Measuring Efficiencies of Academic Departments within a College

Loren W. Tauer, Harold O. Fried, and William E. Fry[1]

Abstract

Technical and allocative efficiencies of academic departments in the College of Agriculture and Life Sciences at Cornell University were computed using Data Envelopment Analysis. Various specifications of outputs and inputs were used to determine sensitivity of results to specification. Allocations of faculty time between teaching, research, and extension vary by department and were used as unique prices in calculating allocative efficiencies. Departments not only varied in ability to convert inputs into outputs, but some also produced an incorrect mix of outputs given the prices placed on the outputs of that department.

I. Introduction

It is imperative that academic departments become more efficient in the production and delivery of research and educational services as public funding becomes more constraining, and as high tuition growth becomes unsustainable. To measure efficiency, quantities of outputs produced and inputs used in the academic process must be collected and compared to ideal or benchmark performance criteria. Academic departments can then begin to determine sources and causes of inefficiencies and adopt policies to improve performance.

The College of Agriculture and Life Sciences, Cornell University, has been collecting detailed output data from it's faculty since calendar year 2003. Those detailed data are aggregated into department measures, permitting comparisons across departments. Combined data from the years 2004 and 2005 are used in this study to measure the technical and allocative efficiencies of twenty-six individual academic

[1] Loren W. Tauer is Professor of Applied Economics and Management, Cornell University. Harold O. Fried is Professor of Economics and David L. and Beverly B. Yunich Professor of Business Ethics, Union College. William E. Fry is Professor of Plant Pathology and Senior Associate Dean, College of Agriculture and Life Sciences, Cornell University. Paper presented at the International Conference on Science, Technology and Innovation Indicators. History and New Perspectives, Lugano 15-17 November 2006.

departments using Data Envelopment Techniques. Output distance specifications are used to measure technical efficiency, which is the ability to efficiently turn inputs into outputs. Except for credit hours where tuition is charged, most outputs produced by the college do not have market determined prices. Faculty, however, are assigned teaching, research and extension allocation percentages, and these summed for a department provide unique prices for teaching, research and extension outputs for each department, which makes it possible to measure allocative efficiency. The measurement of allocative efficiency is particularly interesting and important since it evaluates the extent to which the mix of outputs that departments produce is aligned with the mission of the College. This is a unique contribution of the paper.

Effective administration of departments within a college involves difficult resource allocation and human resource decisions that are based upon a combination of hard data and soft information, both of which are important. This is the science and the art of administration. This paper proposes an intriguing way to analyze the hard data that evaluates the performance of individual departments relative to best practice, and generates benchmark departments that can be used to improve performance. However, it is critical to remember that a quantitative analysis is no better than the quality of the data and the specification of the model, which is essentially a subjective decision. The results should be treated as a preliminary screen to identify departments that perform well, departments that perform poorly, and sources for improving performance. These department assessments do not constitute hard conclusions, but rather, the beginning of a hard discussion that incorporates the soft side of the equation. The process is a difficult one; the reward is a better institution.

The next section briefly discusses the literature on evaluating the performance of institutions of education. We evaluate performance using Data Envelopment Analysis. This technique is explained in the context of academic departments in Section III. The data are discussed in Section IV. The results are presented in Section V, and the final section concludes.

II. Evaluating the Performance of Educational Institutions

This article analyzes the performance of academic departments using Data Envelopment Analysis (DEA), developed by Charnes, Cooper and Rhodes (1978). The concept underlying DEA had earlier been presented by Farrell (1957) and applied by Seitz (1971) to steam power generation. A comprehensive bibliography listing DEA applications is Gattoufi, *et al.* (2004). Worthington (2001) reviews the empirical work on estimating efficiency in education. Most of these studies in education use Data Envelopment Analysis (DEA); one of the earliest is Bessent *et al.* (1982), which measures efficiencies of Houston's 241 school districts. Much of the research that followed focuses on secondary education, grades K – 12. There is some work on universities, less work on departments across universities, and limited work on departments within a college or university.

The closest antecedent to this research is Chiang Kao and His-Tai Hung (in press). Kao and Hung examine forty-one departments (some aggregated) in National Cheng Kung University in Taiwan using Data Envelopment Analysis. The inputs are personnel, other operating expense, and space. The outputs are teaching credit hours, research publications, and grants. Since the specification of inputs and outputs is a critical decision that drives the results, it is interesting to compare inputs and outputs in Kao and Hung to this paper. We use one aggregated expense input, and also disaggregate expenses by personnel allocation into teaching, research and extension. We experiment with a more extensive set of outputs, ranging from three to seven. We make some assumptions to obtain an output price vector and explore revenue and allocative efficiencies.

III. Technical and Allocative Efficiency of an Academic Department

Figure 1 illustrates the identification of a production frontier, which functions as a benchmark to determine technical and allocative efficiencies of academic departments A, B, and D, assuming two outputs (research and teaching) are produced with one input. The production frontier maps out the various combinations of teaching and research output that can be produced using a given quantity of input. This frontier is generated by the extreme observations of teaching/input and research/input of the various departments. The basis of the frontier is best practice. This is a strength and a weakness. The frontier is constructed from feasible observations; however, the frontier is sensitive to the observations included in the sample.

Academic department A produces less teaching and research than academic department B. The point B may be a unique academic department or a linear combination of departments. The frontier is constructed under the assumption that observed points and linear combinations of observed points are feasible. The extent of the technical inefficiency of department A is measured as the ratio distance 0A/0B, which is the ratio of the actual production to optimal possible production. This is a radial measure and is independent of the units used to measure the outputs and the inputs. Any department that lies on the production frontier and thus helps to define that frontier is measured as technically efficient; it operates at best practice. Department D is an example, along with other departments located on the corners of the frontier.

The production frontier and where an individual academic department resides relative to that frontier can be calculated for any number of outputs and inputs using linear programming. Applying a linear program to each academic department envelops the frontier segment for that academic department and measures the ratio distance to that facet of the frontier. If an academic department is not dominated by another department or linear combination of departments, then the linear programming solution determines a point on the frontier and measures the academic department as efficient.

Allocative efficiency measures the extent to which a department produces the correct mix of outputs; in this case, the combination of teaching and research that maximizes the value of the combined output. Deriving allocative efficiency requires knowledge of the price of teaching and the price of research. If prices are known, then it is possible to determine the optimal combination of teaching and research that maximizes the value of output produced. This corresponds to the point where the price ratio of the two outputs is tangent to the production frontier. Not only is department A technically inefficient for example, but it is also revenue inefficient, as measured by the ratio 0A/0C. Since technical efficiency multiplied by allocative efficiency is equal to revenue efficiency, it is possible to derive the allocative efficiency of department A as 0B/0C, which is 0A/0C (revenue efficiency) divided by 0A/0B (technical efficiency).

It is important to recognize that technical and allocative efficiencies are fundamentally different concepts. The former measures the efficiency of production; the latter evaluates the production mix relative to an external mission that is quantified as a price ratio. For example, department B is technically efficient since it is on the production frontier, but it is not allocatively efficient. This means that department B is perfect in converting input into the two outputs of research and teaching, but given the valuation placed on the outputs, department B is producing too much research and too little teaching. The extent of the allocative inefficiency of department B is the same as department A, measured again as 0B/0C. In contrast, department D is both technically and allocatively efficient. It is both on the production frontier and is producing the correct combination of teaching and research.

Although technical efficiency in data envelopment analysis is measured using linear programming, it is inherently defined as the ratio of outputs to inputs. Since an academic department produces many outputs and uses many inputs in that process, it is necessary to be able to combine these outputs and inputs, and then use the ratio of aggregated outputs to aggregated inputs as a measure of efficiency. Aggregation requires assigning weights to the various outputs and inputs. Rather than assign arbitrary weights to these outputs and inputs, Charnes, Cooper and Rhodes (1978) suggested selecting the weights on the outputs and inputs that maximizes the ratio of aggregated outputs and inputs for that department, but choosing these weights such that applying these unique weights to the aggregation of the outputs and inputs of all departments cannot measure those academic departments as being more than completely efficient. This requires a mathematical programming specification, defined by the equations below.

The primary mathematical problem can be specified as:

$$\text{Max} \quad (\mathbf{p}_i^T \mathbf{y}_i)/(\mathbf{w}_i^T \mathbf{x}_i) \qquad [1]$$

$$\text{s.t.} \quad (\mathbf{p}_i^T \mathbf{Y})/(\mathbf{w}_i^T \mathbf{X}) \le \mathbf{1}$$

$$\mathbf{p}_i, \mathbf{w}_i \ge 0$$

Where $\mathbf{y_i}$ is a (k x1) vector of outputs produce by academic department i, and $\mathbf{x_i}$ is a (j x 1) vector of inputs used by that i^{th} academic department. **Y** is a (k x n) matrix containing the output vectors of all n academic departments. **X** is a (j x n) matrix of input vectors for the n academic departments. The dimensions of the $\mathbf{p_i}$ and $\mathbf{w_i}$ selected weights are (k x1) and (j x 1), respectively and **1** is an (n x 1) one vector. The problem is to choose the **p** and **w** weights that maximize the ratio of aggregate output to aggregate input of the i^{th} academic department subject to the constraint that no academic department has measured efficiency greater than unity as a result of applying the determined weights of **p** and **w**.

The weights are selected to render the evaluation of department i to be as favorable as possible. Since the problem is solved separately for each department, the optimal department-specific weights typically vary across departments. These weights can be interpreted as shadow prices and represent department specific valuations of the outputs and inputs. If market prices are known, the department-specific weights (prices) can be compared to market prices to determine allocative efficiency. In this paper, the market prices are the relative weights that the College implicitly assigns to teaching, research, and extension outputs for each department. Where the College weights are misaligned with the department weights, the department is following an objective that does not match the objective of the College, even though it might be technically efficient.

If the condition $\mathbf{w_i}^T\mathbf{x_i} = 1$, is imposed on the problem, which is simply a normalization, then the problem can be solved by linear programming methods. The problem then becomes:

$$\text{Max} \quad \mathbf{p}_i^T\mathbf{y}_i \qquad [2]$$

$$\text{s.t.} \quad \mathbf{p}_i^T\mathbf{Y} - \mathbf{w}_i^T\mathbf{X} \leq 0$$

$$\mathbf{w_i}^T\mathbf{x_i} = 1$$

$$\mathbf{p}_i, \mathbf{w}_i \geq 0$$

The dual of problem [2] is the envelopment model [3], normally specified for measuring output technical efficiency:

$$\text{Max } \phi; \qquad [3]$$

$$\text{s.t.} \quad \mathbf{Y\mu} \geq \phi\mathbf{y}_i$$

$$\mathbf{X\mu} \leq \mathbf{x}_i$$

In this problem $\boldsymbol{\mu}$ is an (n x 1) intensity vector, and the scalar,ϕ is the measure of technical efficiency. It can be interpreted as the maximum radial increase in outputs for the i^{th} academic department to produce at the boundary of the efficient production set. It essentially measures the distance an academic department is from the frontier of the production set conditional on the inputs used. If the optimal value of ϕ is equal to the value of one, the academic department being evaluated lies on the efficient frontier. If the optimal value of ϕ is greater than one, the academic department is inefficient since it would be possible to radially increase its output given its inputs. The extent of that inefficiency is eff=1/ϕ.

This problem is solved separately for each academic department to obtain its maximum measure of technical efficiency (1/ϕ), given the input-output behavior of the other departments in the dataset as represented by the constraints. In particular, the first constraint increases ϕ to the point at which it is equal to the output vector of another academic department or a multiple of another academic department, while requiring that its input vector be at least as large as the other academic department or multiple of another academic department (the second constraint). If no expansion is possible, ϕ equals 1, the department is compared to itself, and it is technically efficient. If ϕ is greater than 1, then the value $(1 - \phi)$ gives the proportional output expansion necessary to move the department to the frontier, and efficiency is measured as $1/\phi$.

The essence of being on the efficient frontier is that the department operates according to best practice. Departments operating below the frontier operate at less than best practice; they are rendered inefficient by other departments in the dataset, or combinations of those departments that are able to perform better in the sense that they produce more outputs with fewer inputs. This comparison to real functioning departments (or constructs of real functioning departments) is the strength of a best practice methodology. However, there is the important implication that efficiency results are a function of the particular set of departments in the dataset. Department efficiency is evaluated relative to peer departments. This is a weakness of a best practice methodology.

If values or prices can be placed upon the various academic outputs, then revenue efficiency can be calculated by selecting the output vector that maximizes revenue, subject to the constraint that the output vector is feasible and the input vector is not greater than a linear combination of the observed input vectors. Feasibility is demonstrated by the output and input vectors currently used by the set of academic departments. Revenue efficiency is then the ratio of actual revenue of an academic department, *R*, to optimal revenue, R^*. The DEA problem for revenue maximization is:

$$\begin{aligned} \text{Max} \quad & c_y^T \mathbf{y} = R_i^* \\ \text{s.t.} \quad & \mathbf{Y}\boldsymbol{\mu} \geq \mathbf{y}_i \\ & \mathbf{X}\boldsymbol{\mu} \leq x_i \\ & \mathbf{y} \geq \mathbf{0}, \boldsymbol{\mu} \geq \mathbf{0} \end{aligned} \qquad [4]$$

The dimensions of $\mathbf{x_i}$, $\mathbf{y}$, $\boldsymbol{\mu}$, $\mathbf{X}$, and $\mathbf{Y}$ are the same as in problems [1] – [3], and $\mathbf{c_y}$ is a (kx1) vector of known output prices. The computed revenue efficiency of the i^{th} academic department is R_i/R_i^*, where R_i is observed revenue given output.

Unique output prices can be defined for each academic department via the $\mathbf{c_y}$ price vector. Thus, for instance, if teaching is more highly valued in one academic department, and research is more highly valued in a second academic department, then the price of teaching can be specified to be higher for the first department and the price of research can be specified to be higher for the second department.

IV. Data

The College of Agriculture and Life Sciences, Cornell University, began collecting detailed academic output from individual faculty beginning for the completed calendar year of 2003. Modifications and extensions to items collected were made for the calendar 2004 after faculty feedback to the process, with more detailed information collected on the various academic activities of the faculty. Data collected for 2005 were similar to data collected in 2004. Items collected from faculty are listed in Table 1. This information is collected by a web survey instrument, with faculty given a month after the end of the calendar year to complete the survey. The completion rate for most departments is 100 percent. In the analysis to follow, data from 2004 and 2005 were combined for each academic department. This allowed a smoothing effect, where some output items can be lumpy, such as journal articles, especially for smaller departments.

Items collected fall into the four academic responsibilities of the faculty – teaching, research, extension, and service. The additions to the survey in 2004 in response to faculty suggestions ensure that all academic activities are collected. Thus teaching includes not only credit hours taught (which is collected at the department level), but also serving as advisors to student organizations and activities, as well as many other activities.

The analysis that follows uses aggregated data of the twenty-six academic departments of the College listed in Table 2. These departments primarily are biologically based, but also include some social sciences, such as development sociology. Departments are located both on the main Ithaca campus and at the Geneva campus, approximately an hour drive north of Ithaca, New York. The Geneva departments are identified as such. These departments do much less teaching than departments on the Ithaca campus.

Table 1 lists one input, the total resources available to the department and many outputs. A limitation of Data Envelopment Analysis is that if a large number of inputs or outputs are defined relative to the number of departments, then most if not all departments will be measured as efficient. That is because with many outputs and inputs, more departments will be found to be unique in the production of at least one of the outputs or the use of one of the inputs. It is thus necessary to reduce the number of outputs and inputs. Two types of procedures were used. The first was to simply select the single most important output in each of the three functional areas – teaching, research, and extension, and complete the analysis with those three outputs and the single input. The second procedure was to aggregate the remaining outputs into teaching, research and extension aggregates and use these aggregated outputs in combination with the primary outputs; the result is six outputs and a single input.

The three most important outputs selected were: (1) the number of credit hours taught by faculty in the department, (2) the number of refereed journal articles published, and (3) the number of extension hours taught. The first two outputs are self explanatory, where credit hours taught are the credit hours of the course multiplied by the class enrollment. Refereed journal articles are articles published during the year in academic journals that were subject to peer review. The number of extension hours taught is comparable to the credit hours taught. These consist of the length of time of the extension workshop or presentation multiplied by the number of individuals in the audience.

Using just these three outputs assumes that other measured outputs are precursors or correlated to these three primary outputs. Thus a department that teaches a large number of students is presumed to also advise a large number of students. Similarly, research publications and refereed conference papers are expected to end up as refereed journal articles; patents are typically also reported in written papers, ending up as refereed articles.

Kao and Hung in measuring department efficiencies, dealt with a University with no formal extension activity, but used grants and contracts received by a department as a third measure of output, along with credit hours taught and journal articles. The ability to obtain external grants and contracts is often used as a measure of the quality of research produced by a department. We added total grants and contracts generated by a department as a fourth output in some of our analysis, but in some analysis we also added the direct component of grants and contracts as an input. Since faculty receive some of the revenue generated from grants and contracts, this variable can be viewed as an input into the production of the research output. However, since the administration also receives some of the revenue from grants and contracts, it tends to view this variable as an output along with a quality and prestige dimension.

The single input consisted of funds available to the department, comprising core budget, plus funds for endowed professorships, plus net transfers in from the Dean's office. These funds are used to carry out the mission of a department. However, Faculty, Research and Extension Associates have their time divided among the three mission components – research, teaching, and extension, and that percentage allocation across a department is used to separate the funds available to the department into three components – inputs for research, inputs for teaching, and inputs for extension. This permits a three input specification. Allocation of faculty time across the three mission areas is made by the College with recommendations from the academic department. This in essence is a valuation process on the output of the three mission areas for each department, since departments with large teaching appointments will teach courses, departments with large research appointments will engage more heavily in research, and departments with large extension appointments will produce more extension outputs. Since this allocation differs across departments, it reflects the desire of the College for various departments to produce different quantities of teaching, research, and extension.

These department allocations are used as unique department output prices in measuring revenue (valuation) efficiency and thus allocative efficiency.

Additional funds not reflected in the core budget are available from grants and contracts allocated to the department of the principal investigators. Direct funds from research are added to the research input, and direct funds for extension are added to the extension input of each department. Indirect funds from grants and contracts are not directly available to faculty in a department and are thus not added to these input categories. Analysis reported will show the sensitivity of results to the separation of total resources into the three functional categories.

Additional analysis entails aggregating the remaining outputs into an aggregated research, an aggregated teaching, an aggregated extension, and an aggregated service output. Aggregation requires a priori weights. Although all of these outputs have value, they are not priced in the market place. However, the total College output of each item is available, and these quantities relative to the total quantity of credit hours taught can be used to formulate weights for aggregation. Relative unit output weights are determined by aggregating college outputs, normalizing on credit hours, with these college output weights used to aggregate remaining output of each individual department in the college. Linear aggregation was used.

The use of Data Envelopment Analysis to measure the technical efficiency of an academic department presumes that it is plausible for that academic department to emulate any of the other academic department in converting inputs to outputs. This assumes that the production process of converting inputs to outputs is similar across academic departments. However, it may be possible that it requires fewer resources to teach students or complete research in some departments than other departments. The technique further assumes that the inputs and outputs are homogeneous across departments. Inputs consist primarily of faculty, and there is no reason to expect that faculty quality should differ across departments with a College and University wide tenure process. It is obvious that the impact of individual journal articles varies considerably, but again there is no reason to expect quality bias across departments.

V. Results

Efficiencies calculated using one defined input are shown in Table 3. These numbers, however, only reflect the three major outputs of the academic department – credit hours taught, journal articles, and extension hours. The departments are listed in random order, signified only by departments numbered 1 through 26 in the first column. The second column shows technical efficiencies using the aggregated input without contracts and grants added as an input. Technical efficiency ranges from a low of 0.33 to a high of 1.00. Interestingly, Kao and Hung measuring academic department technical efficiencies for a Taiwan University also obtained technical efficacies ranging from 0.33 to 1.00.

When grants and contracts (direct funds) are added to the single input, the technical efficiencies of departments may either rise or fall as shown in column four. Those departments with efficiencies that decrease, do so because outputs generated from grants and contracts is relatively small compared to those departments which see an increase in their technical efficiency. This is especially true for department number 13, which sees a decrease in measured efficiency from 0.73 to 0.21 when grants and contracts are added to the input. With grants and contracts omitted from the model, the research output of department 13 is attributed entirely to core funds from the budget, and the department evaluation is relatively good. However, department 13 is probably producing research output with the assistance of additional funds from grants and contracts, but compared to other departments, it is doing a relatively poor job of converting this inclusive input measure into research output. In contrast department number 14 sees an increase in technical efficiency from 0.55 to 1.00 when grants and contracts are added to the input. This implies department number 14 does an excellent job of converting grants and contracts into outputs relative to the other departments. It could also result from department 14 having relatively little grants and contract revenue, so with the inclusive input measure, department 14 is rendered efficient since its research output is now attributed to less input relative to other departments than in the previous specification. This information is lost when grants and contracts are omitted from the model. Useful managerial insights are obtained as a result of comparing the efficiencies for individual departments with and without grants and contracts included in the input measure.

Some departments which are technically efficient are also allocatively efficient, noticeably departments 6 and 12. These departments are not only excellent in converting input into the three outputs, but they are also producing the correct mix of outputs given their assigned allocation of teaching, research, and extension. Their internal goals are aligned with the mission of the college. Other departments, however, are technically efficient but are not producing the optimal combination of outputs. For example, department 14 is technically efficient with grants and contracts included in the input, but its allocative efficiency is only 0.23. Department 14 has implicitly adopted priorities that are inconsistent with the objectives of the College. This is potentially valuable information for College management. It is possible that the administration has misestimated the relative strengths of department 14 and should revisit the allocation of funding across outputs

Separating the aggregated input into teaching, research, and extension based upon funding (and implicitly effort) allocations of the faculty produces the technical efficiencies shown in Table 4. The vast majority of the aggregated input consists of salary and wages, and allocation by funding (effort) produces a better measure of how efficient a department is in producing outputs given these allocations. Many departments which previously had low technical efficiencies with a single defined input now have much higher technical efficiencies. In part, this is an artifact, resulting from the model including a greater number of inputs. Examples include department number 7, which increases from 0.51 to 0.99, and department number 11, which moves from 0.39 to 1.00. Moreover, this richer specification incorporates the College mission directly into the model by disaggregating the input variable according to the College's funding allocation formula for each department, and thus includes some elements of the previous analysis of allocative efficiency. Again, adding grants and contracts to the research input causes some department efficiencies to increase, while others to decrease. An example is department number 5, which increases from 0.48 to 0.82 when grants and contracts are added, indicating that it is very good at converting grants and contracts to outputs. In contrast, department number 22 experiences a decrease in measured efficiency from 0.68 to 0.39 when grants and contracts are added to the research input; that department may not be efficient in converting grants and contracts into outputs.

With three defined inputs many more departments are allocatively efficient. Previously with only one defined input, only departments 6 and 12 were allocatively efficient. Now, not only are departments 6 and 12 still allocatively efficient, but also departments 11, 18, 21, 23, and 25. Some departments are technically efficient but not allocatively efficient. Examples include departments 2, 3, and 7. Others are not technically efficient but are allocatively efficient, such as departments 22 and 26. Although departments 22 and 26 are not producing the most from their inputs, they are producing the correct mix of outputs given the prices placed on their outputs .

The next specification adds grants and contracts as a fourth output and retains the three disaggregated inputs. This will not decrease the measured technical efficiency of any department, but the technical efficiency of departments with large amounts of grants and contracts increase significantly more than departments with few grants and contracts, as shown in Table 5. An example is department 3; technical efficiency decreased when grants and contracts were added as inputs, implying it was not as productive converting these into research outputs. However, when grants and contracts are added as a separate output, technical efficiency increases. In contrast, department 8, although efficiency is low, does not experience a substantial decrease in efficiency when grants and contracts are added to inputs, but increases significantly in efficiency when grants and contracts are added as an output.

Moving to seven outputs (Table 6), where the additional four outputs reflect the remaining outputs produced by departments, but retaining one defined input, causes all technical efficiencies to increase. In part, this is due to the greater number of outputs. However, the technical efficiencies of some department increase more than other departments. Those that have substantial increases do so because these remaining outputs, which are not reflected in just the three major outputs, reflect more comprehensively the outputs produced by these academic departments. An example is department number 11, which has technical efficiency of 0.39 under three outputs (0.21 with grants and contracts added to input), but which has a technical efficiency of 1.00 with the seven outputs. Again, adding grants and contracts to the input cause the technical efficiency of some department to increase, while others to decrease.

Finally, increasing the number of defined inputs from one to three with seven outputs increases the measured technical efficiency of all departments, reflecting the impact increased dimensionality has on measured technical efficiencies. Yet, some of the increases are larger for some departments, reflecting that those departments produce much of their output outside of the three major outputs of teaching, research, and extension. With three inputs with grants and contracts and seven outputs, 20 of the 26 departments are measured as completely technically efficient. Although the model has lost much of its discriminatory power, nonetheless, it does suggest that six inefficient departments warrant close scrutiny.

VI. Conclusions

We estimated technical and allocative efficiencies of 26 academic departments in the College of Agriculture and Life Sciences at Cornell University using Data Envelopment Analysis. Output data came from individual faculty surveys for the years 2004 and 2005, aggregated to the department level, augmented with college input data. Various specifications of outputs and inputs were used to determine the sensitivity of the results to alternative specifications. Technical efficiencies of some departments were sensitive to the specification, with some efficiencies falling and others rising, whereas other departments consistently produced high or low technical efficiency scores regardless of specification.

Because faculty have their time allocated among the three missions of teaching, research, and extension, these allocations can be aggregated to the department level and used as relative prices to calculate allocative efficiencies of individual departments. This acknowledges the fact that departments not only can vary in their abilities to convert inputs into outputs, but can also vary in their ability to produce an output mix that is consistent with the mission of the College. Some departments found to be technically efficient were not allocatively efficient and vice versa. A few departments were both technically efficient and allocatively efficient, implying that they are not only good at converting inputs into outputs, but are also producing the correct mix of outputs.

This paper makes a contribution to the science of academic administration. Careful scrutiny of the quantitative results can reveal departments that appear to be performing well and departments that appear to be performing poorly. Moreover, by comparing the results across model specifications, the sources of good and bad performance can be uncovered. But at the same time, it is important to recognize that any quantitative analysis has limitations. It is essential to supplement the science with judicious subjectivity to incorporate a human element that is difficult to measure. The quantitative results should be treated as preliminary, to be used as a discussion point that might reinforce or reverse the conclusions. Healthy open discussion can lead to strategies to raise the quality of the institution. We should settle for no less.

VII. References

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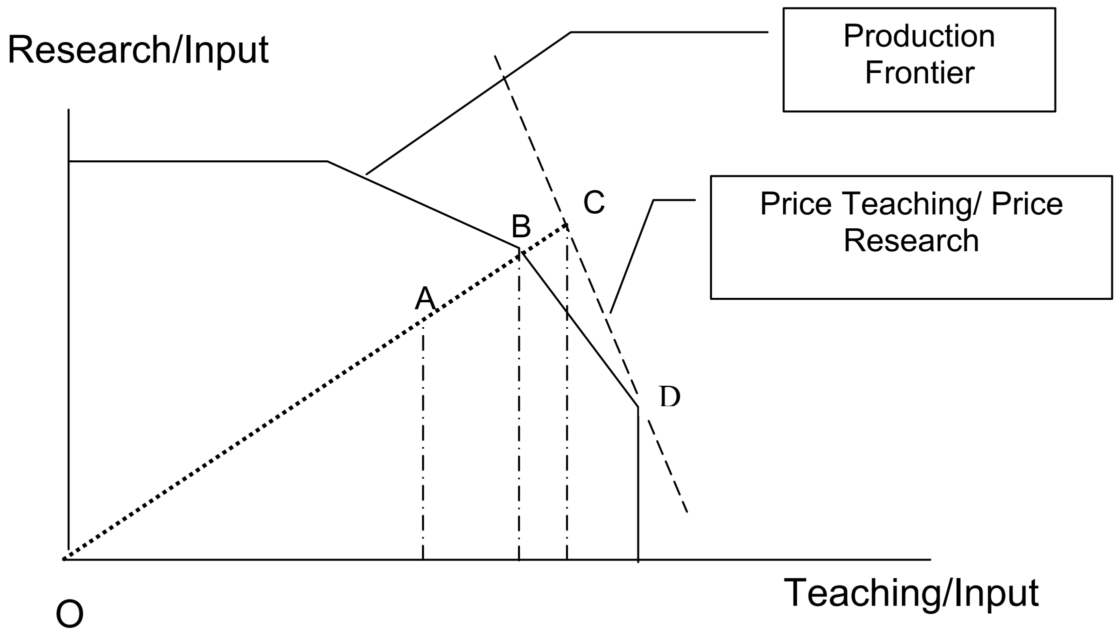

Figure 1. Measuring Technical and Allocative Efficiencies

Table 1. Definitions of Data Collected

Revenues (Input)	Core Funds, Endowed Professorships, Transfer in from the Dean.
Instruction Indicators	
Credit Hours Taught	Based upon Academic Year (2005 = F04, S05; 2004 = F03, S04)
Graduate Students Ph.D Major	Number of Graduate PhD degree Students for whom you were the advisor during the last calendar year.
Graduate Students Ph.D Minor	Number of Graduate PhD degree Students for whom you were not the major professor, but sat on the committee as an advisor during the last calendar year.
Graduate Students Masters Major	Number of Graduate Masters degree Students for whom you were the advisor during the last calendar year.
Graduate Students Masters Minor	Number of Graduate Masters degree Students for whom you are not the major professor, but sat on the committee as an advisor.
Graduate Students MPS	Number of Graduate MPS degree Students for whom you were advisor during the last calendar year.
Undergraduate Student Advises	Number of undergraduate degree students for whom you were the advisor during the last calendar year.
Undergraduate Research	Number of undergraduate students doing research for credit in your lab during the last calendar year.
Undergraduate Student Advisor	Number of undergraduate degree honors students for whom you were the advisor during the last calendar year.
Student Organizations Advise	Number of student organizations for which you were an advisor during the last calendar year:
Instructional Publications	Number of instructional publications.
Service/Leadership	
Committees: Tenure	Number of ad-hoc tenure and promotion committees
Committees: Dept	Number of departmental committees
Committees: CU	Number of college and university committees
Committees: SNI	Number of State/National/International Committees
Professional Organization: Officer	Number of professional societies/organizations outside of Cornell University in which you are active in a leadership/officer role.
Professional Organization: Member	Number of professional societies/organizations outside of Cornell University in which you are active as a member.
Research Indicators	
Refereed Journals	Number of research publications in refereed journals published during the last calendar year. (Please do not include articles in press or submitted).
Refereed Other	Number of other peer-reviewed scholarship/articles (including peer-reviewed conference presentations/exhibitions) published or presented during the last calendar year.
Research Publications	Number of other research publications (e.g. reports or papers in published conference proceedings) produced during the last calendar year. Conferences include those of learned societies, professional bodies, seminars, symposia and other similar activities.
Books Authored	Number of complete books authored and published during the last calendar year.
Books Edited	Number of complete books edited and published during the last calendar year.
Book Chapters Contributed	Number of book chapters published during the last calendar year.
Research Patents Received	Number of research patents received during the last calendar year.
Plants Released	Number of plant varieties released during the last calendar year.

Extension Indicators	
Extension Publications	Number of Extension publications (fact sheets, bulletins, manuals, websites, media) produced during the last calendar year.
Workshops Attended	Number of Extension Conferences/Workshops attended during the last calendar year.
Workshops Organized	Number of Extension Conferences/Workshops organized during the last calendar year.
Non-Credit Instructional Contact Hours	Total number of Extension education/outreach instructional activity contact hours (total number of participants x average length of instruction). (Please enter number as an integer, no symbols or characters).

Table 2. Academic Departments of the College of Agriculture and Life Sciences at Cornell University

Name of Department
Animal science
Applied economics and management
Biological and environmental engineering
Biological statistics and computational biology
Communication
Crop and soil science
Development sociology
Earth and atmospheric science
Ecology and evolutionary biology
Education
Entomology (Ithaca)
Entomology (Geneva)
Food science
Food science and technology (Geneva)
Horticulture
Horticulture sciences (Geneva)
Landscape architecture
Microbiology
Molecular biology and genetics
Natural resources
Neurobiology and behavior
Nutritional Sciences
Plant biology
Plant breeding and genetics
Plant pathology (Ithaca)
Plant pathology (Geneva)

Table 3. Technical and Allocative Efficiencies of Academic Departments with One Input and Three Outputs

	Single Input and Three Outputs[1]		Single Input (with contracts) and Three Outputs[2]	
Department Number	Technical Efficiency	Allocative Efficiency[3]	Technical Efficiency	Allocative Efficiency
1	0.62	0.54	0.57	0.91
2	0.77	0.29	0.96	0.35
3	0.75	0.44	0.42	0.18
4	0.68	0.24	0.82	0.26
5	0.45	0.78	0.71	0.88
6	1.00	1.00	1.00	1.00
7	0.51	0.67	0.83	0.34
8	0.57	0.31	0.54	0.34
9	1.00	0.30	0.51	0.33
10	0.33	0.47	0.63	0.53
11	0.39	0.99	0.21	0.93
12	1.00	1.00	1.00	1.00
13	0.73	0.06	0.21	0.07
14	0.55	0.49	1.00	0.23
15	0.43	0.29	0.42	0.32
16	0.49	0.31	0.50	0.76
17	0.53	0.71	0.22	0.44
18	0.94	0.55	0.83	0.28
19	0.60	0.56	0.52	0.29
20	0.68	0.51	0.49	0.25
21	0.68	0.78	0.35	0.52
22	0.47	0.76	0.24	0.50
23	0.59	0.33	0.53	0.37
24	0.56	0.46	1.00	0.52
25	0.65	0.12	0.78	0.14
26	0.38	0.47	0.68	0.53

[1] Single input is core funds, professorships, and transfers in from the Dean.
[2] Grants and contracts (direct) are added to the single input.
[3] Output prices unique to each department based upon FTE to teaching, research, and extension allocation in that department.

Table 4. Technical and Allocative Efficiencies of Academic Departments with Three Inputs and Three Outputs

	Three Inputs and Three Outputs[1]		Three Inputs (with contracts) and Three Outputs[2]	
Department Number	Technical Efficiency	Allocative Efficiency[3]	Technical Efficiency	Allocative Efficiency
1	0.71	0.72	0.71	0.90
2	0.97	0.36	1.00	0.43
3	1.00	0.67	1.00	0.40
4	0.78	0.24	0.89	0.24
5	0.48	0.95	0.82	0.87
6	1.00	1.00	1.00	1.00
7	0.99	0.66	1.00	0.36
8	0.63	0.35	0.61	0.35
9	1.00	0.48	1.00	0.83
10	0.48	0.55	0.69	0.54
11	1.00	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00
13	0.98	0.10	0.89	0.17
14	0.69	0.74	1.00	1.00
15	0.50	0.36	0.53	0.57
16	0.56	0.38	0.58	0.78
17	0.81	0.99	1.00	1.00
18	1.00	1.00	1.00	1.00
19	0.70	0.65	0.71	0.64
20	0.77	0.61	0.79	0.59
21	1.00	1.00	1.00	1.00
22	0.68	0.99	0.39	1.00
23	1.00	1.00	1.00	1.00
24	1.00	0.91	1.00	1.00
25	1.00	1.00	1.00	1.00
26	0.72	1.00	0.88	1.00

[1] Single input is core funds, professorships, and transfers in from the Dean.
[2] Grants and contracts (direct) are added to the single input.
[3] Output prices unique to each department based upon FTE to teaching, research, and extension allocation in that department.

Table 5. Technical Efficiencies of Academic Departments with Various Inputs and Four Defined Outputs

Department Number	Single Input and Four Outputs[1]	Single Input (with contracts) and Four Outputs[2]	Three Inputs and Four Outputs[3]	Three Inputs (with contracts) and Four Outputs
1	0.65	0.75	0.72	0.83
2	0.77	1.00	0.97	1.00
3	0.92	0.98	1.00	1.00
4	0.68	0.96	0.78	1.00
5	0.45	0.73	0.48	0.82
6	1.00	1.00	1.00	1.00
7	0.51	0.83	0.99	1.00
8	0.57	0.86	0.63	1.00
9	1.00	1.00	1.00	1.00
10	0.33	0.68	0.48	0.73
11	0.50	0.71	1.00	1.00
12	1.00	1.00	1.00	1.00
13	1.00	0.96	1.00	1.00
14	0.55	1.00	0.69	1.00
15	0.43	0.75	0.50	0.77
16	0.49	0.61	0.56	0.70
17	0.80	1.00	1.00	1.00
18	0.94	1.00	1.00	1.00
19	0.60	0.83	0.70	0.84
20	0.69	0.99	0.80	0.99
21	0.80	1.00	1.00	1.00
22	0.64	0.94	0.80	1.00
23	0.59	0.81	1.00	1.00
24	0.56	1.00	1.00	1.00
25	0.65	0.90	1.00	1.00
26	0.38	0.72	0.72	0.88

[1] Single input is core funds, professorships, and transfers in from the Dean. Four outputs are credit hours taught, refereed journal articles, extension hours presented, and total research and extension grants and contracts received (direct and indirect).
[2] Grants and contracts (direct) are added to the single input.
[3] Research and extension grants and contracts (direct) are added to research input and extension inputs, respectively.

Table 6. Technical Efficiencies of Academic Departments with Various Inputs and Seven Outputs

Department Number	Single Input and Seven Outputs[1]	Single Input (with contracts) and Seven Outputs[2]	Three Inputs and Seven Outputs[3]	Three Inputs (with contracts) and Seven Outputs[4]
1	0.87	0.89	0.91	0.93
2	0.85	0.96	0.98	1.00
3	1.00	0.58	1.00	1.00
4	0.79	0.93	0.92	0.93
5	0.76	1.00	0.87	1.00
6	1.00	1.00	1.00	1.00
7	1.00	1.00	1.00	1.00
8	0.71	0.57	0.86	0.65
9	1.00	0.54	1.00	1.00
10	0.71	1.00	1.00	1.00
11	1.00	0.64	1.00	1.00
12	1.00	1.00	1.00	1.00
13	1.00	0.38	1.00	1.00
14	0.70	1.00	0.91	1.00
15	0.53	0.46	0.56	0.55
16	0.93	1.00	0.99	1.00
17	0.60	0.23	0.86	1.00
18	0.94	0.84	1.00	1.00
19	0.60	0.53	0.70	0.72
20	0.73	0.50	0.91	1.00
21	0.68	0.35	1.00	1.00
22	0.47	0.25	0.73	0.39
23	0.79	0.65	1.00	1.00
24	0.67	1.00	1.00	1.00
25	0.92	1.00	1.00	1.00
26	0.77	0.99	1.00	1.00

[1] Single input is core funds, professorships, and transfers in from the Dean. Seven outputs are the three outputs of credit hours taught, refereed journal articles, and extension hours presented, plus aggregated remaining teaching, research, extension, and service outputs.
[2] Grants and contracts (direct) are added to the single input.
[3] Three inputs are core funds, professorships, transfers in from the Dean separated into research, teaching, and extension inputs for each department.
[4] Research and extension grants and contracts (direct) are added to research input and extension inputs, respectively.