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A STUDY ON USING DEA IN MEASURING EDUCATIONAL PRODUCTIVITY

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Abstract
The issue of productivity in education has become more important as the sector has grown and education becomes the norm rather than the exception for all Indians. Measuring efficiency and effectiveness in education is of great relevance considering that resources are usually limited, while needs for such resources are often limitless. Unfortunately, defining and measuring productivity in the education sector has proven to be a difficult task. These problems are often cited as reasons to ignore the issue of productivity in education. For decades, researchers have studied the relationship between educational appropriations and student achievement throughout differing economic environments. Researchers attempt to quantify the ultimate resourceful methods of educational budgeting and spending. DEA is becoming an increasingly popular management tool. The widespread acceptance of this methodology is such that by 1994 there had been over 400 articles written on the subject. Despite its intended use for government, however, application of the technique in the public sector has been scant, mostly limited to the evaluation of school performance. This paper first explains the concept of efficiency, and then focuses on previous research and reviews related to the efficiency of education. Next, the differences in these studies that make efficiency studies hard to compare are discussed. Lastly, importance of DEA method in measuring educational productivity is analysed.

Key Words: Productivity, Efficiency, Effectiveness, Data Envelopment Analysis (Dea), Educational Productivity.

Introduction

The issue of productivity in education has become more important as the sector has grown and education becomes the norm rather than the exception for all Indians. Unfortunately, defining and measuring productivity in the education sector has proven to be a difficult task. These problems are often cited as reasons to ignore the issue of productivity in education .At its most basic level, productivity is a measure of output per unit of input (Griliches, 1987). This is a technical but general definition which can be applied in a variety of different contexts. From the public's perspective, productivity of education sector can be thought of as how much individuals and society are getting from the education sector, given the resources they put in. Productivity also reflects whether the system is "wasteful" in some sense.

The concept of productivity has two dimensions: efficiency and effectiveness. ‘Efficiency’ refers to the level and quality of service which is obtained from the given amount of resources (Epstein, 1992). If the sector can produce a greater quantity and/or higher quality of output with the same amount of resources, it has improved its efficiency. ‘Effectiveness’ relates to the extent to which the provider meets the needs and demands of stakeholders. In the education sector, these stakeholders include students, faculty, local communities, state governments, industry, and the nation-at-large. Using this broader definition of productivity, it becomes clear that productivity improvement is not synonymous with "cost-cutting." Instead, productivity improvement is a multi-faceted concept, inextricably linked with the goals and missions of the institution or system under consideration.

Importance of Productivity Measurement in Education Sector

Measuring efficiency and effectiveness in education is of great relevance considering that resources are usually limited, while needs for such resources are often limitless. The underlying objective of making best use of resources devoted to education requires a drive to maximising both the efficiency and effectiveness quotients for this pursuit. Thus, the concepts of efficiency and effectiveness are applied in order to monitor and evaluate how well resources are used in an educational system and to prioritize the use of such resources. One of the most common conceptual frameworks employed in the economic analysis of education takes the form of a production function. Here the educational institution is seen as analogous to a firm transforming inputs into outputs through a production process. Typical inputs in the education production function are the characteristics of the teaching and learning environment, while outputs are generally defined in terms of students’ test scores. It follows that a strong assumption held in this type of analysis is that technical relationships are of central importance in the educational process. If such relationships exist and can be quantified, policy can be constructed so as to maximize some preferred conceptual outcome. Much of the empirical research in this area has focused on identifying these technical relationships. However, a disturbing pattern in the multitude of studies of this type is that no strong empirical evidence exists to support the contention that traditional educational inputs have the expected positive influence on educational outcomes (Pritchett and Filmer, 1999, p. 223).The failure of educational production functions to identify the purported relationship between key policy variables (such as resource spending) and educational achievement has been the subject of much inquiry.

A large number of empirical studies to date have already considered the possibility that inefficiency exists in education. These studies have used a variety of empirical techniques to identify 'efficient' educational institutions and compare them with 'inefficient' institutions. This work is obviously important because in most developed economies an emphasis has been given to issues of accountability, value-for-money, and cost-effectiveness in education. The measurement of organisational efficiency is thus recognised as an essential part of the implementation, monitoring and evaluation of these public sector reforms.

Introduction of Data Envelopment Analysis (DEA)

Data envelopment analysis (DEA) provides a method to determine the amount of resource conservation and/or output augmentation necessary for a decision-making unit (DMU) to become efficient. DEA was invented and introduced in 1978 by Charnes, Copper, and Rhodes (1978) as a technique that could be used specifically by the public sector to measure efficiency.

The inventors of the technique thought that this approach would be appropriate for the public sector since public managers cannot divert resources to other programs that may be more profitable or attractive.

Further, the data on which DEA is applied are not weighted by reference to market prices or any other economic indicators. DEA also allows the analyst to include in the analysis discretionary and non-discretionary inputs, categorical variables, control variables, and ordinal relationships (Banker and Morey, 1986). DEA is becoming an increasingly popular management tool. The widespread acceptance of this methodology is such that by 1994 there had been over 400 articles written on the subject (Charnes, Cooper, Lewin, and Selford, 1994). For example, DEA has been used to evaluate the performance of educational systems, physicians, court systems, nursing services, banking and coal industries to name a few. Despite its intended use for government, however, application of the technique in the public sector has been scant, mostly limited to the evaluation of school performance.

DEA is an analytical technique that can be used to assist in identifying best practice performance in the use of resources amongst a group of like organizations. Such identification can highlight where the greatest gains can be made from improvements in efficiency and help institutions to achieve their full potential. Measurement tools like DEA are useful in situations where government bodies operate in markets, which are distorted by regulated prices, subsidies and a lack of contestability. In these cases the usual market indicators of performance, like profitability and rates of return, cannot be used to gauge an institution's economic performance accurately. Despite this, governments and the general public are still concerned that these institutions operate in an efficient manner. In these situations DEA provides a comparative monitoring that identifies variations and hence provides encouragement and direction for performance improvement.

Data envelopment analysis (DEA) is a nonparametric method in operations research and economics for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision making units (or DMUs). Although DEA has a strong link to production theory in economics, the tool is also used for benchmarking in operations management, where a set of measures is selected to benchmark the performance of manufacturing and service operations.

Data envelopment analysis (DEA) is a mathematical programming approach for estimating the relative technical efficiency (TE) of production activities. The term DEA was originally proposed by Charnes et al.(1978). The Charnes et al. work extended the Farrell (1957) multiple input, single output measure of TE to the multiple-output, multiple input technology. Since the early Charnes et al. work, however, DEA has developed and expanded to include a wide variety of applications.

DEA is generally used in research to explore technical and scale efficiency. Technical efficiency means that an institution cannot produce more output from its existing inputs. In the case of universities, this means that the technically efficient university is not able to deliver more teaching plus research output (without reducing quality) given its existing labor, capital and other inputs. Technical efficiency is a valid performance measure, as the provision of education and research by universities at a given level of quality, within resource constraints is a major objective of universities. Some authors argue that, next to the delivery of quality education, technical efficiency is probably the only valid measure of performance of tertiary institutions Pestieau & Tulkens, 1993).

An educational institute may be technically efficient but it may still be producing too little or too much output. This information is derived from measures of scale efficiency. Scale efficiency is the extent to which an institution can take advantage of returns to scale by altering its size toward the optimal size (defined as the region in which there are constant returns to scale in the relationship between outputs and inputs). A group of institutes can be found to be technically

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inefficient, however, taxpayers or voters may be willing to trade off some technical efficiency for another objective, such as increased participation and equity.

DEA is a set of non-parametric programming techniques that assist in identifying which set of decision making units may be considered as best practice. Best practice units are given a rating of one and efficiency scores are assigned to other units by comparing them to best practice units. The set of units to be analyzed should be chosen with some caution so that valid comparisons can be made.

DEA is non-statistical and non-parametric in nature. It is non-statistical, because its' estimates are not based on any statistical distribution (e.g., the normal) and noise is not explicitly considered in the estimation; however, it does not that statistical tests of the various estimates cannot be performed. An alternative view is that DEA is deterministic. When we refer to DEA as being non-parametric, we are referring to the fact that we do not have to assume a particular functional relationship between the inputs and outputs; we do not have to assume any statistical distribution; and we do not have to estimate parameters based on assumed statistical distributions.

The DEA technique permits an assessment of the performance or technical efficiency (TE) of an existing technology relative to an ideal, "best-practice," or frontier technology (Coelli et al. 1998). The frontier or best-practice technology is a reference technology or production frontier that depicts the most technically efficient combination of inputs and outputs (i.e., output is as large as possible given the technology and input levels, or input levels are as small as possible given the output levels). The frontier technology is formed as a non-parametric, piece-wise linear combination of observed "best-practice" activities. Data points are enveloped with linear segments, and TE scores are calculated relative to the frontier technology.

The DEA technique may be used to estimate TE scores or efficient levels of inputs or outputs from either an input or output orientation or from an orientation that allows both input and output levels to simultaneously change. The input-orientation provides estimates of the amount by which inputs could be proportionally reduced and still produce a given output level. The output orientation provides estimates of the amount by which outputs could be proportionally expanded given existing input levels. The orientation that allows both inputs and outputs to change by the same proportion (inputs are proportionally decreased while outputs are proportionally increased) provides a measure of what is referred to as hyperbolic graph efficiency; it may be generalized by what is called a directional distance function.

Literature Survey on Application of DEA in Education Sector

Data Envelopment Analysis (DEA) is a relatively new "data oriented" approach for evaluating the performance of a set of peer entities called Decision Making Units (DMUs) which convert multiple inputs into multiple outputs. The definition of a DMU is generic and flexible. Recent years have seen a great variety of applications of DEA for use in evaluating the performances of many different kinds of entities engaged in many different activities in many different contexts in many different countries. These DEA applications have used DMUs of various forms to evaluate the performance of entities, such as hospitals, US Air Force wings, universities, cities, courts, business firms, and others, including the performance of countries, regions, etc. Because it requires very few assumptions, DEA has also opened up possibilities for use in cases which have been resistant to other approaches because of the complex (often unknown) nature of the relations between the multiple inputs and multiple outputs involved in DMUs.

Since DEA in its present form was first introduced in 1978, researchers in a number of fields have quickly recognized that it is an excellent and easily used methodology for modeling operational processes for performance evaluations. This has been accompanied by other developments. For instance, Zhu (2002) provides a number of DEA spreadsheet models that can be used in performance evaluation and benchmarking. DEA's empirical orientation and the absence of a need for the numerous *a priori* assumptions that accompany other approaches (such as standard forms of statistical regression analysis) have resulted in its use in a number of studies involving efficient frontier estimation in the governmental and nonprofit sector, in the regulated sector, and in the private sector.

DEA which was popularized by Charnes, Cooper and Rhodes (1978) actually originated from the idea of Farrell's (1957) seminal work on the measurement of productivity efficiency. Lots of literatures, therefore, have been published since the publication of Farrell's paper on (i) efficiency measurement in different productive sectors using both discretionary and non-discretionary parameters, (ii) application of DEA in measuring efficiency and variations in LPP formulation, and (iii) conditions of existence of convexity in production frontier under both deterministic and stochastic behavior of the parameters.

However, there a number of benefits implicit in the programming approach that makes it attractive on a theoretical level. Given its nonparametric basis, substantial freedom is given on the specification of inputs and outputs, the formulation of the production correspondence relating inputs to outputs, and so on. This is seen as especially useful in education production function where the usual axioms of production activity breakdown (i.e. profit maximisation).

The series of application of DEA in education started with the article by Charnes et. al in 1981. Thereafter several studies have applied DEA in measuring the efficiency of schools. For example Bessent and Bessent (1980), Bessent et al(1982, 1983, 1984), Ludwin and Guthrie (1989), and Fare et al (1989) applied it in measuring the efficiency of the U.S. schools, and Jesson et al (1987) applied it to study the efficiency of school districts (LEAs) in the U.K.

Charnes, Cooper and Rhodes (1981), Sengupta and Sfeir (1988), Ganley and Cubbin (1992), Beasley (1995), Haksever and Muragishi (1998) have applied DEA approaches to educational institutions. More detailed theoretical introductions to frontier efficiency measurement techniques may be found in the works of Fried, Lovell and Schmidt (1993), Charnes, Cooper, Lewin and Seiford (1995) and Coelli, Rao and Battese (1998) .

An important aspect of DEA concerns the calculation and interpretation of ‘slack’ variables. One obvious benefit of DEA is that it provides a single index number indicating the proportional reduction of inputs (or augmentation of outputs) necessary (or desirable) for an institution to reach the efficient frontier. In a single-input, single-output case, a proportional reduction of inputs is always achievable, and therefore the value of the slack variables will always be zero. However, in multiple-input, multiple-output situations, positive input and output slacks are frequently necessary to reach the envelopment surface and achieve full efficiency. In other words, it may be desirable to further augment particular outputs or necessary to further reduce particular inputs (rather than all) even though an educational institution has already reached the frontier of the production set.

The interpretation of educational slacks has been undertaken by several studies. In analysis of Houston elementary schools Bessent et.al.(1982,p.1362) reasoned that relocatable inputs (as suggested by input slacks) could be transferred from ‘high-achieving, near-efficient schools’ to ‘efficient, low-achieving schools’. These ‘relocatable inputs’ included more experienced and more highly qualified teachers. Alternatively Jesson, Mayston and Smith’s (1987) study of English local education authorities (LEAs) uses slacks as an aid to the interpretation of efficiency scores. In this case, the full scope of projected improvements for an inefficient LEA includes improvements in particular outputs over and above the proportional reduction of inputs.

Jesson, Mayston and Smith (1987) also used slacks to evaluate the sensitivity of efficiency scores to environmental influences on educational outcomes, including the proportion of single-parent families and low socioeconomic families in the authority’s catchment area. A similar analysis of specific inputs and outputs as derived from input and output slacks is made in McCarty and Yaisawarng’s (1993) study of New Jersey school districts.

In other European studies Bonesrqnning and Rattsq (1992, 1994) conducted efficiency analysis of Norwegian high schools. The conclusion of these studies usually is that DEA is applicable to efficiency measurement of schools in the sense that it detects differences between schools and the results are fairly robust.

Mancebonand Mar-Molinero (2000) studied the performance in primary schools in U.K. In this study, schools in South atestsmpton and Porstmouth were used in order to assess the factors that influence their productive efficiency. It was found that religious orientation, parental influence and level of exclusions all impacted on the ability of a school to deliver the best possible results in standard assessment.

Despite the importance of efficiency measurement in education, it is only recently that the more advanced econometric and mathematical programming frontier techniques have been applied to primary and secondary schools, university departments and Universities as a whole. Worthington (2001) in his paper attempts to provide a synoptic survey of the comparatively few empirical analysis in education using frontier efficiency measurement techniques. He had examined both the measurement of inefficiency in education and the determinants of educational efficiency.

MA Wing Sze in his M.phil thesis, examined the efficiency of the education sector of China at the provincial level, based on the three cross section data points. In order to have a better understanding of the issue, both technical and scale efficiency were computed for the primary, secondary and tertiary levels. He concluded that the education reform provided room for education expansion while the education institutions were unable to manage the resources in a more effective and efficient way.

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Deway et.al (1998) in their paper, re-examine the educational production function literature, focusing on the role of specification in determining the significance of education inputs.

A number of studies had been made to measure the technical efficiency of different educational institutions. Avkiran (2001) made a study of Australian universities and, while no benchmark was established and he claimed that Australian universities are operating at "respectable" levels of efficiency.

While Flegg et.al.(2004) used DEA to measure the efficiency of British universities to reveal total factor productivity.
Casu and Thanassoulis (2003) used DEA to evaluate cost efficiency in UK universities central administration. Another paper that used DEA in the study of educational institutions was by Salerno(2002) where he made an analysis of the technical and allocative efficiency of research intensive higher educational institutions.

Antonio Afonso and Miguel st.Aubyn (june,2005) in their study addressed the efficiency of expenditure in education provision by comparing the output from the educational system of 25, mostly OECD countries with resources employed. They estimated a semi-parametric model of the education production process using a two stage procedure. By regressing Data envelopment Analysis, output scores on non-discretionary variables, they showed that inefficiency is strongly related to GDP per head and adult educational attainment.

Tyagi, preeti et.al(2009) in their paper assessed the technical efficiency and efficiency differences among 348 elementary schools of Uttar Pradesh state in India by a linear programming based technique, DEA. They had assessed the schools with eight inputs and three outputs. This analysis also provided school wise planning information to policy makers. As per their demand, this is the first application in elementary education sector in India using DEA technique.

Atanu Sengupta and Naibedya prasun Pal (2010; 2012) made a DEA based study of the primary education system in India, using the district level DISE statistics. They have used several indicators to capture the multi-dimensional aspect of primary education system in India. Their analysis reveals serious discrepancies in deprivation, social and policy indicators that greatly infringe upon the efficiency of the system. In their work, resource-use efficiency (as measured by DEA) and standard efficiency indicators indicate wide inter-zonal differences in India.

Roohi Ahmed (2012) in his article investigated the public sectors' efficiency in the educational expenditure in the two major provinces of Pakistan. By using DEA, the author evaluated the performance of each district. The main focus of his analysis is not on how to cut public expenditure but rather more on increasing the value for money of public spending. Education sector has been regarded as the priority social sector by almost all countries of the world; hence the findings of his study brought light on hidden facts regarding the public sector efficiency in a developing country like Pakistan where government are forced to keep public expenditure at minimum level.

Ghose and Bhanja (2014) in their paper measures technical efficiency (TE) scores for primary and upper-primary level of education separately for different districts in West Bengal over the period 2005-06 to 2010-11, assuming variable return to scale and using non-parametric Data Envelopment Analysis. Inter district variation in efficiency score is evident from their work. Their work supports the existence of regional variability with respect to upper primary level of TE score. They concluded that either high level of literacy rate or the Educational Development Index (EDI) not necessarily implies that the districts are more technically efficient. In their study, a comparison of the literacy rate, TE score and EDI reveals that there are some districts in West Bengal which have above average literacy rate and high EDI but below average TE level.

Strength of Data Envelopment Analysis (DEA)
DEA can be a powerful tool when used wisely. A few of the characteristics that make it powerful are:

- DEA can handle multiple input and multiple output models.
- It doesn't require an assumption of a functional form relating inputs to outputs.
- DMUs are directly compared against a peer or combination of peers.
- Inputs and outputs can have very different units. For example, X1 could be in units of lives saved and X2 could be in units of dollars without requiring an a priori tradeoff between the two.
- Proven to be useful in uncovering relationships that remain hidden for other methodologies.
- The sources of inefficiency can be analysed and quantified for every evaluated unit.

Some of the Limitations of DEA are
The same characteristics that make DEA a powerful tool can also create problems. An analyst should keep these limitations in mind when choosing whether or not to use DEA.

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- Since DEA is an extreme point technique, noise (even symmetrical noise with zero mean) such as measurement error can cause significant problems.
- DEA is good at estimating "relative" efficiency of a DMU but it converges very slowly to "absolute" efficiency. In other words, it can tell us how well we are doing compared to our peers but not compared to a "theoretical maximum."
- Since DEA is a nonparametric technique, statistical hypothesis tests are difficult and are the focus of ongoing research.
- Since a standard formulation of DEA creates a separate linear program for each DMU, large problems can be computationally intensive.
- Results are sensitive to the selection of inputs and outputs (Berg 2010).
- The number of efficient firms on the frontier tends to increase with the number of inputs and output variables (Berg 2010).

A desire to improve upon DEA, by reducing its disadvantages or strengthening its advantages has been a major cause for many discoveries in the recent literature. One such approach is the Stochastic DEA, which makes a synthesizes of DEA and SFA, improving upon their drawback.

DEA is one of the most common techniques used in the analysis of efficiency of government organizations. The main alternative to DEA is the use of stochastic production or stochastic cost frontiers (see Coelli et al., 1998). Because it is a non-parametric technique, DEA has the advantage, over the stochastic frontier approach, 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 also readily incorporate multiple outputs and be used to calculate technical and scale efficiency using only information on output and input quantities.

There are some limitations in using DEA. First DEA identifies two or more decision-making units that operate at best practice. That is, at least some universities will be given a score of one, when in reality even the best performing university may not be operating on the frontier. This may be a problem if all institutes are inefficient to some degree. An additional problem is that it is not possible to undertake tests of statistical significance with DEA scores as is possible with regression analysis. Secondly, a common practice with DEA is to derive efficiency scores using only those inputs which managers control, and then use information on the non included inputs to assess their impact. However, detailed data on all inputs may not be available. Ideally, data are needed on non-physical inputs, such as experience, information and supervision.

Conclusion

With growing complexities and increasing number of educational institutions, there is a need for responsible management of its' resources for proper utilization. For decades, researchers have studied the relationship between educational appropriations and student achievement throughout differing economic environments. Researchers attempt to quantify the ultimate resourceful methods of educational budgeting and spending. Performance measurement plays in the improvement of government productivity in general and budgeting and resource allocation more specifically. As noted above, the documented interest in performance measurement of education sector throughout this century can be attributed in part to the increased public skepticism in government and a desire for more accountability on how resources are being used. The belief is that performance measurement can result in improved decision-making, accountability, and performance of public sector educational organizations. The main argument for performance measurement is that it can identify services where productivity is declining or is not up to expectations and can improve performance by allocating resources accordingly (Epstein, 1992).Thus, performance measurement in educational institutions can serve as a feedback mechanism on Educational organizational processes . Teachers, students, policy makers, elected officials, parents of students and Government officials are among those who benefit from performance measurement. By means of productivity measures, Government can hold their personnel accountable. At the same time, the public can hold the people accountable for the efficient and effective use of public funds invested in education. Thus, from the above discussion it can be concluded that productivity measurement in educational sector is imperative and it can be done through Data Envelopment Analysis.

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