CHAPTER - 3
THEORETICAL & CONCEPTUAL FRAMEWORK AND RESEARCH METHODOLOGY

The present chapter explains the theoretical framework related to measurement of technical efficiency of the higher education institutions and the concepts related to the present study. The detailed research design is also explained in this chapter. The chapter is divided into two sections (Section 3.1 and 3.2). Theoretical and Conceptual Framework is discussed in section 3.1. and section 3.2 explains the methodology for conducting the study including sample design and analytical tools used in the study.

3.1 Theoretical and Conceptual Framework

In this section important concepts related to measurement of technical efficiency and demand for higher education are discussed in a sequential manner in the following:

3.1.1 Concepts Related to Technical efficiency

The term efficiency means productive capacity of the producing unit in producing their output and now a day's efficient management of resources in every sector is a central issue from the perspective of our scarce resources from the perspective of management. Recently, different literatures describe various methods to measure the efficiency and then search ways to improve them. This is not only applicable to profit-making organizations, but also in non-profit making organizations and the public sectors, including educational institutions. One of the ways to find efficiency is measurement of technical efficiency, which specifies the relationship between inputs and outputs in production processes. Technical efficiency can be defined in two ways; either from input side or output side. From the input side, technical efficiency refers to the production of a given amount of output with a minimum input combination (input orientated), while from the output side it shows the ability of a firm, sector or institution to produce the maximum output with given inputs (output orientated).

Since the empirical part of this research is focused on measuring technical efficiency, so it is important to define both concepts of efficiency:

Allocative efficiency: Allocative (or price) efficiency refers to the ability to combine inputs and outputs in optimal proportions in the light of prevailing prices, and is measured in terms of behavioural goal of the production unit like, for example, observed vs. optimum cost or observed profit vs. optimum profit.

Technical efficiency: Technical efficiency is measured as the ratio between the observed output and the maximum output, under the assumption of fixed input, or, alternatively, as the ratio between the observed input and the minimum input under the assumption of fixed output.

3.1.2: Approaches to Study Technical Efficiency

Both technical and allocative efficiency can be measured by the following two main approaches

Input Approach: The input approach if one is considering the ability to avoid waste by producing as much output as input usage allows, i.e. we evaluate the ability to minimize inputs keeping outputs fixed.

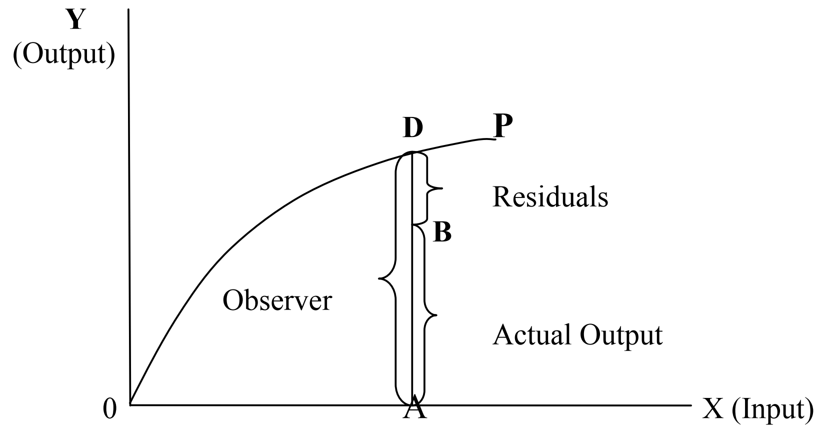
Output Approach: The output approach if one is considering the ability to avoid waste by using as little input as output production allows, i.e. we evaluate the ability to maximize outputs keeping inputs fixed.

3.1.3 Graphical Representation

In production function we consider the average level of output but ignore the residuals. So, it is contradicted when we go for estimation of production function, as it gives average result and not the average level of outputs. On the other hand a production frontier gives us the maximum feasible points on output space.

Consider, a case of single input and single output production frontier, where Y=f(X)

Figure 3.1: Production Frontier



In Figure 3.1, OP is the production frontier where DA is the observed level of output and OB is actual level of output. A producing unit will said to be efficient if it produces on the frontier line OP, while producing below the frontier indicates presence of inefficiency. Here, the firm producing at point B is inefficient as it is unable to produce maximum possible output.

Now let us consider the case of one output and two inputs, say X_1 and X_2. Then production function can be written as:

$$Y=f(X_1, X_2)$$

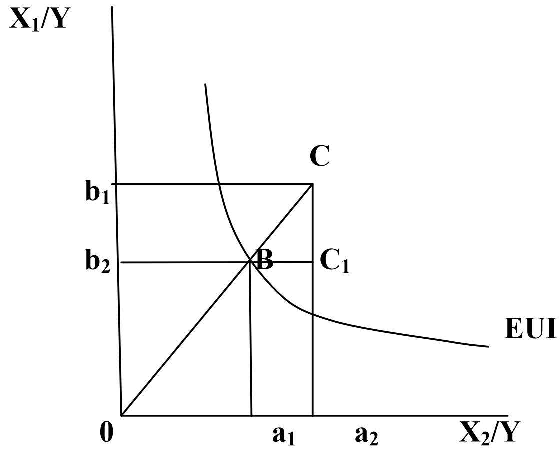
Therefore, $\lambda Y=f(\lambda X_1, \lambda X_2)$

Putting λ=1/Y, therefore we have $1= (X_1/Y, X_2/Y)$ …………………. $(1^{/})$

Equation $(1^{/})$gives us efficient unit isoquant (EUI) which represents different level of inputs for producing one unit of output. Here, inputs are efficient because we are measuring output without measuring errors or residuals, thus efficiency implies no errors in inputs.

Suppose, a firm is producing one unit of output at point C (in Figure 3.2). If the firm is efficient, then it will produce on or below the efficient unit isoquant. Since point C lies above the efficient unit isoquant, so the firm is inefficient.

Figure 3.2: Unit Isoquant



Here, technical efficiency means proportion of actual output required to produce one unit of output. Technical efficiency in terms of first input X_1 is Oa_2/Oa_1 or OB/OC of X_1/Y to produce one unit of output. Again technical efficiency in terms of second input X_2 is Ob_2/Ob_1 or OB/OC of X_2/Y to produce one unit of output.

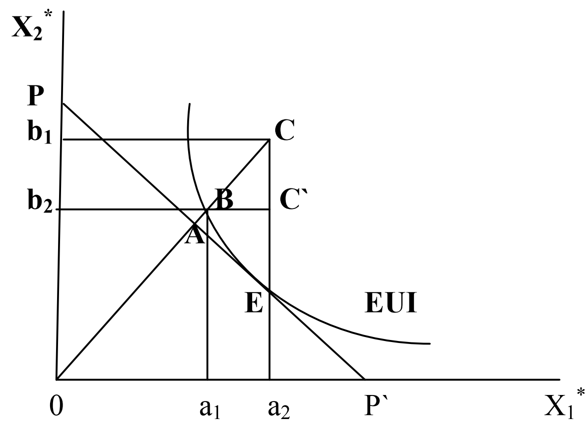
On the other hand technical inefficiency refers to the amount of inputs that can be reduced or reducing the cost of to produce same level of output. From another point of view technical inefficiency refers to the amount of profit that can be increased without changing output. When a firm unnecessarily produces by over utilizing some resources it leads to technical inefficiency. Main consequences of technical inefficiency are

- Loss in output
- Increase in cost of production
- Over or under utilization of resources
- Leads to decline in profit.

In this case a_1a_2 and b_1b_2 are the amount of inefficiencies which is necessary to reduce for going back to the efficient unit isoquant.

Technical inefficiency is measured as: (1– technical efficiency). In this case technical inefficiency is equal to (1–OB/OC) which is equal to BC/OC. In terms of X_1 technical inefficiency = a_1a_2/Oa_1 and in terms of X_2 technical inefficiency = b_1b_2/Ob_1.

Figure 3.3 Unit Isoquant and Isocost Line



Allocative efficiency is defined as minimum cost requirement to the actual cost of production. In Figure 3, PP` is the isocost line, **OA** is the minimum cost needed by firm and OB is the actual cost incurred by firm. Allocative efficiency in this case is equal to **OA/OB** and allocative inefficiency is equal to (1- OA/OB) = AB/OB.

Since the firm cannot go beyond efficient unit isoquant (EUI), it can either stay on EUI or above it, so the firm cannot come to point A rather it can come to point B. Thus allocative efficiency is the proportion of cost that could have been reduced to produce one unit of output.

By combining technical and allocative efficiency, we get over all efficiency. In other words, overall efficiency is the product of technical efficiency and allocative efficiency i.e OE = TE*AE. Therefore in this allocative efficiency is equal to (OB/OC) × (OA/OB) = OA/OC.

3.1.4 Techniques for measurement of Technical Efficiency

Essentially there are two main methodologies for measuring technical efficiency viz; The econometric or parametric approach, which is also known as Stochastic Frontier Analysis (SFA) and the mathematical or non-parametric approach popularly known as Data Envelope Analysis (DEA).

These two techniques use different methods to envelop data, and in doing so they make different accommodation for random noise and for flexibility in the structure of production technology. There are few basic differences between Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). These are following:

Firstly: One difference is that SFA has a stochastic frontier, i.e. there is a probability distribution which is the basis of MLE or method of moment's estimation. DEA has a non-stochastic frontier with no probability distribution, although the efficiency of producers relative to the frontier might be probabilistic. The non-stochastic frontier prevents MLE or method of moment's estimation from being used and prevents a standard error for the estimates from being computed, or even existing.

Secondly: The other difference is that DEA can include, and often does include, more than one output of a producer. SFA usually has only one output or a prior weighted average of multiple outputs. The assumption that is relevant for DEA is "input-output separability". That means that inputs are used in ratios unrelated to the ratios of outputs.

Thirdly: SFA always consider stochastic inefficiencies, while DEA considers it sometimes.

Fourthly: SFA allows statistical noise into the frontier and also allows statistical tests on the estimates, while DEA is advantageous at the times where the specific form of production function and distributional form of inefficiency terms are unknown.

Hence, these two approaches differ in many ways, but the advantages of one approach over the other boil down to two characteristics.

The econometric approach is stochastic and attempts to distinguish between the effects of noise and the effects of inefficiency, while the linear programming approach is deterministic and under the voice inefficiency melt noise and real inefficiency. The econometric approach is parametric and as a result it suffers from functional form of misspecification, while the programming approach is non-parametric and so it is immune to any form of functional misspecification.

3.1.5 Educational institutions

The educational institutions can be easily conceptualized as an organisation to attain certain specific goals and defined by its own boundaries. It operates as a social system in its own right. In order to analyze educational institution, it is found that they have the following characteristics which enable us to set them apart and to study them as social organisations:

- They have definite population.
- They have a clearly defined structure based on specific social interaction.
- They represent the nexus of a compact network of social relationships.
- They are pervaded by we-feeling.
- They have their own culture.

3.1.6 The Educational production function

An educational production function is an application of the economic concept of a production function to the field of education. It relates various inputs affecting a student's learning (schools, families, peers, neighborhoods, etc.) to measured outputs including subsequent labor market success, college attendance, graduation rates, and most frequently standardized test scores. The educational production function can be written as

$$E = f\,(A, I, M)$$

Where; E = level of education (knowledge and attitude)

A = set of characteristics of learners' (age, sex, motivation, socio-occupational category, parent's level of education and income, etc.)

I = set of characteristics of the educational institutions (qualifications, experience and salary of teachers, number of pupils per class, numbers of hours of classroom teaching, size of the institutions, etc.)

M = set of environmental variables

3.1.7 Higher Education Production Process with Inputs and outputs of HEIs

The definitions and measurement of inputs and outputs in the education industry remains a litigious subject among researchers. According to Johnes and Taylor the purpose of attempting to measure the technical relationship between inputs and outputs in the higher education sector is to provide a bench-mark against which each higher education can be compared. Since the production function provides quantitative estimates of the link between inputs and outputs, it is possible to estimate what each higher education could have produced with the inputs available to it. The production function also provides information about the likely effect on output of altering the amount and combination of inputs used by individual institution.

Once a higher education production function has been estimated from data on inputs for HEIs of Barak Valley, it is subsequently feasible to obtain an estimate of the extent to which each institution's actual output matches up to its expected output.

In a simplified theoretical world, a producing unit is assumed to produce a single homogenous commodity and this can be achieved in various ways depending upon the chosen production technique. Writing the production function in general form, we have

$$Y = f(L, K, T, R)$$

Where; Y = output (e.g teaching and research)

L = labour inputs (e.g; academic and non-academic staff)

K = capital inputs (e.g; buildings and equipment)

T = technical knowledge (e.g; knowledge of academic staff)

R = raw material (e.g; students)

A problem which arises in attempting to apply production theory to the higher education sector is that higher education produce more than one output. Moreover, these outputs are quite different and there is no obvious way of adding them together. In the case of private sector firms, output can be measured in monetary units (e.g; total sales or value added). This is not possible in the higher education sector. Since higher education institutions are multi-product organization, it is necessary to specify the individual outputs which are produced and to show the extent to which these individual outputs are dependent upon the wide variety of inputs required. A further problem with attempting to estimate a production function for the higher education sector (or parts of this sector) is that inputs are often used to produce more than output and there is no obvious way of attributing specific inputs to specific outputs. Times spent on reading articles and books for reassures purposes, for example, often provides useful input into teaching; and teaching (particularly at the post graduate level) may also have feedback effects on research. Since research output and teaching output cannot be added together in any meaningful way, this makes it difficult to estimate input and output relationship for specific outputs.

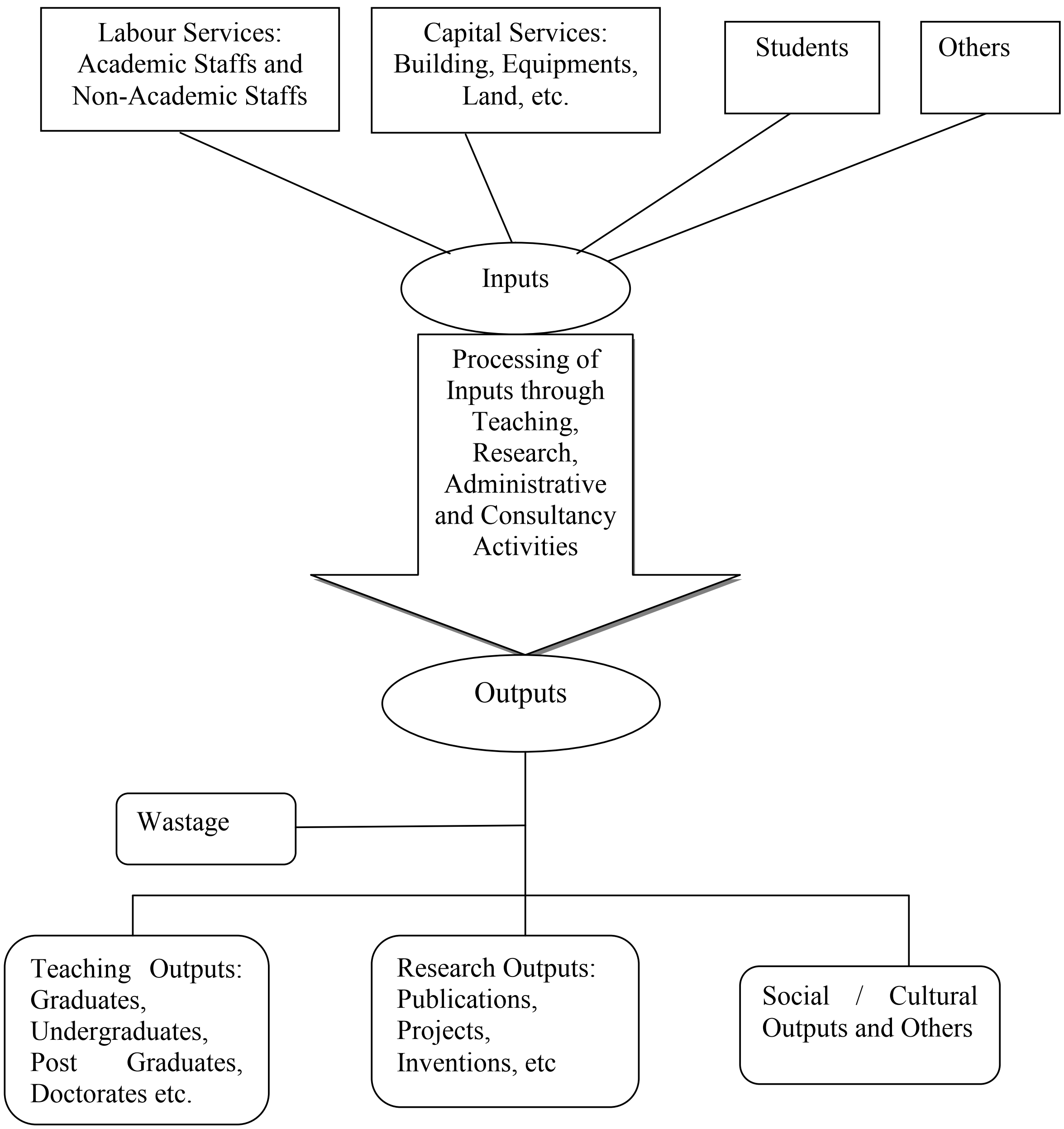
There is also simultaneity problem since higher education (or departments within higher education) which gain a high reputation for their research output are often able to attract students of higher academic ability than higher education with a proper research record. Research output may therefore affect teaching output. Ideally such interrelationships should be taken into account explicitly when attempting to estimate input-output relationship.

Finally, there is the absolutely critical problem of indentifying and measuring the inputs and outputs of the higher education sector at the institutional level.

The inputs used in the higher education production are mainly labour services, capital services, and students. Technical knowledge and quality of these inputs are omitted since it is assumed that this is embodied in labour and capital services. The linkages between these inputs and the outputs of the higher education sector are shown in broad terms in finger 3.1.

One of the most capital inputs of higher education is the students whom they are able to attract. Higher education has to operate in a competitive environment as far as acquiring students is concerned. In general, they attempt to attract students of the highest academic calibre, a characteristic which can be expected to have an effect on several higher education outputs. The academic ability of students, for example, may be expected to affect their performance in examination as well their success in finding a suitable first destination after graduation. However the problems remain to find an acceptable measure of academic ability and hence generally an average level of score of each HEI's students are widely considered.

Figure 3.1 Higher Education Production Function



3.1.8 Demand for Higher Education

Demand for higher education is in reality a derived demand for high wage employment opportunities in the modern sector. But cost of education and background of the students have also great influence on it. Thus, demand for higher education depends on three important factors viz; i) the family's private benefit of education (expecting to get a better paying job in modern sectors), ii) the educational costs, both direct and indirect that a student or family must bear it, and iii) student's socio economic background. Further demand for education depends on institutional factors at micro as well macro level from the point of view of stakeholders. For simplicity these factors are classified into quantitative variables and qualitative variables and the model for estimation is given as:

$$D_i = f(X_i, Q_i)$$

Where D_i = demand for higher education, X_i = quantitative factors, and Q_i = qualitative factors.

Demand can be defined in terms of growth rate of enrollment or applicant-enrollment ratio of the HEIs, or it can be measured by the willingness of the students to get enrolled in higher education. The determinants of the demand are explained already in the above.

3.2 Methodology of the Study

Research methodology is of utmost importance in any research work. It includes the techniques to be adopted in solving a research problem, such as the manner in which the problems are formulated, the definitions of terms, the choice of subjects for investigation, the validation of data-gathering tools, the collection, analysis and interpretation of data and the processes of inferences and generalizations. The selection of a method appropriate in investigating a research problem will depend upon the kind of data that the problem entails. This section is further divided into following two sub-sections viz; methodologies for data collection (sub-section 3.2.1) and methodologies for analysis of the data (sub-section 3.2.2).

3.2.1 Methodologies for Data collection

The study is based on both secondary data and primary data. Secondary data is collected through complete enumeration method. Relevant primary as well as secondary data have been collected from all the general degree colleges of Barak valley. The secondary data collected from the colleges are of both cross-section and time series in nature related to the inputs and output over the last seven years. Other secondary sources are Assam University Annual Reports, Result Booklets, College Development Council Records collected from CDC Office, AUS etc. Some secondary information is collected from government documents namely statistical handbook, Report from Director of Higher Education (DHE) of Assam, MHRD Annual Reports, UGC Annual Reports etc.

For the collection of primary data on students' information purposive random sampling is used. The information has been collected from the students admitted in the year 2012 in the various departments of Assam University. As the study covers up to the time period 2012, so the data has been collected from the students who have passed TDC examination in 2012 and have taken admission in the university. It is not possible to collect the information from the students who do not take admission in the university which is the limitation of the study. But, as it is a sample study, the collected information can represent the population characteristics.

3.2.2 Methodologies for Analysis of Data

Analysis of the data is done by suitable econometric techniques which are here explained in details according to objectives and hypotheses of the study.

To investigate the status as well as infrastructural facilities available in the Higher Education Institutions, composite dimension index and principal component analysis can be used. The status of higher education institutions is measured by using composite index of infrastructure and performance index with equal weights. The infrastructure index has been constructed by using composite dimension indices of physical resources, human resources and teachers' quality as teaching learning in HEIs is determined by all these factors.

$$Dimension\ Index(DI_{ji}) =$$

$$\frac{Actual\ Value\ of\ j^{th}\ variable\ for\ i'th\ HEI - Minimum\ Value of\ j^{th}\ variable}{Maximum\ Value of\ j^{th}\ variable - Minimum\ Value\ of\ j^{th} variable}$$

Where, j=1,2..k and i=1,2,3,...........n. Here K is the number of variable taken into the study for n HEIs. The infrastructure index of i^{th} HEI can be written as $II_i = \frac{\mathbf{1}}{\boldsymbol{k}} \sum_{i=1}^{k} DI_{ji}$

For the construction of physical resource index different variables related to physical resource of the HEIs Principal Component Analysis are used in this study. While construction of human resource index and teachers' quality index are done on the basis of some pre determined justified weights according to the importance of the indicators.

Before using principal component analysis for the physical resource index of the HEIs, a multivariate factor analysis can be used to address the inter-relationship among the set of observed variables. The primary purpose of factor analysis is the derivation of a set of observed variables in terms of new categories called factors. A factor explains the several observed variables. There can be one or more factors depending upon the nature of the study and the number of variables involved in it. Now, Principal Component method can be used for the construction of Infrastructure Index. The aim of Principal Component method is the construction of a given set of variables Xj's (j = 1,2,…..,k) of new variables ($P_{i}\ \forall\ i$ = 1, 2, …………..k), called i^{th} Principal Components which are linear combinations of the X_k

$$P_1 = a_{11}X_1 + a_{12}X_2 + \ldots\ldots\ldots a_{1k}X_k$$
$$P_2 = a_{21}X_1 + a_{22}X_2 + \ldots\ldots\ldots a_{2k}X_k$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$P_k = a_{k1}X_1 + a_{k2}X_2 + \ldots\ldots\ldots a_{kk}X_k$$

The method is being applied mostly by using the standardized variables, i.e.,

$$Z_j = \frac{\left(X_j - \overline{X}_j\right)^2}{\sigma_j}$$

The a_{ij}'s are called factor loadings and are worked out in such a way that the extracted principal components satisfy two conditions: (i) principal components are uncorrelated (orthogonal) and (ii) the first principal component (P_1) has the maximum variance, the second principal component (P_2) has the next maximum variance and so on.

According to the Kaiser's criterion only the Principal Components having latent root or characteristic root greater than one are considered as essential and that should be retained. The Principal Components so extracted and retained are then rotated from their beginning position to enhance the interpretability of the factors. Communality, symbolized as h^2, is then worked out which shows how much of each variable is accounted for by the underline factors taken together. A high communality figure means that not much of the variables are left over after whatever the factors represent is taken into consideration.

So, h^2 of the i^{th} variable = (i^{th} factor loading of factor A)^2 + (i^{th} factor loading factor B)^2 + …

The amount of variance explained (sum of squared loadings) by each Principal Component factor is equal to the corresponding roots. When these roots are divided by the number of variables they show the characteristic roots as proportions of total variance explained. The variables are then regressed against each factor loading and the resulting regression coefficients are used to generate what are known as factor scores. To compute infrastructure related indices of HEIs, the factor scores (f_{jk}) and the corresponding weight are used. So, a composite index is to be developed as weighted sum of scores, the weight being the percentage of the variations explained by the factors. If the percentage of k^{th} factor is denoted by S_k^2, then the index for the i^{th} HEIs can be calculated by using the formulae:

$$H_j = \Sigma S_{kj}^2 f_{jk} \qquad j = 1, 2 \ldots k$$

In this way physical resource index for each HEI will be calculated by taking sum of percentage of variation explained by factors multiplied by the respective factors for each HEI.

For construction of human resource index of the HEIs, a composite index is used by assigning equal weights to teacher-student ratio and non-teaching staffs-teachers ratio. Teacher-student ratio and non-teaching staffs-teachers ratio play an important role in proper functioning and maintenance of HEIs. In addition to this it is necessary and desirable to have favourable non-teaching staffs and teachers' ratio for maintaining documentation and non-academics activities of the HEIs. While availability of teachers in a greater proportion per-student is expected to have positive impact on academic environment and performance of the institution.

Again quality of teachers of any education institution is believed to be a stronger variable than the quantity for its sound effects on student achievement (Schacter and Thum 2004, Abe 2014, etc.); hence quality of teachers of a particular college is here considered as an indicator of infrastructure in this study. However, measurement of quality and its indicators are also subjective in nature which are difficult to compute. From Aristotle and Socrates to Montessori and Piaget to Bruner and Hanushek, philosophers, physicians, psychologists, cognitive scientists, and economists have each attempted to characterize the attributes, dispositions, knowledge, and instructional skills that define effective teachers (Schacter and Thum 2004). Teachers' quality basically includes some key prerequisite qualities viz; verbal ability, content knowledge, education coursework, teacher certification, and teaching experience. In this study the criteria of teachers' quality is proxied as a composite measure of teachers' additional qualifications related to the field of knowledge and experience in relevant field. Hence, in order to construct teachers' quality index of the colleges average additional higher qualifications and average teaching experience of the teachers are taken as indicators of quality. It is generally acknowledged that experienced teachers have increased depth of understanding of the content and how to teach. Additionally, experienced teachers are more effective with students due to their use of a wider variety of strategies in the teaching and learning process. So, in this study teachers experience index is considered as one of the indicator of HEI's infrastructure and calculated by a taking ratio of total teaching experience of all the teachers of the HEI by the total number of teachers in the HEI. Like teaching experience, teachers' additional qualifications is also an important measure of teachers' quality as it denotes depth of the knowledge in the respective subjects, knowledge which they are spreading in the classrooms. Unanma et al. (2013) have examined the relationship between teacher's academic qualifications and academic achievement of Senior Secondary school students in Chemistry and found positive influence on students' academic achievement in the subject. In this study for calculation of teachers' educational index, weights are assigned as per the additional academic qualifications of teachers in the HEIs according to the guidelines for selection of college teachers by Director of Higher Education, Assam (applicable to all government colleges, provincialised colleges and Mahavidyalaya).

Output of the HEIs in the study

One of the primary outputs of every HEI is its quality of successful graduates, which generally measured in terms of the performance of the students in the final examination. Quality of output is however the only aspect of each HEI's contribution to human capital is as the quality of education varies among the HEIs. Degree results are an alternative variable for measuring the quality of education, since it is the most obvious outcome of every HEI (Johnes and Taylor1990). One can easily distinguish two HEIs with same pass rate, it one has more number of first class and second class than the other. Hence, it is more justified to measure output by assigning proper weights with the quality and level of performance (Johnes and Taylor.1990, Kuksal and Naluaci 2006).

In this study performance index is taken as proxy for output of the HEIs, which calculated by using following formula:

$$PI_i = \frac{W_1 \times FD + W_2 \times SD + W_3 \times TD}{\sum_{i=1}^{3} W_i}$$

Here, PI is the performance index of the i^{th} HEI, W_1, W_2 and W_3 are the weights assigned to numbers of first division (FD), number of second division (SD), and third division (TD) students respectively. Here, weights are assigned into 3:2:1 ratio.

Another performance index is constructed to measure the performance of the HEIs after estimating performance index for both pass (WPR) and honours graduates (WHR), further weights are assigned to honours and pass graduates into 18:14 ratio as per the number of papers studying. As honours graduates are considered as better performer than ordinary pass (Johnes and Taylor 1990). This index is denoted by weighted performance index (WPI). In this study WPI is also considered as one of the indicator of status of the HEIs of Barak Valley.

To measure technical efficiency of the colleges and determinants of inefficiency, both Stochastic Frontier Analysis (SFA) and Two-stage output oriented DEA has been used. Literature suggests several alternative approaches to measuring productive efficiency and the most common methods used for efficiency measurement in the field of education are parametric and non-parametric techniques. The non-parametric technique does not impose a functional form on the production frontiers and do not make assumptions about the error term. These are used in linear programming approaches and the most popular non-parametric approach is the Data Envelopment Analysis (DEA). Parametric frontier approaches impose a functional form on the production function and make assumptions about the data. The most common functional forms include the Cobb-Douglas, Constant Elasticity of Substitution and Translog production functions. The stochastic frontier model decomposes the error term into a two-sided random error that captures the random effects outside the control of the firm (the decision making unit) and the one-sided efficiency component. The recent literatures have showed a convergence of the two approaches. However, there is a lack of empirical evidence in the literature about the proximity of these two approaches in measuring technical efficiency. Policy formulations based on only one of these efficiency estimates may not be accurate because of the inherent limitations of each. Before any correctional measures are taken, the stability of the technical efficiency estimates obtained from a parametric method should be evaluated by comparing them against those found when using the non-parametric method. In the two-stage DEA model, technical efficiency scores obtained from DEA using controllable inputs are regressed on student socio-economic status and other environmental factors. The residuals of this regression measure pure technical efficiency after accounting for fixed socio-economic and environmental factors.

Stochastic Production Frontier Models

A stochastic frontier captures all the possible combinations and involves fitting stochastic production or cost frontier models to data. The stochastic frontier production function was independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). The original specification involved a production function specified for cross-sectional data which has an error term with two components, one to account for random effects and another to account for technical inefficiency.

Battese and Coelli (1993) proposed a stochastic frontier model for use with panel data in which the inefficiencies can be expressed as specific functions of explanatory variables. The model can be expressed as

$$Y_{it} = X_{it}\, \beta_k + (V_{it} - U_{it}) \qquad \text{where, } i = 1, \ldots, N,\ t = 1, \ldots, T \qquad \ldots\ldots\ldots (1)$$

Where; Y_{it} is the production of firm i in time period t; X_{it} is a (Kx1) vector of inputs; β is the vector of unknown parameters; V_{it} are random variables which are assumed to be independently and identically distributed $N(0, \sigma_v^2)$ and independent of U_{it} which are non-negative random variables that account for technical inefficiencies in production; U_{it} are assumed to be independently distributed as truncations at zero of the $N(m_{it}, \sigma_u^2)$ distribution. The mean inefficiency is a deterministic function of p number of explanatory variables (Z_{it}):

$$m_{it} = Z_{it}\delta \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where; δ is a column vector of the parameters of order (px1) to be estimated. $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \frac{\sigma_u{}^2}{\sigma_v{}^2 + \sigma_u{}^2}$ are the composite parameters which show the presence of inefficiency. Consequently, if γ is 0, all deviations are caused by noise rather than inefficiency; if is 1, all deviations are due to inefficiencies.

Couple of models has been developed in order to explore the relationship between exogenous (environmental) factors and inefficiencies as well as separating them from each other. The earliest paper conducted this analysis is the study of Pitt and Lee (1981) whom used two-stage approach. In the initial stage, they has estimated conventional frontier function without taking any environmental variables into consideration, and secondly, the projected efficiencies are regressed onto exogenous (environmental) factors. The inefficiencies, U_{it}, in equation (1) can be specified as:

$$U_{it} = Z_{it}\delta + W_{it} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where; Zs are the exogenous (environmental) factors and Wit is defined by the truncation of the normal distribution with mean zero and variance σ^2. Then, the technical efficiency of the i^{th} firm at time t is

$$TE_{it} = exp(-U_{it}) = \exp(-Z_{it}\delta - W_{it})$$

The parameters of the model β, δ, σ and γ can be estimated by using the maximum likelihood estimation (MLE). Given the specifications of the stochastic frontier production function, defined by equation (1), the null hypothesis, that technical inefficiency is not present in the model, is expressed by the following null hypothesis $H_o : \gamma = 0$, where γ is the variance ratio, explaining the total variation in output from the frontier level of output attributed to technical efficiencies and defined by $\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$. The parameter γ must lie between 0 and 1. This is done with the calculation of the maximum likelihood estimates for the parameters of the stochastic frontier model by using the computer program FRONTIER Version 4.1 (Coelli 1996). If the above null hypothesis is accepted, this would indicate that σ_u^2 is zero and hence that the U_{it} term should be removed from the model, leaving a specification with parameters that can be consistently estimated using ordinary least squares. Further, the null hypothesis that the technical inefficiency effects are time invariant and that they have half-normal distribution are defined by $H_o : \eta = 0$ and $H_o : \mu = 0$ respectively. These hypotheses are tested using the generalized likelihood ratio test and the generalized likelihood ratio statistic, λ is defined by $\lambda = -2 \ln [L(H_o) / L(H_1)]$, where H_o and H_1 are the null and alternative hypotheses involved. If the null hypothesis, H_o, is true, then λ is asymptotically distributed as a Chi-square (or mixed Chi-square) random variable. If the null hypothesis involves $\gamma = 0$, then λ has mixed Chi-square distribution (Coelli 1995, 1996) because $\gamma = 0$ is a value on the boundary of the parameter space for γ.

To analyze the determinants of inefficiency, effects model (Battease and Coelli 1993) has been used, which is shown in equation (3) and can be estimated for some environmental variables viz; percentage of teachers with extra qualification, years of establishment of the HEIs, type of its affiliation, location of the college, courses or subjects offered by the HEIs, etc.

Further for the same objectives two-stage DEA has been used where in the first stage efficiency scores is obtained by using DEA and for determining responsible factors of inefficiency Tobit regression is used for same set of variables used in the SFA effect model and then finally compared the validity of the findings for two separate techniques.

For measuring technical efficiency, Translog production frontier is used in this study because Translog production is advantageous compared to other forms of production function like Cobb-Douglas, CES etc., because it assumes less restrictions on coefficients and allows partial elasticity to vary with each response with a variable elasticity of substitution which is more practical in nature. The specification of Translog Production frontier is framed in the following:

$$\ln WPPS_{it} = \beta_0 + \beta_1 \ln(TSR_{it}) + \beta_2 \ln(EPS_{it}) + \beta_3 [\ln(TSR_{it})]^2 + \beta_4 [\ln(EPS_{it})]^2 + \beta_5 \ln(TSR_{it}) \ln(EPS_{it}) + \beta_6 T + (v_{it} - u_{it}) \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Here, all the variables are in natural logarithmic form except trend variable (T) which measures change over time (Battesse & Coile 1992, 93). $WPPS_{it}$ is the weighted performance per students of the i^{th} college for t^{th} time period, which is obtained by normalizing WPI_{it} with total enrollment of the colleges. TSR_{it} is teacher-student ratio of i^{th} college for time period t. The definitions and justifications of the variables used in the above specification are explained later in the sub-section 5.1.1 of section 5.1 of Chapter 5 in detail.

To analyze the determinants of inefficiency, effects model (Battease and Coelli 1993) has been used, which is shown in equation (2) and can be estimated for some environmental variables viz; percentage of teachers with extra qualification, years of establishment of the HEIs, type of its affiliation, location of the college, courses or subjects offered by the HEIs, etc.

For Translog production frontier, inefficiency effect model is specified in the following:

$$U_{it} = \delta_0 + \delta_1 YOE_{it} + \delta_2 TAD_{it} + \delta_3 CO_{it} + \delta_4 LD_{it} + \delta_5 CMH_{it} + \delta_6 CMP_{it} + \delta_7 T + W_{it} \ldots\ldots \quad (5)$$

Here, the independent variables are structural / environmental variables that might play an important role in the production of successful graduates and W_{it} is pure white noise error. YOE_{it} is the years of establishment of ith college for t-th time period, TAD_{it} is the type of affiliation of ith college for t-th time period, CO_{it} is course offered by ith college for t-th time period, LD_{it} location of the college which is a dummy variable (the value one for the colleges belonging to urban area and value zero for the colleges belonging to rural area), T is a trend variable, CMH and CMP denotes the cut-off marks for honours course and pass course. The definition and justifications of the variables are explained later in the sub-section 5.1.1 of section 5.1 under Chapter 5 in detail.

Further for the same objectives two-stage DEA has been used where in the first stage efficiency scores is obtained by using DEA and for determining responsible factors of inefficiency Tobit regression is used for same set of variables used in the SFA effect model and then finally compared the validity of the findings for two separate techniques.

Data Envelopment Analysis (DEA)

DEA is the most common technique used in the analysis of efficiency of social sector. As it is a non-parametric technique, it has an advantage of avoiding the need to make assumptions regarding the functional form of the best practice frontier (e.g; Cobb-Douglas or Translog) as well as avoiding the need to make distributional assumptions regarding the residuals in the regression analysis. DEA can readily incorporate multiple inputs and is used to calculate technical and scale efficiency as it only requires information on output and input quantities. The study adopts output oriented DEA which consider capacity of firm to produce maximum possible level of output subject to the given level of inputs.

DEA estimation measures the efficiency of observed decision making units (DMU) and compares them among themselves to achieve a relative efficiency indicator. This method uses DMUs as the best practices observed to construct an empirical production frontier known as an efficient frontier. This non-parametric approach assumes that the efficiency of a production unit is measured by calculating the ratio of (weighted) outputs over (weighted) inputs. The efficiency of a particular college has been calculated relative to this frontier. Here, only relative efficiency is measured but not absolute efficiency. Efficient production units lie on the frontier whereas inefficient DMUs are enveloped by the frontier.

Charnes, Cooper and Rhodes (1978) have extended a model that generalizes the single-input, single-output ratio measure of efficiency of a single Decision-Making Unit (DMU) in multiple-inputs, multiple outputs setting. In this study, an individual college constitutes a DMU. The technical efficiency of a DMU is computed as ratio of virtual output produced to virtual input consumed: $Technical\ Efficiency = \frac{\sum weighted\ outputs}{\sum weighted\ inputs}$

Let there be n number of DMUs using varying amounts of inputs to produce outputs. There are ‘s’ number of inputs x_i, i = 1...s, and m number of outputs y_r, r = 1...m. For each DMU_j, where j = 1......n, the problem is to

$$Max.(h_j) = \frac{\sum_r u_{rj} y_{rj}}{\sum_i v_{ij} x_{rj}} \qquad (6)$$

Subject to $\sum_r u_{rj} y_{rj} / \sum_i v_{ij} x_{rj} \leq 1$ for j=1, ….. n and $u_{r,} v_r \geq 0$

Where, u_{rj} is the weight assigned each unit of output ‘r’ from DMU_j and v_{ij} is the weight assigned each unit of input i used by DMU_j. The solutions are sought to maximize the ratio of weighted output to weighted input for each DMU. Due to normalization, the efficiency scores range from zero to one. The same weights (virtual multipliers) that maximize h_j (Average Productivity for DMU_j) are applied to the inputs and outputs of all DMUs in the solution to the problem for DMU_j.

Panel data DEA: The Slack-Based Malmquist Index

In case of Panel Data, linear programming DEA methodology allows calculation of (input-oriented or output-oriented) Malmquist Index (Caves, Christensen and Diewert 1982), which helps to measures change in productivity growth of producing units and its sources. Due to the availability of a panel data set, we are not only interested in the relative performance of the HEIs in a particular year but also in how the efficiency of HEIs have changed over time. Hence, in this study the Malmquist index, which is able to capture total factor productivity (TFP), changes from one year to another, is applied here. The Malmquist index is constructed in such a way that the radial distance of observed output and input vectors in periods t and (t+1), relative to a reference technology, is measured. The output-oriented approach of the Malmquist index considers the maximum level of outputs with a given input vector and a given production technology relative to the observed outputs.

Considering there are *n* inputs to produce *m* output of the firms. Denote $x \in R_+^n$ and $y \in R_+^m$ as, respectively, the input vector and output vector of those firms. The set of production possibilities of a firm at time *t* can be written as:

$$S^t = \{(x^t, y^t) \mid x^t \text{ can produce } y^t\} \quad \ldots\ldots\ldots\ldots\ (7)$$

Fare et al. (1994) define the output distance function at time t as:

$$D_0^{\,t}(x^t, y^t) = \inf\{\theta \mid (x^t, y^t/\theta) \in S^t\} = (\sup\{\theta \mid (x^t, \theta y^t) \in S^t\})^{-1} \quad \ldots\ldots\ldots\ (8)$$

The subscript 0 is used to denote the output-based distance function. Note that, $D_0^{\,t}(x^t, y^t) \le 1$ if and only if $(x^t, y^t) \in S^t$, and $D_0^{\,t}(x^t, y^t) = 1$ if and only if (x^t, y^t) is on the frontier of the technology. In the later case, Farrell (1957) argued that the firm is technically efficient.

To define the Malmquist index (MI), Fare et al. (1994) defined distance functions with respect to two different time periods:

$$D_0^{\,t}(x^{t+1}, y^{t+1}) = \inf\{\theta \mid (x^{t+1}, y^{t+1}/\theta) \in S^t\} \text{ .... } (9)$$

And $$D_0^{\,t+1}(x^t, y^t) = \inf\{\theta \mid (x^t, y^t/\theta) \in S^{t+1}\} \text{ .... } (10)$$

The distance function in (9) measures the maximal proportional change in output required to make (x^{t+1}, y^{t+1}) feasible in relation to technology at time t. Similarly, the distance function in (10) measures the maximal proportional change in output required to make (x^t, y^t) feasible in relation to technology at time (t+1). The output Malmquist TFP productivity index can then be expressed as:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \left[\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}} \text{ .... } (11)$$

The term outside the brackets shows the change in technical efficiency while the geometric mean of the two ratios inside the brackets measures the shift in technology between the two periods t and (t+1); this could be called technological progress. So,

$$\text{Efficiency change (E)} = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \text{ .... } (12)$$

$$\text{Technical change (P)} = \left[\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}} \text{ .... } (13)$$

In each of the above formulas, a value greater than one indicates an improvement and a value smaller than one presents deteriorations in performance over time. Thus, if $MI > 1$ shows the improvements of technical efficiency; $MI = 1$ signifies no change in production technology and $MI < 1$ shows a gain in production technology. This approach can be extended by decomposing the constant returns-to-scale technical efficiency change into scale efficiency and pure technical efficiency components. By running different linear programs with the same data under a constant returns-to-scale (without convexity constraint) and variable returns to scale (with convexity constraint), measures of overall technical efficiency (TE) and 'pure' technical efficiency (PT) are obtained. Dividing overall technical efficiency (TE) by pure technical efficiency then yields a measure of scale efficiency (SE). Using these models, it is thus possible to provide five efficiency / productivity indices for each college and a measure of technical progress over time. These are (i) technical efficiency (TE) change (i.e. relative to a constant returns-to-scale technology); (ii) technological change (P); (iii) pure technical efficiency change (PT) (i.e. relative to a variable returns-to-scale technology); (iv) scale efficiency (SE) change; and (v) total factor productivity (TFP) change.

Recalling that TFP indicates the degree of productivity change, then if TFP exceeds one then productivity gains occur, whilst if TFP less than one productivity losses occur. Regarding changes in efficiency, technical efficiency increases (decreases) if and only if TE is greater (less) than one. An interpretation of the technological change index is that technical progress (regress) has occurred if P is greater (less) than one. An assessment can also be made of the major sources of productivity gains / losses by comparing the values of TE and P. If TE is greater than P then productivity gains are largely the result of improvements in efficiency, whereas if TE is less than P productivity gains are primarily the result of technological progress. In addition, recall that overall technical efficiency is the product of pure technical efficiency and scale efficiency, such that $TE = PT \times SE$. Thus, if PT is greater than SE then the major source of efficiency change (both increase and decrease) is improvement in pure technical efficiency, whereas if PT is less than SE the major source of efficiency is an improvement in scale efficiency. Subtracting one from any index provides the change in efficiency, technology or productivity from one period to the next.

In order to provide final ranking of the HEIs in terms of technical efficiency two composite indices namely; efficiency index by using principal component analysis for justified statistical weights and average technical efficiency index with for six different set of technical efficiency scores that considers equal weights are considered in the study.

To compare the variation in efficiency of NAAC Accredited with non-NAAC accredited HEIs independent test for group mean difference is applied with prior consideration to equality of variance. Further to compare these technical efficiency scores with NAAC ranking of NAAC Accredited HEIs simple tabular analysis is done in this study.

In order to examine the significant demand for the HEIs of the region enrollment growth and applicant to enrollment ratio (AER) is taken as proxy for demand for the HEIs and one-sample t test for assumed mean value of applicant to enrollment ratio (AER=1) at entry level in the HEIs of the region is tested in this study. Further for estimation of enrollment growth in the HEIs of Barak Valley over the sessions, least-squares growth rates estimation method is used in this study.

$$ln\, E_t = \alpha + \beta t + e_t \; \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Where; t= 1, 2, …,7. E_t stands for enrollment in t-th time period, t is time, α and β are parameters. e_t indicates an error term which $e \sim N(0, \sigma^2)$. β is the average annual growth rate, and it is multiplied by 100 for obtaining the rate into percentage.

In this study demand is defined in terms of applicant to enrollment ratio of the HEIs and few selected variables are tested as determining factors for demand for HEIs. The empirical model for estimating institutional enrollment demand for higher education can be framed as follows:

$$AER_i = \beta_0 + \beta_1 LD_i + \beta_2 PP_i + \beta_3 TQI_i + e_i \ldots\ldots\ldots\ldots (15)$$

Here, TQI_i is stands for the teachers' quality index of the i^{th} HEI which is defined in Chapter 4; LD_i is the location dummy which takes value 1 for the HEIs which are situated in urban areas and zero otherwise; PP_i is the past performance of the i^{th} institution measured in terms weighted performance index of the HEI in the previous year. All these three factors are expected to have positive impact on demand for higher education institution in different ways. Location plays an important role in determining infrastructure and status of any educational institute which generally induce enrollment students in a greater scale due to situational advantages. Further quality of teachers and past performance of any HEI indicate positive spillover effect on students performance, hence inclusion of these variables as determinants of demand for HEIs is justified in this study. Further to analyze the factors influence demand for higher education and demand for HEIs from the perspective of students in Barak Valley, simple percentage analysis of students' opinion on factors related to demand for higher education is done in this study. Further percentage analysis of students' opinion related to the factors influencing demand for higher education across different academic and socio-economic groups is done in this study for examining variation in students' perception across different groups.

Further to check whether the technically efficient colleges have higher demand or not, Pearson's correlation coefficients of enrollment demand for HEIs with technical efficiency scores estimates of the HEIs is applied in this study.