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ABSTRACT

This study explores data envelopment analysis (DEA) as a tool for assessing and benchmarking the performance of public research universities. Using of national databases such as those conducted by the National Science Foundation and the National Center for Education Statistics, DEA analysis was conducted of the research and instructional outcomes of public research I universities. The study also presents an in-depth analysis of Ohio State University. Instructional variables considered included: instructional faculty full-time equivalency (FTE), expenditures/FTE student, faculty/student ratio, graduation efficiency, six-year graduation rate, degree completions, and admissions selectivity. Research variables included: total FTE faculty, expenditures/FTE faculty, number of publications, number of citations, government grants/contracts, total grants/contracts received, and availability of medical research centers and hospitals. Sections of the paper discuss: the use of DEA in performance measurement; data envelopment analysis; the study methodology; using DEA with a minimum number of variables; integrative performance analysis of multiple variables; strategic positioning of universities; and policy implications of the study findings. The paper concludes that DEA analysis allows academic leadership to more clearly articulate the resource and productivity requirements associated with institutional improvement and, additionally, to plan the direction and magnitude of necessary changes. (Contains approximately 40 references.) (CH)

Assessing the Effectiveness of Public Research Universities

Using NSF/NCES Data and Data Envelopment Analysis Technique

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Assessing the Effectiveness of Public Research Universities

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Abstract

This study explores the use of Data Envelopment Analysis (DEA) as a multi-dimensional and multi-criteria tool for assessing and benchmarking the performance of public research universities through the use of national databases such as the annual institutional surveys conducted by the National Science Foundation and the National Center for Education Statistics.

DEA, as a tool for obtaining multivariate performance indices, has been used extensively to study the performance of public sector and service-oriented private organizations. In studying the performance of higher education institutions, DEA's mathematical formulation for measuring university performance can be verbally stated as: "find a multivariate ratio which (1) characterizes each university in terms of its outcomes and resources, and (2) provides an ordering, from best to worst, of universities with similar outcomes, resources, and environmental constraints."

In applying the DEA method, we examine the research and instructional outcomes of public research I universities and perform an in-depth analysis of the Ohio State University. Our analysis progresses from simple three-variable models to a full-blown model with multiple variables for the comprehensive assessment and comparison of university performance. The results of this study demonstrate how DEA as an "attention focusing" device can be used by university decision-makers to assess their strategic positions and to locate key areas for improvement.

Assessing the Effectiveness of Public Research Universities[1]

Using NSF/NCES Data and Data Envelopment Analysis Technique

Introduction

The annual release of *US News and World Report's* college ranking brings "cries of elation, howls of anger, or muted mutterings in the offices of college administrators throughout the land" (Sanoff, 1998). Despite the controversies surrounding them, college ranking systems are here to stay. In addition to *US News*, *Time*, *Money*, *Forbes* and various other publications are all eager participants of the ranking game. Recently, there has also been talk of designing a national "report card" system to grade the performance of higher education institution in all 50 states (Sellingo, 2000) and creating a ranking of U.S. research universities and their international peers (Southwick, 2000).

This popularity of college rankings, while reflecting its appeal as a marketing tool for newsmagazines, underscores a significant shift in both public opinion and policy attention on the outcomes of higher education. With the cost of higher education continues to escalate at a rate much higher than inflation, taxpayers and tuition-paying parents justifiably demand to know whether their money is well spent. Sensing the public's greater level of scrutiny, state governments and legislatures have begun to link funding for public universities to their "performance." In Ohio, Governor Bob Taft has asked that the Board of Regents issue annual "Report Cards" for the state's public colleges. Other states already have such systems in place. For instance, in South Carolina, funding for the state's public universities is determined by a balanced scorecard system that comprises of 37 performance indicators (SCCHE, 1999).

Assessing the performance of institutions of higher learning poses unique challenges. The primary challenge comes from their diversity. The 1987 Carnegie classification identifies nine different types of institutions of higher learning where each group has its own set of goals and mission. Across these different types of institutions, there is tremendous diversity in the student body, expectations and standards regarding the quality of teaching and level of research commitments. Many commonly used performance measures suffer from several weaknesses: they have a mechanistic view of higher education; they offer partial and often simplistic views based on readily available data, and they are often applied without due regard for institutional differences (Gaither, 1995). Some ranking systems rely heavily on input indicators such as ACT or SAT test

[1] This paper is still a work in progress. Please **do not cite or quote** without the authors' explicit consent. The authors would like to express their gratitude to Dr. Anand Desai for his technical assistance and helpful comments

scores. This reliance may create an unintended and pernicious effect in keeping many perfectly good applicants, many of them minorities, from higher education institutions of their choice.

Being mindful of the need for a more systemic and comprehensive performance assessment tool for higher education institutions and the inherent limitations of commonly used methods, we pursue the exploration of Data Envelopment Analysis (DEA) technique as an alternative approach in assessing the overall performance of higher education institutions. Our objectives are to demonstrate how DEA, when coupled with national databases, can complement traditional performance measures and to provide an alternative approach for universities to examine their overall performance in comparison to newsmagazines' rankings.

Specifically, we utilize publicly available data that have been collected over time in a consistent manner and determine how they might be used in a performance assessment of institutions of higher learning. These data are available primarily from the National Science Foundation (NSF) and the National Center for Educational Statistics (NCES). We attempt to couple these data resources with a powerful analytical tool called Data Envelopment Analysis (DEA) to develop a multi-dimensional, multi-criteria method for developing performance measures and compare and contrast its findings with other commonly used performance measures. We present in this paper the findings about the instructional and research performance of America's public Research I universities as defined by the Carnegie Classification System.

Performance Measurement in Higher Education

Performance measurement practices in higher education have, by and large, followed developments in organizational theory where there are three major approaches to performance assessment: input-output ratio analysis, outcome-based assessment, and stakeholder-based evaluation (Altschuld and Zheng, 1995). Depending on the core value systems of the institutions and their assessment objectives, different approaches have different utilities (Campbell, 1977; Rohrbaugh, 1983). Each of these approaches is useful and relevant, depending on the degree to which it fits the specific needs and situations of the organizations concerned. Typically, a number of performance indicators are used to reflect an organization's relative position in utilizing its resources, managing its organizational processes, and achieving outcomes. These performance indicators are typically ratio-based quantitative measures in ordinal, cardinal or comparative terms (Kells, 1994). Many universities compare their performance indicators with those of a group of peer schools in a process commonly known as "benchmarking" (Alstete, 1995).

Individually, each performance indicator is useful in identifying the position of a university relative to its benchmark peers in a specific performance area. However, when multiple performance indicators are involved, problems arise. For example, some universities may choose to emphasize in certain areas for strategic purposes. Hence, a university may be ranked lower in some areas but higher in others. To solve this problem, a weight is often assigned for each performance indicator (i.e., the balanced scorecard). Such a weighting scheme is often applied uniformly without due regard for institutional differences. Because they often involve subjective judgement and political negotiations, weighting schemes are also controversial. Furthermore, ratio-based measures generally entail comparisons with the mean or median values in order to determine whether the performance of the unit in question is above or below "average". These comparisons rarely capture the complexity inherent in the multidimensional nature of performance evaluations (Desai, 1999).

DEA and Its Use in Performance Measurement

Over the last two decades, Data Envelopment Analysis (DEA) has emerged as a truly multi-dimensional approach to assessing the overall performance of organizations (Seiford, 1990). While some of the earliest applications of DEA were in the area of elementary and secondary education (Charnes, Cooper and Rhodes, 1978; Bessent and Bessent, 1982, Desai, 1986; 1992), its application to measure the performance of university faculty (Walters, Cornia and Cameron, 1997; Walters, Cornia and Chabries, 1998), of university departments (Johnes and Johnes, 1993; Sinuany-Stern, Mehrez, Barboy, 1998; Tomkins and Green. 1988), and of institutes of higher learning as a whole (Kao, 1994; Sarrico, Hogan, and Athanassopoulos, 1997), is fairly recent.

In a study of Canadian public universities, McMillian and Datta (1998) use DEA to demonstrate how university decision makers can use DEA study results to examine their standing relative to their peers and assess the strategic planning options with the information generated. McMillian and Datta control the contextual variations by separating sampled Canadian public universities into three groups: comprehensive with medical school, comprehensive without medical school, and undergraduate only institutions. They use several models with different mixes of input and output variables. Their findings suggest that despite their use of different variables, small subsets of universities are consistently ranked as "best-practice" performers. This small group of universities represents a set of reference points against which other schools may find their relative positions in overall performance.

In another study, Haksever and Muragish (1998) use DEA to measure the outcomes of MBA programs in the United States. Their study focuses on the added values of MBA program. They use the average starting salaries and job placement rate of MBA graduates as the primary outcome variables. Their assessment takes into account the differences in faculty, financial, and student resource available to each school. Their study finds that despite general perceptions, public universities provide as much added values to their MBA graduates as their private counterparts. Moreover, regardless of public and private sector differences, the top 40 MBA programs vary very little in their effectiveness in generating added value.

Because of its relative newness, studies of organizational effectiveness in higher education through the use of DEA technique are mostly exploratory in nature. However, the small number of studies that have been done show clear promise that DEA, when coupled with reliable data, can be used to map the relative performance of universities with similar missions and contextual constraints. Minimally, a DEA study can serve as an attention-focusing device to help higher education decision-makers to identify peer groups for comparison or for locating strategies for institutional improvements. One nice feature of DEA analysis is that its findings can be used to locate the optimal resources allocation strategies for organizations with different mission focuses. Organizations can be compared by how they managed their resources or by how they achieve their outcomes.

Data Envelopment Analysis – A Brief Introduction

DEA has its origins from economic theory of production and linear programming. Linear programming is concerned with the general problem of allocating limited resources among competing activities in the best possible way. Hillier and Lieberman in their classic textbook, refer to linear programming as being "among the most important scientific advances of the mid-twentieth century" (1984, p.29). Charnes, Cooper, and Rhodes (1978) are credited with the development of DEA based on the principles of linear programming. DEA provides a quantitative measurement tool for evaluating the efficiency of public and non-profit organizations, where some inputs and outputs cannot be measured in monetary units and therefore may not have a "bottom-line" for measuring performance.

Through DEA analysis, efficiency can be examined in two ways: maximizing the outputs given a certain level of inputs or minimizing the inputs given a certain level of outputs. Consider monitoring the performance of a university that, for the sake of simplicity of exposition, uses two resources, R1 and R2 to achieve two outcomes, O1 and O2. Using data on these four variables from a number of universities, we can obtain figures similar to those shown in Figure 1.

In the figure on the left, the axes measure two resources R1 and R2 being used to produce the desired outcomes. The data from the different universities would yield a scatter plot. Assuming that the three universities, A, B and C represent the minimal combinations of resource utilization they identify the best-observed practice. The frontier, RABCR denotes a "best practice frontier." We may thus construct performance measures based on the distance from the frontier. Similarly, the universities can be compared on the basis of outcomes achieved. Assuming more to be preferable in this instance, universities S, T, U, and V would define the best practice frontier in the figure on the right. Thus, distance from the frontier OSTUVO could be used to define outcome performance measures. As in the case of resource utilization, universities on the frontier (that is, S, T, U and V) are deemed to be effective while the other agencies "below" the frontier are deemed to be lagging behind in their performance.

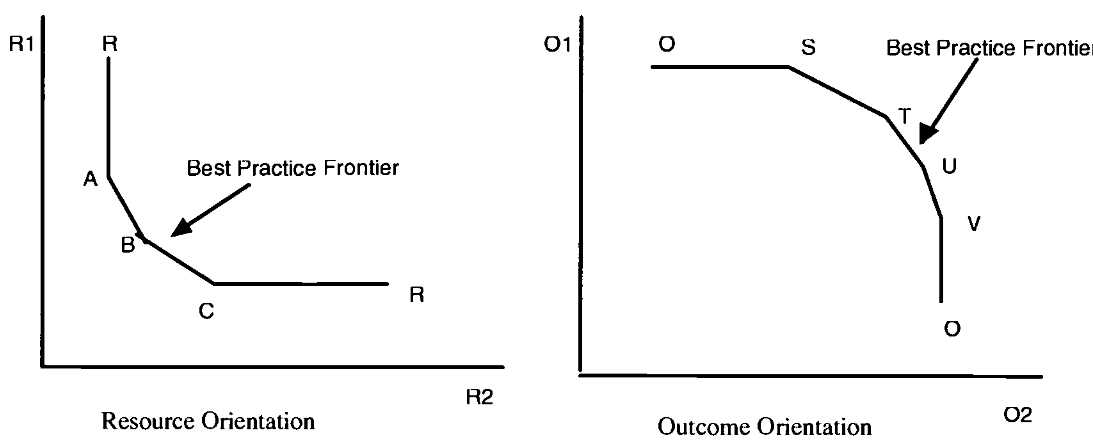


Figure 1: Best Practice Frontiers

To provide a simplified illustration of DEA, let us use the benchmarking of university research performance as an example. In this example, only three variables are used: research expenditure, number of faculty, and number of journal publication. From these three variables, we come up with two ratio-based measures: number of publication per $1000 research spending and number of publication per faculty FTE. The graph below shows how DEA can be used in such a simple case to identify best practices and identify performance gaps.

The graph on next page illustrates how DEA maps the performance frontier. Points A, B, C and D connect to form a curved line that defines the frontier of research outcome. College A represents the highest possible publication numbers per $1000 research expenditure whereas College D represents the highest possible publication per faculty FTE. Any school that lies on the line ABCD is considered effective and a best practice school. Any school that lies under the best practice frontier is considered less effective (not the best). A university that is not on the best practice frontier needs to look for best-practice schools that have similar resource allocation structures to improve its performance. For example, E has the same publication outcome per $1000 investment as C but lower publication per faculty input. E also has the same publication numbers per faculty input as B but lower publication outcomes per $1000 research expenditure than B. Either B or C can be E's best-practice reference. E needs to emulate B's or C's practices in order to improve its research effectiveness.

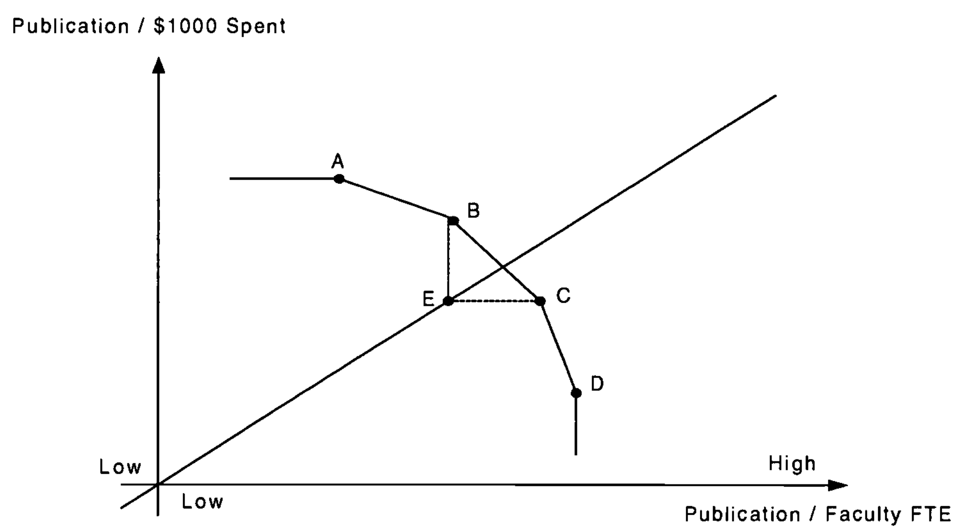


Figure 2: Simple Case of Research Productivity

Of course, this illustration oversimplifies the issues. Performance assessment in higher education is far more complex than this example and requires the simultaneous consideration of multiple variables that reflect not only the inputs, outputs, but also the process and environmental factors. However, DEA models with more than two variables cannot be easily represented graphically. In such cases, we need to formulate the problem in mathematical terms.

The mathematical formulation of the problem is not restricted to two dimensions and the best practice frontiers as well as the performance indices can be readily constructed using multiple resources and multiple outcomes. In the context of university performance, the index that is to be developed corresponds to the following verbal statement:

> *Find a multivariate ratio, which (1) characterizes each university in terms of its outcomes and resources and (2) provides an ordering, from best to worst, of universities with similar outcomes, resources, and environmental constraints.*

A multivariate ratio that meets the above description can be expressed, for each of n universities, as:

$$\sum_r u_{rj} Y_{rj} / \sum_i w_{ij} X_{ij} \qquad (1)$$

Where: Y_{rj} = Level of outcome r of university j;
X_{ij} = Amount of resource i being used by university j; and
u_{rj} and w_{ij} are weights assigned to the outcomes and the inputs.

In creating DEA, Charnes, Cooper and Rhodes (CCR) (1978) proposed a mathematical programming formulation of this problem which simultaneously solves for the weights and provides a relative ordering of these programs. Ideally, each university would want to maximize (1). Since the weights are to be "objectively" assigned so as to maximize this ratio, there is no upper limit to the size of the ratio. Hence, in order to bind the maximum value that any program could obtain, CCR proposed an upper bound of 1. CCR operationalized the above verbal statement of the problem as follows:

> *Find weights u_{rj} and w_{ij} such that the ratio of virtual outcomes to virtual inputs is maximized subject to the constraint that no ratio exceeds unity.*

Thus, we have in (1) the ratio of a *virtual* outcome to a *virtual* resource, where the virtual outcome is the weighted linear combination of outcomes and the virtual resource is the weighted linear combination of resources. Given this characterization of the university's activity, the computational issue to be addressed is (a) how should the weights u and w be obtained and subsequently, (b) how should the ordering of these programs be achieved.

Hence the performances score, h_k, for the *kth* university given n universities using m resources to result in s outcomes is obtained by solving a fractional program (Desai, 1999). Charnes and Cooper (1962) developed a transformation that yields a linear equivalent for this fractional program thereby considerably simplifying the computation of h_k. Hence, the computation of these performance scores entails solving the following linear program:

Maximize:

$$h_k = \sum_{r=1}^{s} \mu_{rk} Y_{rk}$$

Such that:

$$\sum_{r=1}^{s} \mu_{rk} Y_{rj} - \sum_{i=1}^{m} v_{ik} X_{ij} \leq 0 \, ; \; j = 1, \ldots, n$$

$$\sum_{i=1}^{m} v_{ik} X_{ik} = 1$$

$$\mu_{rk} \geq 0 \, ; \; r = 1, \ldots, s$$

$$v_{ik} \geq 0 \, ; \; i = 1, \ldots, m$$

The performance score for each university is obtained by solving n such linear programs, one for each university in the study sample. Computer software for efficiently solving such complex mathematical programs is readily available.

Study Scope, Variables and Models

For this study, we focus on the assessment of America's public Research I universities as defined by the Carnegie Classification System. The restriction of the research scope to only public Research I universities is an attempt to control for variations in missions, organizational structures, human capital and financial capacity. Even among public Research I universities, we recognize the diversities in academic emphases and strategic orientations. We take into account these differences by selectively controlling for mission, contextual and functional differences among these institutions. For instance, in assessing instructional outcomes, we control for student selectivity, assuming that universities with higher admission standards have a higher probability of student success. In assessing research outcomes, we control for the availability of medical research centers and hospitals, assuming that universities with medical research centers and hospitals have greater advantages in obtaining grant funding and in publishing research findings.

The use of DEA to analyze organizational performance has its unique data requirements. One of these requirements is that all resource and outcome variables be specified and measured consistently across all measuring units. Failure to include a valid resource or outcome variable could result in a bias. Thus, due care must be taken in identifying relevant variables that are valid for all universities. To fulfill this requirement, we turn to the databases available from Integrated Higher Education Data Systems (IPEDS) of the US Department of Education and WebCaspar from the

National Science Foundation. We believe that both agencies have by far the most consistent and accurate data resources for this type of analysis. The fact that IPEDS and WebCaspar have multiple years of data affords us the opportunity to examine organizational performance not only for a particular point in time but also longitudinally over a long span of time.

Table 1 summarizes the key variables that we use in this study. This list is part of a much longer list of variables that we use in a broader examination of the performance of higher education institutions in the United States. It should be noted that all variables, except "six-year graduation rate" and the two control variables, are three-year averages of data reported for FY 1995 - FY 1997. The use of three-year averages instead of data for a particular year is to avoid bias caused by possible fluctuations in a university's performance. This is especially true in assessing research outcomes whereas an occasional dip or jump in publication or citation numbers may or may not represent the normal state.

Table 1
Key Variables Used in This Study

	Instructional Variables	**Research Variables**
Inputs or Resources	• Instructional Faculty FTE • Student-related Expenditure per Student FTE - Instructional Expenditure - Student Services Expenditure - Scholarship/Fellowship • Faculty to Student Ratio	• Total Faculty FTE • Research-related Expenditure per Faculty FTE - Direct Research Expenditure - Academic Support Expenditure - Plant & Equipment Expenditure • Number of publications
Outputs	• Weighted Graduation Efficiency Score - Total Student - Undergraduate - Graduate / Professional • Six-year Graduation Rate • Degree completions	• Number of publications • Number of citations • Government Grants and Contracts received • Total Grants and Contracts received
Control	• Admission Selectivity	• Availability of Medical Research Centers and Hospitals

In assessing instructional performance, the following input variables are used to measure available resources: (1) total number of Full-time Equivalent (FTE) of instructional faculty (IPEDS - Faculty Salary Surveys), (2) expenditures per student FTE on instruction, student services, and scholarships and fellowship (the sum of these three expenditure is called student-related expenditures), and (3) instructional faculty to student ratio. The output variables include weighted graduation efficiency score (separated for total student, undergraduate, and post-baccalaureate), six-year graduation rate (institution self-reported), and degree completions.

One of the key output variables, Weighted Graduation Efficiency Score (WGE_Score), is calculated based on the following formula:

$$WGE\_Score = \frac{\sum UG\_\deg + 1.5\sum M\_\deg + 1.75\sum P\_\deg + 2\sum Doc\_Deg}{Total\_Student\_Headcount}$$

Whereas the variables UG_deg, M_deg, P_deg, and Doc_deg represent total numbers of baccalaureate, masters, professional, and doctoral degrees, respectively.

The WGE_score is basically the ratio between number of total degree completions and the total number of students in a specific period of time. Logically, it is reasonable to assume that the higher the score the more successful a university is able to produce graduates. Universities with low attrition rates and high graduation rates are by definition more likely to have higher WGE_score. Traditional graduation rate, like the one used by US News and World Report, measures only the success of students who enter the university as first-time freshman. The success of transfer students or students of subsequent degrees are not considered in the traditional graduation rate equation. A key advantage of the WGE_score is its ability to reflect comprehensively a university's overall effort in adding values to the society by graduating not only traditional undergraduates but also non-traditional students or students of more advanced degrees. This measure to a certain extent minimizes the potential bias against universities that have greater percentage of part-time or non-traditional students.

The WGE_score is a weighted score. We assign a unit weight of 1 to baccalaureate degrees. We assign higher weights to post-baccalaureate degrees: 1.5 to master degrees, 1.75 to professional degrees, and 2.0 to doctoral degrees. These weights are subjectively assigned to reflect considerations that the resources devoted to educating various levels of graduates are different and that the society places different values on various levels of degrees. These subjective weights are by no means uncontestable and may be adjusted when we have more information and time to evaluate their usefulness.

In assessing research performance, the input variables include: (1) total faculty FTE, inclusive of instructional, research, and public service faculty; (2) research-related expenditure per faculty FTE, comprised of direct research, academic support, and plant and equipment expenditures; (3) total number of publications (also an output variable). On the output side, the variables for assess research performance include: (1) total number of publications; (2) total of citations of publications; (3) total amount of government grants and contracts generated; and (4) total public and private grants and contracts generated.

Student admission selectivity (percent of applications rejected) and availability of university hospitals or medical centers are used as control variables when we assess instructional and research performance separately. Student selectivity provides a proxy variable to determine the input quality of a university's incoming students. In assessing instructional performance, we divide the sample of 58 public Research I universities into two groups: those with higher than 40% rejection rate and those below or 40% rejection rate. In assessing research performance, we divide the sample universities into two groups: universities with and without medical centers or hospitals.

In this paper, our models for assessing the performance of public Research I universities are outcome-focused and assume a constant rate of return for the production function. In other words, we assume that the same amount and mixture of resource should generate a similar level of outcomes for all the universities in question. For example, a graduate from UC-Berkeley is considered equally valuable as a graduate from any other public Research I universities. With these assumptions in place, we seek to maximize the outcomes given the levels of resources available to universities. Universities are compared based on their ability to maximize their outcomes in relation to their available resources. In such an outcome-based evaluation, universities who can maximize their outcomes based on the level of resources available to them are considered as "best practice" organizations. Other universities who are not ranked as "best practice" organizations will be arrayed into different ranks by their efficiency scores.

In this study, we use a stepwise approach in conducting the DEA study process: we start with one output variable and two input variables and progress to full-blown models with multiple input and output variables. In the following sections, we will present findings from models from the two extremes: simple models with minimum number of variables and more sophisticated models with multiple input and output variables.

Research Finding I: DEA Analysis with Minimum Number of Variables

In performing DEA studies, the minimum number of variables that are required is three: either one input or two output variables or two input and one output variables. We can also specify the model option to either maximize the output given the resources available or minimize the resource inputs given the level of output generated. In this study, we choose to focus on the output maximizing aspects of the DEA analysis.

The universities included in this study are all public Research I universities. Three Research I universities are excluded due to missing data: Rutgers University at New Brunswick, Temple University and University of California at San Francisco. Most of the data elements come from IPEDS surveys and NSF WebCaspar. We also use data from Institute for Scientific Information and the US News and World Report. Most of the variables reflect three-year average or three-year total from fiscal year 1995 to 1997. The decision to use three-year data rather than one single year is to recognize the fact that institutional performance may fluctuate from year to year and a longer time span will provide a more realistic reflection of an institution's normal state of affairs.

The selected variables are divided into two groups: research outcome variables and instruction outcome variables. In Table 2 and Table 3, we present findings from several basic DEA models with samples limited to schools that share Ohio State University's basic characteristics. For example, for research performance, Table 2 covers only public Research I universities with medical research centers or hospitals. For instructional outcome evaluation, Table 3 includes only public Research I universities with less selective admission standards (admission rejection rate lower than 30% in 1996). In the following discussion, we will discuss findings presented in Table 2 and 3 with graphical illustrations on how the information from even the basic models can help us understand research and instructional performance for Ohio State University.

Table 2: Research Performance -- Basic Models

Public Research Univerisities	*Model 1 Publications*		*Model 2 Citations*		*Model 3 Grants & Contracts*	
With Medical Ctr / Hospitals	*Score*	*Rank*	*Score*	*Rank*	*Score*	*Rank*
COLORADO STATE	57.3	33	44.1	33	49.8	29
IOWA STATE	62.4	29	44.3	32	44.7	35
LOUISIANA ST UNIV	74.0	21	43.5	34	29.1	41
MICHIGAN STATE	62.9	27	59.1	18	55.3	25
NORTH CAROLINA STATE	62.6	28	40.6	37	50.0	28
OHIO STATE UNIVERSITY	85.9	9	52.3	25	72.6	14
OREGON STATE UNIV	43.6	38	39.5	39	48.9	31
PURDUE UNIVERSITY	82.7	10	46.0	31	55.8	23
SUNY AT BUFFALO	69.9	22	55.5	23	48.2	32
SUNY AT STONY BROOK	92.4	8	73.7	9	57.5	21
TEXAS A & M UNIVERSITY	82.6	11	42.9	36	63.1	17
UNIVERSITY OF ALABAMA	67.4	25	86.9	6	74.0	13
UNIVERSITY OF ARIZONA	78.9	19	59.5	17	74.8	12
UNIVERSITY OF CA-DAVIS	81.8	12	56.4	22	57.7	20
UNIVERSITY OF CA-IRVINE	69.7	23	71.8	10	53.4	26
UNIVERSITY OF CA-LOS ANGELES	100.0	1	87.2	5	95.9	5
UNIVERSITY OF CA-SAN DIEGO	98.9	6	100.0	1	95.8	6
UNIVERSITY OF CINCINNATI	62.0	30	63.8	15	42.6	37
UNIVERSITY OF CONNECTICUT	80.4	16	50.1	28	32.5	40
UNIVERSITY OF FLORIDA	81.1	15	49.0	29	62.4	18
UNIVERSITY OF GEORGIA	51.3	36	39.6	38	53.0	27
UNIVERSITY OF HAWAII	40.9	40	51.1	27	44.0	36
UNIVERSITY OF IL AT CHICAGO	58.9	31	52.3	26	49.4	30
UNIVERSITY OF IL AT URBANA	79.3	18	53.9	24	75.5	11
UNIVERSITY OF IOWA	80.3	17	68.1	12	65.8	16
UNIVERSITY OF KENTUCKY	54.8	34	48.5	30	45.6	34
UNIVERSITY OF MICHIGAN	100.0	1	78.9	8	99.4	3
UNIVERSITY OF MINNESOTA	100.0	1	69.3	11	100.0	1
UNIVERSITY OF MO-COLUMBIA	81.2	14	43.2	35	35.4	39
UNIVERSITY OF NEW MEXICO	43.6	37	57.2	20	76.2	10
UNIVERSITY OF NORTH CAROLINA	81.7	13	87.3	4	98.6	4
UNIVERSITY OF PITTSBURGH	100.0	1	96.4	3	83.2	8
UNIVERSITY OF TENN-KNOXVILLE	75.8	20	56.6	21	39.3	38
UNIVERSITY OF UTAH	66.7	26	81.9	7	66.0	15
UNIVERSITY OF VIRGINIA	69.6	24	66.5	14	77.2	9
UNIVERSITY OF WASHINGTON	100.0	1	100.0	1	100.0	1
UNIVERSITY OF WISCONSIN	95.3	7	61.2	16	93.0	7
VIRGINIA COMMONWEALTH UN	42.7	39	67.1	13	55.7	24
VIRGINIA POLYTECHNIC INST	52.3	35	34.2	40	57.5	22
WAYNE STATE UNIVERSITY	58.5	32	58.6	19	59.0	19
WEST VIRGINIA UNIVERSITY	30.2	41	31.3	41	47.7	33

Notes:
For all models: Inputs = Total Faculty FTE, Research-related Expenditure per FTE
Model 1: Output = Total Number of Journal Publications 1995-97.
Model 2: Output = Total Number of Journal Citations, 1995-97.
Model 3: Output = Total amount of Research Grants and Contracts generated 1995-97.

Table 3: Instructional Performance – Basic Models

Public Research Universities with Admission Rejection Rate < .30	*Model 1* *WGE_Score* Score	Rank	*Model 2* *Weighted Total Degrees* Score	Rank
ARIZONA STATE	87.4	6	93.7	4
COLORADO STATE	75.8	19	66.8	24
FLORIDA STATE	100.0	1	100.0	1
GEORGIA INSTITUTE OF TECH	97.7	3	68.6	23
INDIANA UNIVERSITY	70.1	22	83.0	11
IOWA STATE	73.0	20	66.6	25
LOUISIANA ST UNIV	79.1	11	55.8	33
MICHIGAN STATE	63.0	29	73.7	18
OHIO STATE UNIVERSITY	55.7	34	85.7	10
OREGON STATE UNIV	100.0	1	77.1	15
PURDUE UNIVERSITY	63.0	28	73.6	19
SUNY AT BUFFALO	83.4	9	86.0	9
TEXAS A & M UNIVERSITY	58.5	31	86.3	8
THE UNIVERSITY OF TX AUSTIN	79.8	10	100.0	1
UNIVERSITY OF ALABAMA	91.1	5	66.4	26
UNIVERSITY OF ARIZONA	63.5	26	72.7	20
UNIVERSITY OF CINCINNATI	57.4	32	61.4	29
UNIVERSITY OF CO BOULDER	71.0	21	72.6	21
UNIVERSITY OF CONNECTICUT	78.0	15	66.4	27
UNIVERSITY OF IL AT URBANA	76.1	18	87.8	7
UNIVERSITY OF IOWA	68.0	24	78.9	14
UNIVERSITY OF KENTUCKY	62.0	30	54.4	34
UNIVERSITY OF MASS-AMHERST	63.2	27	58.2	31
UNIVERSITY OF MINNESOTA	57.2	33	91.5	5
UNIVERSITY OF MO-COLUMBIA	69.2	23	76.5	16
UNIVERSITY OF NEBRASKA	78.1	13	57.2	32
UNIVERSITY OF NEW MEXICO	76.8	16	71.7	22
UNIVERSITY OF TENN-KNOXVILLE	78.1	14	65.3	28
UNIVERSITY OF UTAH	76.3	17	75.5	17
UNIVERSITY OF WISCONSIN	64.3	25	89.7	6
UTAH STATE UNIVERSITY	87.2	7	59.1	30
VIRGINIA COMMONWEALTH UN	78.3	12	79.6	12
WAYNE STATE UNIVERSITY	93.7	4	100.0	1
WEST VIRGINIA UNIVERSITY	83.8	8	79.1	13

Notes:
For all models: Inputs = Instructional Faculty FTE, Student-related Expenditure per Student FTE
Model 1: Output = Weighted Graduation Efficiency Score (WGE_Score) for Total Student Population
Model 2: Output = Weighted total number of degree completions between 1995 - 1997.

In Table 2, findings from three basic models are presented. As Figure 3 illustrates, each of the models has total faculty FTE and research-related expenditures per faculty FTE as the resource variables. The outcome variable for each model is different: total number of journal publications, total number of publication citations, and total research grants and contracts received are outcome variables for models 1, 2, and 3 respectively.

Figure 3: Basic Research Performance Models

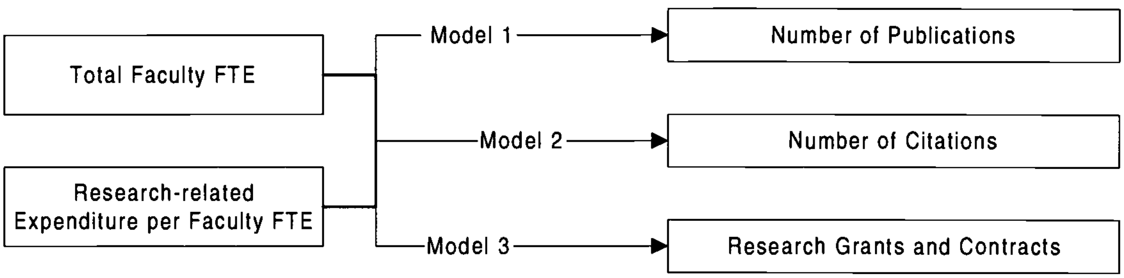
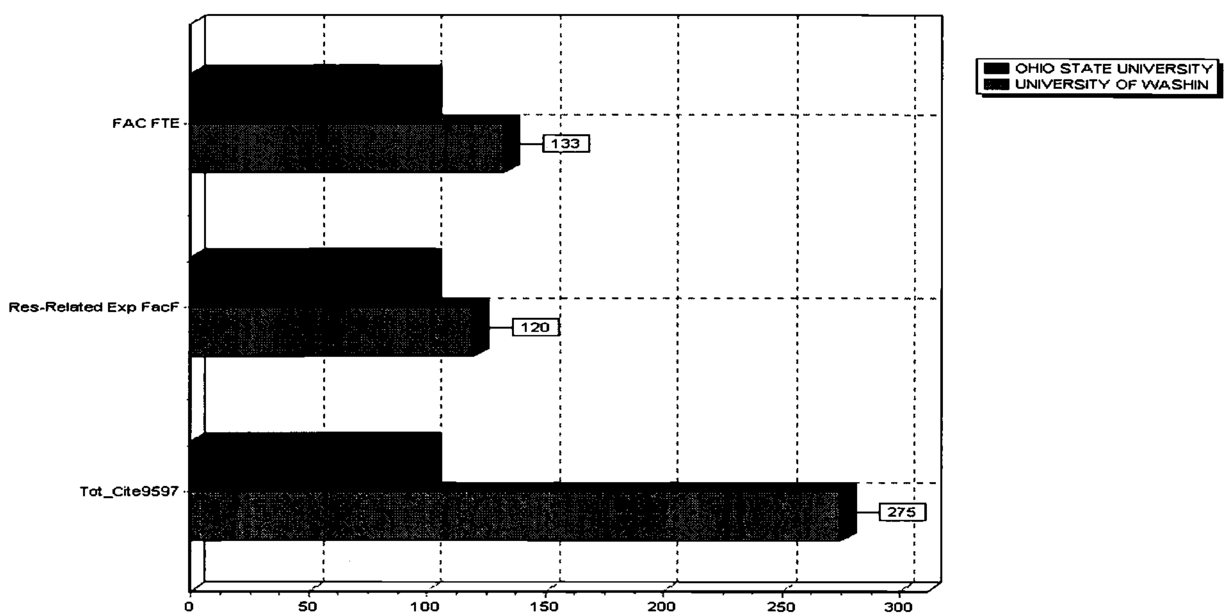


Figure 4: OSU vs. U of Washington when Citation is the Outcome

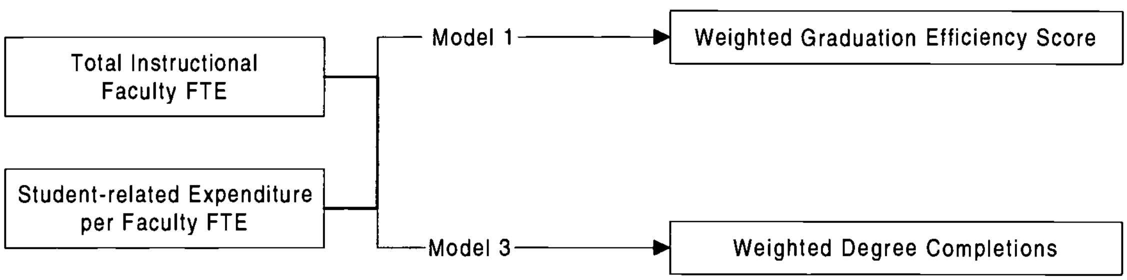


The Ohio State University (OSU) achieves a high score when publication number is the outcome and a low score when citation is concerned. OSU is above the average in generating research grants and contracts. The best practice school that OSU needs to emulate is University of

Washington who has the highest score in all three models. For example, in Model 3, while University of Washington has about 20-30% more resources than OSU, its research impact in the form of publication citations is 175% greater.

With regard to instructional performance, two basic models are used (see Figure 5). The input variables for both models are: total instructional faculty FTE and total student-related expenditure per student FTE. The outcome variable for Model 1 is the WGE_score (discussed in preceding section) and the weighted total degree completions.

Figure 5: Basic Models of Instructional Performance



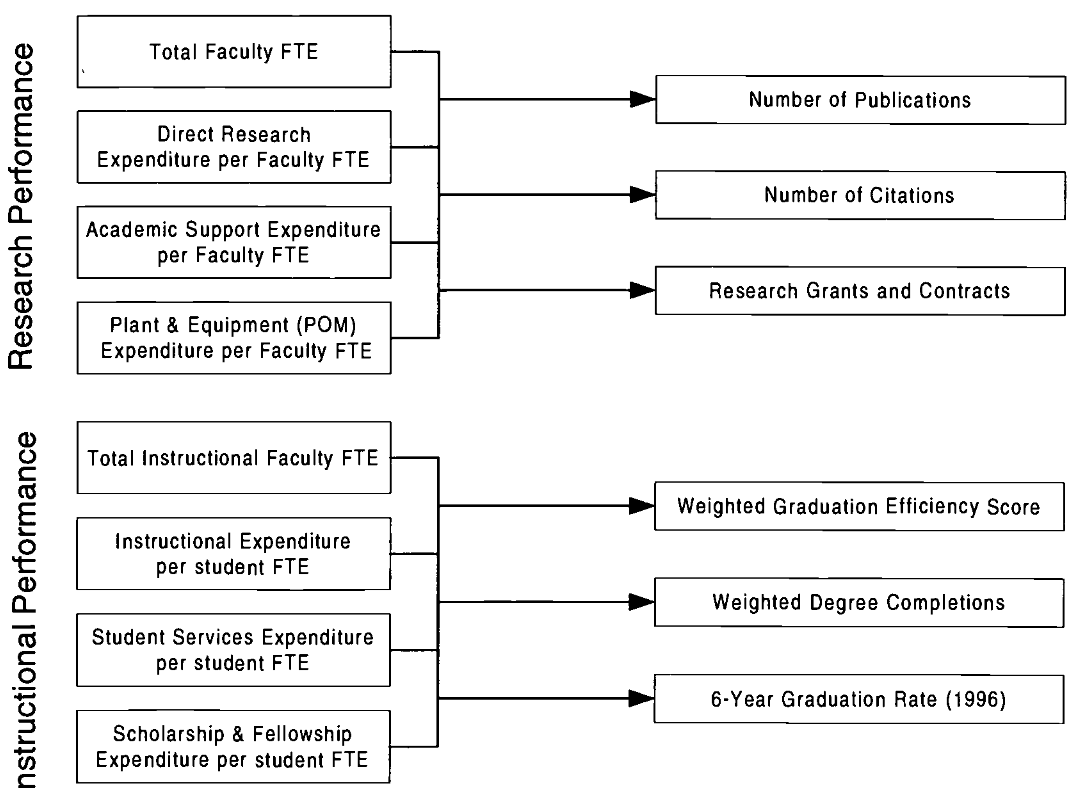
As Table 3 indicates, OSU's performance in instructional outcomes varies greatly. Among public research universities who are relatively less selective in admission standards, OSU is ranked quite high in turning out degree recipients (Model 2). However, when the WGE_score is considered in Model 1, OSU slips to the bottom of the list. As explained earlier in this paper, WGE_score measures the overall value-added effort of the university in producing college graduates. In essence, WGE_score indicates the ratio between total degree completions and the total enrolled student population in a specified time period. The higher the WGE_score, the more likely a university is able to promote student success through better process management and higher retention rates.

The fact that Ohio State is somewhat efficient in turning out large number of degree recipients but lags far behind other schools in overall value-added efforts indicates a strategic trade-off. Being the second largest campus in the United States, the huge student base at OSU certainly provides an advantage of a critical mass in producing degree recipients. However, despite the faculty and financial resources available, the university is not effective in bringing the success rate of its student population to a level that is supposed to be. Interestingly, two of OSU's internal benchmark schools, University of Minnesota and University of Wisconsin, both have the same problem. Without even getting into the more sophisticated models, it is obvious that these state flagship type schools have ample room to improve the success rate even when they are able to move large number of student to graduation.

Research Finding II: Integrative Performance Analysis with Multiple Variables

Moving from the basic models to more integrative models which are what DEA analysis is best suited, more variables are added. Once again, we separate the research and instructional performance variables into two groups and run separate analysis. For the purpose of examining the strategic strengths of all public Research I universities, the integrative models do not control for variations in student selectivity and the availability of medical centers or hospitals. As Figure 5 indicates, each model has multiple resources and outcome variables.

Figure 5: Integrative Models for Evaluating Performance



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In Table 4, the overall research and instructional performance of all public research I universities is summarized. Based on the DEA scores, we make some initial assessment on how to understand each university's positions relative to other public research I universities in terms of research and instructional outcomes.

Table 4: Overall Research and Instructional Performance

Universities	Research Performance		Instructional Performance	
	DEA Score	Rank	DEA Score	Rank
ARIZONA STATE	65.7	39	96.2	25
COLORADO STATE	58.3	48	100.0	1
FLORIDA STATE	48.3	56	100.0	1
GEORGIA INSTITUTE OF TECH	100.0	1	100.0	1
INDIANA UNIVERSITY	100.0	1	86.3	38
IOWA STATE	63.3	44	89.6	36
LOUISIANA ST UNIV	74.4	32	100.0	1
MICHIGAN STATE	71.1	34	91.6	35
NEW MEXICO STATE	56.8	49	96.7	24
NORTH CAROLINA STATE	64.9	41	100.0	1
OHIO STATE UNIVERSITY	88.7	16	78.1	44
OREGON STATE UNIV	52.9	52	100.0	1
PENNSYLVANIA STATE	74.2	33	100.0	1
PURDUE UNIVERSITY	82.3	20	100.0	1
SUNY AT BUFFALO	71.1	35	92.9	32
SUNY AT STONY BROOK	92.2	14	92.3	33
TEXAS A & M UNIVERSITY	95.3	13	100.0	1
THE UNIVERSITY OF TX AUSTIN	91.9	15	94.2	31
UNIVERSITY OF ALABAMA	81.8	21	99.5	21
UNIVERSITY OF ARIZONA	81.5	22	86.4	37
UNIVERSITY OF CA-BERKELEY	100.0	1	83.6	39
UNIVERSITY OF CA-DAVIS	76.6	30	71.1	49
UNIVERSITY OF CA-IRVINE	67.2	38	100.0	1
UNIVERSITY OF CA-LOS ANGELES	100.0	1	60.2	56
UNIVERSITY OF CA-SAN DIEGO	100.0	1	98.5	23
UNIVERSITY OF CA-SANTA BARBAR	76.9	29	100.0	1
UNIVERSITY OF CINCINNATI	74.8	31	65.6	53
UNIVERSITY OF CO BOULDER	100.0	1	79.7	41
UNIVERSITY OF CONNECTICUT	80.7	24	100.0	1
UNIVERSITY OF FLORIDA	78.7	27	75.5	47
UNIVERSITY OF GEORGIA	54.5	51	100.0	1
UNIVERSITY OF HAWAII	48.5	55	100.0	1
UNIVERSITY OF IL AT CHICAGO	82.9	19	66.3	52
UNIVERSITY OF IL AT URBANA	79.6	26	95.1	27
UNIVERSITY OF IOWA	77.5	28	77.0	45
UNIVERSITY OF KANSAS	56.8	50	94.9	28
UNIVERSITY OF KENTUCKY	52.7	53	75.6	46
UNIVERSITY OF MARYLAND	64.4	43	81.7	40
UNIVERSITY OF MASS-AMHERST	80.9	23	67.7	51
UNIVERSITY OF MICHIGAN	100.0	1	62.3	55
UNIVERSITY OF MINNESOTA	100.0	1	64.9	54
UNIVERSITY OF MO-COLUMBIA	85.1	17	72.7	48
UNIVERSITY OF NEBRASKA	64.7	42	95.1	26
UNIVERSITY OF NEW MEXICO	83.2	18	78.3	42
UNIVERSITY OF NORTH CAROLINA	100.0	1	100.0	1
UNIVERSITY OF PITTSBURGH	100.0	1	67.8	50
UNIVERSITY OF TENN-KNOXVILLE	67.6	37	100.0	1
UNIVERSITY OF UTAH	70.9	36	94.3	30
UNIVERSITY OF VIRGINIA	79.7	25	100.0	1
UNIVERSITY OF WASHINGTON	100.0	1	94.5	29
UNIVERSITY OF WISCONSIN	100.0	1	78.2	43
UTAH STATE UNIVERSITY	58.7	47	99.1	22
VIRGINIA COMMONWEALTH UN	58.8	46	100.0	1
VIRGINIA POLYTECHNIC INST	58.9	45	100.0	1
WAYNE STATE UNIVERSITY	65.1	40	100.0	1
WEST VIRGINIA UNIVERSITY	51.8	54	91.8	34

Strategic Positioning of Universities

The use of the DEA technique in this study has provided descriptive information on the research and instructional efficiency of public Research 1 universities. Though this itself is useful information on university performance, the results provided by the DEA analysis can also be used to identify the strategic capability of each university.

In the strategic management literature, superior organization performance is often posited to be the result of superior use of resources. In the resource-based theory of organizations (Barney, 1992) a firm's strategic use of resources is the basis for competitive advantage. In the resource-based view, organizations vary in their ability to effectively leverage common resources and vary in their access to unique resources. The extent to which firms or organizations can utilize resources often affects their market position and the probability of long term survival.

From the resource-based research it is apparent that not all organizations have the same distribution of resources or the ability to leverage all resources equally well. Thus a common approach is to perform at a level which provides competitive parity on many resources, but to identify at least one resource or capability in which the organization excels and build the organizational strategy from that base. Generally, strategy research has found that maximizing efficiency and effectiveness in one resource area is enough of a challenge for most firms. Firms that can excel in more than one resource area create multiple forms of competitive advantage and often exhibit superior performance.

Analysis of the extent to which universities excel in the use of their resources can provide information about their source of strategic advantage. Identifying a strategic position from empirical analysis can inform both policy making and resource allocation decisions within a university. In the DEA analysis, results identified the relative position of universities on two resource dimensions, research performance and instructional outcomes.

The two dimensions were distributed into three categories: high, threshold, and low. A high score indicated that the efficiency on the dimension was a source of competitive advantage. If a school scored 85 or higher on the DEA resource analysis or greater than 90 on the instructional analysis it was assigned to the "high" category. If a university scored between 70 and 84 (inclusive) on the research dimension and between 80 and 89 (inclusive) on the instructional dimension it was assigned to the "parity" category. This indicated that while not a source of competitive advantage, the university was operating at an acceptable, but not competitive, level of performance on that dimension. If a university received a score below 70 on the research dimension or below 80 on the instructional dimension, it was assigned to the "low" category. This score indicates that the university is operating at a low level of efficiency on that dimension. This low level of efficiency may or may not be purposeful. Using these distinctions each university was assigned to a strategic position based on the combination of research and instructional DEA scores.

Though subjectively assigned, this strategic typology can be illuminating. The resource-based theory suggests that universities that achieve excellence on multiple dimensions will be superior performers. Superior performance can also be identified by universities that excel on at least one dimension and achieve parity on others. Complete parity is to have no source of excellence thus the university is simply "treading water". What is worse is to utilize resources more inefficiently than peers and competitors. This suggests that the university is at a competitive disadvantage and will have difficulty in the long run.

Examining the two dimensions together can also provide insight on the set of tradeoffs being made by the university. If resource replenishment is difficult, university administration, either explicitly or implicitly, may make choices to support one strategic capability at the expense of another. If a university can maintain a threshold level of performance, that suggests the tradeoffs between the two performance dimensions have achieved some level of balance. There will be a strategic focus, but not at the expense of a parity position. If a university achieves a high efficiency on one position and a notable inefficiency on another, this suggests that the university's strategic focus is achieved by purposely cannibalizing internal resources and accepting some level of inefficiency within the university on one of the two dimensions. Thus the DEA analysis may show the source of advantage for universities and provide some insight about the internal tradeoffs being made.

In Table 5, we show how the 56 Research 1 universities are distributed across the strategic typology. The most enviable position is that of "Powerhouse". The seven universities in that dimension are achieving efficiency on both the instructional and the research dimensions. This strategic type accounted for approximately 13% of the total sample. The largest category of Research I universities occurred in the "Teaching Cannibal" category. Twenty-nine percent of the sample was assigned to this category. In the DEA analysis, these schools were characterized by low research efficiency with extremely high instructional efficiency.

Instructional efficiency though means simply that these institutions are producing a large number of degrees relative to their resource base. It says nothing about the student experience or quality of instruction. This caveat must also be applied to the "Research Cannibal" category (9 percent of the sample). The schools in this category were of two sub-types. One grouping represents highly research intensive universities. They may be cannibalizing their instructional mission by actually admitting fewer students and conferring fewer degrees than what is indicated by their size and resource base. The other "Research Cannibal" subgroup, though, may more likely be characterized by schools that may be trying to build research reputations by reallocating resources from the instructional side. In both cases low instructional efficiency would be the result in the DEA model.

The other notable category is "Balanced Teaching". Twenty-two percent of the sample was assigned there. These schools are producing graduates at a very efficient rate, but are able to allocate enough resources to research to maintain a parity position. Within this category may also be sub-groups based on the level of investment in the instructional mission of the institution.

Strategic Position and Institutional Effectiveness

To assess the relative effectiveness of the strategic typology, additional more traditional measures of effectiveness were overlaid on the efficiency based strategic types. Though the cell sizes are small, the trends in the data are quite interesting. Table 6 provides a summary of the cell means for student quality data and academic reputation data. The implicit hypothesis is that there should be a relationship between the institutional efficiency (as calculated in the DEA analysis) and institutional effectiveness (as described by the U.S. News academic reputation score and the percent of the freshman class who were in the top 10% of their high school cohort.) Though cell sizes are small, we examine the correlation of these data by strategic type.

The results of this data analysis show some amount of consistency between the efficiency and effectiveness measures. Table 6 shows that the Powerhouse type on average has the largest proportion of high quality students. The reputation scores of the cells with high research productivity are substantially higher than the average scores in the other cells. The overall correlation between USN academic reputation score and the DEA research efficiency score is .68. The relationship between instructional efficiency and the ability to attract high quality students is not as strong. The correlation was only .12 for the overall sample. We conclude that there are additional elements that may be necessary to develop a complete picture of the link between instructional efficiency and the ability to attract students.

Though cell sizes are small, cell level correlation analysis was done as well. The correlation of the academic reputation and research efficiency differed widely by cell. Interestingly, in the "Balanced Teaching" cell, the correlation between academic reputation and research efficiency was very low, though the correlation between student quality and instructional efficiency was much higher. This result was completely contrary to the result for the overall sample. The instructional result was the same for each of the cells associated with high instructional efficiency. In the

"Balanced Research" and "Research Cannibal" cells, the research correlation was as expected, however the instructional correlation showed an inverse relationship between efficiency score and student quality.

In the "Stuck in Parity" cell, correlations on both dimensions were negative; particularly concerning research. Given the list of schools in the cell, this suggests that academic reputation has not caught up with the research performance of the faculty. Analysis of the data in the two "Treading Water" cells suggests that a teaching parity may be more useful than research parity for inefficient institutions. The "teaching" institutions were at least able to leverage their instructional parity into a reasonable number of quality students. The "research" institutions, though, were not able to leverage their research parity into gains in academic reputation. Only the "Teaching Cannibal" institutions have a lower average academic reputation.

Table 5: Balancing Research & Teaching – Public Research I Universities

Instructional Performance	Research Performance: High	Research Performance: Parity	Research Performance: Low
High	Georgia Tech University SUNY at Stonybrook Texas A&M University UC - San Diego Univ. of North Carolina Texas at Austin University of Washington	Louisiana State University Michigan State University Penn State University Purdue University SUNY Buffalo University of Alabama UC Irvine UC Santa Barbara University of Connecticut U of Illinois - Urbana University of Utah University of Virginia	Arizona State Univ. Colorado State Univ. Florida State University New Mexico State North Carolina State Oregon State University University of Georgia University of Hawaii University of Kansas University of Nebraska U Tennessee - Knoxville Utah State University Virginia Commonwealth Virginia Polytechnic Wayne State Univ. West Virginia Univ.
Parity	Indiana University Ohio State University UC - Berkeley U of Colorado - Boulder University of Wisconsin	University of Arizona University of Florida University of Iowa University of New Mexico	Iowa State University University of Kentucky University of Maryland
Low	UC - Los Angeles University of Michigan University of Minnesota U of Missouri - Columbia University of Pittsburgh	UC - Davis University of Cincinnati U of Illinois - Chicago U Mass - Amherst	

Table 6: Categorization and Strategic Choices

Instructional Performance	Research Performance		
	High	Parity	Low
High	***Powerhouse Universities*** Top 10% 43.8 Top 25% 81.2 Reputation Score 3.8 Research Score 97 Instructional Score 97 Research/Reputation Correlation 0.54 Instructional/Top 10% Correlation 0.81 N=7, 12.7% of the sample	***Balanced Teaching*** Top 10% 33.4 Top 25% 64.7 Reputation Score 3.4 Research Score 75.8 Instructional Score 97.7 Research/Reputation Correlation 0.14 Instructional/Top10% Correlation 0.32 N=12, 22% of the sample	***Teaching Cannibal*** Top 10% 29.5 Top 25% 59.4 Reputation Score 3.01 Research Score 58.2 Instructional Score 98.3 Research/Reputation Correlation 0.30 Instructional/Top 10% Correlation 0.28 N=16, 29% of the sample
Parity	***Balanced Research*** Top 10% 29.2 Top 25% 64.5 Reputation Score 4 Research Score 97.7 Instructional Score 81.1 Research/Reputation Correlation 0.38 Instructional/Top 10% Correlation -0.56 N=5, 9% of the sample	***Stuck in Parity*** Top 10% 31.3 Top 25% 60.5 Reputation Score 3.4 Research Score 80.2 Instructional Score 79.3 Research/Reputation Correlation -0.82 Instructional/Top 10% Correlation -0.18 N=4, 7% of the sample	***Treading Water –Teaching*** Top 10% 32 Top 25% 60 Reputation Score 3.3 Research Score 60.1 Instructional Score 62.3 Research/Reputation Correlation 0.86 Instructional/Top 10% Correlation -0.25 N=3, 5.4% of the sample
Low	***Research Cannibal*** Top 10% 37.2 Top 25% 68.5 Reputation Score 3.8 Research Score 97 Instructional Score 65.5 Research/Reputation Correlation 0.58 Instructional/Top 10% Correlation -0.58 N=5, 9% of the sample	***Treading Water – Research*** Top 10% 19.3 Top 25% 47.6 Reputation Score 3.2 Research Score 78.7 Instructional Score 67.6 Research/Reputation Correlation 0.01 Instructional/Top 10% Correlation 0.02 N=4, 7% of the sample	***No Focus*** N=0

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Discussions of Study Findings and Policy Implications

The strategic types identified by the DEA analysis can provide useful information to institutions interested in pursuing goals associated with instructional and research excellence. Generally, performance of universities is evaluated one dimension at a time, even though most academic leaders recognize the multiple missions of most universities. Public Research 1 universities are particularly likely to experience the schizophrenic tension of trying to excel on multiple dimensions. This is especially difficult in state environments characterized by limited resource expenditures for higher education.

The value of the DEA method is that it allows academic leadership to more clearly and explicitly articulate the resource and productivity requirements associated with institution improvement. While many universities strive to be "in the top 20", few leaders have a clear sense, at an operational level, of what that entails or exactly how the institution may achieve that goal.

In addition to helping understand the demands of such an institutional aspiration, the strategic positioning that is observable through application of the DEA results also allows institutions to more clearly plan the directionality as well as the magnitude of the change necessary. For example, if an institution is in the "Treading Water - Teaching" category there are multiple paths to improvement. Instruction is at parity and research is below parity. The question is which should be addressed first? The detail of the DEA analysis can provide specific information on the resource commitment necessary to move the university in one direction of another. One goal may be to eventually become either balanced in teaching or in research. DEA can assist in determining the best path through the strategic types to achieve that goal. For the "Treading Water - Teaching" cell, the institution has the choice of improving efficiency in either instruction or research. Improvement in research will lead them to "Stuck in Parity" while an improvement in instructional efficiency may lead them to become a "Teaching Cannibal". Neither of these positions are idea, but DEA may help determine which of these is the most feasible first step.

In an environment of higher performance expectations and shrinking levels of financial support efficient utilization of resources is becoming a critical part of the strategic assessment of many universities. While excellence is desired by both internal and external stakeholders, the path to excellence is often difficult to find. Though many academicians and trustees can see the end result, clear articulation of the trade-offs and resources required is often lacking. DEA can provide clarification and allow articulation of trade-offs to a degree that has yet to be used in most institutions of higher education. With this type of analysis, real improvements in resource utilization and university performance may be within reach.

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