INTERNATIONAL JOURNAL OF HIGHER EDUCATION AND RESEARCH
IJHER, Vol., 9(1), 2019, 54-71.
www.ijher.com

IJHER
(ISSN 2277 260X)

CODEN:IJHER

ORIGINAL ARTICLE

# EFFICIENCY MEASUREMENT OF RURAL PUBLIC HEALTHCARE IN ASSAM: A TWO-STAGE DATA ENVELOPMENT ANALYSIS

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**ABSTRACT**

Efficiency measurement for rural primary healthcare services of Assam are investigated using data envelopment analysis on selected districts of Assam. Considering technical efficiency scores as dependant variable, a simple ordinary least square (OLS) stage-II model was undertaken to assess how the other environmental variables have determinant role played on the overall performance of district healthcare service. Our findings suggest that 63.6 percent district rural primary healthcare services are inefficient as because it has been utilising larger number of inputs to reach the existing output level. Further we have also found that density and growth rate of population, rural literacy, rural road length, life expectancy at birth are the important environmental variables to determine the efficiency in rural health facilities in Assam. Out of them DGROP and RRL were found at 10 percent whereas PD, RL LEAB were at 5 percent significant level.

***Keywords:*** *Rural primary healthcare, Technical efficiency, OLS regression, Data Envelopment Analysis, Public Healthcare, Assam.*

***JEL Classification:*** *I18, H11, H21, R15*

## 1. Introduction and Motivation of our Research:

Providing healthcare service to a nation is a biggest challenge in the 21$^{st}$ century. Resource optimisation in this perspective is now considered to be a striking apprehension in allocation of those resources across social sectors in the world. Raising health status in the developing country is a great challenge due fund shortage. Earlier providing funds were considered a sufficient strategy for delivering effective healthcare [1]. However, over the years it has been notice, especially in developing countries utilisation of these funds remains a question marks to the health policy maker and administrator [2]. Therefore, to achieve optimum health goal those countries needs to focus on efficiency [3, 4]. In modern efficiency literature, there are numerous studies on primary healthcare efficiency measurement which have laid stress on systematic performance and health outcomes [5]. The applications of frontier method and multi- criteria decision are the most advantageous one in recent years [6, 7]. Over the time it is an established method (data envelopment analysis (DEA)) of productivity and efficiency measurement in hospital and its co-related units [8, 9]. Due to an unique characteristics of health compared to standard neo-classical production economics, the multi-criteria decision approach has been adopted extensively in the performance analysis of healthcare sector [10]. Certainly there exists a numerous review in healthcare which enriches us niceties ladder and empirical problems raised by the researchers [10].

Now talking to developing countries, particularly in the Indian context, so far there are few studies have been undertaken mostly in central or mainstream India focussing either pan India or state level [8, 11, 12]. It is also to be noticed that according to a latest ICMR, 2017 report [13], the state Assam has performed one of the lowest rank in all India level in the delivery of primary healthcare services. This descent has motivated the researchers to study healthcare performance and scope to address the gaps and the determinants of healthcare efficiency in the rural areas of Assam.

### 1.1: Objectives of the Study:

The investigative objectives are:

1. To investigates the relative performance of selected districts rural healthcare of Assam using the application of envelopment technique.
2. To find out the degree and determinants of the inefficiency of rural healthcare of Assam.

## 2. Literature Review of the Study:

An attempt was made to study the available efficiency measurement literature in primary healthcare.

The issue of weaker performance of primary healthcare has been witnessed in advanced European countries, Chile but their quest for resource optimisation and constant innovation to improve the health system performance distinguished them from developing countries [14]. The study also addresses the issue of sound management practices and its nascent role in performance measurement in healthcare. They advocated multistage techniques to address the management of healthcare practice in PHCs. John et. al [15] have found covering a database of 1978- August 2010 a total 63.2 percent of the DEA investigation are rooted on empirical issues and rest of the them are addressing only methodological issues only. They were also found that in ranking of sectoral implication of DEA, healthcare stood second followed by banking.

Deidda, et. al., [16] came up with a fourth fold DEA extension model to measure the influence of technology in primary care centres. The study uses a complete new dataset of the Basque city of Spain to assess how the usage of electronic health information could mark a distinguish role in performance and efficiency of those primary care centres. The study was further extended to the variables which remain outside (environmental variable) the health system but had a significant influence the overall performance of primary healthcare. Finally, they have found that it’s not the mere physical fund flow rather application of those resources in actual field can bring changes in the efficiency of primary healthcare. The study was also reported that development primary healthcare is an integrative concept, where each and every stakeholder performs a significant contribution including environment variable as well. Penchalaiah, et. al., [11], wrote that, for the large sparsely Indian population, the available resources to manage healthcare are not adequate enough. The raising health demand and declining resources to mange it are also gets reflected in their dismal socio-economic health profile. In a vast extreme, complex socio-economic and health culture, it is the distribution of those resources, which raised inequality and debarring basic health service facility to the poor, particularly in rural area. They said the mere inclusion of private players doesn't solve the problem rather an urgent need to build efficient and performance centric joint (both public and private) approach to address the problem.

Nayak et. al., [12], Utilising the household level information of East Midnapore district of West Bengal, India, the study has undergo an index measurement for overall service flow using interplay between demand side dimension *('attending meetings, raising voice, lodging complaints, making contribution')* and supply side dimension *('availability, accessibility, reliability, quality')* in primary healthcare. Finally, came to a conclusion that, spaced out from socio-economic indicators, the political participation also takes an important role in getting admittance of the basic services in healthcare.

According to MoHFW[3], 2016-17 annual report the health ministry has indentified nine problems in northeast primary healthcare, out of that first six are directly related to the efficiency and performance of public health institution and provisioning health service delivery in rural areas in northeast including Assam. This justifies the importance of the performance in public health institution for provisioning healthcare service took a front row in order to bring efficiency and quality improvement in outcomes of healthcare service delivery in the north-eastern states.

Das et. al 2018 [17] came up with a district level study in Barak valley on 'efficiency and performance of Maternal and Child health using DEA method and found 31 (51%) sampled were technically efficient earmarking the '*best practice frontier'* whereas 49 percent were technically inefficient with a mean score of 0.70. They have also identify outputs, to be raised such as the number of cases Prenatal care (PNC) by 224.63, BCG by74.08, ANC by 49.38, and FSA by 49.26 with current level of input to reach an optimal efficiency combinations of input-output mix.

## 3. Methodology, Sample selection and Data

### 3.1. Study Area

The present study is based on 22 sampled districts out of 33 districts in Assam. The reasons for selecting the sampled districts are dual; firstly non-availability of total district information and secondly being a study of rural primary healthcare performance measure we are not considering urban setup districts. Assam being a pioneered and one of the oldest easternmost states, the basic division of districts by the state government administration are three folds; Brahmaputra Valley (twenty three districts) Barak Valley (three district) and district under sixth schedule for different tribal population (four district under Boroland Territorial Area Districts (BTAD), two under Karbi Anglong Autonomous District Council (KAADC) and

[3] '*Annual Report of the Ministry of Health and Family Welfare (MoHFW) 2017-18, Government.of India.'*

one under North Cachar Hills Autonomous Council (NCAC)). The basic reasons of the above being such divisions are its multi-cultural, multi–ethnicity multi-lingual and multi-socio-economic diversity. As latest Census 2011 the state has 3.11 crore population (out of total 86 percent rural and only 14 percent urban inhabitant) spread across 78,438 sq km geographical area and stood second following Arunachal Pradesh in North-eastern Region. As in another Census 2011 report, 40 percent population are in below poverty lines, for those public health institutions are the only option left for taking care of their healthcare issues. In this backdrop the efficiency and performance of public health institution in the state took a prominent role in the delivery of better and quality healthcare services.

**Table: 3.1.1. Population Norms of Rural Healthcare in Assam**

| Centres | Populations Norms | |
|---|---|---|
| | Plain Area | Hilly/Tribal/Difficult Area |
| Sub-Centre (SC) | 3,000 | 5,000 |
| Primary Health Centre (PHC) | 20,000 | 30,000 |
| Community Health Centre (CHC) | 80,000 | 1,20,000 |

Source: Ministry of Health and family Welfare, Govt. of India

Unlike other services, formal primary health services are provided by district administration through Sub-Centres (SCs), Primary Health Centres (PHCs), and Community Health Centres (CHCs) aligning with state and national healthcare programmes in the rural areas of Assam. Despite of being considered as a special category state under National Health Policy, the state performances in rural health outcomes was not significant enough comparing with national averages. This is reflected in below table of latest National Family and Health Survey (NFHS)-4, 2015-16.

**Table: 3.1.2. Comparison of rural health outcomes of Assam and India as per NFHS-4**

| **Indicators** | **Assam** | **India** |
|---|---|---|
| Infant mortality rate (IMR), NFHS-4 | 49* | 46 |
| Maternal Mortality Rate (MMR) | 301* | 167** |
| Institutional Birth, NFHS-4 | 68.2 | 75.1 |
| Mothers 4 antenatal care visits, NFHS-4 | 44.8 | 44.8 |
| Children (12-23 months) fully immunised, NFHS-4 | 44.4 | 61.3 |
| Mothers below normal BMI, NFHS-4 | 27.0 | 26.7 |
| Children (6-59 months) who are Anaemic, NFHS-4 | 36.5 | 59.4 |
| Average out of pocket expenditure per delivery in public health facility, NFHS-4 | 3646 | 2947 |
| *'Registered Pregnancies for which mothers received mother and child protection card,'* NFHS-4 | 96.4 | 90.0 |
| *'Mother who received post natal care from* | 51.9 | 58.5 |

| | | |
|---|---|---|
| *doctor/nurse/LHV/ANM/Midwife/Other health personnel within two day of delivery,'* NFHS-4 | | |

Source: National Family and Health Survey-4, 2015-16.

* AHS-2012-13. **'*Special Bulletin on Maternal Mortality of India 2011-13, Office of the Register General of India.*'

However in another report of ICMR[4], 2017 says that Assam has one of the highest, that is, 38.5 percent proportion of total disease burden from *'communicable, maternal neonatal and nutritional diseases (CMNNDs)'* across states in India. Most of these services are delivered to public under the ages of primary healthcare system in Assam. Hence, against the resource constraints and reduce wastage in the healthcare system, it is crucial to examine the relationship between efficiency of state rural public healthcare system and access to public health provisioning in rural areas of Assam, which has been attempted in this study.

### 3.2. Base Model of DEA

Data envelopment analysis (DEA) technique combing with linear programming stood the second most choices for evaluating performances of various empirical issues in healthcare since late seventies to till first decade of 21$^{th}$ century [15].The method has got its momentum after the classical work by Charnes et. al,1978 [6]. It generates an optimum frontier line taking different production combinations based on most proficient input-output mix. ***Input-oriented technical efficiency'*** means how the more and more input quantities can be in proportion abridged without making any changes in the quantities formed as output. On the other way round, the reverse of that process is designated as '***Output-oriented technical efficiency'.***

Comparing traditional efficiency measurement (how the activities transform input into output) it allows determining how well resources are used to produce the desired outputs. The unit involved in the analysis of input and output is known as decision making unit (DMU).

It has certain advantages over parametric technique; apply to more than one input and output, doesn't required specific functional form, can handle small sample size, better discrimination but highly sensitive [8].

### 3.3. Justification of considered model

There are two prime divisions of efficiency measurement; *'technical and allocative efficiency'*. The underlying firms/units etc. based on which efficiency are measured is known as '*Decision Making Units' (DMU)*. A DMU is said to be technologically efficient only if is competent enough to produce highest possible output from available set of inputs and in addition a DMU is allocatively efficient only, if it is capable highest i.e either maximum or minimum inputs in proportions to its given and respective costs. Considering non-availability of input cost data, we are not performing '*allocative efficiency measure*' rather we limited to '*technical efficiency measure*' only. Moreover talking about orientation of DEA, we are employing '*output orientation'*. In our study the underlying objectives are to see the

[4] A joint report published with titled on '*India: Health of the Nation's State 2017-a state level disease burden initiative since 1990-2016'* by '*Indian Council of Medical research (ICMR)'* in collaborations with *'Public Health Foundation of India (PHFI)*' and '*Institute for Health Metrics and Evaluation (IHME)'* ,USA.

performances of rural public institutions which get reflected through the outcomes or output of the healthcare units. Now, since district hospitals under investigation have limited control of their outcomes or outputs, therefore we considered '*output orientation'* in our study. The fundamental question raised through the study is that; *to what extent the sampled district hospitals can raise their output without making any changes in the corresponding input?*

The '*technical efficiency'* is again sub-divided in to two parts; *'Pure Technical efficiency'* (PTE) and '*Scale Efficiency*' (SE). The composition of two is known as '*Economic Efficiency'* (EE). Again the question of viability and non viability of any performance measurement will be addressed how the respective DMU's scale of operation was. The available choices in returns to scale are three types; '*Constant Returns to Scale'* (CRS), '*Variable Returns to Scale'* (VRS), and *'Decreasing Returns to Scale'* (DRS). As we are set our objectives of the study to assess how more and more outcomes or outputs can be realised without doing any adjustment in existing level of inputs. Moreover, based on preliminary scrutiny it was found that all the DMU under investigation are not in an optimum scale. So, VRS assumption will be the most relevant one in our study.

However, being an extreme point measure, the technique has certain disadvantages, that is, susceptive to normal range, disturbance factors and accidental influences of the information. Internal generation of weight is another disadvantage of DEA. Apart from all these disadvantages, DEA method positioned second in efficiency measurement literature in healthcare [10].

The presentation of DEA method taking plural cases of input and output with DMU up to K level , where K ranges from 1,2,3,4……n, specified [19] as below;

$$\frac{\sum_j u_j y_{jk}}{\sum_i v_i x_{ik}} = \theta_K \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \textbf{(}i\textbf{)}$$

Whereas, $u$ takes the corresponding weight of each output $y_j$ (j=1,2,……,s),

$v$ signifies the weight of each input $x_i$ (i=1,2,………,m).

The productive frontier of the combination (ratio of output by input, θ = 1) is represented by the most efficient DMUs to which other productive frontier combinations of the remaining DMUs needs to follow.

The '*best performer*' or '*benchmarker*' DMUs is the one who doesn't let go waste any input for delivering optimal output. This is called *'peers'* for the *'units/firms/entities'* attaching poor evaluation and a lesser amount of efficiency. The score is represented as symbol θ and varies in between 0 and 1.

To maximise objective function of our study, we are considering CCR over BCC approach [18] which taken care of the solution of CRS and DRS function. Accounting only VRS function we are formulated the problem.

Using '*output orientation measure'* with help of advanced mathematical technique *'Liner Programming'* the required envelopment for sampled DMUs of investigation K are:

$$\text{Max.} \quad \eta, \quad \eta\,\phi$$

$$\text{Subject to,} \quad xik \geq \sum_j \phi j \cdot xij$$

$$\eta \cdot yjk \leq \sum_j \phi \cdot yij \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(ii)$$

$$\phi j \geq 0,$$

Whereas, $\eta$ is decided on available efficiency scores of DMUs k;

$$\eta k = \frac{1}{\phi_k} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(iii)$$

Whereas, the '*vector*' $\phi$ stands for strength of variables, signifies the required productive combination of entities for the creation of *'benchmark'* on the frontier line. The rise and fall of $\phi$ ('*thita*') value tells us whether a scale is IRS, CRS and DRS. It envisages us that in the long run how the direction of output responds to a corresponding size of inputs of the district hospital. Moreover, considering DMUs size, IRS, DRS and CRS means total size of DMUs are small, large and remain balanced in capacity to undertake the volume of operations respectively [10, 20].

### 3.4. Second-Stage DEA Analysis

The stage one DEA involves only basic efficiency measurement; however it can be extended to second-stage using efficiency score as dependent variable on environmental or discretionary variable (which are prevail in outside of the system) through simple classical linear regression. The basic classical linear regression can be expressed as following:-

$$Y = \beta_0 + \beta_i \chi_i + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots (iv)$$

Where Y, a '*dependent variable'*, is explained by a vector sovereign variable $\chi_i$.The $\beta_i$ are the '*unknown regression coefficients'*, $\beta_0$ represents the *'constant'* and $\varepsilon_i$ is the unexplained factor outside the preview of *'residual'*. The '*regression equation'* as outlined in (iv) can be estimated by '*ordinary least squares'* (OLS), which reduces the '*sum of squared'* distances between observed and actual *'residuals'* in the model. It is the case when OLS model justifies '*BLUE property'* based on '*Independently Identically Distributed'* (IID) observations with fixed '*mean*' and '*variance*'.

It would be interesting to see that 'healthcare' being a representation of social well being, how the socio-economic and demographic variable impacts the overall efficiency of a particular healthcare system. The integrated nature and function of people-health-performance, where individual preferences might be influenced by socio-economic, demographic and other inhabitant setting are accountable for self conduct of health. The literatures [21, 22, 10] indicates that some of the environmental factors that impact healthcare facility efficiency include population growth rate and density, road length, literacy, per-capita income, life expectancy, average length of stay, quality, location (rural/urban), out patients. These factors can be considered as the determinants of the hospital efficiency.

However, our task was to assess a parsimonious least square model that would facilitate to explain the possible reasons of efficiency. Such a model would be significant based on probability value. Using a thorough iterative process of multiple model combinations, finally we were selected an empirical model based on F statistic and R square value as below:-

$$T\ E = \beta_0 + \beta_1\ DGROP + \beta_2\ PD + \beta_3\ RL + \beta_4\ RRL + \beta_5\ APCL + \beta_6\ LEAB + \varepsilon_i \ldots\ldots\ldots\ldots\ldots (v)$$

Where,

T E= Technical efficiency score of the relevant districts

DGROP (decadal growth rate of population 2001-11), PD (population density), RL (rural literacy), RRL (rural road length), APCL (annual per capita income) and LEAB (life expectancy at birth) are the explanatory or discretionary variables.

$\beta_0$ = constant or intercept term

$\beta_1\ \beta_2\ \beta_3\ \beta_4\ \beta_5\ \beta_6$ = coefficients of discretionary variables which describe one unit change in an efficiency score due to change in corresponding explanatory or discretionary variables

$\varepsilon_i$ = unsystematic error term

### 3.5. Sources of Information

The investigation is based on the secondary information source as, websites, journals and published reports of government. The principal information source are Annual Health Survey Assam 2012-13, Health Management Information System (HMIS) provisional data for April to November for financial Year 2016-17 updated 23rd December 2016, Narional Helath Mission, Assam accessed from http://www.nrhmassam.info as on 23.08.2017 and latest Assam Human Development report 2014.

### 3.6. Inputs and Outputs Variable Selection

It is very an important step to undergo an investigation using DEA technique due high sensitive features of the method. In production of healthcare, hospital and its associated factors turns input whereas the delivery results using those input attached a certain process is termed as outcomes or output. The usual classifications of inputs are labour (human resources), capital (infrastructure and equipment) and materials (medicine and drugs) [10]. It is an established fact from literature reviews of healthcare [10] that any outcome or output in health production process is judged by its benefit transmitting capacity to the overall health population of that stratum. However due to inapplicability of standard demand-supply paradox in healthcare the immediate outputs; '*infant mortality*, '*fertility*', '*institutional birth'*, '*out-patient served'* etc are used as preferred choice in performance measurement [18].

For modelling the health service production, keeping an eye on the similar past studies [23,] we have used two composite input and two composite output variables in our study. The choice of variables used in the investigation was steered from available literature [21], availability of data series, time and awareness in the field. In order keep the analysis simple, we have used a balanced DEA panel. '*Health Workers'* per one thousand persons

(accumulation of doctors, nurses and paramedical staff in the district) and '*Health Centres*' per one thousand persons (including all available SCs, PHCs and CHCs in the district) are used as inputs and '*Infant Survival Rate'* per one thousand live births in the district and '*Institutional Deliveries'* in percentage term are used as outputs in our investigation.
Since, the objective of the investigation is to raise the quantum of outputs without making any changes in inputs; the previous literature suggests [23] that '*Infant Mortality Rate'* (IMR[5]) should be replaced by '*Infant Survival Rate'* (ISR). The reason behind this was, the underlying principle of IMR goes against the standard hypothesis that higher health outcomes will lead higher performances in health sector with fixed inputs level. The simple formula for converting IMR into ISR is stated below:

$$\text{Infant Survival Rate} = \frac{\text{1000-Infant Mortality Rate}}{\text{Infant Mortality Rate}}$$

It is the proportion of children who attains less than one year of age is survived, to the number of children who died. The sampled inputs and outputs of the districts are shown in Table: 3.5.1.

**Table: 3.5.1. Selected Inputs and outputs of the Sampled Districts in Assam, India**

| Districts | '*Infant Survival Rates'* (Per 1,000 Live Births) | '*Institutional Deliveries'* (Percentage) | '*Health Centers'* (SCs, PHCs and CHCs) (Per 1,000 Population) | '*Health Workers'* (SCs, PHCs and CHCs) (Per 1,000 Population) |
|---|---|---|---|---|
| Barpeta | 22.26 | 96 | 0.21 | 0.26 |
| Bongaigaon | 19.83 | 72.2 | 0.19 | 0.62 |
| Cachar | 17.87 | 81.3 | 0.22 | 0.52 |
| Darrang | 13.29 | 93.2 | 0.23 | 0.00 |
| Dhemaji | 22.81 | 97.7 | 0.19 | 0.70 |
| Dhubri | 13.49 | 98 | 0.17 | 0.50 |
| Dibrugarh | 18.61 | 73.2 | 0.25 | 0.74 |
| Goalpara | 17.87 | 90.8 | 0.23 | 0.54 |
| Golaghat | 16.86 | 81.7 | 0.20 | 0.70 |
| Hailakandi | 18.23 | 100 | 0.20 | 0.58 |
| Jorhat | 19.00 | 77 | 0.22 | 0.76 |
| Karbi Anglong | 15.67 | 100 | 0.23 | 0.74 |
| Karimganj | 14.38 | 83 | 0.23 | 0.54 |
| Kokrajhar | 12.51 | 95 | 0.25 | 0.58 |
| Lakhimpur | 19.83 | 88.9 | 0.20 | 0.60 |

[5] *'It is the proportion of children who dies less than one year of age, in one thousand live births to the corresponding year'.*

| | | | | |
|---|---|---|---|---|
| Marigaon | 14.87 | 99.8 | 0.19 | 0.48 |
| Nagaon | 15.13 | 80.1 | 0.18 | 0.51 |
| Nalbari | 16.24 | 66.2 | 0.26 | 1.01 |
| Dima Hasao | 17.52 | 98 | 0.51 | 1.82 |
| Sibsagar | 16.86 | 74.1 | 0.26 | 0.85 |
| Sonitpur | 15.39 | 75.9 | 0.19 | 0.53 |
| Tinsukia | 19.00 | 67.4 | 0.18 | 0.56 |

**Source:** Annual Health Survey Assam 2012-13, Health Management Information System (HMIS) provisional data for April to November for financial Year 2016-17 updated 23rd December 2016, State Health Society, National Health Mission, Assam and Human Development report 2014, http://www.nrhmassam.info accessed on 23.08.2017.

It is an essential to use optimal combinations of input and output, being a sensitive distance measure tool it is proclaimed that too many inputs and outputs for a small sample size (22 DMUs in our case) may provide misleading results.

## 4. Analysis and Interpretation

The descriptive information results of all inputs and outputs variables considered in our investigation have shown a wide variation, which can easily be traced out from their respective highest and lowest values presented in table 4.1.

On average, a district engaged 0.64 percent health workers for every 1,000 population to deliver primary health service in rural area and has an average 0.23 percent health institution available for every 1,000 population healthcare needs in rural area.

**Table: 4.1. Descriptive Statistics the of selected inputs and outputs.**

| Statistics | *'Infant Survival Rates'* | *'Institutional Deliveries'* | *'Health Centres'* | *'Health Workers'* |
|---|---|---|---|---|
| Mean | 17.16 | 85.89 | 0.23 | 0.64 |
| Standard Deviation | 02.73 | 11.49 | 0.07 | 0.33 |
| Median | 17.19 | 85.95 | 0.21 | 0.58 |
| Highest | 22.81 | 100 | 0.51 | 01.82 |
| Lowest | 12.51 | 66.2 | 0.14 | 0.00 |

**Source:** Authors' own compilation.

The efficiency score result used for output oriented DEA in our study was carried out by using freeware DEAP software program, version 2.1, developed by Professor Tim Coelli[6] of Queensland University. To raise standard and quality in healthcare it is imperative for a given level of output, attempts should made with minimum level of inputs. However the limitation of the government and the very nature of service in health sector, it would very difficult for the public authority to curb inputs for a set outputs.

[6] Founder of DEAP 2.1 freeware DOS software licensed to Queensland University.

To deliver requisite healthcare service, public authority requires huge amount of finances and assets for employment and infrastructure facilities, which is unidirectional and non reversible due to prevailing service laws and agreement in health system, is a great challenge in India. Therefore, we have considered output-oriented approach rather than input-oriented approach in our study. It is also to be noted that in our study, we have considered a fixed quantity of resources with time invariant nature and DMUs have to consume the available resources optimally to reach the desired output level.

**Table: 4.2. Efficiency Scores and Scale of Output-Oriented Approach**

| **Districts** | **TE Scores** | **Districts** | **TE Scores** |
|---|---|---|---|
| **Barpeta** | **1.00** | **Karbi Anglong** | **1.00** |
| Bongaigaon | 90.5 | Karimganj | 0.83 |
| Cachar | 0.83 | Kokrajhar | 0.95 |
| **Darrang** | **1.00** | Lakhimpur | 0.91 |
| **Dhemaji** | **1.00** | **Marigaon** | **1.00** |
| **Dhubri** | **1.00** | Nagaon | 0.88 |
| Dibrugarh | 0.82 | Nalbari | 0.71 |
| Goalpara | 0.92 | Dima Hasao | 0.98 |
| Golaghat | 0.83 | Sibsagar | 0.76 |
| **Hailakandi** | **1.00** | Sonitpur | 0.78 |
| Jorhat | 0.83 | **Tinsukia** | **1.00** |

**Source:** Authors' own compilation.

The technical efficiency (TE) scores of 22 districts are depicted in the above Table: 4.2. A score of 1.00 implies efficient and be recognised as the efficiency frontier, whereas the score less than 1.00 shows inefficiency means fall below the frontier.

Out of 22 districts (DMUs), 8 districts, that is 36.4 percent are efficient having score 1, recognised as the efficiency frontier, while other 16 districts that is 63.6 percent are inefficient. All other districts, except four, such as, Lakhimpur, Goalpara, kokrajhar and Dima Hasao had an efficiency score less than the average of 90.6. Nalbari was ranked the lowest efficient district with a TE score 0.71 followed by Sibsagar district 0.76 and then Sonitpur district 0.78.

**Table: 4.4. Estimated Input and output Slacks of Output-Oriented Approach**

| Districts | *'Infant Survival Rates'* | *'Institutional Deliveries'* | *'Health Centres'* | *'Health Workers'* |
|---|---|---|---|---|
| Barpeta | 0.00 | 0.00 | 0.00 | 0.00 |
| Bongaigaon | 0.00 | **11.03** | 0.00 | 0.00 |
| Cachar | 0.00 | 0.00 | **0.02** | 0.00 |
| Darrang | 0.00 | 0.00 | 0.00 | 0.00 |
| Dhemaji | 0.00 | 0.00 | 0.00 | 0.00 |
| Dhubri | 0.00 | 0.00 | 0.00 | 0.00 |
| Dibrugarh | 0.00 | **7.98** | **0.06** | **0.04** |
| Goalpara | 0.00 | 0.00 | **0.03** | 0.00 |

| | | | | |
|---|---|---|---|---|
| Golaghat | 0.00 | 0.00 | **0.01** | **0.06** |
| Hailakandi | 0.00 | 0.00 | 0.00 | 0.00 |
| Jorhat | 0.00 | **5.26** | **0.03** | **0.06** |
| Karbi Anglong | **2.56** | 0.00 | **0.03** | **0.16** |
| Karimganj | 0.00 | 0.00 | **0.03** | 0.00 |
| Kokrajhar | **5.06** | 0.00 | **0.05** | 0.00 |
| Lakhimpur | 0.00 | 0.00 | **0.01** | 0.00 |
| Marigaon | 0.00 | 0.00 | 0.00 | 0.00 |
| Nagaon | 0.00 | 0.00 | 0.00 | 0.00 |
| Nalbari | 0.00 | **4.72** | **0.07** | **0.31** |
| Dima Hasao | **0.35** | 0.00 | **0.31** | **1.24** |
| Sibsagar | 0.00 | 0.00 | **0.07** | **0.16** |
| Sonitpur | 0.00 | 0.00 | 0.00 | 0.00 |
| Tinsukia | 0.00 | 0.00 | 0.00 | 0.00 |

**Source:** Authors' own compilation.

It can easily be distinguished using the above table no 4.4 corresponding to their respective highlighted inputs and outputs '*slack'*. The '*Slack'* represents the remaining unproductive or unutilised or missing outputs that operate in the system, despite the fact that there has been optimum proportional change of inputs or the outputs occur [24]. The '*slack'* output results are an approximation idea, based on which based on which necessary improvement or reduction were sought to covert the inefficient district as efficient one.

Surprisingly, there are only few districts, which requires modification of both; improvement in outputs and reduction in inputs to attain the ('*most productive'*) frontier. Kokrajhar, followed by Karbi Anglong, one of the inefficient districts, bring about escalating its survival rate by 5 and 2.5 per 1,000 populations, along with dropping number of health centres by 0.05 and 0.03 per 1,000 populations respectively. Further, Karbi Anglong district also needs to reduce their numbers of health workers by 0.16 per 1,000 populations. Similarly, Dima Hasao district need to make changes ISR by 0.35 per one thousand persons, beside with minimising the number of health centres by 0.31 and 1.24 per one thousand persons to reach to the frontier. Likewise, for institution delivery percentages, the districts, Bongaigaon, Dibrugrah, Jorhat and Nalbari have also requires to changes their respective inputs except Bongaigaon to be on frontier.

**Table: 4.5. Peers of Inefficient Districts in Assam, India**

| **Districts** | **Peers** |
|---|---|
| Barpeta | Barpeta |
| Bongaigaon | Barpeta, Dhemaji, Tinsukia |
| Cachar | Barpeta, Hailakandi, Dhemaji |
| Darrang | Darrang |
| Dhemaji | Dhemaji |
| Dhubri | Dhubri |

| | |
|---|---|
| Dibrugarh | Dhemaji |
| Goalpara | Barpeta, Hailakandi, Dhemaji |
| Golaghat | Hailakandi, Dhemaji |
| Hailakandi | Hailakandi |
| Jorhat | Dhemaji |
| Karbi Anglong | Hailakandi |
| Karimganj | Hailakandi, Marigaon, Barpeta |
| Kokrajhar | Hailakandi |
| Lakhimpur | Barpeta, Hailakandi, Dhemaji |
| Marigaon | Marigaon |
| Nagaon | Dhemaji, Dhubri, Barpeta, Tinsukia |
| Nalbari | Dhemaji |
| Dima Hasao | Hailakandi |
| Sibsagar | Dhemaji, Hailakandi |
| Sonitpur | Dhemaji, Marigaon, Dhubri, Barpeta |
| Tinsukia | Tinsukia |

**Source:** Authors' own compilation.

Now in order to benchmarking or find out, 'best performing' district among altered inefficient districts, peers are lay down a budding role models, in categorizing the most efficient one. On a leading edge or frontier, each district attempts to shift either in landscape direction or in portrait, means to raise outputs or minimising its inputs followed by the nearest district as efficient one.

For each set of uneconomical district, a single or set of unproductive districts performs as a '*peers*', which the uneconomical district wants to track for becoming efficient or productive. From the above Table no.4.5 which summarises the peers for all the districts, where Dhemaji came up to be the most excellent efficient district, followed by remaining unproductive districts. It has achieved the best possible levels of inputs blend to reach the most efficient output. However, using '*Stochastic Frontier Analysis'* (SFA) based on time invariant panel data, one of the study has [25] reported, the district 'Dhemaji' act as the top resourceful district in Assam-lends supports to our finding as well.

It is also to be noted that four (18 percent) district rural primary healthcare systems (Barpeta, Darrang, Dhemaji and Dhubri) had '*scale efficiency'* (SE) of cent percent signals for deliberation of '*Most Productive Scale Size'* (MPSS) for the said input-output combinations. The remaining 18 (78 percent) district healthcare systems were reported to be scale inefficient, showing an average of SE score 0.84 percent. This indicates the usage of inputs reduction by scale productive system of district hospitals has gone down up to 16 percent without make any changes in the present output status.

**Table: 4.6. Summary of outputs (inputs) increases (reductions) needed to make inefficient public rural primary healthcare systems efficient.**

| Variables | Original Value | Projection | Difference (%) |
|---|---|---|---|
| Infant Survival Rate (Output) | 358.52 | 304.69 | -15.01 |
| Institutional deliveries Percentage (Output) | 1822.1 | 1363.26 | -25.18 |
| Health Centres (Input) | 4.8 | 1.96 | -59.17 |
| Total Health Workers (Input) | 13.57 | 4.58 | -66.25 |

**Source:** Authors' own compilation.

The above Table no.4.6 result shows that to become efficient, the inefficient district rural primary healthcare systems combined would need to reduce the outputs, infant survival rate by 15.02 percent and institutional delivery percentage by 25.18 percent keeping the current level of output unchanged. Likewise, in case of inputs the districts have to reduce by 59.17 percent and 66.25 percent for health centres and total health workers respectively.

### *4.1. Econometric analysis of the determinants of efficiency*

The result of the stage-II least square model for explaining the observed hospital efficiencies are presented referring to our earlier presented in equation no. (v). The model contained the following variables; technical efficiency (T E) scores (as dependent variable), decadal growth rate of population 2001-11 (DGROP), population density (PD), rural literacy 2011 (RL), rural road length (RRL), annual per capita income (APCI), life expectancy at birth (LEAB). However in order to comply with OLS properties all variables are normalise using Z score formula ($Z=Xi- \mu / \sigma$).

In sensitive analysis, correlation coefficients among all explanatory variables used in our study were calculated and found nil or weak pair wise correlation. Additionally, using STATA version-13, multicolinearity of the explanatory variables considered were checked by calculating '*variance inflation factor'* (VIF) for the same (with mean VIF, 1.90) and was found in permissible limits. Similarly, heteroskedasticity was checked and also found in permissible limits. The results of second stage DEA using OLS is presented in the table no.4.7.

**Table No. 4.7: Results of Second Stage DEA using OLS model**

| Variables | Coefficients | t Value | P Value |
|---|---|---|---|
| DGROP | .0062574* | 1.91 | 0.0758* |
| PD | -.0002065** | -2.63 | 0.019** |
| RL | -.0059125** | -2.30 | 0.036** |
| RRL | -.0000457* | -2.02 | 0.061* |
| APCI | -2.24e-06 | -0.70 | 0.494 |
| LEAB | 0.0038806** | 2.29 | 0.037** |
| constant | 1.205512*** | 5.31 | 0.000*** |
| No of Observation | 22 | | |
| $R^2$ | 0.7507 | | |

| | |
|---|---|
| Adjusted $R^2$ | 0.6510 |
| F statistic | 0.0007 |

Source: Calculated by authors

*Note: the dependent variable is TE Scores using DEA-VRS model based on two inputs and two outputs. The superscript '*', '**', and '***' represents significance of variables used at 10, 5 and 1 percent levels respectively.*

It is evident from the above table that out of six explanatory or discretionary variables used as determinant of the efficiency in our least square stage-II model, three variables were significant at 5 percent level, two of them were at 10 percent level and one remain insignificant. Moreover the F statistic (0.0007) and Adjusted $R^2$ (0.6510) values are signalling the model capturing capacity in our research.

In our second-stage model out six exogenous variables DGROP and RRL are significant at level 10 percent, PD,RL and LEAB are significant at 5 percent level and one variable APCI is remain insignificant. The variable DGROP has positive impact and its significant status justifies that, over a period of time Assam has progress large enough to deliver of primary healthcare services in the rural area. For, variable PD is found significant with a negative impact on efficiency of rural healthcare service in the state. The specific finding is in accordance with similar studies [25, 26] and it can be explained in terms of raising demand for health services in the rural areas and it is the over burdened population pressure in health system in rural area that creates the demand for additional health system [27].

The RL and RRL variables are also remains significant and had an inverse relationship with efficiency score. The possible reasons are; lower literacy in rural area impedes efficient delivery of health services while size of RRL will have positive impacts on efficiency of rural healthcare [28]. The longer rural road length to health facilities in rural area appears to have depressing impacts on efficiency which is reflected in the negative sign of the RRL variable.

Moreover it is quite surprising that APCI variable remain insignificant with a negative sign in the model which represents that as income grows people are shifting towards private healthcare system for health needs or else due better efficiency and response they may be bound to approach private healthcare system.

Finally, LEAB variable is found significant and shown expected positive sign enlightens us that efficiency must have positive impact on health status of the rural populations in Assam.

## 5. Conclusion

In this investigation, we used distribution free '*non-parametric'* DEA technique to evaluate the '*Technical Efficiency*' of 22 districts of Assam state. The method provides an insight of the performance of DMUs (districts) and how the improvement to be made in the DMUs that perform under the frontier (mark or level). Our results and analysis presented in the study, that DEA categorizes the districts, which have been using additional inputs to achieve current level of output in comparison to standard input-output combination. Output and input reduction and slack calculated (Table: 4.6 and Table: 4.4) facilitate the policy makers to come to a decision upon optimal input-output mix to achieve efficiency. Moreover we have also found that DGROP, PD RL, RRL and LEAB are the important environmental variables to determine the efficiency in rural health facilities in Assam. The finding of the study showed a remarkable scope and also identifies some of the possible reasons for inefficiency in the performance of rural primary healthcare in Assam. Specific input-output mix and time invariant uses of data are the big limitations of the study.

**6. Scope of Further Research:**

The environment (discretionary) variables used in stage-II model of our study can further be filtered or purify by de-attaching the influence of those environmental factors on relative efficiency through the fitment of the original input. This process can be undertaken in Stage-III model for more specified and refine result which is beyond of our study preview.

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