# Efficiency Measure for Colleges of Engineering

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# Efficiency Measures for Colleges of Engineering

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**Abstract**

As the need for engineers increases, there is a parallel decrease in public funding of higher education. The press for increased efficiency in the system of higher education is inevitable. Although each college of engineering has its own unique mission, there may be exemplar programs that can provide guidance to them for the continuous improvement of engineering education.

A Data Envelopment based model is developed using the number of faculty as the educational system input and B.S., M.S., PhD degrees, and research expenditures as measures of output for colleges of engineering in the U.S. Data was drawn from the ASEE data mining tool over a three year period (2010-2012) for 186 colleges of engineering. A non-dominated set of 24 efficient engineering colleges was identified and compare with the set of less efficient colleges. The relationship between the level of funded research and PhD production is the same for the efficient and less efficient programs. There is a marked difference between the efficient set and others in the relationship between BS and MS production and funded research. In the less efficient programs, there appears to be no relationship between the number of degrees granted and the amount of research funding. A regression surface fit to these programs and demonstrates the range of efficient programs. Implications for individual programs and further developments are discussed.

## Introduction

Today the demand for higher education is increasing in the US, especially in the field of engineering. As the need for adopting new technologies and technical skills plays a vital role in the survival of individual companies and entire industries. Employees sense the need to enhance their knowledge in order to compete in this new world. On the other hand, the cost of higher education has been increasing in the US. Increasing the economic efficiency of education is becoming a major concern for many schools and there is a wide range of new competitors in the education market. The "efficiency" of education from the viewpoint of public policy may be the ratio of economy valued outputs to economy valued inputs with the arbiter of value assumed to be a market based system. Engineering colleges would like to define a feasible and practical strategy to enhance their efficiency based upon their unique objectives.

Data Envelopment Analysis (DEA) is a wieldy used non-parametric method is used to determine the relative efficiency of decision making units (DMU). This paper presents a DEA approach to measure the relative efficiency of different engineering programs in the US, and identify a set of efficient programs.

The paper is organized as follows: a brief discussion of the issue of efficiency in engineering education and some relevant studies. A summary of Data Envelopment Analysis method is presented with some relevant applications from literature. The set of relevant programs is selected and an efficient set identified. The efficient and less efficient programs are compared.

**Efficiency in higher education**

The demand for higher education is increasing significantly [1]. The world today is facing challenges that motivate the growth of technology in every aspect of life [2]. From 2000 to 2010, the number of full-time undergraduates increased by 45% and the number part time undergraduates increased by 27%.

Although the number of engineering BS degrees increased by 5% in 2012 and MS degrees increased by 6%, there are still unmet needs. Each year over 500,000 new engineers come into the world market from China, India and Eastern European, at 20-30% lower cost than an engineer graduated in the US [4]. Thus, the efficiency of universities and the value of their knowledge creation is a relevant issue. In order to compete, universities look for innovative ways to increase their efficiency.

The average net price that a full time student pays for public four year colleges increased significantly in 2012-13 [3]. Average published instate tuition and fees increased by 4.8% and average out-of-state tuition and fees increase by 4.2% both of which exceed the inflation rate of 2.1%. Nearly 2/3 of all college students will receive some form of grant, federal financial aid, or assistantship to pay their tuition [3]. The value of higher education is a very hard to determine. Typically, we assume that the increased earning potential is worth the investment in education. With the growth of global technology based education, the value proposition historically offered by a US institution comes into question

Attempts to "rate" academic programs are always viewed with caution. The most noted is the US News and World Report rankings. [20]. These are based on the Carnegie categories of universities using a weighting of both inputs and outputs of up to 16 measures. This model implies that the "value" of an institution is the sum of the values of both inputs and outputs, not an efficiency or effectiveness measure. The quality of the "system" is thus hidden because a higher score on outputs is the natural (unmanaged) result of higher scores for inputs.

In order to stay competitive, each organization must determine its performance compared to others in similar markets and; if possible, an ideal theoretical target. This is valid for industries, governments, as well as educational institutions. Efficiency in general, can be described as the amount of cost, effort, and other resources used to realize an intended purpose. The term is often used with the purpose of assessing the capability to produce a specific amount of output with minimum input, or alternatively to generate a maximum possible outcome with specific inputs.

Determining the efficiency of higher education institutions is difficult. They are typically non-profit, there is an absence of a standard for documenting outputs and inputs, and each presents a unique mix of inputs and outputs [9]. Each school may have unique objectives depending on the policies of the governing system, geography, current economic situation, mix of programs, public image, and a host of other factors. Comparing schools with the same objective function does not provide the institution with any actionable information for improvement. According to the definition of efficiency, if a school has the highest outcomes, comparing it to others does not mean that the school is the most efficient unless inputs or resources are considered.

Since there is no single objective function describing all universities, the efficiency cannot be measured by direct comparison using a single objective function score. Because of the nature of the variety institutional objectives and resources, there is not one school that can dominate all others in terms of economic efficiency. Thus, many programs could be efficient in terms of their resources and the outcomes. Each school that is efficient lies on the efficient frontier, and those who are not as efficient can define a strategy based similar efficient programs.

We define the value of the outputs of an engineering college to be a function of the number of productive individuals graduated and the value of the knowledge generated by the institution through research. As a proxy for the number of productive units generated to the economy, we use the number of degrees awarded. This measure could be improved with an economic measure of quality of contribution such as starting salaries, but that information was not available and anecdotal evidence indicates that there are not large differences among engineering colleges in starting salaries. The dollars of externally generated research is used as a surrogate measure for the economic contribution of the knowledge produced.

Our model uses number of faculty positions (tenure and non-tenure) as the single input to the engineering education process. Faculty positions are basis for resource allocation within the university system. Many other inputs such as; staff, equipment, and laboratories are considered to be a function of the number of positions allocated to engineering education. In the current model we do not consider the quality of students as an input.

Each institution is assumed to have an objective (output) that is a combination of the number of BS degrees, MS degrees, PhD degrees, and amount of externally funded research. Some programs may have an undergraduate emphasis, other have a focus on professional masters programs, while others emphasize PhDs and funded research.

**Data envelopment analysis**

To compare schools (or any systems) with each other, in terms of efficiency, there are some numeric methods are useful in determining efficiency. Data Envelopment Analysis (DEA) is a method to evaluate the efficiency of different systems without any specific assumptions about their objective functions.

Data Envelopment Analysis (DEA) is a methodology that has been used to evaluate the efficiency of decision making units with respect to their inputs and outputs [7, 8, 9, 10, 11, 12, 13, 14, 15, 18, and 17]. DEA is a non-parametric method to compare the efficiency of decision making units (DMUs), against the best possible decision making unit. In the DEA methodology, there is no specific assumption for the objective functions and DMUs are allowed to be compared only based on their inputs and outputs. The method has been used in different areas such as economic, health care, management, business and education [7, 10, 12, and 17].

Jill Johnes [9] implemented the DEA method to find the technical efficiency of higher education in England. In the study, an output oriented DEA has been used to examine over 100 universities, using multiple inputs and outputs. The result has been statistically tested to find the significant factors that contributed to the outcomes. There was no assumption about the objective functions and the production functions. The efficiency was assumed to be the ratio of outputs to inputs. In another study [8], Reka Toth examined the efficiency of higher education in European countries using the DEA method. In that study, DEA was been used to evaluate the production efficiency of higher education and its relationship to certain elements of the financing mechanism and socio-economic factors. DEA has been used to evaluate the efficiency of candidates for graduate schools at the University of Bridgeport. They implemented the technique to enhance the quality of evaluation process for their graduate school [13, 14].

DEA is a non-parametric approach that can provide the relative efficiency scores for different DMUs. Unlike parametric approaches like Regression Analysis, DEA can optimize each DMU based on its inputs and outputs and does not need a single function that can be fit to all DMUs [15].

DEA methods can be clustered into two main categories: input or output oriented. Input-oriented DEA focuses on finding the minimum amount of input to achieve an objective. Output oriented DEA concentrates on maximizing outputs generated from constant inputs. DEA models can also be classified based on their "optimally scale" criterion. Models can assume a Constant Return to Scale (CRS), or Variable Return to Scale (VRS). [16]. VRS was first introduced by Banker et al. [18] as a development of the CRS method. VRS provides for increasing or decreasing efficiency based on size, however CRS assume a linear scale for the inputs and outputs thus providing no scaling efficiency [16]. In this paper we employ an output oriented VRS DEA method. Further explanation for the VRS has been provided below.

A basic DEA method finds the efficiency score of each DMU as a ratio of output/input by allowing multiple inputs and outputs in the model. Defining the efficiency as the weighted sum of outputs over the inputs, in the CRS model, the efficiency score for each DMU can be found by solving the equation (1). Equation (1) can be transformed to a linear program equation and then represented as a dual model as it represented in the equation (2). [15, 16]

$$e_p = \max \frac{\sum_{r=1}^{s} u_r y_{rp}}{\sum_{i=1}^{m} v_i x_{ip}}$$

s.t.

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \qquad \forall\, DMU_j$$

$$v_r, u_i \geq 0 \qquad \forall\, k, j.$$

Where,
$y_{ri}$ = amount of output r produced by $DMU_j$,
$x_{ij}$ = amount of input i produced by $DMU_j$
$u_r$ = weight given to the output r,
$v_i$ = weight given to the input i.

$$\min \emptyset_p - \varepsilon\left(\sum_r s_r^+ + \sum_i s_i^-\right)$$

s.t.

$$\sum_j \lambda_j x_{ij} + s_i^- = \emptyset_p x_{ip} \qquad \forall\, input_i$$

$$\sum_j \lambda_j y_{rj} - s_r^+ = y_{rp} \qquad \forall\, input_i$$

$$\lambda_j, s_r^+, s_i^- \geq 0 \qquad \forall\, k, j.$$

$$\emptyset_p \; unconstraind$$

Adding just one constraint to the equation (2) can change the model from VRS to CRS, which is represented in the equation (3). The result of the model, $Ø_p$, is the efficiency for $DMU_p$. Then (1/Ø), is the technical efficiency for each DMU. The maximum possible technical efficiency score is 1 (100%) for each DMU. In VRS, $DMU_p$ is considered efficient if the technical efficiency is equal to 1, and all the slacks ($S_i^+$, $S_r^-$) are equal to zero [16].

$$\min \emptyset_p - \varepsilon\left(\sum_r s_r^+ + \sum_i s_i^-\right)$$

s.t.

$$\sum_j \lambda_j x_{ij} + s_i^- = \emptyset_p x_{ip} \qquad \forall\, input_i$$

$$\sum_j \lambda_j y_{rj} - s_r^+ = y_{rp} \qquad \forall\, input_i$$

$$\sum_j \lambda_j = 1$$

$$\lambda_j, s_r^+, s_i^- \geq 0 \qquad \forall\, k, j.$$

$$\emptyset_p \; unconstraind \qquad (3)$$

In an output oriented DEA, if a DMU has a score of less than one, which means there is at least one DMU who can produce a better outcome given the input of the inefficient unit. When the best DMUs, with score of 1 are identified and the efficient set identified. Efficient frontier describes the best possible set of inputs and outputs. If a college lies on the efficient frontier, this implies that it is generating the best possible outcome given its inputs.

**Data used in analysis**

In our study, the information for all universities has been gathered from the American Society of Engineering Education ASEE website. ASEE collects a variety of self-reported data for each engineering college and program. The data includes: the number of degrees awarded, enrollment, faculty and other teaching / research personnel, students appointments and research expenditures. The research expenditure includes and budgets from external sources such as federal government state government industry, etc. The accuracy of the self-reported data may be a source of debate, especially when it is used as the basis of the model.

In this paper for each college, the number of bachelor degrees awarded, the numbers of masters and PhD degrees awarded, and the amount of research dollars are classed as outputs, and the number of faculty members used as a measure of inputs. The simple conceptual model is an engineering college has two fundamental classes of outputs; educated professionals who have the ability to contribute to society throughout their careers and the generation of knowledge. The number of degrees granted and the dollars of funded research are surrogate measures for the value of these outputs. Given that personnel costs are the largest portion of a college of engineering budget, the number of faculty is used as a surrogate for the value of input. For each university, the average of the three years (2009-2012) was calculated to use in the model. Table 1 provides an example of the data set after finding the average inputs and outputs for each university.

Only colleges that reported that they had graduated at least one BS, one MS, one PhD in any of the reporting years, was included. It is important to include only those programs that are comparable to the majority of engineering colleges. Also, colleges that did not report funded research were excluded because of the incompleteness of the data. There were outliers (more than 3 standard deviations away from the mean) on each of the measures. Fourteen programs were dropped with these criteria leaving 172 colleges.

Table 1. The means for three years of colleges drawn from the ASEE website

| Engineering College | Total Fac. | Total BS Degrees | Total MS Degrees | Total PhD Degrees | Total Res. |
|---|---|---|---|---|---|
| 1 | 18.33 | 62.67 | 10.33 | 4.67 | $4,611,811 |
| 2 | 225.00 | 682.00 | 537.67 | 118.67 | $74,946,845 |
| 3 | 161.33 | 500.67 | 165.33 | 58.33 | $57,631,667 |
| 4 | 55.33 | 168.33 | 46.67 | 1.67 | $7,163,066 |
| 5 | 110.00 | 266.33 | 156.67 | 56.33 | $73,401,058 |
| 6 | 76.00 | 356.67 | 96.33 | 21.67 | $9,615,157 |
| … | … | … | … | … | … |
| 168 | 43.67 | 203.00 | 208.33 | 9.00 | $5,873,451 |
| 169 | 123.00 | 215.33 | 107.33 | 75.00 | $48,789,853 |
| 170 | 94.33 | 482.33 | 301.00 | 20.00 | $10,266,666 |
| 171 | 76.00 | 204.00 | 190.00 | 18.33 | $12,612,333 |
| 172 | 61.33 | 64.33 | 70.33 | 21.67 | $27,731,285 |

**DEA model of engineering colleges**

After collecting the required information, a DEA model was created. It was assumed that colleges want to get greater outputs with the current resources, because inputs may be much more difficult to alter. The return scale for different outputs may be different, thus, a variable return to scale (VRS) model is considered. The model generated is based on an input oriented VRS-DEA model with four outputs and one input.

Using the above assumptions, an output oriented VRS DEA model was developed with PIM-DEA software [22], which is designed to solve DEA models and generate efficiency scores with a range of assumptions. Table 2 represents the final DEA set of efficient colleges. To keep the information for each school confidential, the results have been presented without their names. It was assumed that programs with 95% or greater efficiency scores are assumed efficient. Presented in Table 2 is the input and output data for the 24 programs is in the efficient set.

Table 2. Data from the 24 efficient colleges identified from the DEA analysis.

| School | Total Fac. | Total Bachelor's | Total Master's | Total Doctoral | Total Res. | Efficiency Score |
|---|---|---|---|---|---|---|
| A | 18.33 | 62.67 | 10.33 | 4.67 | $4,611,811 | 100 |
| B | 428.00 | 1674.33 | 992.33 | 284.33 | $207,424,291 | 100 |
| C | 328.33 | 1359.33 | 472.67 | 214.00 | $202,752,123 | 100 |
| D | 58.00 | 148.00 | 346.00 | 23.00 | $5,635,967 | 100 |
| E | 127.00 | 328.00 | 755.50 | 31.00 | $25,786,293 | 100 |
| F | 364.00 | 1238.00 | 638.00 | 197.33 | $274,680,333 | 100 |
| G | 87.50 | 95.50 | 530.00 | 46.50 | $13,966,120 | 100 |
| H | 167.00 | 325.00 | 836.33 | 79.33 | $73,477,000 | 100 |
| I | 115.33 | 515.33 | 156.33 | 72.67 | $68,701,000 | 100 |
| J | 195.00 | 807.00 | 341.67 | 135.33 | $151,155,031 | 100 |
| K | 141.00 | 735.67 | 325.00 | 65.00 | $66,951,404 | 100 |
| L | 281.67 | 994.67 | 908.00 | 223.00 | $78,595,333 | 100 |
| M | 414.67 | 1361.33 | 536.67 | 285.67 | $223,340,012 | 100 |
| N | 123.00 | 365.33 | 436.33 | 61.00 | $85,842,104 | 100 |
| O | 94.33 | 482.33 | 301.00 | 20.00 | $10,266,666 | 100 |
| P | 146.67 | 731.67 | 228.00 | 74.00 | $48,452,394 | 99.61 |
| Q | 105.00 | 262.00 | 239.00 | 49.00 | $74,392,134 | 99.38 |
| R | 200.00 | 646.67 | 382.33 | 132.67 | $150,514,179 | 99.37 |
| S | 37.33 | 128.00 | 133.00 | 4.00 | $2,155,104 | 98.58 |
| T | 377.67 | 1294.33 | 916.00 | 236.33 | $188,390,621 | 98.39 |
| U | 278.00 | 1029.00 | 457.00 | 191.33 | $161,379,281 | 98.37 |
| V | 49.33 | 169.00 | 205.00 | 2.33 | $1,939,628 | 97.09 |
| W | 86.67 | 214.00 | 60.67 | 57.33 | $35,865,784 | 96.9 |
| X | 374.67 | 1440.00 | 381.00 | 177.33 | $138,262,299 | 95.63 |

A simple comparison of the set of efficient colleges with the less efficient set is presented in Table 3. The ranges for each of the outputs and the input variables are quite similar indicating that the both sets include a wide range of program sizes. There is a significant difference in means between the efficient and less efficient sets. This is to be expected because the objective of DEA analysis is to identify the most efficient set of colleges.

Table 3. A summary of input and output data for the efficient and less efficient programs.

| | **Faculty** | **BS Degrees** | **MS Degrees** | **PhD Degrees** | **Research** |
|---|---|---|---|---|---|
| **Efficient** | | | | | |
| **Min** | 18.3 | 62.7 | 10.3 | 2.3 | $1,939,628 |
| **Max** | 428.0 | 1674.3 | 992.3 | 285.7 | $274,680,333 |
| **Mean** | 191.6 | 683.6 | 441.2 | 111.1 | $95,605,705 |
| **Sdev** | 127.2 | 491.7 | 271.3 | 90.2 | $80,256,853 |
| **Less Efficient** | | | | | |
| **Min** | 21.0 | 27.0 | 7.0 | 1.0 | $1,242,109 |
| **Max** | 441.0 | 1644.0 | 948.0 | 285.0 | $267,449,000 |
| **Mean** | 119.2 | 346.3 | 181.8 | 43.1 | $36,941,431 |
| **Sdev** | 79.1 | 285.4 | 178.5 | 50.6 | $45,255,817 |
| **Difference** | **72.4** | **337.3** | **259.4** | **68.0** | **$58,664,274** |
| **Z** | **2.70** | **3.27** | **4.52** | **3.60** | **3.49** |

A comparison of raw efficiency scores provides some insight to the difference between efficient and less efficient colleges. Initial analysis indicated that by combining BS and MS degrees, more robust analysis was obtainable. This does make sense in that both BS and MS degrees require similar amounts of faculty effort for a degree to be earned. Figures 1, 2, and 3 present the relationships between Research/Faculty, (BS+MS)/Faculty, and PhD/Faculty. Table 4 summarizes the regression analysis for pairs of variables.

Figure 1 presents the relationship between the number of PhD/Faculty and Research/Faculty. The relationship for both the efficient and less efficient sets are strong with $R^2$ of 0.50 and 0.46. The plots in Figure 1 indicate that there is no difference between efficient and less efficient programs in the relationship between PhD degree production and research funding with each PhD degree per year having $700,000 to $800,000 in research funding per year for both sets. This may be interpreted as indicating that $700,000 of research is required to support a PhD graduate or the each PhD graduate generates $700,000 in funded research. The interesting point is that this is true for both the efficient and less efficient colleges.

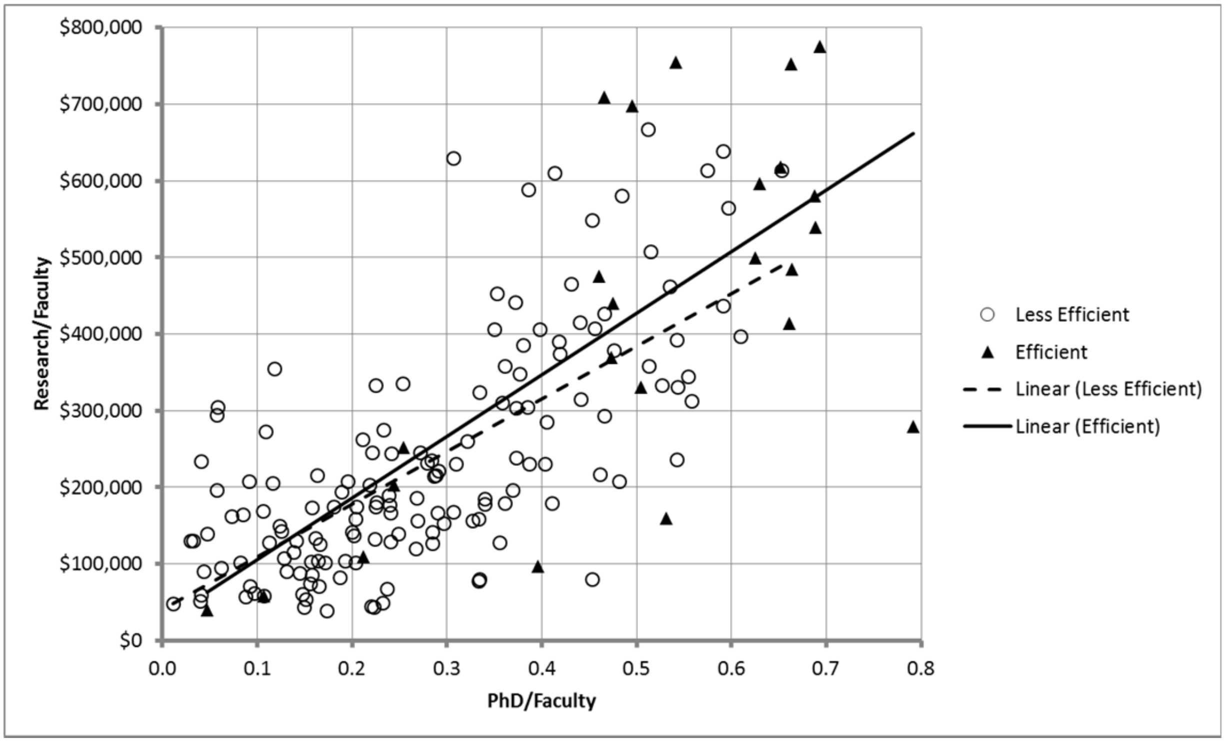

Figure 1. Relationship between the number of PhD degrees granted per faculty and the amount of funded research per faculty

Figure 2 illustrates the relationships between the number of (BS+MS)/Faculty granted per year and the number of PhD/Faculty granted per year. There is no clear relationship for the set of less efficient programs, $R^2 = 0.03$. However, the set of efficient programs indicates a negative relationship, $R^2=0.46$. The more PhD degrees granted the fewer (BS+MS) degrees granted for efficient colleges. There appears to be some constraint that relates (BS+MS)/Faculty and PhD/Faculty for the more efficient programs while the efficient programs graduate more (BS+MS) for a given levels of PhDs.

In addition to comparing efficient with less efficient programs across input and outputs, a model for the set of efficient colleges was developed. The objective was to identify an “optimal” surface identified by the efficient set. A wide range of models was developed and the model with the highest F score is presented for discussion. The statistics for the ANOVA and regression equation are presented in Table 5.

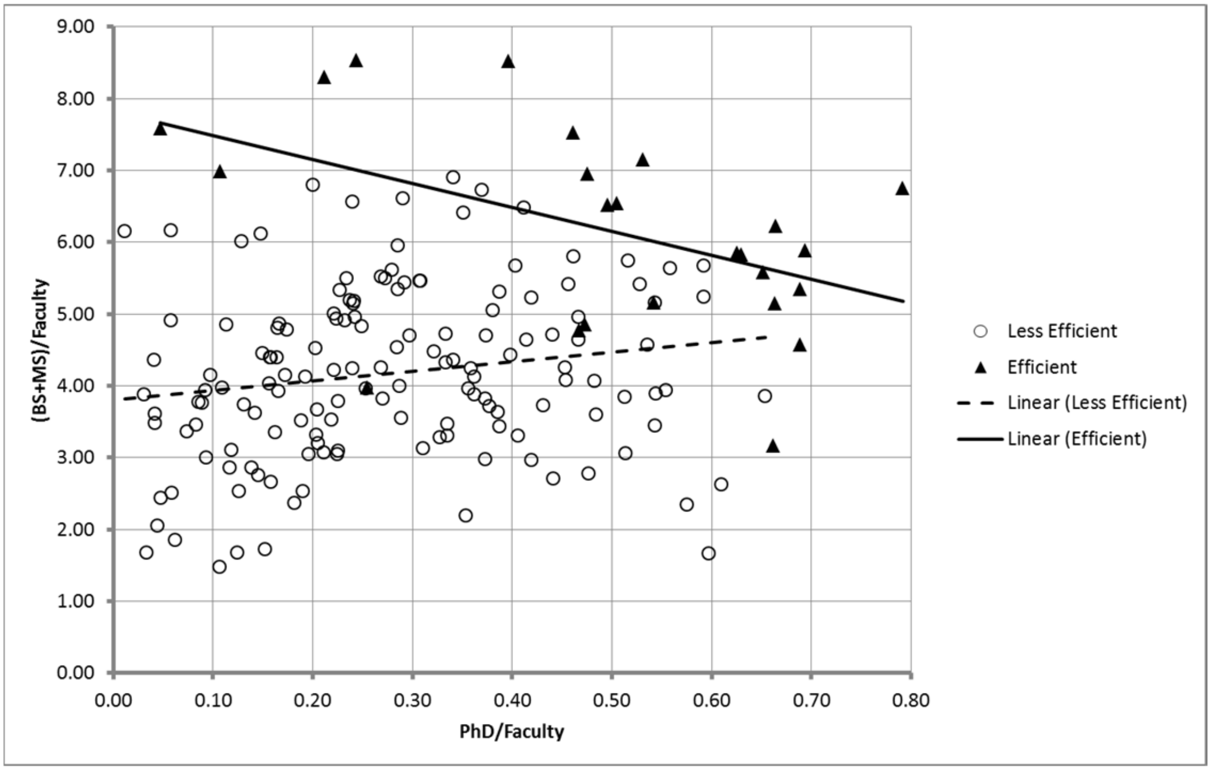


Figure 2. The relationships between the number of BS and MS degrees granted per year and the number of PhD degrees

Table 3. Linear regression equations for data in Figures 1 through 3.

| | | | |
|---|---|---|---|
| | **Research and PhD Figure 1** | | |
| Less Efficient | Research/Fac = | \$40,909 + \$685,763 * PhD/Fac | $R^2$ = 0.50 * |
| Efficient | Research/Fac = | \$25,275 + \$803.768 * PhD/Fac | $R^2$ = 0.46 * |
| | **(BS+MS) and PhD Figure 2** | | |
| Less Efficient | (BS+MS)/Fac = | 3.80 + 1.34 * PhD/Fac | $R^2$ = 0.03 |
| Efficient | (BS+MS)/Fac = | 7.81 – 3.33 * PhD/Fac | $R^2$ = 0.46 * |
| | **Research and (BS+MS) Figure 3** | | |
| Less Efficient | Research/Fac = | \$241,065 - \$1,918 * (BS+MS)/Fac | $R^2$ < 0.01 |
| Efficient | Research/Fac = | \$991,803 - \$91,876 * (BS+MS)/Fac | $R^2$ = 0.30 * |

Figure 3 illustrates the relationship between (BS+MS)/Faculty production and Research/Faculty. Efficient programs demonstrate a strong negative relationship between degree productivity and research productivity, $R^2$=0.30. Teaching load and research productivity have a strong negative relationship. The same cannot be said for the less efficient programs. Teaching load (BS+MS)/Faculty appears to have little effect on research productivity, Research/Faculty, $R^2$<0.01.

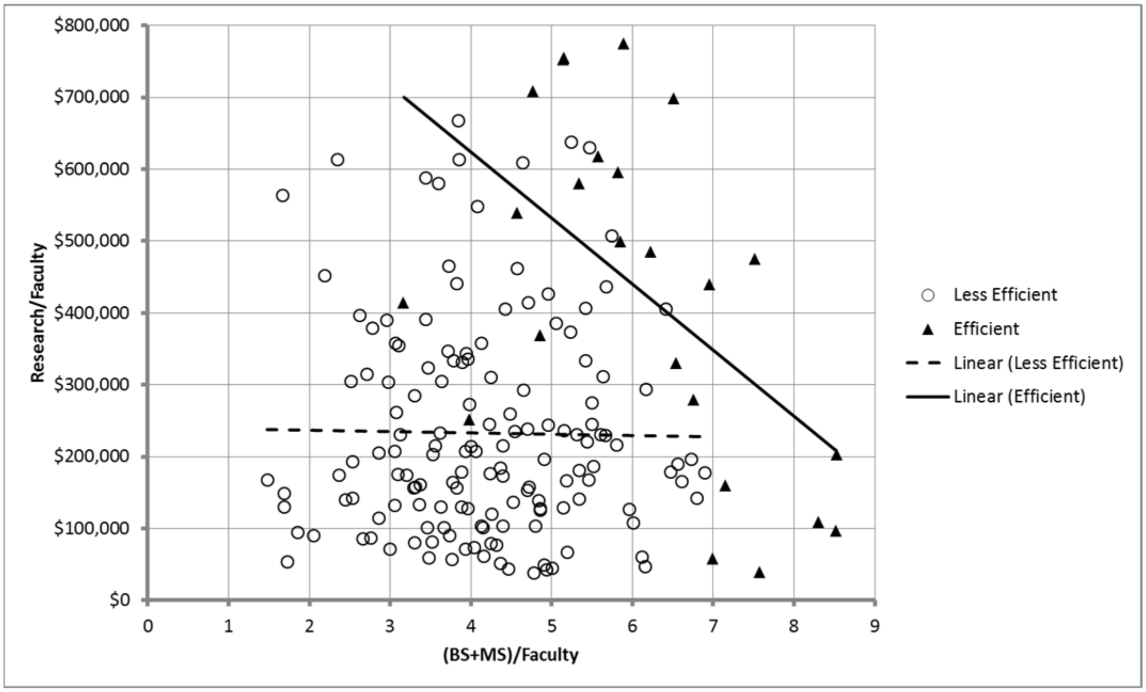


Figure 3. The relationship between (BS+MS) degree production and research productivity

The set of efficient programs may define an "efficient" surface that describes relationships between the input and output variables for a range of objective functions. The slope of this surface at any point indicates the relative contribution among parameters. In order to determine the structural relationship between the output parameters for the efficient set of programs, numerous models were evaluated. The model with the highest F is presented in Table 5.

Table 5. ANOVA and Regression model of the efficient surface

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.851 |
| R Square | 0.723 |
| Adjusted R Square | 0.647 |
| Standard Error | 140,406 |
| Observations | 24 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 5 | 9.28E+11 | 1.86E+11 | 9.413642 | 0.000152 |
| Residual | 18 | 3.55E+11 | 1.97E+10 | | |
| Total | 23 | 1.28E+12 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | -2,324,126 | 909,978 | -2.55 | 0.020 |
| BS+MS | 675,493 | 234,793 | 2.88 | 0.010 |

| | | | | |
|---|---|---|---|---|
| PhD | 4,146,586 | 1,398,483 | 2.97 | 0.008 |
| (BS+MS)^2 | -49,681 | 16,091 | -3.09 | 0.006 |
| PhD^2 | -2,143,746 | 808,432 | -2.65 | 0.016 |
| (BS+MS)*PhD | -300,254 | 152,030 | -1.97 | 0.064 |

This model defines a nonlinear surface describing the relationship between (BS+MS), PhD, and Research. An illustration of this surface is presented in Figure 4 and may be a representation of the efficient frontier. The slope of this surface is quite different for different sets of parameters indicating a wide range of objective functions in the efficient set.

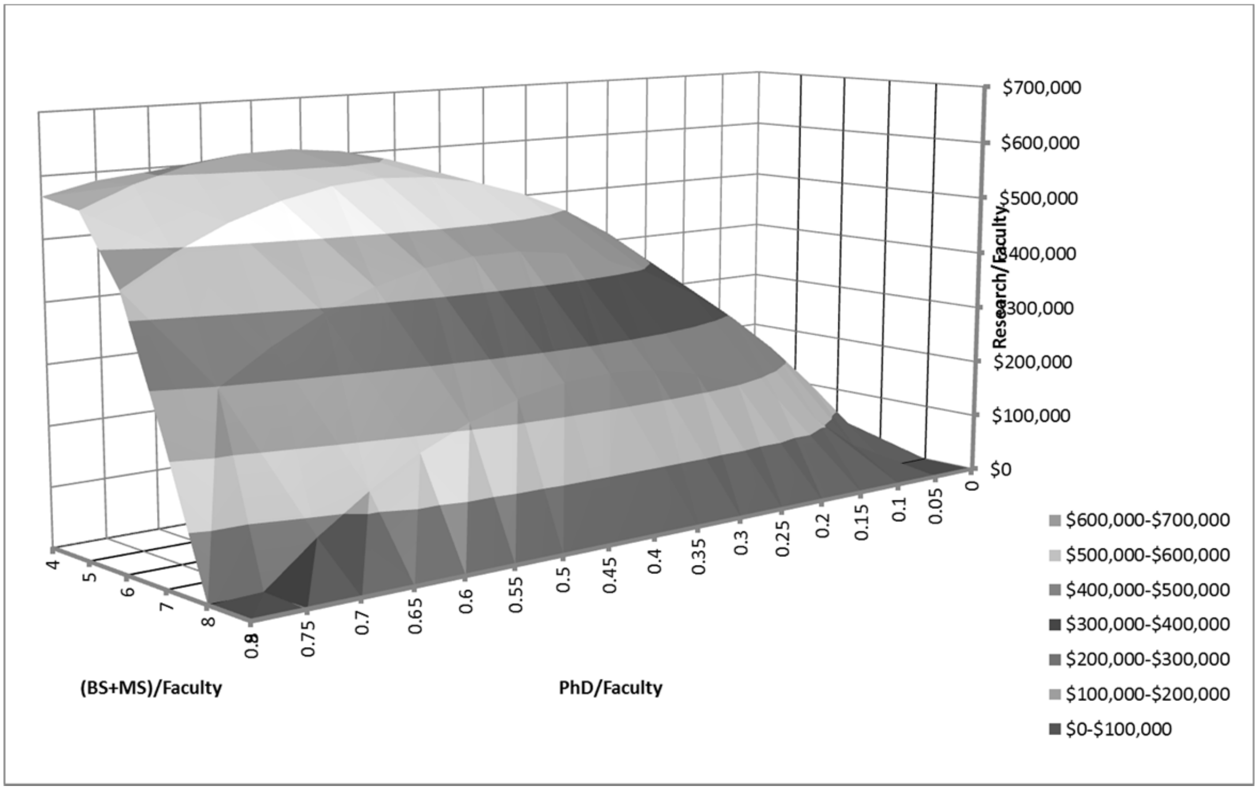


Figure 4. A surface fit though the set of efficient programs

**Conclusion and Discussion**

This work has provided at least the initial characteristics of the most efficient engineering colleges independent of their unique objectives. The underlying premise is that any program can then identify the most direct path from its position to the efficient surface. This path then can be interpreted in terms of specific strategies with the accompanying measures of improvement. The few “elite” schools as general models for emulation may not address the unique nature of each institution.

There are numerous issues with this approach, the first being the relative accuracy of the data. Although attempts are made for standardization in the ASEE database, the self-report process raises concerns. There is no assessment of the “quality” inputs or outputs. Are all faculty equivalent or are all degrees of the same value? Obviously there are more inputs into the system of higher education than number of faculty and there are likely other outputs. This is a very simple structural model.

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