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Efficiency Measurement in Higher Education: Concepts, Methods and Perspective

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Abstract

The aim of this research is to provide a conceptual basis for addressing efficiency in economics, focusing on higher education. The definition of economic efficiency using the Pareto criteria is presented. It is followed by the application of these concepts to higher education framework. The concepts and methods for estimating efficiency in higher education are quite complex and this may impair policy recommendations stemming from an incorrect definition or understanding, still, efficiency is a suitable and needed goal for any educational system, especially in a developing country.

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1. Introduction

In the current literature on education, there is an apparent lack of theoretical guidance and the term ‘efficiency’, although extensively used, is either not carefully defined or the definitions differ. The aim of this paper is to provide a conceptual basis for addressing efficiency in a higher education (HE) framework. Although the concepts of efficiency are quite complex, and this may impair policy recommendations stemming from their

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inappropriate use or incorrect understanding, still, efficiency is a suitable and essential goal for any educational system, especially for a developing country.

The paper is organised as follows. In section 2 the origin of the theory of efficiency is analysed, the definitions of consumption, production and allocative efficiency are presented, and the concept of efficiency in the neoclassical framework is examined. Further modifications to the efficiency concept are examined in section 3 when the concept is applied in the HE framework. Section 4 introduces methods and techniques used in measuring efficiency in education and also presents some of their problems. Given the limitations apparent in the critical appraisal of efficiency in HE several definitions for efficiency are proposed and techniques for measuring them are considered. Concluding remarks are offered in section 5.

2. The Theory of Efficiency

To ensure a Pareto efficient allocation there must be consumption, production and allocative efficiency. Assuming a two-person, two-commodity pure exchange model, an allocation is Pareto efficient when, firstly, the consumers have the same marginal rates of substitution between any two goods (consumption efficiency or exchange efficiency), secondly, the producers have the same marginal rates of technical substitution between any two inputs and these (production efficiency) and finally, when the consumers’ marginal rate of substitution is equal to the producers’ marginal rate of transformation between the two goods and (allocative efficiency or product-mix efficiency). This analysis of consumption efficiency assumes that the commodities are fixed in supply and hence, the inputs devoted to their production are also fixed. Contrastingly, in the analysis of the production efficiency one assumes that the quantities of various commodities can be altered by reallocating inputs between their productions.

Symbolically, in a two-good (X, Y), two-input (L, K), two-person (A, B) exchange economy necessary conditions for Pareto efficiency are:

Table 1. Pareto efficiency conditions

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Efficiency</th>
</tr>
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<tbody>
<tr>
<td>MRS\text{\textsubscript{\text{A}}}=\text{MRS} \text{\textsubscript{\text{B}}}</td>
<td>consumption (exchange) efficiency</td>
</tr>
<tr>
<td>MRTS\text{\textsubscript{LX}}=\text{MRTS} \text{\textsubscript{LX}}</td>
<td>production efficiency</td>
</tr>
<tr>
<td>MRS\text{\textsubscript{X}}=\text{MRT} \text{\textsubscript{XY}}; MRS\text{\textsubscript{Y}}=\text{MRT} \text{\textsubscript{XY}}</td>
<td>allocative efficiency</td>
</tr>
</tbody>
</table>

Only under these conditions is Pareto efficiency attained and no individual can improve his/her position without making another individual worse off. Achieving only the consumption and production efficiency does not ensure that the right combination of goods is produced in the economy. Therefore, it is only when allocative efficiency is attained that all the alternatives for Pareto improvements are exhausted. However, not every Pareto efficient outcome can be considered as desirable and the Pareto efficiency criterion does not imply equity. Therefore, Pareto efficiency is a necessary but not a sufficient condition for social welfare.

The foundation of the theory of efficiency and its measurement was laid out by Farrell (1957) who used three main measures of efficiency. He explicitly decomposed total economic efficiency (referred to by Farrell as the overall economic efficiency) into two components: technical and price (allocative) efficiency. However, the difference between total economic efficiency and allocative efficiency in Farrell’s framework remains unclear. A different view can be found in Devine, Lee, Jones, and Tyson (1985) who acknowledge two main elements of productive efficiency: technical and factor price efficiency. In their view, technical efficiency implies producing
a maximum level of output from a given set of inputs and unchanged technology. Factor price efficiency assesses the ability to use the most favourable combination of inputs given their relative prices.

In general, allocative efficiency refers to the distribution of productive resources among alternative uses which allows the production of an optimal output mix, i.e. allocative efficiency is focused on selecting between different technically efficient combinations. In a competitive market, allocative efficiency is attained when three conditions are fulfilled: each level of output is realised by equating the marginal cost to price, each consumer’s marginal benefit is equal to the price and, finally, the relative marginal benefits are the same for all consumers. Next we will analyze how these concepts are transposed to an HE framework.

3. Concepts of Efficiency in Higher Education

Efficiency concepts are frequently found in national education planning documents but without clarification as to whether efficiency is a final goal or a channel to achieve a certain educational objective. When used by economists the term efficiency is mostly context-specific, whereas practitioners affix diverse, conceptually different, uses to the term. In this section the conceptual and definitional issues regarding efficiency in education is presented. In order for efficiency in education to be defined it is necessary to point out some of the characteristics of the education sector, focusing on higher education.

Firstly, higher education institutions can be considered as multi-product enterprises (e.g. Belfield, 2000, and Cohn and Cooper, 2004) which produce multiple outputs and have multiple inputs which are difficult to measure since many of them do not have market prices, e.g. number of students enrolled, their prior attainment and teacher characteristics. Furthermore, higher education providers use what Rothschild and White (1995) call ‘customer-input’ technology i.e. customers (students) are also inputs in the production (function) and the quality of students recruited may serve as a signal of the quality of the HEI. Along these lines Dixit (2002) points out that the education system consists of multitask, multiprincipal and multiperiod organisations that are quite similar to monopolies and have poorly observable, complex goals. Given the multiple goals it is difficult to apply some simple criterion for measuring success or failure in achieving the specified goals and it follows that there are no absolute criteria that can lead us in the measurement of efficiency and effectiveness of a HE system.

The commonly examined types of efficiency in both the public sector and education studies cover both technical and allocative efficiency. An extension of these two concepts can be found in McMahon (1983) who discusses four concepts of efficiency in the provision of education. These are technical, price, exchange and allocative efficiency and each is described in turn. According to McMahon’s terminology, technical efficiency examines the time and resources used in the production of a given output (these resources include teaching methods, instructional materials, student’s learning activities, over some time period). Price efficiency is an extension of technical efficiency since it takes into consideration the relative costs of resources (e.g. whether the educational services in the HEIs priced in a cost efficient way). To provide a distinction from Farrell’s (1957) original concept of price efficiency, a more appropriate term in this case would be factor price efficiency; this can then be linked to the definition by Devine, Lee, Jones, and Tyson (1985). Continuing with McMahon’s terminology, exchange efficiency represents education’s ability to meet the needs of other institutions (business, civic and religious organisations), and concerns questions like whether the credentials are valued in the labour market or whether workers are overqualified. Allocative efficiency is attained when there is technical, (factor) price and exchange efficiency, i.e. it represents the maximisation of satisfaction given scarce resources with competing uses (and it allows for a comparison of educational costs with its expected benefits). Related to the four concepts considered, the concept of exchange efficiency is sometimes conflated with allocative efficiency. Given that price efficiency is an extension of technical efficiency, often there is not as clear a distinction between
these efficiency concepts. The two dominant concepts in education (i.e. technical and allocative efficiency) are analysed next, while also examining additional concepts applied in educational studies and how they are incorporated in the proposed efficiency framework.

Blank (2000) defines technical (in)efficiency as the extent to which services can be expanded without increasing resources, or alternatively, the amount by which resources can be contracted without reducing the services. This seems consistent with the previous classification. Allocative efficiency is here defined as the extent to which a service bundle can be expanded by selecting another mix of resources at given costs, or by which a resource bundle can be contracted by changing the mix of service deliveries at given revenue. However, this definition of allocative efficiency is oriented towards costs and revenues without taking into consideration the social benefits and is not consistent with the features of public sector providers (and HEIs), where cost minimisation and revenue maximisation are not the dominant economic goal. More relevantly, this allocative efficiency concept is not considering the other aspects of efficiency as described by McMahon, thus Blank’s definition of allocative efficiency actually corresponds to McMahon’s price efficiency.

Another description of allocative efficiency can be found in Hoxby (1996) who argues that allocative efficiency is “getting the amount of education right” (p. 54), while productive efficiency concerns minimising the cost of schooling provision. Hoxby also uses the cost aspect when examining productive efficiency which is expected considering that she is examining school finance in a sample of secondary schools in the USA. In a similar vein, Barr (2000) points out that allocative efficiency is centred on producing the types of educational outcomes which equip individuals, socially, politically and culturally, for the societies in which they live. The efficient level of educational output is, thus, at the point where expected marginal social benefit equals the resulting marginal social cost. However, quantifying this relationship is complex and some of the main problems in doing so are discussed in the next section.

The above discussed studies introduced various concepts of efficiency used in the education framework. The goal of this section was not to devise new efficiency concepts but to provide a critical examination of the ones already in use. Although in some cases the terminology between the authors differs, many of the efficiency concepts can be related back to the framework developed by Devine, Lee, Jones, and Tyson (1985). This particularly refers to productive efficiency, consisting of technical and factor price components. The definitions differ more when the concept of allocative efficiency is taken into consideration. This concept is often confounded with factor price efficiency and some authors do not acknowledge that this concept goes beyond the boundaries of a decision making unit (e.g. HEI). The terminology proposed in this paper is similar to definitions by Hoxby (1996) and Barr (2004a) where allocative efficiency refers to a comparison of marginal social costs and benefits, and does not solely relate to a comparison of HEI costs and revenues, as some authors state. In terms of estimating efficiency in education, several very distinct techniques have developed in the literature. The next section provides a survey of these techniques and introduces an approach that will be followed in this paper.

4. Measuring Efficiency in Education

Two most widely applied approaches in efficiency measurement are the Stochastic Frontier Estimation (SFE) and the Data Envelopment Analysis (DEA). The former is developed along statistical lines and pioneered by Aigner, Lovell, and Schmidt (1977) and the latter is a non-parametric technique based on linear programming and developed by Charnes, Cooper, and Rhodes (1978). The majority of this type of research has been related to education institutions in the USA and, lately, in the UK and the Netherlands. Although widely used, both methods have a number of disadvantages. A third method for examining efficiency in HE is also presented, it uses regression analysis and is rooted in the educational production function literature. Some of their main
characteristics are presented next and the main problems encountered when using these approaches are identified and discussed.

**Stochastic Frontier Estimation (SFE).** When using stochastic frontier analysis, the researcher establishes a functional form for the relationship between a set of explanatory variables and the dependent variable. The estimated coefficients are assumed to be constant across observations. Stochastic frontier estimators, as previously noted, provide parametric estimates of efficiency. The difference between stochastic frontier estimators and traditional parametric regression is that the error term in SFE is composed of two parts: a normally distributed random error term \( u \) and a second term capturing the remaining error i.e. inefficiency \( v \). The presence of the first type of residuals \( u \) allows the tools of statistical inference to be employed, and this is often considered a considerable advantage of this techniques. However, an assumption regarding the distribution of this noise needs to be made along with those necessary for the inefficiency term \( v \) and the production technology. Given that a considerable structure is imposed upon the data from stringent parametric form and distributional assumptions, misspecifications can be incorporated in the efficiency measure. Additionally, SFE uses information on prices and costs which, according to Worthington (2001), may introduce additional measurement errors.

A recent application of SFE is Agasisti and Johnes (2010) who use a panel dataset to estimate a stochastic frontier models of costs for 57 public Italian universities from 2001-2003. Costs are defined as current expenditures during the year and exclude capital costs and depreciation. Outputs include measures of student numbers and of research activity (number of students on undergraduate courses in sciences, number of students on other undergraduate courses such as the arts, humanities, and social sciences, the total number of research students and, as a measure of research activity, the value of grants for external research and consultancy). The authors find that the estimated technical efficiencies are high, with an average efficiency score of 81 percent. Average costs are in line with studies of university costs conducted in other countries. However, it may be argued that all of these output variables can actually be considered as educational inputs, as suggested by the discussion at the beginning of this section. Furthermore, there are some outliers in the estimation of technical efficiency (universities with very low scores) which the authors cannot account for, this may suggest that there may be some problems in the statistical method used.

In the UK, a study using the SFE by Izadi, Johnes, Oskrochi, and Crouchley (2002) specified a constant elasticity of substitution (CES) cost function and used data for 99 universities in 1994-1995. The dependent variable was the total expenditure of the institution and there were four independent variables (undergraduate student load in arts subjects, in science subjects, postgraduate student load and the value of contracts and research endowments). Again in this study no proposal was made as to how the inefficiencies can be remedied and what were their causes.

**Data Envelopment Analysis.** In contrast to the previous approach, DEA is a non-parametric method thus it provides efficiency estimates which are not conditional on the specific functional form, although it does impose some restrictions such as monotonicity and convexity (in Thanassoulis, Portela, & Despic, 2008). Linear programming methods are used to assign an observation-specific set of weights to outputs and inputs in such a way that the ratio of weighted output to weighted input is maximised for each observation, subject to certain constraints. This approach amounts to constructing a piecewise linear surface over the data so that the actual input/output quantities are either on or in the interior of this frontier. The method can handle multiple inputs and multiple outputs and this makes it an appealing choice for measuring the efficiency of HEIs (examples of this technique include Johnes and Yu, 2008; Johnes, Johnes, Thanassoulis, & Kortealainen, 2011). This method seeks to evaluate the efficiency of a given decision making unit (DMU) relative to the performance of other DMUs producing the same good or service. The unit of analysis for DEA is in most cases an institution or a department,
however a new approach has been developed that performs individual-level DEA, i.e. it is applied to individual students (Johnes, 2006b). Still, preliminary evidence indicates that the results of institutional ranking obtained by using individual-level DEA and the university-level DEA differ and hence further research is necessary to determine the way DEA should be applied in evaluating efficiency in education.

There are several disadvantages of this approach identified in the literature. Primarily, there is no scope for (regression-type normal) residuals to be evaluated, and hence statistical inference cannot be used to examine for the possible bias resulting from external shocks, measurement error or omitted variables. Furthermore, the entire deviation from the frontier (‘envelope’) is examined as being the result of inefficiency which may lead to an under or over-statement of efficiency and, as Worthington (2001) notes, being a non-stochastic method there is no technique with which probability statements on the shape and the placement of this frontier can be made. Some authors have also brought into question the validity and stability of DEA efficiency results. For example, Smith and Mayston (1987) evaluated the sensitivity of DEA measures to omissions of outputs and inputs. In their evaluation of UK’s local education authorities they find that the exclusion of an important output distorts the results of the analysis. Furthermore, DEA only provides relative efficiency scores so it might just be that the selected decision making units are all actually underperforming compared to global best-practice. Performance in DEA analysis is evaluated entirely on the basis of a physical transformation process without taking into account the behavioural objectives of service providers i.e. maximizing service provision or revenue (service-oriented approach) or, in contrast, minimizing resource consumption or resource expenditure (resource-oriented approach) and efficiency is measured against a benchmark of current best practices.

Regression analysis. An additional approach to examining efficiency in HE is from the education production function literature and uses regression analysis (Smith & Naylor, 2001; Johnes & McNabb, 2004; Beirne & Campos, 2007). Here, the use of economic principles to assess the efficiency of HEIs relies on the analogy between educational enterprises and firms, where educational enterprises produce educational outcomes in a way similar to firms producing outputs. Hence, the underlying economic principles from the neoclassical theory of the firm (Baumol, Panzar & Willig, 1982; Varian, 1999) are applied to model the functioning of educational enterprises in which a production function can be used to express the relationships between an institution’s inputs and outputs. In a higher education system, universities comprising of faculties, art academies, colleges and polytechnics can be considered as multi-product enterprises using what Rotschild and White (1995) label as a customer-input technology. The quality of students recruited has an impact on peer effects in the HEI which in turn have been found to have a significant effect on student attainment and non-completion (e.g. in Sacerdote, 2001; Smith & Naylor, 2001; Johnes & McNabb, 2004; Winston & Zimmerman, 2004; Stinebrickner & Stinebrickner, 2006). Some other inputs which serve to measure an HEI’s contribution to educational outcomes are the socioeconomic background of students, parental income and occupation, student’s gender, age, marital status, tuition fee status, race, country of origin, etc. (e.g. in Smith & Naylor, 2001; McNabb & Johnes, 2004; Kokkelenberg, Dillon & Christy, 2008). These inputs and outputs, although being important determinants of educational outcomes, are rarely considered in the two previous approaches leading to questionable results and potentially misleading policy proposals. Using the above mentioned variables is particularly important in light of the reforms in education in Europe since, for example, it allows the examination of the possibly adverse effects on completion and student attainment associated with increased tuition fees and other costs of study. Additionally, the use of regression analysis may identify students who are more at risk of prolonging their studies thus enabling the HEI to act before this inefficiency occurs and the student drops out or extends the duration of their studies. This type of analysis is beyond the scope of DEA or SFE. Another advantage of this approach is that the focus is on students as the main decision making units, a level which is mostly disregarded when using SFE or DEA. The regression method also provides estimates of parameters whose significance can be tested.
5. Conclusion

A substantial amount of research has been carried out focusing on inputs and outputs of the education system, in most cases in order to obtain some ranking of institutions in terms of efficiency scores. However, published indicators that are appearing in e.g. ‘league tables’ often take the form of some simple ‘efficiency’ ratios such as costs per student or ratio of students achieving a certain qualification divided by the total number of students in a year. The problems of using such indicators have often been pointed out and are related to the specific nature of the educational system. Ideally, all inputs and outputs should be included in an efficiency analysis. However, a separate issue is the level of the analysis, i.e. the unit which is observed and characteristics related to it that should be considered. In HE studies the units in most cases are the individual students, the HEI, the same subject across different HEIs, different departments at the same university or individual universities. In the empirical studies where an individual level approach is taken (similar to Smith & Naylor, 2001) there is an advantage over the aggregate-level studies in that they provide more information and may point out to significant determinants of educational outcomes. In contrast, results from aggregate level studies analysed using DEA or SFE are more easily analysed and interpreted, but there is a considerable loss of information due to the aggregation process and there are also limitations using the mathematical programming approach in examining efficiency and this was presented above.

There is an evident gap in the research in measuring HE efficiency and a diversity of definitions of efficiency may be encountered. This is to some extent understandable given the complexity of the educational process and the general lack of relevant information and data. The terminology proposed in this paper is consistent with that customarily found in the literature on efficiency measurement and provides a clearer understanding of technical and allocative efficiency concepts in the context of higher education.

The review of empirical work on efficiency measurement reveals that the calculation of efficiency scores using DEA or SFE dominates the empirical work. However, there are problems primarily related to the difficulty in measuring educational outputs, inputs and establishing a connection (causal link) between them. Moreover, there are significant limitations in producing simple technical efficiency estimates (i.e. scores) of HEIs in order to rank them. Indicators appearing in ‘league tables’ often take the form of simple ‘efficiency’ ratios, such as costs per student or ratio of students achieving a certain qualification divided by the total number of students in a year. The problems in using such indicators have often been pointed out and are related to the specific nature of the educational system. As Adnett, Bougheas, and Davies (2002) caution, ‘league table’ results are usually based on unadjusted attainment and do not capture objectively the educational value added. Hence they encourage dysfunctional effects, i.e. schools trying to improve their position in the league tables through ‘cream-skimming’ or grade inflation (Adnett and Coates, 2003; Johnes, 2004). Additionally, when using DEA or SFE a problem may arise in explaining these efficiency scores, because they are relative rather than absolute. This means that the technique identifies benchmark HEIs (from the dataset) which themselves may have scope for efficiency gains relative to some absolute standard not captured by the dataset. Other problems are mostly related to the difference in results stemming from different specifications of inputs and outputs (and data availability) and the choice of technique for estimation. Caution should be taken in how the information stemming from efficiency research is used and this leads to a conclusion that results from such investigation cannot be considered as providing definite guides to policy measures and recommendations. This does not imply that there should be no efficiency studies, but that caution should be taken in interpreting any particular set of results given the conceptual and measurement issues raised in this paper.