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ABSTRACT

Data Envelopment Analysis (DEA) is an objective statistical technique for discovering the comparative ranking of organizations with respect to their efficiency. The technique, which assesses the relationship between resources (inputs) and outcomes (outputs) may also be used to discover what variables make organizations effective and efficient in order to improve them. This report explains the use of DEA to assess the effectiveness of schools and to bring about school improvement. The Organizational Health Inventory for Elementary Schools (Hoy, Tarter, and Kottkamp, 1991) was chosen as a framework for examining school effectiveness and efficiency. DEA has the advantage of allowing multiple sources of input and multiple outputs. The use of DEA is illustrated through a hypothetical study of elementary schools in an urban context that used the following school-level variables as inputs: student achievement in vocabulary, reading, and mathematics; attendance; stability; expenditures per student; number of teachers per 100 students; and percentages of students for whom English is the home language. The linear programming of the DEA system allows the development of minimum and maximum efficiency scales. An appendix presents the DEA model for a specific case. (Contains 3 tables, 2 figures, and 21 references.) (SLD)

Publication Series

A Primer for Analyzing Educational Effectiveness and Efficiency

by L. Anderson, T. Weinstein, B.F. Strykowski, and H. J. Walberg

The National Center on Education in the Inner Cities

Temple University Center for Research in Human Development and Education

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 # 94-5

Introduction

Data Envelopment Analysis is an objective, statistical technique for discovering the comparative ranking of organizations with respect to their efficiency. DEA (as it is abbreviated) may also be used to discover what variables make organizations effective and efficient in order to improve them.

For the purposes of this primer, effectiveness may be defined simply as the extent to which an organization attains its purposes or ends (also known as outcomes or outputs). Efficiency, on the other hand, is the degree to which an organization successfully uses its resources in combination so that it gets the most for its total set of resources. We'd like all organizations to be effective--to attain their ends to the fullest extent possible. Such a consideration requires that we also reckon with the scarcity of money, human time and energy, and other resources that are the means (or inputs) by which ends are attained.

To illustrate, we might say that the Jones School and the Smith School are equally effective if they are identical in achievement test scores, graduation rates, parent satisfaction, and other outcomes. If the Jones School, however, has a smaller budget, students of lower socioeconomic status, and other limitations, we might characterize it as more efficient. Schools like Jones equal others in outcomes, but combine limited resources more effectively, and are therefore to be regarded as more efficient than--although equally effective as--Smith.

Schools rarely have identical outcomes: They usually vary somewhat in the goals toward which they are working, their student composition, teaching staff, size, and other inputs. It is necessary, though, if policymakers aim to compare these schools, that some agreement be reached on a common set of objectives to be attained. Such an agreement will first identify the list of schooling outcomes to be used for comparison, and might specify that schools will be compared on their outcomes in mathematics and science and on average grade-to-grade promotion rate. Additionally, resources must be used well because they are limited and need to be combined in the best way to achieve the outcomes desired.

Until recently, however, no technique existed to accomplish these two tasks simultaneously for organizations such as schools or hospitals. DEA was developed to enable the comparison of a set of schools or a set of hospitals or other organizations that produce many outcomes and do not operate in the private sector. It enables analysts and those responsible for schools and other such organizations to detect what makes some work better than others in achieving the outcomes specified for them.

A fundamental question is why school comparisons are made at all. Because of the National Commission on Excellence in Education's A Nation at Risk (1983) and subsequent reform reports, there is great interest by policymakers and practicing educators in improving schools. One way to do so is to find those that are doing comparatively well and study their exemplary features. Information on rankings and their causes can be confidentially fed back to principals and others so they can take informed action for school improvement. It is with this purpose in mind that the present primer has been written.

In addition, however, some citizens, especially in the business and policymaking communities, want to use rankings for an additional purpose--to evaluate schools, possibly with incentives for superior performance and sanctions for poor performance. Some states, such as Illinois and South Carolina, publish school rankings and plan such performance consequences. Unless school rankings are adjusted for student background, they can be misleading and unfair. That is an additional reason for DEA: It enables analysts to compare schools that are unlike in various ways.

This primer is intended for nontechnical users--principals and other educational leaders. For those interested in gaining a technical understanding of DEA, an appendix is included. In addition, several references for further reading on the technique and on variables associated with school effectiveness and efficiency are included.

Purpose

This primer is designed to assist school principals and district-level administrators in understanding and using effectiveness and efficiency analysis as a diagnostic tool for making improvements in their schools. DEA is a mathematical programming technique used to assess the relationship between resources (inputs) and outcomes (outputs). Therefore, it is a helpful tool in implementing effectiveness and efficiency analysis. It is aimed at serving the needs of managers and other administrators who need feedback on the efficiency with which their resources are being utilized. By improving efficiency, educators will be better equipped to raise school productivity, that is, to become more effective. In the field of education, efficiency is usually conceptualized with student achievement as an output and district- or school-level expenditures and other resources as inputs. DEA can provide information about the degree to which multiple inputs and outputs are being maximally utilized. In layman's terms, DEA shows which resources are producing the greatest returns to investments.

Concern for accountability in the field of education has been mounting for over a decade, especially in the wake of declining achievement scores and increasing expenditures. In 1987, over $160 billion was spent on elementary and secondary education in the public sector (U. S. Government, 1985-1986). That was over 20% of all state and local expenditures. Pressures to improve effectiveness are felt at the district level by administrators and, in turn, by principals in the schools. DEA, as a tool for examining efficiency of resource allocation, can lay the groundwork for improving effectiveness. This is accomplished by providing school administrators with information about which resources produce the greatest returns to investment, given preexisting social and budgetary constraints.

Literature Review

Efficient and Effective Schools

Educators, psychologists, and sociologists have contributed to an extensive literature based on effective schools. Edmonds (1979) was one of the first to systematically examine highly effective schools, particularly those serving the urban poor. Other contributions to the literature were made by Brookover (1979), Brookover and Lezotte (1977), and Rutter, Maughan, Mortimore, Ouston, and Smith (1979). Some of the more salient variables associated with effective schools were identified by Purkey and Smith (1983). These include the degree of curriculum articulation and organization; schoolwide staff development; parental involvement and support; schoolwide recognition of academic success; maximized learning time; district support; clear goals and high expectations; orderly and disciplined school environment; and leadership of the principal, characterized by attention to the quality of instruction (Wang, Haertel, & Walberg, 1990).

More recent studies of effective schools in large urban areas identified newer variables associated with learning. Research by Van De Grift (1990) identified close reporting of student progress; the principal's selective influencing of teaching strategies; and expressing high expectations for pupils' achievement as factors which influence learning in inner-city school interventions.

A theoretical framework delineated by Wang et al. (1990) was employed in our research with effective and effective schools. A comprehensive set of variables related to learning which includes both cognitive and affective schooling outcomes was identified and analyzed through a "meta-review" and synthesis of research (Wang et al., 1990). This synthesis yielded 228 variables related to school learning, organized into 30 scales within six categories. The conceptual framework includes state and district variables, out-of-school contextual variables, school-level variables, student variables, program design variables, implementation, classroom instruction, and climate variables which were organized from the more distal to the more proximal factors. These are shown in Table I (Wang et al., 1990). An analysis of these outcomes confirmed that the more important variables associated with schooling outcomes are those that are more proximal to student learning as illustrated by quality and quantity of instruction, home environment, and student characteristics.

More recently, Wang et al. (1993) expanded and updated their synthesis to provide a knowledge base for school learning. Their research represents a degree of agreement among experts about the factors important to school learning and the relationships among those factors. An extensive literature search comprised of reviews, syntheses and chapters in handbooks yielded over 11,000 statistical relationships. The results indicated that the proximal variables, including individual student characteristics and instructional and home environments, more strongly influenced learning than did the more distal variables, including demographic, organizational, or policy-level variables.

Organizational Health, Organizational Resilience, Organizational Learning

Our research also draws upon the literature addressing organizational resilience. When applied to educational settings, resilience is based on the proposition that some schools are effective and efficient over time despite typical disabling urban conditions. These schools demonstrate evidence of powerful internal enabling conditions, such as high involvement of all the participants coupled with an organizational capacity for continuous learning. Our theoretical framework employs conceptions of organizational health and resilience to explain effectiveness and efficiency. These conceptions refer to the school's social system and technical capacity as evidenced by measures of its effectiveness and efficient resource utilization (Anderson & Walberg, 1994).

Organizational resilience requires evidence of superior performance. Such evidence can be linked to processes internal to the organization that result from design and redesign efforts to sustain performance.

We reviewed the research on school health and chose the Organizational Health Inventory for Elementary Schools (Hoy, Tarter, & Kottkamp, 1991) for part of our work. The 37-item instrument is soundly anchored in theory and, although it has not to our knowledge been applied to urban schools, it appears appropriate for the tasks we wished to accomplish. Five subtests, representing the dimensions necessary for school health, comprise this inventory: (a) Institutional Integrity, (b) Collegial Leadership, (c) Resource Influence, (d) Academic Emphasis, and (e) Teacher Affiliation. These dimensions are associated with the four organizational functions--adaptation, goal achievement, integration, and latency--necessary for the growth and survival of organizations (Parsons, Bales, & Shils, 1953). Parsons and his colleagues defined these functions as follows: adaptation--the ability of an organization to respond to its environment; goal attainment--the ability to set goals and to achieve them; integration--the ability to maintain cohesiveness among system elements; and latency--the ability to foster and sustain appropriate motivational driving value systems within the organization. Schools regarded as healthy "effectively meet the instrumental needs of adaptation and goal achievement as well as the expressive needs of social and normative integration" (Hoy et al., 1991, p. 68).

This thinking about organizational health is also reflected in the efforts of researchers to understand high-involvement organizations (Lawler, 1986; Mohrman, Lawler, & Mohrman, 1992). High-involvement organizations empower all employees in the organizational hierarchy. In so doing, they foster organizational commitment, deep alignment, and high individual energy (Mohrman et al., 1992). The creation of high-involvement organizations requires self-conscious effort in design, information flow, and social support. Lawler (1986) indicates that such organizations show superior performance, and are flexible and adaptive in their problem solving. Leadership is critical in the development of high-involvement organizations. All of the characteristics found to be critical in defining healthy schools (Hoy et al., 1991) are present: visioning, clear focus, trust among the participants in the enterprise, collegiality, and shared leadership. Principal leadership, energized by a desire to achieve these ends, is likely to be found in such resilient schools.

Organizational learning requires a clear sense of objectives, and continual monitoring of their accomplishment. Over time, such exercises build collective memory to be called upon in later problem-solving situations (Argyris & Schon, 1978). Resilient organizations detect changes in the environment requiring changes in the organization's normal operating procedures.

Hedberg's (1981) work compares and contrasts individual learning and organizational learning. In particular, the difference between imitative learning and generative learning is drawn; and the interactive nature of learning is underscored. Effective learners and their environments change in the process of learning, and stability can often be a hindrance to learning. Organizational learning is a function of individual learning but is not the sum of such learning. Because organizations have memories that preserve the recollections of behavioral norms over time, organizations as well as individuals learn.

Argyris and Schon (1978) show that real organizational learning takes place only when assumptions are reexamined for their fit with current reality (see also Morgan, 1990, on "learning to learn"). Argyris and Schon (1978) also distinguish single-loop and double-loop learning modalities:

> Single-loop learning is sufficient where error correction can proceed by changing organizational strategies and assumptions within a constant framework of norms of performance. It is concerned only with effectiveness. . . .[In] double-loop learning, there is [a] double feedback loop which connects the detection of error not only to strategies and assumptions for effective performance but to the very norms which define effective performance. (pp. 22-23)

Thus our methodology can be seen to consist of a two-stage process: (a) identifying effective and efficient schools through effectiveness and efficiency analysis; and (b) testing for the presence of organizational health and a capacity for organizational learning postulated to be critical to the achievement of organizational resilience.

The Case for Utilizing Effectiveness and Efficiency in School-Based Research

Schools, in a manner typical of most organizations, particularly those in the public sector, produce multiple outputs using a range of inputs. Carrying out an assessment of the performance of such entities requires a measurement of the efficiency with which they use their resources in producing valuable outputs. For a variety of reasons, however, it has been difficult to assess such efficiency in public-sector organizations, schools being particularly difficult cases. Schools utilize material resources of various kinds, in conjunction with nonmaterial resources, to generate a range of outputs. Efficiency evaluation normally requires some estimate of the maximum possible output levels to be compared with actual performance levels. In the case of other organizations in the public sector, such evaluations have not easily been possible. Obstacles to these evaluations include the fact that outputs are often not measurable in ways which would allow for aggregation to a single measure. Furthermore, production processes in fields such as education are usually not known in the same way that engineering descriptions of similar processes in industrial firms are known.

Another limitation on efficiency assessment of public-sector organizations resides in the largely nonprice domain in which they operate, making evaluations of social usefulness of specific outputs difficult to achieve. In the case of schools, social usefulness can often be inferred from broad national and state policy, but it is still difficult to bring each organization's production process, and therefore its outputs, in line with higher-level objectives identified with those policies. This difficulty is therefore inherent in the way such production units relate to higher-order governmental units in a policy sense. Schools could use national norms and state norms to guide their operations, and in recent years, much discussion has centered on this mechanism for improving schooling performance. Nonetheless, apart from knowing whether or not they meet such norms, typical analyses do not provide much guidance as to the reasons for either attainment or nonattainment of such objectives.

One particular problem with such limitations is that production processes are either fixed and nonmanipulable or totally unknown. Schooling production processes evidence both of these difficulties. In the first place, some important elements of the school process are fixed either by custom or by some general understanding of what would be minimally necessary. The case of class size is a very obvious one. There are others, however. For example, some students do better with particular types of teaching resources and methods of instruction than others; and in general attention must be paid to these aspects of the learning environment. Given any set of resources which normally are not changeable in the short term, it is clearly important for such resources to be combined in the most efficient manner to produce the maximum in learning gains for students.

Current methods for measuring efficiency are fraught with shortcomings. Ratio analysis, a fairly common methodology for assisting in the identification of efficient production units in various parts of the public and private sectors, might appear measurable, but does not provide unambiguous indicators of efficiency. For example, the ratio of achievement scores to district spending may be misleading. In any situation, moreover, in which small inputs are utilized, an organization may score high on one ratio (having a high output-input ratio) but low on another. No theoretical argument supports placing higher significance on one ratio than another. Across organizations, these patterns of ratios are not likely to be constant, and so, in addition to the problem identified above, there is the added problem of determining which pattern is appropriate for comparison purposes. The analyst or the organization is simply presented with a measure set of ratios, with no way of making good sense of them.

A second method often used to study efficiency in and among organizations is regression analysis. Here the organizations' output level is represented as a function of—that is, determined by--a set of inputs. This analysis generates an estimated relationship of inputs to outputs by isolating the magnitude of the effect on organization output by changing the inputs by one standard deviation unit. It also identifies the sign of the relationship, that is, whether the relationship between inputs and outputs is positive or negative. If this methodology is used for studying efficiency between organizations, those organizations that lie above the predicted (average) relationship of inputs to outputs are regarded as efficient, those below are inefficient. But this methodology also has difficulties.

First, the measured relationship is only an average one, while what is being sought in consideration about efficiency, especially among similarly placed organizations, is a measure of best performance. Secondly, the shape of the production relationship must be specified in advance although that is precisely what is not known. Regression analysis can be therefore, quite inappropriate for studying questions of organizational efficiency.

DEA solves these problems associated with ratio analysis and specification of the production function by allowing multiple outputs and inputs, as are typical with schools, to be considered simultaneously. Measures of efficiency derived are also sensitive to the sample of organizations--in our case, schools--being considered, and so organizations that are regarded as serving the same function (such as schools in a public school district), may be compared with each other. The typical data envelopment analysis thus generates a set of measures of relative efficiency for the reference set of organizations. This information is of substantial value in determining which units are in need of assistance. Diagnosis of specific shortcomings characteristic of organizations which employ similar production models may be derived through comparisons allowed by DEA.

Tools for Implementing Effectiveness and Efficiency Analyses

In educational settings, the selection of input variables used in DEA often falls into two categories, discretionary and nondiscretionary. Discretionary variables may be influenced by policies set by the school or the district. Examples are teacher-student ratios, expenditures per student, teacher salaries, and time per school of math and language instruction. Nondiscretionary variables, chiefly student characteristics not controllable by educators, include the percentage of nonminority students (operationalized in these terms in order to provide a variable positively correlated with other efficient inputs), percentage of students not classified as poverty level, percent of students who are native English-language speakers, and stability, i.e., the percentage of students enrolled continuously throughout the year.

As a means of facilitating discussion between school administrators, insight to questions like the following can be offered by DEA and its companion software (Bessent, Bessent, Elam, & Long, 1984): 1) Given similar levels of discretionary resources and student characteristics, which schools produce greater levels of achievement? 2) Within the parameters imposed by available resources and student characteristics, what levels of effectiveness (achievement) can be expected? 3) What aspects of school operations can be improved? 4) What levels of optimum effectiveness can be obtained from best performance in the face of reductions in resource levels? 5) How well are schools meeting productivity goals?

Answers to these questions have facilitated discussions in a Texas school district regarding allocation of resources, setting of priorities, and enhancing communication with concerned public (Bessent et al., 1984). Moreover, the employment of DEA in a time series analysis provides the basis for comparisons within a given set of schools at two or more observation points. The efficiency frontier will, in all likelihood, advance or retreat from one assessment to the next. By examining a school's outputs relative to its inputs at the later point, changes in its position relative to the frontier can be determined. Performance that qualifies as efficient at one point may not be efficient subsequently. This would result from an increase in the magnitude of output-input ratios required for efficiency at the later assessment.

District or school administrators can gain technical information about resource utilization after a single DEA application, with respect to a school's efficiency relative to other schools. Multiple assessments can provide them with information pertinent to their own progress as well as their comparative performance.

A more detailed, technical explanation of DEA is found in the appendix.

**An Urban Elementary School and its Comparison Set:
Policy Implications**

To illustrate the multiple input/output situation in DEA, we focus on the hypothetical results of a scenario involving elementary schools in an urban context. The following school-level variables are inputs for the model: students' achievement in vocabulary, reading, and math for the prior year; attendance; stability; expenditures per student; number of teachers per 100 students; and percentages of students for whom English is the native language spoken at home and who come from standard income homes. Current achievement in vocabulary, math, and reading are the outputs.

DEA software produces several reports detailing measurement and efficiency listings for units (schools) under analysis. The Measurement of Local Frontier for the hypothetical case is presented in Table II.

Entry-level outputs and inputs for the target school are listed under Unit Analyzed. The Linear Combination of Frontier Units are the corresponding levels of outputs and inputs for schools operating at peak efficiency (E=1. 00). Schools X, Y, and Z, which lie on the frontier, operate at combined output levels of 3.300 for vocabulary, 4.032 for reading, and 4.000 for math. Their combined input levels include percent attendance of 72.85, student expenditures of $4019.51, and percent standard (native) English-speaking students of 54.66. These are some of the resource and outcome quantities associated with maximum efficiency. To the right of the frontier data are the lower bound inputs and outputs. These data indicate the quantities of these variables resulting from extending the frontier facet downward in order to envelop less-than-efficient schools.

The multiplier, derived from the linear programming employed in DEA, produces increases or decreases in the inputs and outputs consistent with its sign. A summary of the multiplier's effect on each variable is available in a report produced by PASS (Bessent & Bessent, 1988), the linear programming software which performs DEA.

Complete listings of upper and lower bounds and technical efficiency for each school unit can be obtained from PASS, showing relative standing with respect to the frontier facet and its linear combination of inputs and outputs. The numbers of schools enveloped, efficient, and inefficient, along with minimum and maximum efficiency scales, are provided in the Efficiency Listing.

The usefulness of DEA as a diagnostic tool derives in large part from the linkage it establishes between resources and outcomes. To probe this relationship, school administrators have used DEA to assess the efficacy of instructional expenditures by determining whether these investments are producing commensurate outcomes. As a result, policy decisions are better informed with the aid of formative productivity evaluation. Some of the functions of DEA output for the benefit of local school boards include the following (Bessent & Bessent, 1988): evaluation of yearly progress; site-based information for developing budget requests and curricular plans; superintendent audits of proposed plans to monitor schools' improvement goals, to assess whether resources are being maximally exploited, and to determine whether requests for additional resources are justified; and to assist in the management of valuable resources across schools in a district.

To determine excess resource consumption, DEA produces "slack" values for each output and input value across all decision-making units (schools). Slack is represented by the distance from the frontier along the Y axis (Bessent, Bessent, Kennington, & Reagan, 1982). Essentially, slack measures inefficiency for each variable in the model. This is consumption which can be eliminated while maintaining the same amount of output.

Detailed effects of slack values can be found in output augmentation and input conservation reports produced by PASS. Shortages for outputs and excesses for inputs are listed for each variable. Table III shows the output and input levels, adjusted output levels, and the slack measurements associated with each of these variables. Adding the shortages to their respective adjusted outputs and subtracting the excesses from their inputs shows the amount of inefficiency or slack. For example, adding the shortage to the adjusted reading outcome factor would put School A on the frontier level at 5.236. To reach efficiency for the input variable percent standard (native) English, we subtract 29.022 from 100.000, yielding 70.978.

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Appendix

The DEA Model: Geometric Explanation of Efficient Resource Allocation (the two input, one output case)

The geometric formulation in Figure 1 of the DEA model shows its properties and utility in the case of a single output and two inputs. Figure 1 is the geometric representation of a simple DEA problem, one with six schools, each producing a single output with two inputs, teaching and administrative resources. The axes define input/output space in normalized inputs (per unit of output). The managers of each school are presumed to be attempting to use resources as efficiently as possible, but may not know how other schools use scarce resources. On the basis of actual output levels and known resource availabilities, each school can be located in input/output space for the two inputs.

Figure 1 presents the mathematical programming problem of minimizing input per unit of output. Maximizing output per unit of input is an equivalent way of stating the same decision objective by exploiting the duality of relationships of mathematical programming.

Since the staff of each school tries to use its resources economically, those schools that have the lowest ratios of inputs to output are by definition the most efficient ones. In Figure 1, schools A, B, and C can be seen to be efficient. To illustrate, lines are drawn to join school A to school B and School B to school C. The line ABC represents the efficient set of schools and their efficient technologies for nonteaching producing the single output. Schools F, D, and E all achieve their respective output levels with greater amounts of resource use than is the case with schools A, B and C. In DEA terminology, schools A, B, C are efficient, and schools D, E and F are less than fully efficient. An important benefit of the DEA approach can now be demonstrated, since it is possible to calculate precisely the degree of inefficiency of schools F, D, and E.

For example, D's efficiency (or lack of it) can be measured by taking the ratio of OD' to OD. Clearly this ratio is less than unity (which is what it would be if D were efficient. Since all units on the line ABC are efficient, they form the reference units for the evaluation of inefficient or enveloped schools like D, which in this case is related to its reference school D'.

With respect to school D, it is instructive to note the relationship of the line BC to its evaluation regarding efficiency. Clearly D uses the same ratio of normalized inputs to outputs as reference unit D' which is on the line BC. Since all points on BC can be expressed as linear combinations of the coordinates of the points B and C, D's efficiency can be evaluated using those coordinate values in conjunction with values to be derived from the solution of the implied mathematical programming problem for that unit D. A straightforward statement of the problem in algebraic terms is presented below.

The line from the origin to school F does not cut a line segment but can be related naturally to both of the efficient line segments AB and BC. School E is clearly inefficient, and its level of inefficiency must be calculated by other means since line OE does not cut any part of ABC. Schools F and D are enveloped by Schools A, B and C while School E is not naturally enveloped by any of the efficient schools.

The fact that unit E is not naturally enveloped suggests the need to construct facets with which it could be evaluated for efficiency purposes. Charnes, Cooper, and Rhodes (1978) suggest the construction of a fictitious school G which differs from a rightward (horizontal) extension of C by an arbitrarily small amount, while Bessent, Bessent, Clark, and Elam (1988) construct their fictitious school from the extension of the facet BC to OE. The unit G is used by Bessent et al. (1988) to identify upper bounds of relative efficiency for E, whereas unit H is used to identify the greatest lower bound for such an evaluation. For units that are not naturally enveloped, then, upper and lower bounds are computed and become part of the output from the efficiency analysis. The case of the not naturally enveloped school turns out to be empirically more the rule than the exception, making this extension of the original DEA model an important one (Bessent et al., 1988).

It should be pointed out that the efficiency concept utilized here is that of technical efficiency. Schools that are evaluated using this methodology are evaluated only on the degree to which they achieve desirable weighted-input-to-weighted-output ratios in natural terms, not in value terms. For example, effects on test scores rather than their monetary benefits are estimated.

Information Derivable from the Model in This Simple Case

Returning to the example, each of the schools A, B, C, D, E, and F can be associated with a measure of technical efficiency depending on whether or not it is on the efficient frontier ABC. Efficiency levels are constrained to lie within the range from zero to unity, with schools on the frontier having levels of efficiency of unity, whereas those not on the frontier have efficiency levels of less than unity.

It is important to note that the derived indices of efficiency are measured relative to the reference set. Therefore, a change in the reference set is likely to result in a change in the derived set of efficiency measures. In other words, the efficiency measures derived are interpretable only in the context of the reference set used to derive them. Accordingly, the derived measures of efficiency have greatest evaluative significance in analyzing comparable units.

Extension of Efficiency Analysis to Multiple Output Case

Figure 1 is the geometric representation of the analysis of organizational efficiency in the two-input, single-output case. It is possible to extend the single representation of efficiency determination to the multiple output case geometrically so as to retain the transparency of the analysis. One way to accomplish this is through the use of a familiar constraint from elementary economics called the production possibility curve. This is the approach we will follow here, since it is possible to demonstrate all of the characteristics of the data envelopment approach to efficiency analysis in the case of an organization with two outcome variables. Figure 2 shows this to be the case.

The curve ABFCDE typically represents the maximum combinations of the two outputs that can be achieved given the resources available to a particular organization. As resources are shifted for the production of one output as opposed to the other, the total output attainable for the organization as a whole will take the shape of the ABFCDE curve. It can be read differently, however, for the case of several organizations. Now the curve still represents the maximal amounts of output concerned, but the points ABCDE represent maximally efficient organizations. A point like G therefore, indicates an organization that is less than maximally efficient, although it uses resources in the same way as organizations B and C.

Note that an extension of the ray from the origin through G onto the part of the curve ABCDE intersects the facet BC at point F. This is an important observation. Organization G, say school G, is less than fully efficient, and it is now possible to represent this shortfall of G from the maximally possible output combination represented by the fictitious school or organization F, by comparing the points G and F. GF/OF is the measure of the shortfall of G from the empirically maximal point F in terms of outputs one and two. Therefore OG/OF is a measure of G's relative efficiency in comparison to F's. This measure of relative efficiency can be shown to be equal to l-GF/OF. If we were to assume, for simplicity's sake, that GF = OG, then the ratio GF/OF is equal to 0.5, and OG/OF = 1 - 0.5 = 0.5. Thus G has a relative efficiency of 50% in relation to F, its fictional comparison unit on the maximal ray BC. School or organization G is now known to be only half as efficient as efficient unit F, which is a combination of B and C units.

The analysis of Figure 2 corresponds exactly to the analysis of the single output case in being able to demonstrate efficient and less-than-efficient units, and by showing how one might measure the degree of shortfall from full maximal efficiency. What is assumed is that total resource availability remains constant as we move from unit A to unit E, the curve ABFCDE representing the empirically maximal amount of outputs shown to be derivable from the available levels of inputs. Data envelopment analysis allows for the specific measurement of these levels of shortfall for all the outputs considered for each individual organization that is not on the boundary curve ABFCDE, and shows what the levels of output are for the organizations that are maximally efficient. Reading from Figure 2, if G were maximally efficient, it would be associated with OE_2 and OA_2 of outputs 1 and 2 and unit F, whereas the actual levels of the two outputs it has achieved are OE_1 and OA_1, clearly less than OE_2 and OA_2. Actual data from a data envelopment analysis of Chicago public schools will show what these results might look like in an actual case.

References

Bessent, A., Bessent, W., Clark, T., & Elam, J. (1988). Efficiency frontier determination by constrained facet analysis. Operations Research, 36(5), 785-786.

Charnes A., Cooper W. W., & Rhodes, E. (1978). Measuring the efficiency of decision-making units. European Journal of Operational Research, 429-444.

Table I

Category/Subcategory[a]	Illustrative Variable
Category 1. State and District Variables: These variables are associated with state- and district-level school governance and administration. They include state curriculum and textbook policies, testing and graduation requirements, and teacher licensure, as well as specific provisions in teacher contracts, and some district-level administrative and fiscal variables.	
District-level Demographics and Marker	School district size
State-Level Policy	Teacher licensure requirements
Category 2. Out-of-School Contextual Variables: These variables are associated with the home and community contexts within which schools function. They include community demographics, peer culture, parental support and involvement, and amount of time students spend out of school on such activities as television viewing, leisure reading, and homework.	
Community	Socioeconomic level of community
Peer-Group	Level of peers' academic aspirations
Home Environment and Parental Support	Parental involvement in assuring completion of homework
Student Use of Out-of-School Time	Student participation in clubs and extracurricular school activities.

Table I (continued)

Category/Subcategory[a]	Illustrative Variable
Category 3. School-Level Variables: These variables are associated with school-level demographics, culture, climate, policies, and practices. They include demographics of the student body, whether the school is public or private, and levels of funding for specific categorical programs; school-level decision-making variables, and specific school-level policies and practices, including policies on parental involvement in the school.	
Demographic and Marker	Size of school
Teacher/Administrator Decision-Making	Principal actively concerned with instructional program
School Culture (Ethos conducive to teaching and learning)	School-side emphasis on and recognition of academic achievement
School-Wide Policy and Organization	Explicit school-wide discipline policy
Accessibility	Accessibility of educational program (overcoming architectural, communication, and environmental barriers)
Parental Involvement Policy	Parental involvement in improvement and operation of instructional program.

Table I (continued)

Category/Subcategory[a]	Illustrative Variable
Category 4. Student Variables: These variables are associated with individual students, including demographics, academic history, and a variety of social, behavioral, motivational, cognitive, and affective characteristics.	
Demographic and Marker	Gender
History of Educational Placement	Prior grade retentions
Social and Behavioral	Positive, non disruptive behavior
Motivational and Affective	Attitude toward subject matter instructed
Cognitive	Level of specific academic knowledge in subject area instructed
Metacognitive	Comprehension monitoring (planning: monitoring effectiveness of attempted actions, monitoring outcomes of actions; testing, revising, and evaluating learning strategies)
Psychomotor	Psychomotor skills specific to area instructed

Table I (continued)

Category/Subcategory[a]	Illustrative Variable
Category 5. Program Design Variables: These variables are associated with instruction as designed and with the physical arrangements for its delivery. They include the instructional strategies specified by the curriculum and characteristics of instructional materials.	
Demographic and Marker	Size of instructional group (whole class, small group, one-on-one instruction)
Curriculum and Instructional	Alignment among goals, contents, instruction, assignments, and evaluation
Curriculum Design	Materials employ advance organizers
Category 6. Implementation, Classroom Instruction, and Climate Variables: These variables are associated with the implementation of the curriculum and the instructional program. They include classroom routines and practices, characteristics of instruction as delivered, classroom management, monitoring of student progress, and quality and quantity of instruction provided, as well as student-teacher interactions and classroom climate.	
Classroom Implementation Support	Establishing efficient classroom routines and communicating rules and procedures
Classroom Instructional	Use of clear and organized direct instruction

Table I (continued)

Category/Subcategory[a]	Illustrative Variable
Quantity of Instruction	Time on task (amount of time students are actively engaged in learning)
Classroom Assessment	Use of assessment as a frequent, integral component of instruction
Classroom Management	Group alerting (teacher uses questioning/recitation strategies that maintain active participation by all students)
Student and Teacher Interactions: Social	Student responds positively to questions from other students and from teacher
Student and Teacher Interactions: Academic	Frequent calls for extended, substantive oral and written response (not one-word answers)
Classroom climate	Cohesiveness (members of class are friends sharing common interests and values and emphasizing cooperative goals)

[a] Subcategories are listed below the description of each broad category and are each illustrated with representative variables. For example, the first broad category includes two subcategories, "District-Level Demographics and Marker Variables" and "State-Level Policy Variables."

Source: Wang, Haertel, & Walberg. (1990). What influences learning? A content analysis of review literature. Journal of Educational Research, 84 (1), 30-43.

TABLE II

	Unit Analyzed	Combination of Frontier Units	LOWER BOUND Frontier Referents		
School Unit Year	A 2480 1989		X 6360 1989	Y 3170 1989	Z 5420 1989
Multiplier			-0.239	-0.070	-0.585
Outputs					
VOCABULARY	3.300	3.300	4.300	4.700	4.700
READING	3.800	4.032	4.500	4.800	3.700
MATH	4.000	4.000	5.000	5.700	3.800
Inputs					
VOCABULARY	3.400	1.892	4.100	4.900	4.000
READING	3.700	2.849	4.500	4.800	3.200
MATH	3.700	2.849	4.500	5.100	3.400
ATTENDANCE	94.600	72.853	95.300	94.000	94.300
STABILITY	95.100	73.238	97.000	85.300	88.200
BUDGET	5219.346	4019.511	3405.293	4269.785	3515.260
TEACHERS	7.547	5.812	5.020	6.393	4.762
PSTANENG	100.000	54.662	91.800	90.900	100.000
PSTANINC	66.900	51.521	83.000	95.900	69.400

Variables listed above include:

<u>Outputs</u>
Vocabulary (1989)
Reading (1989)
Math (1989)

<u>Inputs</u>
Vocabulary (1988)
Reading (1988)
Math (1988)

<u>Inputs</u>
Attendance
Stability
Budget
Number of teachers per 100 students
Percentage of native English speaking students
Percentage of students from standard income homes

Table III

Efficiency: Output Adjustment	77.012 Factor: 1.299			
	Output Levels	Adjusted Output Levels	Shortage	Levels if adjusted to Frontier
Outputs				
VOCABULARY	3.300	4.285	0.000	4.285
READING	3.800	4.934	0.302	5.526
MATH	4.000	5.194	0.000	5.194
Inputs	Input levels		Excess	Levels if adjusted to Frontier
ATTENDANCE	94.600		0.000	94.600
STABILITY	95.100		0.000	95.100
BUDGET	5219.346		0.000	5219.346
VOCABULARY	3.400		0.943	2.457
READING	3.700		0.000	3.700
MATH	3.700		0.000	3.700
TEACHERS	7.547		0.000	7.547
PSTANENG	100.000		29.022	70.978
PSTANINC	66.900		0.000	66.900

Variables listed above include:

<u>Outputs</u>
Vocabulary (1989)
Reading (1989)
Math (1989)

<u>Inputs</u>
Vocabulary (1988)
Reading (1988)
Math (1988)

<u>Inputs</u>
Attendance
Stability
Budget
Number of teachers per 100 students
Percentage of native English speaking students
Percentage of students from standard income homes

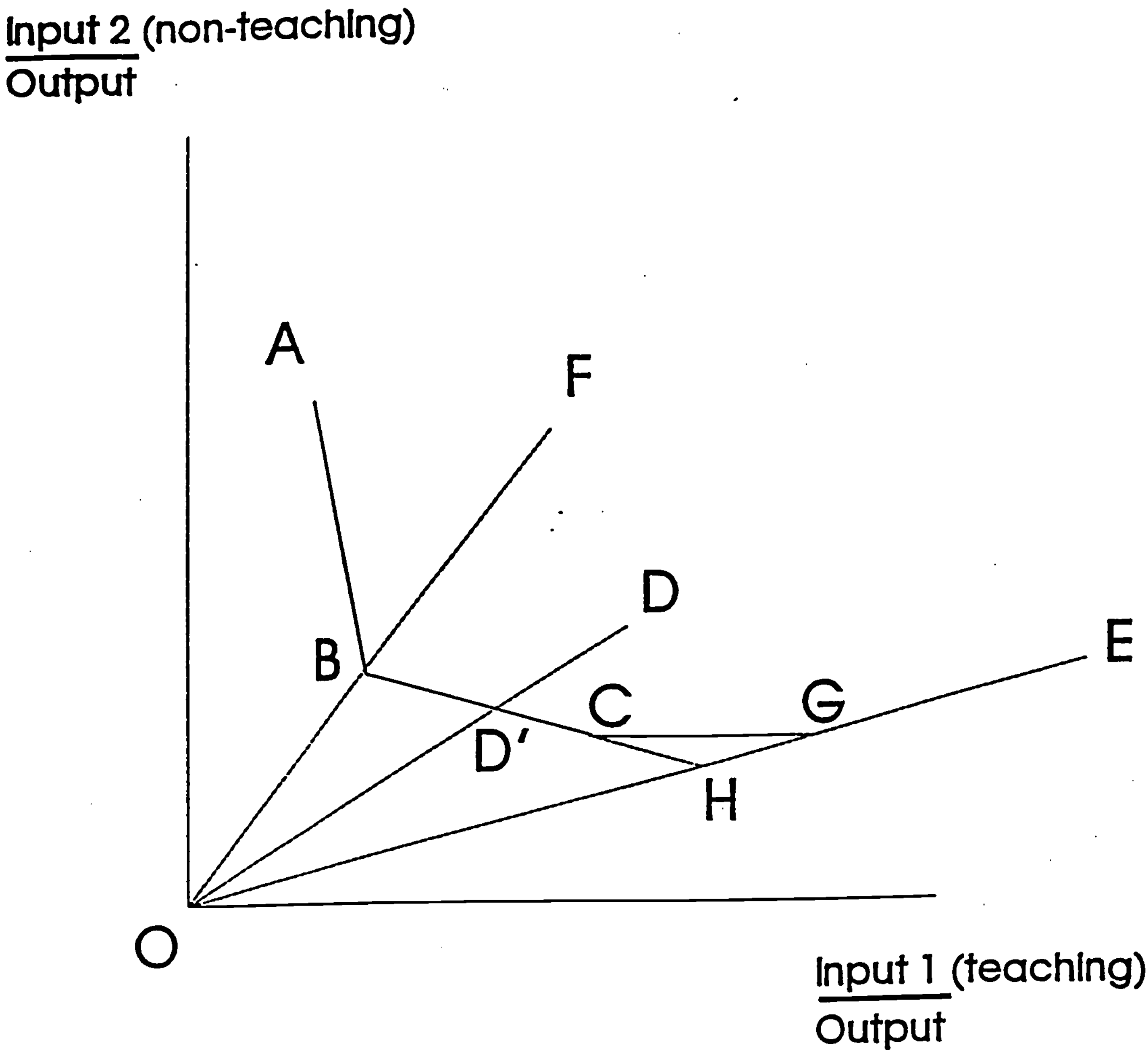

Figure 1: Geometric Representation of DEA

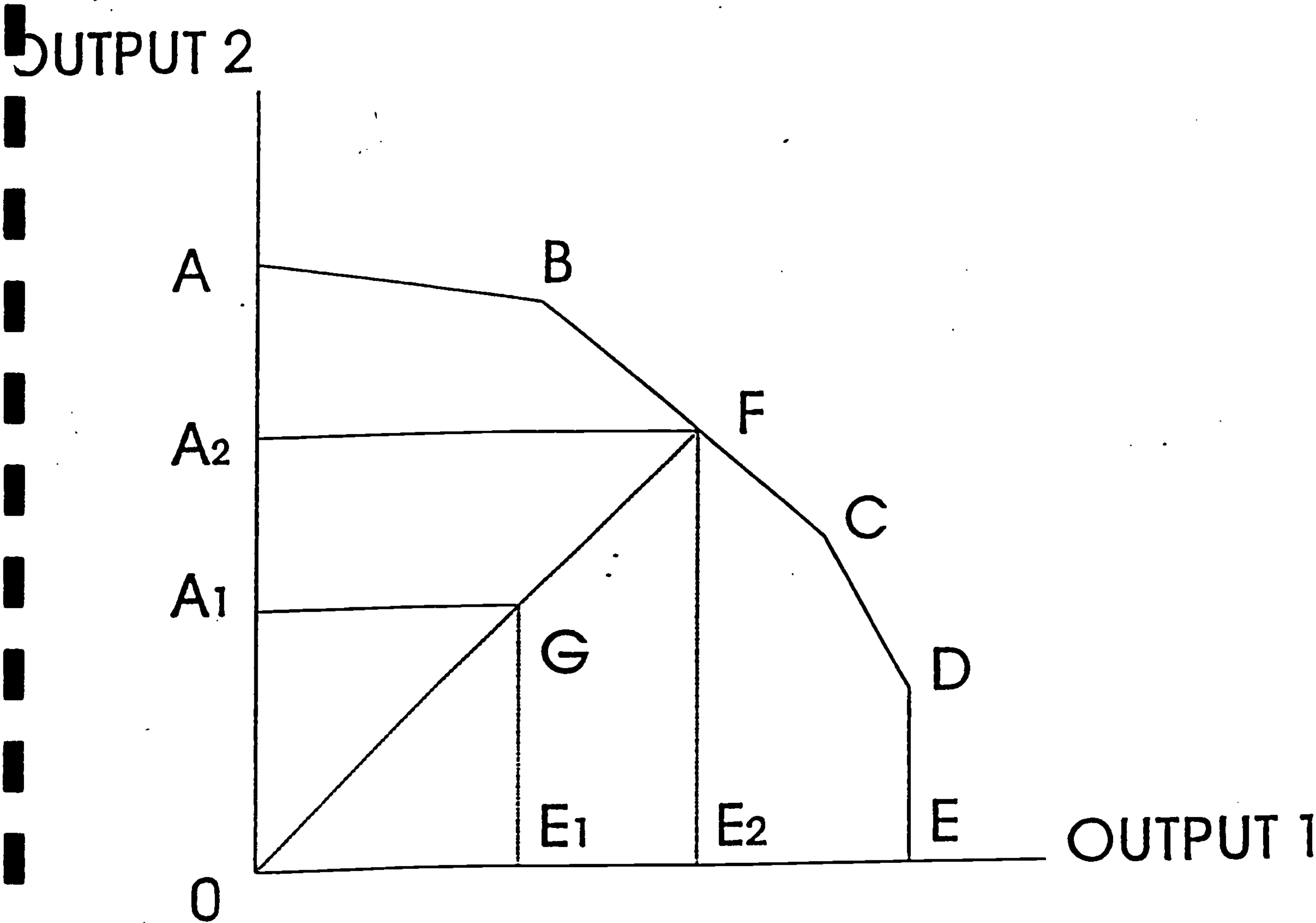

Figure 2: The Production Possibility Frontier

THE NATIONAL CENTER ON EDUCATION IN THE INNER CITIES

The National Center on Education in the Inner Cities (CEIC) was established on November 1, 1990 by the Temple University Center for Research in Human Development and Education (CRHDE) in collaboration with the University of Illinois at Chicago and the University of Houston. CEIC is guided by a mission to conduct a program of research and development that seeks to improve the capacity for education in the inner cities.

A major premise of the work of CEIC is that the challenges facing today's children, youth, and families stem from a variety of political and health pressures; their solutions are by nature complex and require long-term programs of study that apply knowledge and expertise from many disciplines and professions. While not forgetting for a moment the risks, complexity, and history of the urban plight, CEIC aims to build on the resilience and "positives" of inner-city life in a program of research and development that takes bold steps to address the question, "What conditions are required to cause massive improvements in the learning and achievement of children and youth in this nation's inner cities?" This question provides the framework for the intersection of various CEIC projects/studies into a coherent program of research and development.

Grounded in theory, research, and practical know-how, the interdisciplinary teams of CEIC researchers engage in studies of exemplary practices as well as primary research that includes longitudinal studies and field-based experiments. CEIC is organized into four programs: three research and development programs and a program for dissemination and utilization. The first research and development program focuses on the *family* as an agent in the education process; the second concentrates on the *school* and factors that foster student resilience and learning success; the third addresses the *community* and its relevance to improving educational outcomes in inner cities. The focus of the *dissemination and utilization* program is not only to ensure that CEIC's findings are known, but also to create a crucible in which the Center's work is shaped by feedback from the field to maximize its usefulness in promoting the educational success of inner-city children, youth, and families.

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