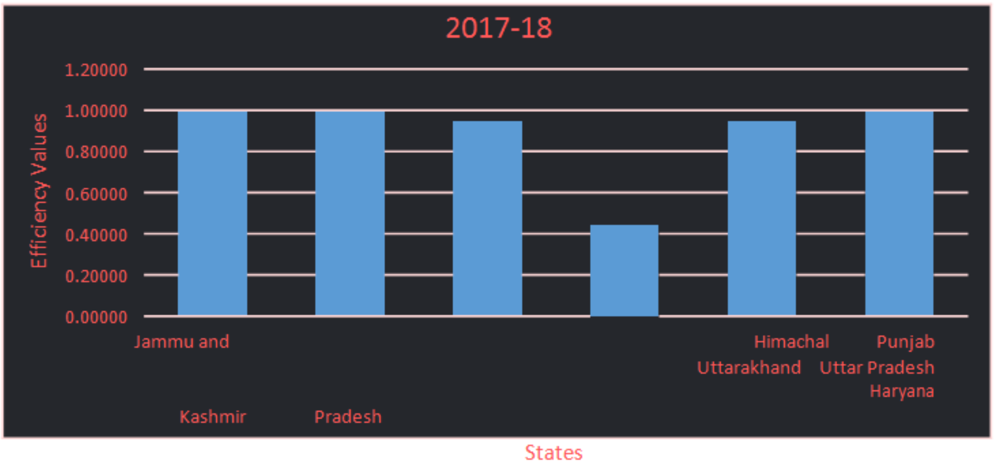

Figure 17. *Environmental efficiency of North Zone*

Table 32

Statistical data of North Zone 2018-19

STATES	NE	FC	EC	GDP	E CO2	ISW
Jammu and Kashmir	6.5022	577.918	5966.1	10268.1	4.506	16425.675
Himachal Pradesh	34.4031	4875.483	43841.9	10110.8	11.384	416373.025
Punjab	63.247	4114.017	116895.4	36801.1	10.557	317073.6
Uttarakhand	37.4861	8794.812	54622	16493.1	10.845	85342.95
Uttar Pradesh	74.4026	10896.835	218790	104199.7	14.228	676461.042 5
Haryana	88.3331	8794.812	108153	44186.4	10.975	733924.55

Table 33

Environmental efficiency of the North Zone 2018-19

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Jammu and Kashmir	1.00000
2	Himachal Pradesh	1.00000
3	Punjab	1.00000
4	Uttarakhand	0.47607
5	Uttar Pradesh	1.00000
6	Haryana	1.00000

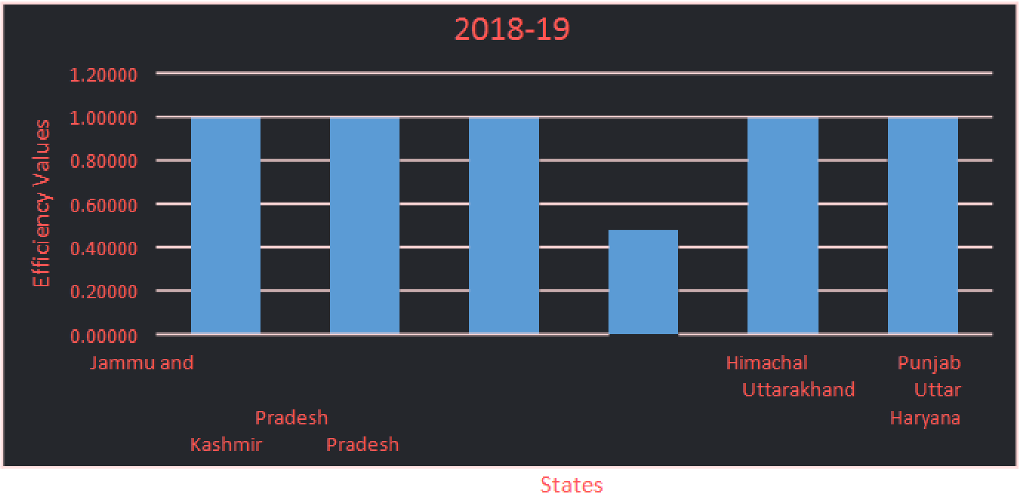

Figure 18. *Environmental efficiency of North Zone*

Table 34

Statistical data of North-East Zone 2015-16

STATES	NE	FC	EC	GDP	E CO2	ISW
Assam	18.0531	1515.746	20330.8	12582	5.389	17978.8
Sikkim	0.8906	113.924	783.3	861.6	1.142	2713.104
Nagaland	0.2521	12.731	58.7	1320.3	2.134	13440.257
Meghalaya	1.1005	281.066	5656.4	1641.2	2.287	21481.464
Manipur	0.5303	5.826	5.3	1050.4	1.975	8335.44
Tripura	0.2521	35.095	1263.4	2098.2	2.018	25060.5

Table 35

Environmental efficiency of the North-East Zone 2015-16

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Assam	0.11987
2	Sikkim	0.17108
3	Nagaland	1.00000
4	Meghalaya	0.25264
5	Manipur	1.00000
6	Tripura	1.00000

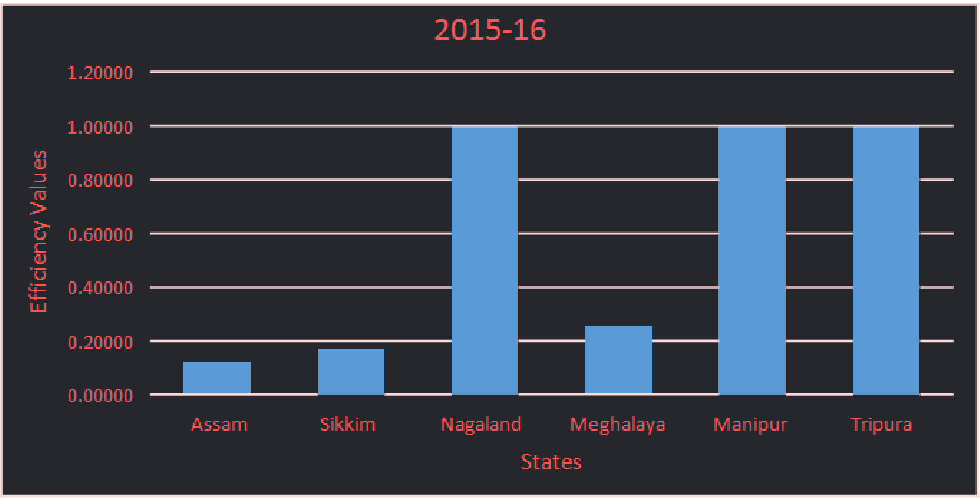

Figure 19.*Environmental efficiency of the North-East Zone*

Table 36

Statistical data of North-East Zone 2016-17

STATES	NE	FC	EC	GDP	E CO2	ISW
Assam	16.7835	1310.951	21124.3	15740.6	6.279	21610.4
Sikkim	1.0278	144.075	591	1233.8	2.086	3257.904
Nagaland	0.3039	17.412	68	1361.9	4.287	15891.817
Meghalaya	1.1986	349.006	7627.1	2159.7	2.878	24477.94
Manipur	0.6084	7.561	320.5	1323.8	4.189	9697.44
Tripura	2.8526	33.927	1299.1	2166.3	3.578	29419.2

Table 37

Environmental efficiency of the North-East Zone 2016-17

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Assam	0.20928
2	Sikkim	0.26787
3	Nagaland	1.00000
4	Meghalaya	0.40207
5	Manipur	1.00000
6	Tripura	0.69751

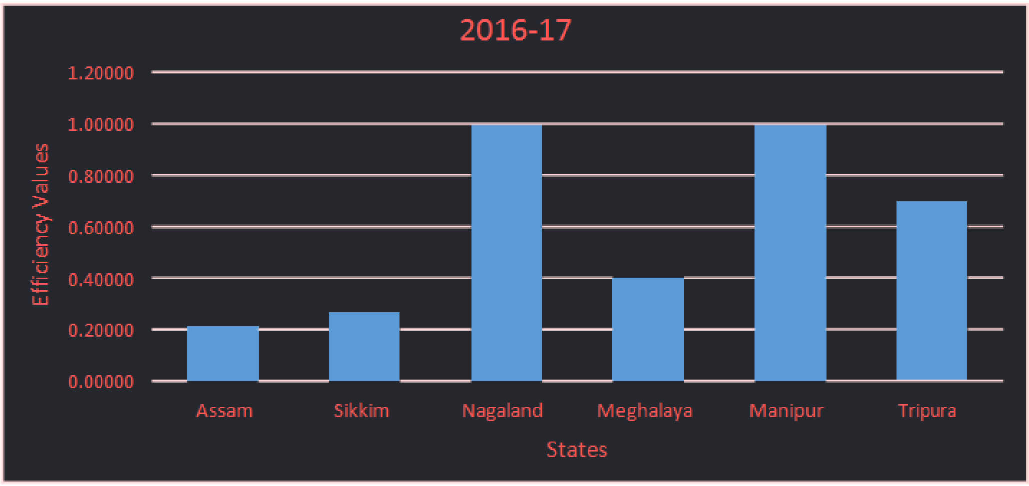

Figure 20.*Environmental efficiency of the North-East Zone*

Table 38

Statistical data of North-East Zone 2017-18

STATES	NE	FC	EC	GDP	E CO2	ISW
Assam	18.6483	1444.632	33361.8	17488.4	7.285	25878.45
Sikkim	1.2749	173.938	721	1386.2	2.398	3639.264
Nagaland	0.3746	17.872	89.7	1605.9	4.464	16981.416
Meghalaya	1.3434	362.758	8139.2	2369.7	3.088	25839.86
Manipur	0.5879	9.793	359.4	1544.1	4.508	10242.24
Tripura	2.9121	27.221	1501.7	2559.3	3.925	32688.451

Table 39

Environmental efficiency of the North-East Zone 2017-18

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Assam	0.21876
2	Sikkim	0.25363
3	Nagaland	1.00000
4	Meghalay a	0.42431
5	Manipur	1.00000
6	Tripura	1.00000

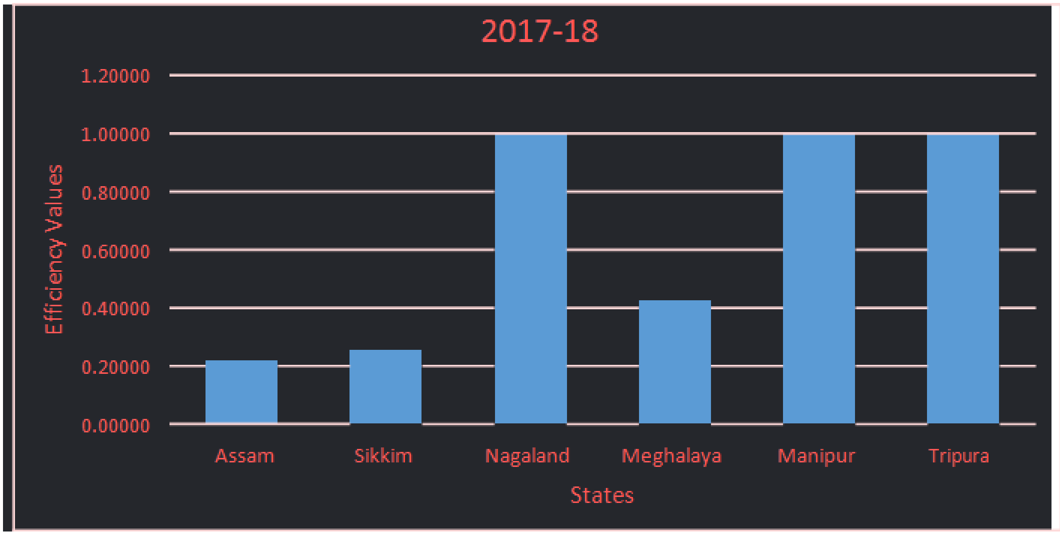

Figure 21.*Environmental efficiency of the North-East Zone*

Table 40

Statistical data of North-East Zone 2018-19

STATES	NE	FC	EC	GDP	E CO2	ISW
Assam	9.7156	1616.94	26855.4	19514.5	7.342	32348.0625
Sikkim	1.3675	176.248	877.1	1520.9	2.579	4549.08
Nagaland	0.5519	20.029	121.7	1772.7	4.537	21226.77
Meghalaya	1.4339	350.312	9175	2517.2	2.464	32299.825
Manipur	0.7591	11.374	678	1804.2	4.576	12802.8
Tripura	0.3684	32.428	1468.4	2966.7	4.048	40860.56375

Table 41

Environmental efficiency of the North-East Zone 2018-19

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Assam	0.30986
2	Sikkim	0.29634
3	Nagaland	1.00000
4	Meghalaya	0.21799
5	Manipur	1.00000
6	Tripura	1.00000

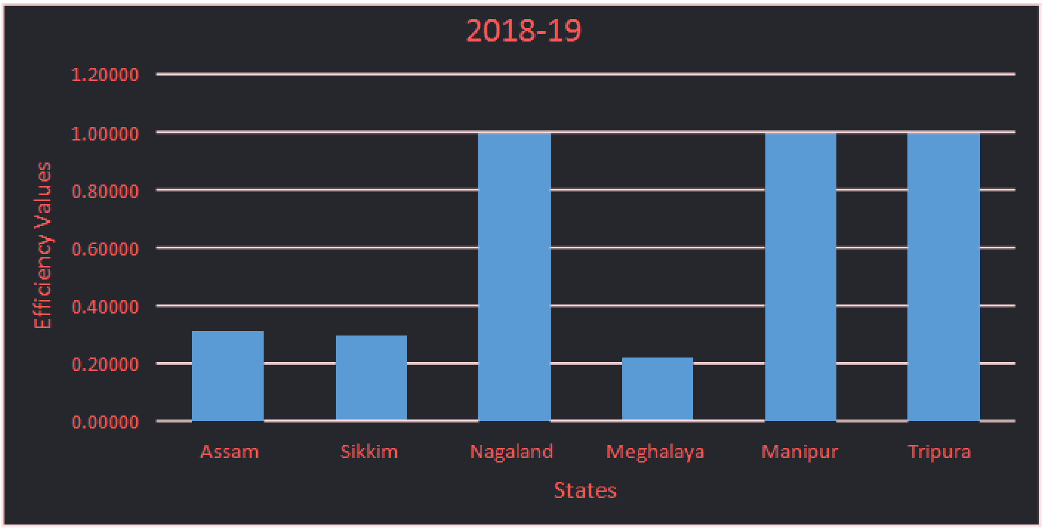

Figure 22.*Environmental efficiency of the North-East Zone*

Table 42

Statistical data of South Zone 2015-16

STATES	NE	FC	EC	GDP	E CO2	ISW
Andhra Pradesh	136.2788	25393.903	187134.8	66259.2	9.885	358024.4
Telangana	58.2372	0	98456.2	0	0	0
Karnataka	90.6473	13192.146	101265.9	45521.2	7.212	489412.408
Kerala	39.3425	1546.086	50291.6	30790.6	5.528	517107.824
Tamil Nadu	194.0819	16145.171	244944.6	66531.2	7.259	816655.8

Table 43

Environmental efficiency of the South Zone 2015-16

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Andhra Pradesh	0.62124
2	Telangana	0.00000
3	Karnataka	0.73422
4	Kerala	1.00000
5	Tamil Nadu	0.44364

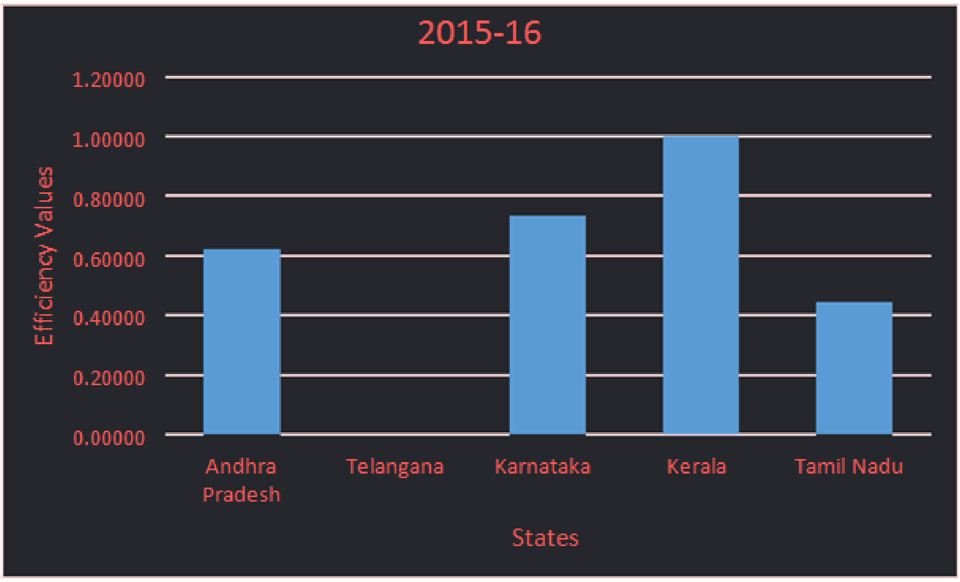

Figure 23*.Environmental efficiency of the South Zone*

Table 44

Statistical data of South Zone 2016-17

STATES	NE	FC	EC	GDP	E CO2	ISW
Andhra Pradesh	50.3615	13081.848	130552.2	81506.6	10.643	393164.2
Telangana	70.111	5847.297	102441.9	0	0	0
Karnataka	86.2203	14515.109	102879.6	69001.5	9.026	511204.85
Kerala	38.0498	1870.369	55491.1	41231.3	7.542	593652.45
Tamil Nadu	196.502	18724.233	264031.8	85148.5	8.883	965615.8

Table 45

Environmental efficiency of the South Zone 2016-17

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Andhra Pradesh	1.00000
2	Telangana	0.00000
3	Karnataka	0.90266
4	Kerala	1.00000
5	Tamil Nadu	0.43403

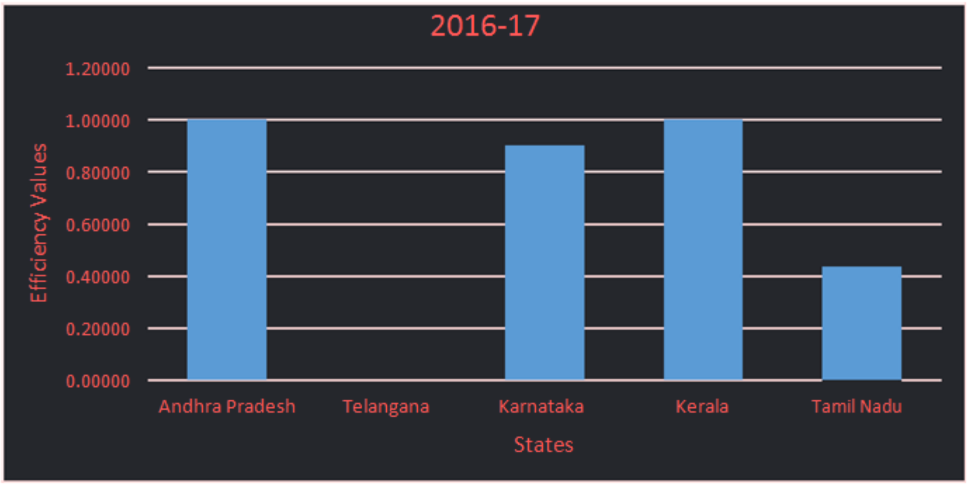

Figure 24*.Environmental efficiency of the South Zone*

Table 46

Statistical data of South Zone 2017-18

STATES	NE	FC	EC	GDP	E CO2	ISW
Andhra Pradesh	52.2057	14862.643	144157.7	92866.6	13.256	397340.8
Telangana	74.7062	5694.436	96163	0	0	0
Karnataka	92.7392	16731.05	130489.8	79775	11.078	590200.90
Kerala	35.1662	232.965	56306.9	46291.6	9.419	757092.21
Tamil Nadu	204.6553	27081.648	301664.3	98646.1	12.098	1135363.2

Table 47

Environmental efficiency of the South Zone 2017-18

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Andhra Pradesh	1.00000
2	Telangana	0.00000
3	Karnataka	0.74362
4	Kerala	1.00000
5	Tamil Nadu	0.39775

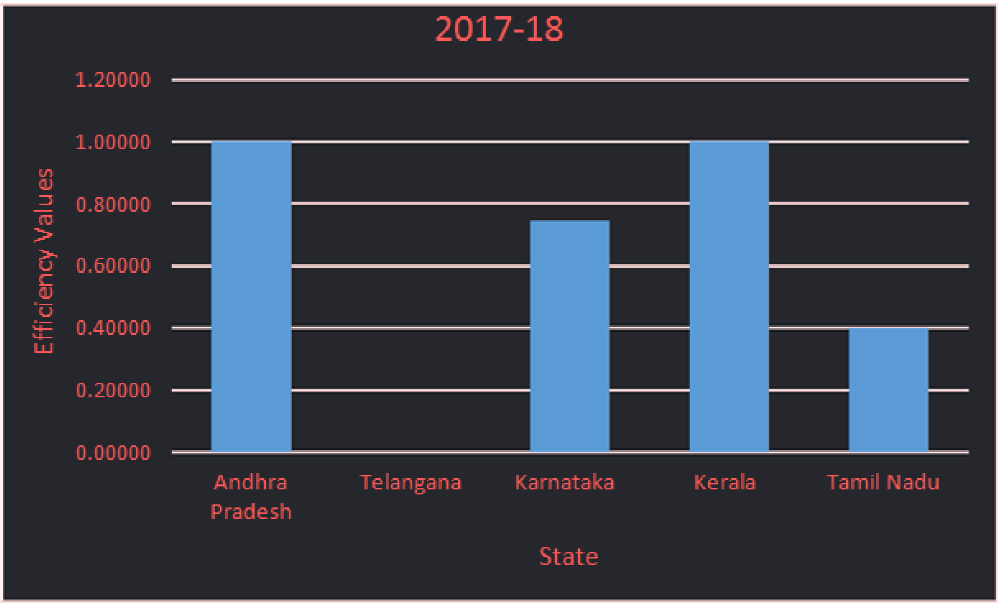

Figure 25.*Environmental efficiency of the South Zone*

Table 48

Statistical data of South Zone 2018-19

STATES	NE	FC	EC	GDP	E CO2	ISW
Andhra Pradesh	69.2301	14824.439	151641.6	53292.2	12.052	496676
Telangana	20.8781	5739.296	84601.3	52200.1	8.459	548931.48
Karnataka	97.4022	16902.324	131977.8	90783.9	11.134	737751.135
Kerala	38.4058	2934.983	52393.6	51989.6	9.515	946365.27
Tamil Nadu	212.7703	22131.634	294418.9	112062	12.387	1419204

Table 49

Environmental efficiency of the South Zone 2018-19

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Andhra Pradesh	0.58787
2	Telangana	1.00000
3	Karnataka	0.69322
4	Kerala	1.00000
5	Tamil Nadu	0.38669

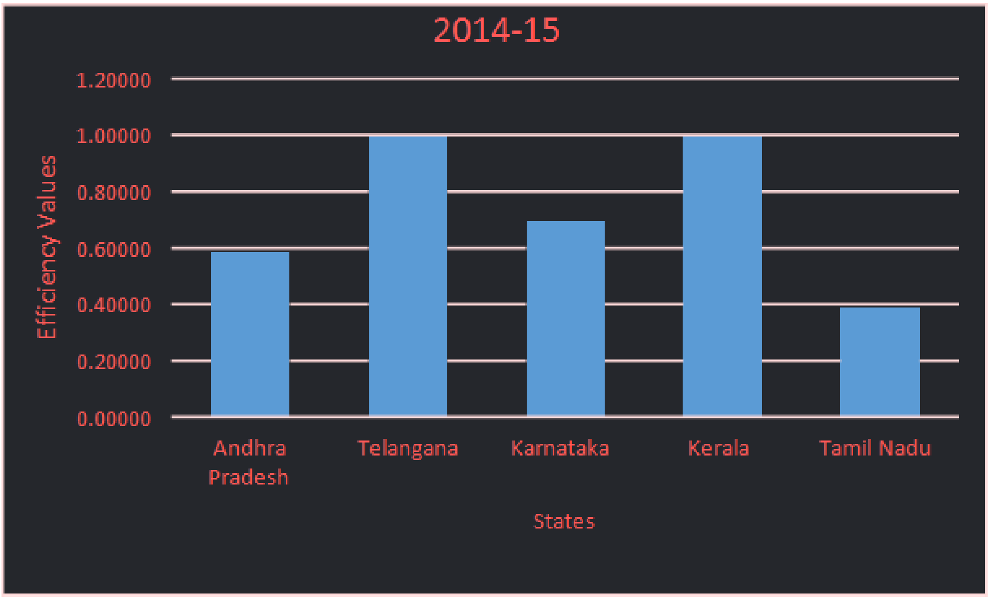

Figure 26*.Environmental efficiency of the South Zone*

Table 50
Statistical data of West Zone 2015-16

STATES	NE	FC	EC	GDP	E CO2	ISW
Rajasthan	47.4883	5301.625	104052.2	40342.2	9.395	403179.24
Gujarat	138.3773	31274.639	356813.5	59456.3	9.845	5668158.25
Goa	6.5974	860.627	13731.2	3602.5	2.515	21895.65
Maharashtra	188.0606	26096.562	70853.8	119954.8	11.256	570133.2

Table 51
Environmental efficiency of the West Zone 2015-16

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Rajasthan	1.00000
2	Gujarat	1.00000
3	Goa	1.00000
4	Maharashtr a	1.00000

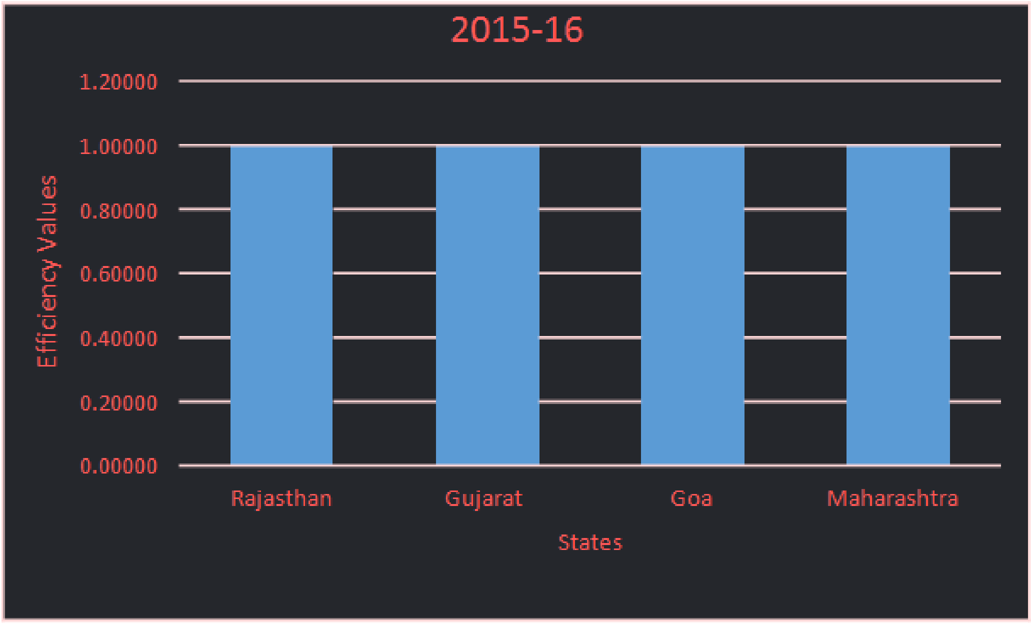

Figure 27.*Environmental efficiency of the West Zone*

Table 52

Statistical data of West Zone 2016-17

STATES	NE	FC	EC	GDP	E CO2	ISW
Rajasthan	44.3027	6142.162	127599.9	49400.4	10.385	411078.61
Gujarat	136.3628	32612.528	379193.9	71212.3	12.042	6152658.23
Goa	5.5831	827.836	13776.2	3864.7	3.895	22990.25
Maharashtra	178.4909	34492.959	348804.8	144846.6	12.208	689989.2

Table 53

Environmental efficiency of the West Zone 2016-17

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Rajasthan	1.00000
2	Gujarat	1.00000
3	Goa	1.00000
4	Maharashtra	1.00000

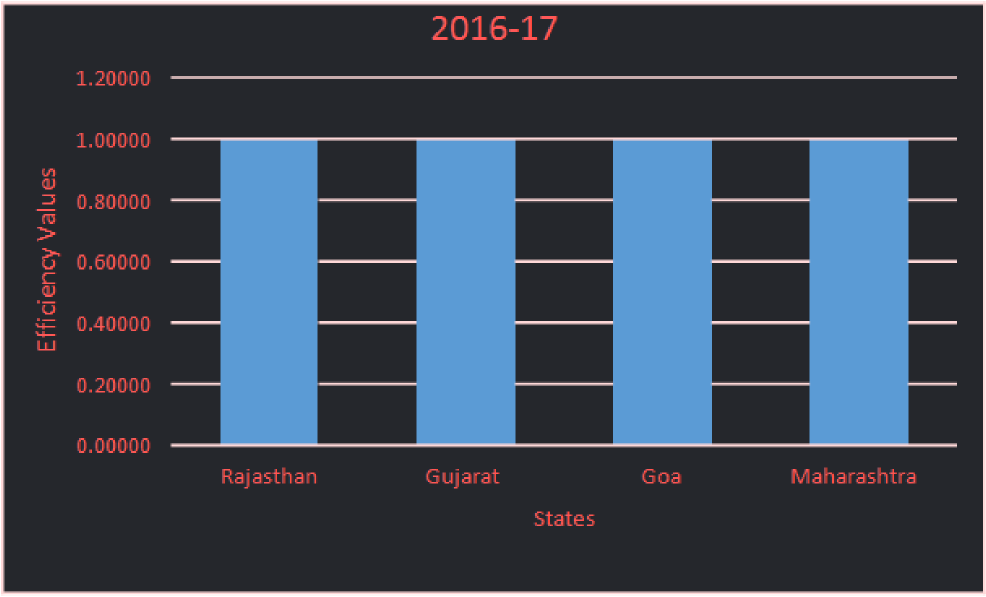

Figure 28.*Environmental efficiency of the West Zone*

Table 54

Statistical data of West Zone 2017-18

STATES	NE	FC	EC	GDP	E CO2	ISW
Rajasthan	47.0078	7149.502	131482.4	54970.1	10.562	457386.84
Gujarat	137.2669	38265.385	397992.3	80674.5	14.619	6544158.45
Goa	5.6684	793.409	13348.8	4224.3	4.032	23481.67
Maharashtra	188.6025	32636.16	435530.3	164750.6	14.455	826189.2

Table 55

Environmental efficiency of the West Zone 2017-18

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Rajasthan	1.00000
2	Gujarat	1.00000
3	Goa	1.00000
4	Maharashtra	0.90479

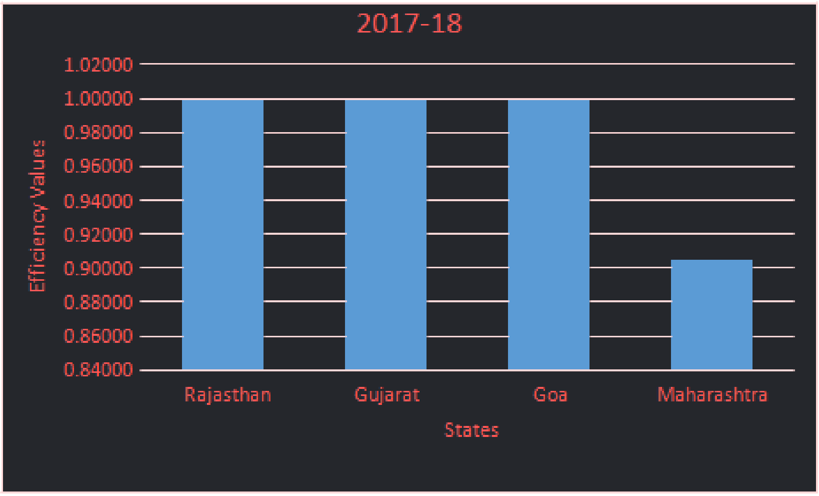

Figure 29.*Environmental efficiency of the West Zone*

Table 56

Statistical data of West Zone 2018-19

STATES	NE	FC	EC	GDP	E CO2	ISW
Rajasthan	48.752	7654.382	152960.6	61219.4	10.354	571733.55
Gujarat	146.2206	43770.158	455632.1	89520.2	13.398	8180198.063
Goa	19.5567	887.143	12308.9	4554.8	4.058	29352.0875
Maharashtra	188.3675	33714.366	380923.8	179212.2	14.565	1032736.5

Table 57

Environmental efficiency of the West Zone 2018-19

DMU No.	DMU Name	Input-Oriented CRS Efficiency
1	Rajasthan	1.00000
2	Gujarat	1.00000
3	Goa	1.00000
4	Maharashtr a	1.00000

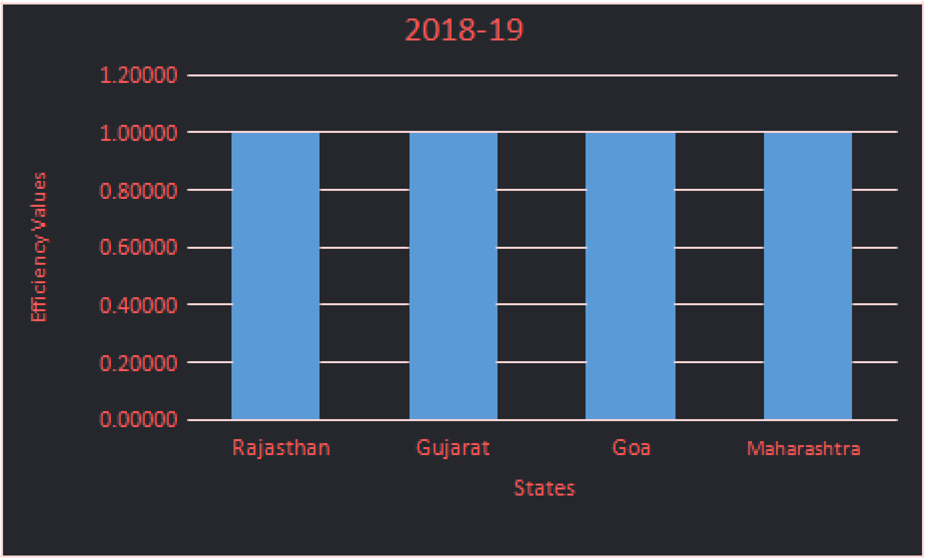

Figure 30.Environmental efficiency of the West Zone

Environmental efficiency analysis of regions

To analyse the environmental efficiency of the regional industries from a relatively lager scale, we divide the states into six lager regions. These regions and their constitutions are listed in Table 58. Then we give the environmental efficiencies of these six larger regions in Table 59.

Table 58

The state's division.

EAST	WEST	NORTH	SOUTH	Central Zone	North East Zone
Bihar	Rajasthan	Jammu and Kashmir	Andhra Pradesh	Madhya Pradesh	Assam
Orissa	Gujarat	Himachal Pradesh	Telangana	Chhattisgarh	Sikkim
Jharkhand	Goa	Punjab	Karnataka		Nagaland
West Bengal	Maharashtra	Uttarakhand	Kerala		Meghalaya
		Uttar Pradesh	Tamil Nadu		Manipur
		Haryana			Tripura

Table 59

Average Environmental efficiency of the large regions of INDIA from 2015 to 2019

Big Region	2015-16	2016-17	2017-18	2018-19	Average
East	0.7749	0.75076	0.784985	0.88515	0.79895
West	0.9929	0.79582	0.831045	0.81126	0.85776
North	0.69059	0.66459	0.62784	0.64415	0.65679
South	0.54277	0.667	0.6282	0.7049	0.63572
North East Zone	0.737286667	0.727908333	0.767441667	0.737473333	0.74253
Central Zone	0.96341	0.9359	0.911845	1	0.95279

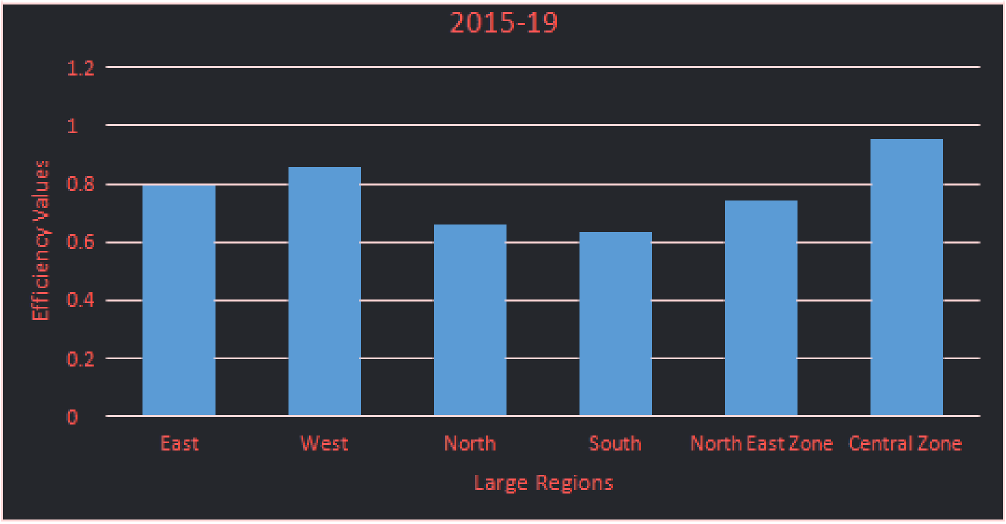

Figure 31.Average Environmental efficiency of the big regions

From Table 59 and Fig. 31, several results can be founded. Firstly, the environmental efficiencies of the big regions are not high except central zone. This indicates that the environmental efficiencies in the regions of India need to be improved. Secondly, we can see that the environmental efficiencies of the Central India and West India are generally higher than that of the other regions. This tells us that regional differences appeared in India in the development of the industries. Thirdly, we do not see any increasing or decreasing trend of the environmental efficiencies of the big regions during the four years. They all show a kind of stable case, the fluctuations of their environmental efficiencies are within 0.1. This is also not a good phenomenon because it indicates that the efforts, enhanced by the Indian governments, which aimed to improve the environmental efficiencies of the regions in India have not worked. Based on the analysis results, we suggest the Indian government to focus on the low environmental efficiency and the unbalanced development of its regional industries.

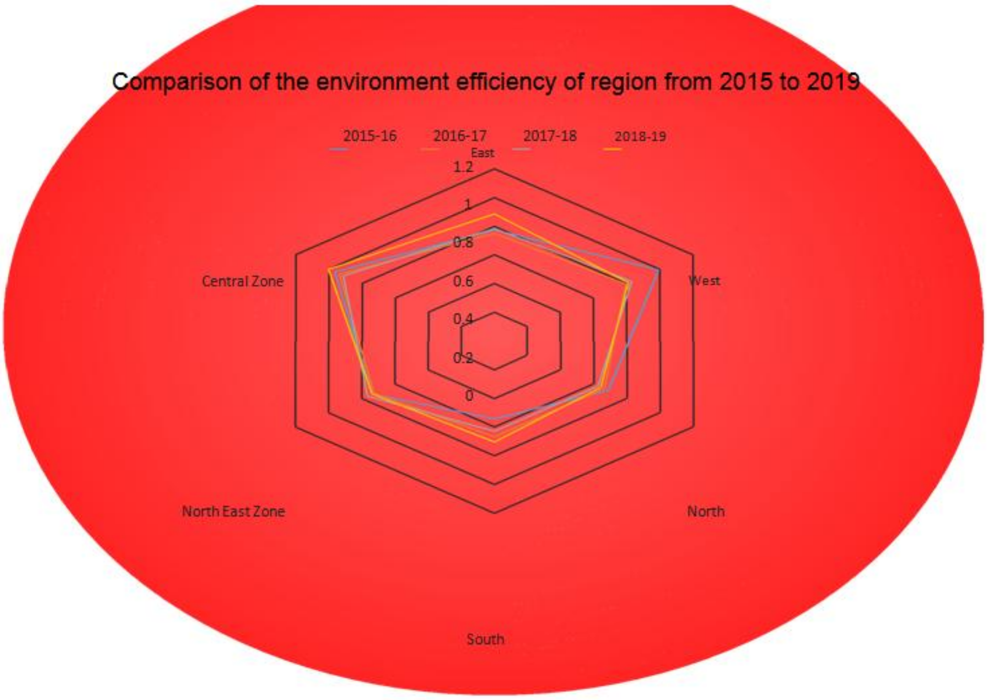

Figure 32.*Comparison of the environment efficiency*

III. CONCLUSIONS

The economy of India is the sixth-largest in the world measured by nominal GDP and the third-largest by purchasing power parity (PPP). During the last two decades, theeconomy of India has increased 7%. It brings the growth of gross domestic product. But a serious environmental problem occurs such as waste and pollution. And the public are troubled by the environment deterioration, which the government has been focused on. Naturally, it is not rational to evaluate the performance of regional industry by GDP.

In this paper, we take the undesirable outputs into consideration to measure the efficiency of large regions' industry since undesirable outputs have significance impacts on Indian environment directly and most part waste and pollution come from the industries. Then, the corresponding indicators of inputs and outputs are found by considering environmental factors. We measure the environmental efficiency of states and regions by using data from the year 2015 to 2019 based on a DEA approaches. It should be noted that the undesirable outputs in our model are handled as extra inputs. It is a common way to solve undesirable outputs. Through the analysis, firstly, apart from Jharkhand, Kerala, Goa, Nagaland and Manipur, we see that the environmental efficiencies of the India's regions are generally low. Secondly, we found that the environmental efficiencies of the regions did not show any increasing trend through the past 4 years. Finally, less differences exist in environmental efficiencies between the regions in India. Therefore, we suggest the Indian government to focus on the low environmental efficiency and the unbalanced development of its regional industries.