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Factors Affecting Instructional Costs at Major Research Universities

Introduction

The purpose of this article is to analyze in quantitative terms why unit instructional costs differ among major research universities. Previous studies have uncovered many of the factors that account for costs in higher education. The primary task here is to specify the relative importance of these and additional factors. Particular attention is given to the effects of enrollment size on unit instructional costs.

In the *California and Western Conference Cost and Statistical Study*, [5] a benchmark analysis of ten research universities, it was found that the most important determinant of variations in faculty salary expenditures was faculty teaching load. Curriculum breadth, level of instruction, and student mix were also important, but average faculty salary was not, at least when compared to the former variables. Calkins [6], in a study of 145 liberal arts colleges, found that average faculty salary was the most important variable with respect to differences in unit instructional costs, followed by size of enrollment, curricular emphasis, and number of courses. In studies where enrollment size was a matter of emphasis, the results are mixed, but overall it appears that positive returns to scale, or so-called "economies of scale," are more difficult to achieve than theory might suggest. Maynard [17] found that public four-year institutions (in thirteen states) were realizing economies of scale up to enrollment levels of about 5,300 full-time equivalent (FTE) students. The Carnegie Commission on Higher Edu-

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cation [7] found evidence of economies of scale in larger community colleges. On the other hand, Layard and Verry [16] found an absence of substantial economies of scale with respect to departmental costs at universities in the United Kingdom, while Broomall et al. [4] found no such economies in a variety of expenditure categories at twenty-two public senior institutions.[1] In a recent study of 1,347 public four-year colleges and universities, McLaughlin et al. [18] reported that the faculty-student ratio and the complexity of the curriculum were far more important than enrollment size in accounting for variations in unit instructional costs, results that the authors interpreted as confirming the earlier findings of Blau [2] to the effect that economies derived from increased enrollments are typically negated by corresponding increases in the degree of institutional complexity.[2]

The findings of the present study, with respect to variations in unit instructional costs at major research universities, can be summarized as follows:

1. Considered apart from measures of output, the input variables in the study accounted for 71 percent of the variation in costs, with the faculty-student ratio being by far the most influential variable.
2. Considered apart from measures of input, the output variables in the study accounted for 88 percent of the variation in costs, with the proportion of graduate students, the complexity of the curriculum, and the overall enrollment size all contributing importantly to explained variance.
3. Considered together, the output variables were more effective than the input variables in accounting for variations in costs.
4. The private institutions in the sample typically had higher unit instructional costs than did the public institutions, a situation apparently explainable on the basis of the input and output variables used in the study.
5. Evidence was found for economies of scale for the sample as a whole, but not for a subsample of public institutions.

The next section is devoted to the conceptual framework for the study and following sections to the sample data and the methodology,

[1]As reported in [18, p. 5].
[2]Extensive reviews of cost analysis literature can be found in [1, 29].

the analytical models and their respective results, and some implications of the findings.

Framework

Microeconomics provides the theoretical tools for analyzing an organization's economic activities. Suitably adapted, the concepts and methods contained therein are thought to be applicable to any organization, whether or not it operates for profit. Within microeconomics, costs may, of course, be viewed as being dependent on the levels and the prices of inputs to the production process. On that basis it is possible to estimate the respective impact of levels and prices of inputs on variations in costs among institutions. It is also appropriate in microeconomics to view costs as being dependent on output, using a so-called "cost function."[3] On that basis it is possible to estimate the impact of various aspects of output on costs.

Varieties of input prices, input levels, and output levels, then, are the variables that are to be used in accounting for differences in unit instructional costs. The three types of variables are in accord with the three categories of higher education cost factors enunciated by Robinson, Ray, and Turk [23], namely, environment, decision, and volume factors.

Method

The sample for the study, consisting of twenty-nine public and twenty-one private institutions, included all but one of those institutions designated as "Research Universities I" by the Carnegie Commission on Higher Education [8], with the one exception being Rockefeller University. The fifty institutions accounted for an enrollment of nearly one million FTE students and about three billion dollars in expenditures for instruction and departmental research in 1976–77.

For purposes of the study, "cost" was taken to mean "reported expenditures." Thus, the dependent variable in the analysis that follows is the reported expenditures by institution for the category covering instruction and departmental research. The Higher Education General

[3]It is legitimate in microeconomics to empirically study the structure of production using either a production or a cost function. The latter is preferable when the level of output is exogenous, which is probably more characteristic of public than of private institutions. In any event, a cost function approach is used in this study. See [20] for a frequently cited application of a cost function to the electric utility industry, and [16] for a similar application to higher education.

Information Survey (HEGIS) [27] was the source for all of the expenditure data, which were gathered for 1976–77.[4]

The relationships among the variables were analyzed using multiple regression, an approach frequently used in similar circumstances.[5] The beta weights and various kinds of correlation coefficients that are generated by a regression analysis provide estimates of the influence that each independent variable has on the dependent variable. Since collinearity among the independent variables reduces the reliability of such estimates,[6] an important consideration in constructing the regression model was to limit the extent of that collinearity as much as possible, while remaining within the microeconomic framework. The strategy adopted was to develop two regression models, one accounting for costs in terms of inputs and the other doing so in terms of outputs. A third equation was formulated in which both input and output variables were present, but with the realization that multicollinearity would probably limit its usefulness.

Findings

Unit instructional costs among the fifty universities in the sample varied widely. The range of expenditures per FTE student for instruction and departmental research went from $1,619 to $12,171. The median expenditure was $3,199 and the mean was $3,694. Expenditures per FTE student at all but one of the private institutions were higher than the median. While the variability of per student instructional costs was considerable, it was not as great as the variability of per student costs in other cost categories such as academic support, instructional support, and student services (not tabled). This might be an indication that there was more consistency in the measuring and reporting of cost data in the instructional area, or that there was more consistency in the instructional activity itself than in the other areas mentioned.

The first regression model to be considered consists of inputs to the production process. The rationale for such a model is straightforward.

[4]There is a problem in any comparative cost study of maintaining consistency in the measuring and reporting of the cost data. For studies of the reliability and validity of HEGIS data, see Mintor and Conger [19] and Patrick and Collier [21]. The former conclude that HEGIS data are to be used with caution, while the latter take a more favorable view, at least with respect to those portions of the data which they directly examined.

[5]For examples in higher education, see [6, 16, 28]. For a detailed study of the regression technique as used in industrial cost analysis, see [14]. Also see Appendix A.

[6]See note 9 for further comments on this problem.

Costs, when defined as expenditures, are the result of payments to inputs. Thus, if costs differ among institutions it must be because of differences in those payments.[7] Since the instructional activity is labor intensive, the input model consists primarily of labor-related variables. HEGIS [25] provided the number of full-time faculty and their compensation at each institution. Together these two variables directly measure the major components of the model. HEGIS [25] also provided the number of nonfaculty employees at each institution, classified by type but not by expenditure category. Inspection of the data suggested that the typology was probably not applied in comparable fashion at the respective institutions in the sample. Thus only the total number of nonfaculty employees was used as a variable.[8] Its role in the model was to represent, in an indirect way, all nonfaculty labor in the instructional budget, on the assumption that an institution's overall level of nonfaculty staffing would be a reasonable indication of the level of nonfaculty staffing in the instructional area. Finally, county per capita income [24] was used as a proxy for the relative salary levels of nonfaculty employees and the relative prices of non-labor-related items, such as supplies, that are included in expenditures for instruction and departmental research.

The results of the regression analysis for the input model are shown in Table 1. As shown by column (2), which gives the squares of the beta weights, the faculty-student ratio had by far the largest influence, in relative terms, on unit instructional costs, followed by county per capita income, average faculty compensation, and the staff-student ratio. Column (3) shows the total contribution of each of the variables to explained variance. The total contribution includes each variable's direct contribution plus that which it shares with the other variables in the model. As shown in column (3), the faculty-student ratio accounted for slightly more than half of the variance explained by the input model.[9]

[7]This approach is inspired by, but is not the same as, the "cost equation" for a firm, which equates cost with the sum of the rate times the amount of each variable input plus the fixed costs [12, p. 71]. Fixed inputs are ignored in the present model, and rates and amounts of inputs are treated additively. See Appendix A.

[8]With the dependent variable in ratio form—instructional costs divided by total FTE enrollment—the faculty, nonfaculty, and compensation variables were also expressed as ratios. The number of faculty and the number of nonfaculty employees were divided by total FTE enrollment, and total faculty compensation was divided by the number of full-time faculty.

[9]It is important to note that there is collinearity among the independent variables in this and in succeeding regression models presented here. Thus the estimates of the contribution each variable makes to explained variance may be taken as approxima-

TABLE 1

Regression of Input Variables on Unit Instructional Costs

(1) Variable	(2) Beta Weight²	(3) Beta Weight × Simple R	(4) F	(5) Level of Significance
Faculty-student ratio	0.2564	0.3697	27.36	0.999
County per capita income	0.0717	0.1212	9.73	0.997
Average faculty compensation	0.0513	0.1106	6.82	0.988
Staff-student ratio	0.0361	0.1089	3.89	0.945

NOTE: R^2 = 0.71; overall F = 28.

Although the overall staffing ratio and county per capita income were only indirect measures of the deployment of resources and their prices, both contributed significantly to the explanatory power of the input model. If better measures for the latter dimensions were available, their influence within the model might well be enhanced.

The rationale for an output model is not as straightforward as for an input model. Since payments are not made to outputs, the latter cannot be the immediate reason for expenditures being what they are. Instead, outputs have their effect on expenditures indirectly, by requiring, or at least influencing, the kinds and amounts of inputs that are deployed in the production process.

Four variables were used as output measures: the reciprocal of total FTE enrollment,[10] the ratio of the number of FTE graduate students to total FTE enrollment, the ratio of the number of degree programs offered to total FTE enrollment, and expenditures for sponsored research per full-time faculty member. The data on degree programs were taken from *Peterson's Guides* [10, 11], while the data for the other three variables came from HEGIS [25, 26, 27].

The four variables represent an attempt to develop plausible indicators for a portion of the instructional output of a university, particularly the sort of output that might be expected to have a bearing on inputs, and thus on costs. From the latter perspective it would appear that only the fourth variable requires clarification. Since the dependent variable included expenditures for both instruction and departmental research, it seemed appropriate to include a variable that represented relative levels of research output. A direct measure of the output from departmental research was not available, so expenditures for sponsored research were used as a proxy, the assumption being that a faculty that

tions only. Derivations of beta squared and beta times simple r as measures of unique and total contribution, respectively, can be found in [22]. A discussion of the use of beta squared when orthogonality is lacking can be found in [15, p. 296].

[10]The reciprocal was used because the relationship between unit instructional costs and total FTE enrollment was curvilinear, resembling a rectangular hyperbola.

TABLE 2

Regression of Output Variables on Unit Instructional Costs

(1) Variable	(2) Beta Weight[a]	(3) Beta Weight × Simple R	(4) F	(5) Level of Significance
Curriculum diversity	0.1421	0.3061	22.85	0.999
Graduate student proportion	0.1271	0.2516	33.69	0.999
Total FTE enrollment	0.0994	0.2514	14.33	0.999
Research emphasis	0.0149	0.0741	3.58	0.935

NOTE: R^2 = 0.88; overall F = 83.

could generate relatively more sponsored research would tend to have a higher level of output in departmental research as well, and that there would be higher costs attendant to the greater output.

Table 2 shows the results of the regression analysis for the output model. The results indicate that the latter was more effective in explaining variation in unit instructional costs than was the input version. The R^2 value was 0.88 compared to 0.71 for the input model, and the overall F value was much higher, 83 versus 28. Also, explanatory power was spread more evenly among the output variables. Curriculum diversity and the proportion of graduate students were the most influential,[11] with total enrollment also contributing heavily.[12] The contribution of the research variable was small, although it was significant at the 0.935 level.

The rationale for the combined model is that putting the input and output variables together provides an opportunity to compare their respective influence on costs when operating within the same equation. Table 3 shows the results of the combined model. As expected, in view of the collinearity among the independent variables, only a few of the variables retained a high degree of statistical significance. Three output variables—curriculum diversity, the proportion of graduate students, and total enrollment—contributed all but 10 percent of the explained variation in unit instructional costs and were the only variables to be significant above the 0.95 level.

[11]Note that the F value in column (4) for curriculum diversity is less than the F value for graduate student proportion. The F-statistic provides another indicator of relative importance, since the proportionate relationship among the F values is the same as the proportionate relationship among the values obtained for each variable's contribution to R^2 when the variable is entered last in the regression equation. The latter values are sometimes taken as the proper measure of unique contribution to explained variance, for example, when doing commonality analysis. In any case, the degree of multicollinearity in the present model is too large to resolve the ambiguity between the results shown in columns (2) and (4) for the variables in question.

[12]Since the variable is a reciprocal that is positive in sign, the model indicates that a

TABLE 3
Regression of all Variables on Unit Instructional Costs

(1) Variable	(2) Beta Weight²	(3) Beta Weight × Simple R	(4) F	(5) Level of Significance
Curriculum diversity	0.1798	0.3444	19.45	0.999
Graduate student proportion	0.0934	0.2157	9.19	0.996
Total FTE enrollment	0.0806	0.2265	6.12	0.987
Average faculty compensation	0.0121	0.0538	2.65	0.889
Research emphasis	0.0055	0.0433	0.98	0.673
Faculty-student ratio	0.0021	-0.0338	0.21	0.350
County per capita income	0.0014	0.0170	0.18	0.328
Staff-student ratio	0.0013	0.0211	0.24	0.373

NOTE: R^2 = 0.89; overall F = 41.

A possible explanation for the unimportance of the faculty-student ratio, which was the most influential variable in the input model, is that the ratio was largely determined by the output variables and thus had little to add to a model that included those variables. That possibility would run counter to the notion that the ratio is highly manipulable. If it is largely a product of an institution's role and scope, as characterized in part by the output variables, then the ratio will not be easily changed. On the basis of the regression analysis alone, however, the most that may be said is that the faculty-student ratio and the output variables apparently explained the same variation in costs.[13]

As noted at the outset, recent studies seem to indicate that increases in institutional size tend to be accompanied by corresponding increases in complexity, thus negating economies of scale. That conclusion is both supported and challenged by the findings of the present study, as the following discussion will show.

The output model provides direct statistical evidence for the presence of economies of scale. The enrollment variable was inversely related to unit instructional costs and was significant at the 0.99 level.

The case for the existence of economies of scale can be further strengthened by considering the situation of the private institutions in the sample. Typically they had higher unit instructional costs than did the public institutions. The data in Table 4 suggest why this was the case. The sample was divided into two groups on the basis of private

decrease in unit instructional costs is associated with an enrollment increase, other things being equal.

[13]McLaughlin et al. [18] assumed that the faculty-student ratio was the more fundamental variable, in a causal sense, and were able to find some supportive evidence using a path analysis technique. Their sample included all kinds of public colleges and universities, however, so their results are not strictly comparable to those reported here.

TABLE 4
Comparison of Private Research Universities with Public Research Universities

Variable	Means: Private	Means: Public	Implied Impact On Unit Costs at Private Institutions
Instructional cost per student	$ 5,306	$ 2,537	
Students per faculty member	14.53	20.30	Up
Average faculty compensation	$26,634	$25,261	Up
Students per staff member	4.56	5.78	Up
County per capita income	$ 7,680	$ 6,276	Up
Degree programs per student	0.0132	0.0065	Up
Graduate student proportion	0.4482	0.2229	Up
Total FTE enrollment	10,914	26,241	Up
Sponsored research per faculty	$57,143	$34,690	Up

versus public sponsorship, and group means were calculated for each of the variables used in the regression analyses. In every instance, differences between the respective means implied higher costs for the private institutions. Since enrollment is involved in five of the eight independent variables, it would seem at least plausible to argue that enrollment really does make an important difference for unit costs at research universities. With perhaps a few exceptions, the fifty institutions, public and private alike, share several goals: to offer a broad, diverse curriculum; to train relatively large numbers of graduate students; and to maintain a substantial research effort. There is, however, no common commitment to enrollment size. A major research university tends to be complex by its very nature. Without a substantial enrollment base to diffuse the costs attendant to that complexity, unit costs are likely to be relatively high. It is just such an enrollment base that is missing at many of the private institutions. With a number of these relatively small, yet complex, institutions in the sample, it is not surprising that curriculum diversity and enrollment size were highly influential variables in the regression analysis.

It might be expected, therefore, that if the output model were applied to just the public institutions in the sample, the influence on unit costs of curriculum diversity and enrollment size would decrease. As Table 5 shows, this was indeed the case. The extremely low significance of curriculum diversity was possibly due to multicollinearity, as the curriculum variable had a high correlation ($r = 0.82$) with total FTE enrollment.[14] The latter correlation itself suggests that at the public institutions enrollment had generally caught up with the complexity that is more or less inherent in a research university. Although the

[14]See the correlation matrix for Table B5 in Appendix B.

TABLE 5

Regression of Output Variables on Unit Instructional Costs for Public Research Universities

(1) Variable	(2) Beta Weight[2]	(3) Beta Weight × Simple R	(4) F	(5) Level of Significance
Graduate student proportion	0.6162	0.5253	53.89	0.999
Research emphasis	0.1446	0.1963	8.70	0.993
Total FTE enrollment	0.0660	0.0528	1.37	0.747
Curriculum diversity	0.0018	0.0014	0.05	0.176

NOTE: R^2 = 0.78; overall F = 21.

enrollment variable remained inversely related to unit instructional costs, it was no longer statistically significant at a high level. This suggests the possibility that the public institutions were not achieving economies of scale.[15]

Finally, a discussion of economies of scale at research universities requires that consideration be given to the role of graduate student enrollment. The graduate student variable was a major factor in both the original output model and the combined model, and as Table 5 shows, it was by far the most important variable when the output model was applied to the subsample of public institutions. In regard to economies of scale, the point is simply that the more graduate students there are among additional students, the less chance there is for achieving such economies. This conclusion can be readily addressed in a quantitative manner through the use of another regression model. In this instance, as shown in Table 6, the public institutions once again comprise the sample, but the combined input-output model employed is in nonratio form. As can be seen from the table, both undergraduate and graduate enrollments were included as independent variables. Both were highly significant, and both were positively related to the dependent variable, which in this model was total, rather than average, expenditures for instruction and departmental research. The regression coefficients in column (2) indicate that an additional undergraduate student would add $684 to total instructional costs, compared to $3,535 for an additional graduate student.[16] If these respective additional costs are added to total instructional costs, and the latter then divided by the new total enrollment figure, the net results are that aver-

[15]The range of total FTE enrollments at the twenty-nine public institutions was considerable: 10,836 to 47,074.

[16]The figures shown can be thought of as marginal cost estimates. The ratio between them, 3,535 to 684, or 5.17 to 1, is within the range of average cost ratios found in other studies. See [13] for an extended discussion of the comparative costs of graduate versus undergraduate education, and the implications thereof.

TABLE 6

Regression of all Variables on Instructional Costs for Public Research Universities

(1) Variable	(2) B	(3) Beta Weight²	(4) F	(5) Level of Significance
FTE graduate enrollment	3.535	0.1904	9.49	0.994
Number of nonfaculty staff	3.207	0.0740	8.36	0.991
FTE undergraduate enrollment	0.684	0.0326	4.80	0.959
County per capita income	4.199	0.0211	5.12	0.965
Average faculty compensation	12.659	0.0099	2.32	0.857
Number of full-time faculty	2.310	0.0015	0.12	0.267
Sponsored research	0.028	0.0004	0.10	0.248
Number of degree programs	-0.263	0.0000	0.00	0.003

NOTE: R^2 = 0.96; overall F = 54.

age costs decline by $0.069 for each additional undergraduate student, but increase by $0.039 for each additional graduate student,[17] other things being equal.

Conclusion

The variation in unit instructional costs among major research universities is substantial. Much of that variation can be accounted for in terms of institutional differences in instructional output—even when that output is measured in a rather simplified manner. An obvious implication is that instructional cost comparisons that ignore differences in output are liable to be quite misleading. Taken in isolation, the average cost data suggest great disparities in the way these institutions provide instructional services. When differences in the size and mix of the output are taken into account, their respective instructional operations are apparently quite similar.

If the research universities should experience enrollment declines in the 1980s, the findings presented here suggest that, on average, unit instructional costs at private institutions would be more likely to be adversely affected by the downward change in scale than would similar costs at public institutions. A concurrent, and perhaps more serious, problem would be the tendency for the proportion of graduate students to increase. If, as expected, enrollment declines resulted from annual decreases in the number of high school graduates, then each year's decline would impact on the universities at the undergraduate level first. Thus, unless graduate enrollments were deliberately lowered, or declined for some other reason, the proportion of graduate

[17]Calculations are based on mean instructional costs of $67,667,310 and mean enrollment of 26,241 FTE students.

students would increase. On the basis of this study, it appears that the latter development would be a greater threat to unit instructional costs than would diseconomies of scale, especially from the perspective of the public institutions.

Appendix A

The regression equations for the two basic models are as follows:

$$C_i = a_0 + a_1F_i + a_2I_i + a_3A_i + a_4S_ie_i,\ i = 1, \ldots, n,$$

where C_i is instructional cost per FTE student, F_i is number of full-time faculty divided by number of FTE students, I_i is county per capita income, A_i is average full-time faculty compensation, S_i is number of nonfaculty employees divided by number of FTE students, and e_i is an error term; and

$$C_i = b_0 + b_1D_i + b_2G_i + b_3E_i + b_4R_iu_i,\ i = 1, \ldots, n,$$

where C_i is instructional cost per FTE student, D_i is number of degree programs offered divided by number of FTE students, G_i is number of FTE graduate students divided by number of FTE students, E_i is the reciprocal of number of FTE students, R_i is expenditures for sponsored research divided by number of full-time faculty, and u_i is an error term.

The number of observations for the regression analyses were fifty and twenty-nine, which are within the range of the number of observations used in similar regression studies. For example, in their study of costs at universities in the United Kingdom, Layard and Verry [16] ran a series of regressions in which the set of observations ranged from forty-two to fifty-nine. In the industrial sector, Dhrymes and Kurz [9] report on regressions with as few as seventeen observations in a study of returns to scale in the electric utility industry, while Borts [3] uses regressions on subsamples of twenty observations in a study of costs among railway companies.

APPENDIX B

Correlation Coefficients for Regression Analyses (Tables B1, B2, B3, B5, B6)

	1	2	3	4	5	6	7	8	9
Table B1									
1 Unit instructional costs									
2 Faculty-student ratio	0.730								
3 County per capita income	0.452	0.176							
4 Average faculty compensation	0.488	0.375	0.127						
5 Staff-student ratio	0.574	0.482	0.351	0.201					

APPENDIX B (*Continued*)

Correlation Coefficients for Regression Analyses (Tables B1, B2, B3, B5, B6)

	1	2	3	4	5	6	7	8	9
Table B2									
1 Unit instructional costs									
2 Curriculum diversity	0.812								
3 Graduate student proportion	0.706	0.450							
4 Total FTE enrollment	0.797	0.731	0.397						
5 Research emphasis	0.586	0.363	0.447	0.532					
Table B3									
1 Unit instructional costs									
2 Curriculum diversity	0.812								
3 Graduate student proportion	0.706	0.450							
4 Total FTE enrollment	0.797	0.731	0.397						
5 Average faculty compensation	0.488	0.275	0.403	0.385					
6 Research emphasis	0.586	0.363	0.447	0.532	0.466				
7 Faculty-student ratio	0.730	0.781	0.465	0.754	0.375	0.312			
8 County per capita income	0.452	0.156	0.716	0.297	0.127	0.361	0.176		
9 Staff-student ratio	0.574	0.437	0.374	0.649	0.201	0.541	0.482	0.351	
Table B5									
1 Unit instructional costs									
2 Graduate student proportion	0.669								
3 Research emphasis	0.516	-0.010							
4 Total FTE enrollment	0.203	-0.368	0.520						
5 Curriculum diversity	0.034	-0.384	0.207	0.821					
Table B6									
1 Instructional costs									
2 FTE graduate enrollment	0.948								
3 Number of nonfaculty staff	0.851	0.803							
4 FTE undergraduate enrollment	0.685	0.602	0.547						
5 County per capita income	0.597	0.597	0.351	0.216					
6 Average faculty compensation	0.617	0.586	0.498	0.282	0.379				
7 Number of full-time faculty	0.711	0.725	0.518	0.775	0.300	0.249			
8 Sponsored research ($'s)	0.555	0.558	0.487	0.204	0.387	0.525	0.344		
9 Number of degree programs	0.499	0.445	0.469	0.661	0.090	0.173	0.674	0.090	

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