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INSTITUTIONAL AND TECHNICAL CONSTRAINTS ON FACULTY GROSS PRODUCTIVITY IN AMERICAN DOCTORAL UNIVERSITIES

Jeffery E. Olson

Scholars disagree about the manner and extent of environmental structuring of university activities. This study supports arguments that the environment highly structures the relationships between faculty and the academic products of undergraduate instruction, graduate instruction, and research. Multiple correlation coefficients exceeded 90 percent for regressions of faculty size on counts of undergraduate and graduate enrollments and published articles for all universities classified as Research I or II or Doctoral I or II, demonstrating how constrained is doctoral faculty gross productivity in doctoral universities in the United States. Possible institutional and technical constraints are discussed. The regressions reveal economies of scale and economies of scope for some mixes of faculty academic activities, but not for others. Implications on productivity are explored for university type, control, and science emphasis. A typology for productivity studies is also outlined.

Tuition for enrollment and cost recovery for research continue to rise faster than the consumer price index, raising some concerns about the financing of American universities (for example, Clotfelter and Rothschild, 1993, p. 2). These concerns underscore the importance of continuing study of productivity and cost in higher education. This article addresses the question of how much American doctoral universities differ from each other in the gross productivity of their faculties and explores how important and statistically significant at the level of an entire university are some of the characteristics of universities. It also discusses potential constraints on faculty productivity.

Scholars disagree about the extent that the environment structures American universities. For example, James (1990) and Froomkin (1990) state that there is great variation in the productive relationships within American universities.

Productivity studies have many types (Baumol, Blackman, and Wolff, 1989):

Jeffery E. Olson, DAIL, St. John's University, 8000 Utopia Parkway, Jamaica, NY 11439.

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- They can be gross productivity studies, which ignore differences in quality or value; or value productivity studies, which control for such differences. Baumol, Blackman, and Wolff (1989) refer to value productivity as social welfare productivity. Most studies of faculty productivity are of gross productivity.
- They can be crude productivity studies, which examine actual levels of production; or productive capacity studies, which explore the technical limits of production. All identified studies of faculty productivity are studies of crude productivity.
- They can be single product studies, such as studies of undergraduate instruction; or multiple product studies, such as studies of undergraduate instruction, graduate instruction, and research. Most studies of faculty productivity examine a single type of product, usually research publications.
- They can be single factor productivity studies, which measure only one input, such as labor; or total factor productivity studies, which measure all inputs, often in dollars expended. Faculty productivity studies are by definition single factor productivity studies.
- They can be average productivity studies, where productivity is the measurement of all output divided by all input; or they can be marginal productivity studies, where productivity is a ratio of the change in output associated with a change in input.

Productivity and cost are two sides of the same coin. Productivity is a ratio of some measurement of output to some measurement of input, and cost is a ratio of some measurement of input to some measurement of output. The output can be goods, such as articles published; or services, such as instruction. The inputs can also be goods, such as equipment; or services, such as custodial services. Cost and productivity were used interchangeably throughout the study to best approach the particular question being addressed.

In this article the results are presented of a study of marginal gross faculty multiple-output productivity. As a gross productivity study, it does not control for differences in quality or value. As previously mentioned, most studies of faculty productivity have been studies of gross productivity (for example, Allison and Stewart, 1974; Baird, 1986, 1991; Bayer and Dutton, 1977; Bieber and Blackburn, 1989; Blackburn, Behymer, and Hall, 1978, p. 137; Cole, 1979; Ellwein, 1989; Folger, Astin, and Bayer, 1970; Gilmore and To, 1992; Golden and Carstensen, 1992a, 1992b; Golden et al., 1986; Havighurst, 1985, p. 102; Jones, Lindzey, and Coggeshall, 1982; Jordan, Meador, and Walters, 1989; Konrad and Pfeffer, 1990; Kroc, 1984; Meador, Walters, and Jordan, 1992; Neumann, 1977; Orczyk, 1990; Pelz and Andrews, 1976; Russell et al., 1991; Smart and McLaughlin, 1984; Soldofsky, 1984; Tan, 1992).

As these and other studies demonstrate, gross productivity studies have merit. They recognize that you cannot have something of quality unless you first have something, and that quantity is a central consideration in analyzing many important organizational phenomena, for example, budgets and expenditures (Baumol, Blackman, and Wolff, 1989). In higher education there are some quality limits on gross productivity resulting from the accrediting of instructional programs; the refereeing of publications; and the disciplining of markets for students, faculty, financial support, and other resources.

The university level provides an important perspective on faculty productivity. Most previous studies of faculty productivity were made at the individual or departmental level rather than the university level. They provide some guidance but it is limited because of the potential in universities for complementary and substitutive activity that can make one faculty member or department productive at the expense of others. There are substantial opportunities for universities to organize their activities so that productivity in research or instruction is high for certain individuals or departments because other responsibilities such as administration and service are shifted to other faculty members. For example, Braxton and Bayer (1986, p. 26) note that a university may have a segment of its faculty designated as research faculty who have major time assignments in research and who are evaluated on the basis of research performance. A university or campus level of analysis largely controls for these differences by including all faculty members serving the same university, or at least the same campus. Searches of ERIC and references of the most widely circulated studies have revealed only one study of faculty productivity conducted at the university level (Bentley and Blackburn, 1990) and it addresses a different but related question of whether universities accumulate advantage over time from their prior success.

Braxton and Bayer's (1986) comment also underscores the need for faculty productivity studies to be multiple product studies, which control for differences in all types of productive activity. The faculty of one university might appear more productive than another when only one academic product is analyzed and not when all academic products are considered. Gilmore and To (1992) stress this need.

The measures of productivity in this study are ones whose direct influence extends beyond the boundaries of the university. Administration and service internal to the university are intermediate products, not final products. Implicitly these activities are involved, because they have the potential to reduce instruction, publishing, and external service.

METHODOLOGY

The multiproduct nature of our study makes it more convenient to perform the statistical analyses in terms of cost rather than productivity, with cost measured in terms of full-time-equivalent faculty. As previously mentioned, cost is the inverse of productivity, so we can obtain equivalent information. Our measurement of the similarity of faculty productivity of the universities is the multiple correlation coefficient associated with the regression of faculty on the academic products and various characteristics of the universities. The multiple correlation coefficient is the square root of the r-square of the regression. This coefficient is the proportion of the variation in faculty explained by the regression, whereas r-square is the squared variation explained.

The population was defined to include a wide variety of universities while focusing on ones that have at least some involvement with research doctoral degrees. The year 1990 was selected to be studied because the data were more readily available for that year than for other recent years. The population for the study consisted of the more than 200 universities in the United States (1) classified as either Research or Doctoral by the Carnegie Foundation for the Advancement of Teaching (1987) and (2) that granted bachelor's degrees in 1990. The sources of the data are described in Table 1, and the descriptive statistics are in Table 2.

The dependent variable was the full-time-equivalent faculty of each university. The independent variables were the full-time equivalents of undergraduate and graduate students and the number of articles published. Scholars have usually asserted that the central productive activities of university faculty are research, teaching, and service (for example, Boyer, 1990, p. 1) or just research and teaching (for example, Clark, 1987, p. 70) The biggest distinction in levels

TABLE 1. Sources of Data for Measuring the Products and Characteristics of American Doctoral Universities

Faculty Size	
	National Center for Education Statistics. Integrated Postsecondary Education Data System (IPEDS), Fall Staff Data 89-90 (S8990).
Undergraduate Enrollment and Graduate Enrollment	
	National Center for Education Statistics. Integrated Postsecondary Education Data System (IPEDS), Fall Enrollment Data 89-90 (EF8990).
Articles Published	
	Institute for Scientific Information. SciSearch, Social SciSearch, and Arts and Humanities Search Databases on Dialogue, using 1991 accession numbers.
Count of Doctoral Science Staff for 1989–1990	
	National Science Foundation. Computer Aided Science Policy & Research Database System (CASPAR) Database 4.0.
Research University Classification	
	National Science Foundation. Computer Aided Science Policy & Research Database System (CASPAR) Database 4.0.
Private University Classification	
	National Science Foundation. Computer Aided Science Policy & Research Database System (CASPAR) Database 4.0.

TABLE 2. Descriptive Statistics

Variable	*N*	*M*	*SD*	Minimum	Maximum
Faculty					
Population	203	1,160	865	60	5,513
Subpopulation	176	1,108	860	60	5,513
Undergraduates					
Population	203	10,975	7,175	93	35,234
Subpopulation	176	10,030	6,505	93	33,280
Graduate students					
Population	203	3,292	2,409	380	11,476
Subpopulation	176	3,091	2,331	380	11,476
Articles published					
Population	203	1,666	2,218	0	11,921
Subpopulation	176	1,573	2,209	0	11,921
Science emphasis					
Population	176	0.593	0.348	0.110	2.106
Subpopulation	176	0.593	0.348	0.110	2.106
Research I or II					
Population	203	0.507	0.501	0.000	1.000
Subpopulation	176	0.460	0.500	0.000	1.000
Private control					
Population	203	0.350	0.478	0.000	1.000
Subpopulation	176	0.386	0.488	0.000	1.000

of instruction is between graduate and undergraduate (Clark, 1987, and Boyer, 1990). Although hours of consulting and service have been measured at the individual and departmental levels, usually in terms of hours of activity, I was not able to identify an estimate of service collected at the university level, so this dimension is missing from the analysis. The omission of service should reduce the goodness of fit of the regression.

Full-time-equivalent enrollment is a common indicator of gross teaching productivity. It is the basis for many studies of higher education instructional costs. For example, full-time-equivalent enrollments are used in studies of expenditures per student (for example, Bowen, 1980; Getz and Siegfried, 1991) and instructional production and cost functions (for example, Cohn, Rhine, and Santos, 1989; De Groot, McMahon, and Volkwein, 1989). Full-time equivalents for faculty and undergraduate and graduate students were computed by adding one-third of the part-time counts to the respective full-time counts.

The most common indicator of gross research productivity is articles published in refereed journals (for example, Baird, 1986, and 1991; Bayer and Dutton, 1977; Bieber and Blackburn, 1989; Folger, Astin, and Bayer, 1970; Gilmore and To, 1992; Golden and Carstensen, 1992a, 1992b; Golden et al., 1986; Havighurst, 1985, p. 102; Jones, Lindzey, and Coggeshall, 1982; Jordan, Meador, and Walters, 1989; Konrad and Pfeffer, 1990; Meador, Walters, and Jordan, 1992; Neumann, 1977; Orczyk, 1990; Pelz and Andrews, 1976; Russell et al., 1991; Smart and McLaughlin, 1984; Soldofsky, 1984; Tan, 1992). Usually this indicator is operationalized as counts of articles referenced in the science, social science, and arts and humanities indexes of the Institute for Scientific Information (ISI). This was the method used in this study as well. Article counts do not fully represent scholarly productivity for all disciplines. For example, when the National Research Council (NRC) studied graduate programs in 1982, its working group in the humanities felt that article counts alone would be inadequate and misleading, that book counts would also be needed but were too difficult to obtain (Jones, Lindzey, and Coggeshall, 1982). On the other hand, the working groups in the sciences and social sciences did use article counts from ISI indexes. In a major research university Washburn (1980) found that faculty members across disciplines, including the arts and humanities, regarded article counts as the most important quantitative indicator of departmental productivity. A multidimensional measurement of research productivity that included at least articles and books would have improved the analysis, but the necessary data were not readily available at the level of an entire university.

Three measures of university-level characteristics were also assembled: Carnegie classification, university control, and science emphasis. These are university-level characteristics often associated with differences in faculty productivity in single product studies (for example, Russell et al., 1991). Carnegie classification was operationalized as one for universities classified as Research I or II and zero for Doctoral I or II. University control was operationalized as one for privately controlled universities and zero otherwise. Universities with mixed control, such as Cornell, were classified as privately controlled. Science emphasis was operationalized as a ratio of science and engineering doctoral staff to full-time faculty. In some cases this ratio exceeded one because doctoral staff includes nonfaculty members. Science faculty were not separately identified in the available data. The counts of doctoral staff were taken from the National Science Foundation survey of university personnel in the sciences and engineering (see Table 1). Social scientists were excluded from the counts.

The regression analyses were conducted conventionally in the Proc Reg and Proc RSReg procedures of SAS. Most of the variables were transformed mathematically to increase the linearity and normality of their univariate distributions. Table 3 displays the transformations that were used and provides a Kolmogorov D statistic of the normality of each distribution (SAS Institute, Inc., 1985, p. 1187). Plots of regression results revealed that the transformations largely eliminated problems of heteroscedasticity that often occur where observations differ dramatically in scale and have a nonnegativity constraint. Nova

TABLE 3. Transformations Toward Normality of Faculty, Enrollments, Articles Published, and Characteristics of American Doctoral Universities

Variable	Transformation (W: Normal)	Kolmogorov D Statistic	N
Faculty	Natural Log	0.983	203
Undergraduates	Natural Log	0.918	203
Graduate students	Natural Log	0.971	203
Articles published	Natural Log	0.948	203
Science emphasis	Natural Log	0.969	176
Research I or II	None	0.613	203
Private control	None	0.581	203

University and Golden Gate University were excluded from the analysis because they were extreme outliers statistically that have adopted unconventional production technologies, but all other universities with Research or Doctoral Carnegie classifications were included if they enrolled undergraduates and data were available. Multiple campus universities were analyzed at the lowest level of aggregation permitted by the data. All transformed variables were standardized to control for differences in their units of measurement. The results of the regressions were transformed to show the proportionate increase in the mean number of faculty members associated with a 100 percent increase in each continuous variable or with a shift in value from 0 percent to 100 percent for dichotomous variables. These transformations make the results more intuitively interpretable than would have been the coefficients of the logarithmic terms. The inferential statistics have also been transformed as necessary to correspond to the transformed results.

Four separate regressions were performed to provide different perspectives on faculty productivity. Faculty counts were regressed first on just the three products; second, on a quadratic equation of the three products; third, on the three products and the dichotomous variables research and private; and fourth, on the three products and the complete set of characteristic variables. Only 176 of the universities had a complete set of characteristic variables, so the final regression involves a subset that does not fully represent the original population. The results of these regressions are presented in Tables 4 through 9. Table 2 compares the descriptive statistics of the subsample and the full population.

RESULTS

All of the regressions resulted in multiple correlation coefficients exceeding .90 (see Table 4). As rough as are the measurements of full-time equivalent faculty, undergraduate and graduate students, and articles published, they still

TABLE 4. Multiple Correlation Coefficients of Faculty Size for American Doctoral Universities from Regressions of Academic Products and University Characteristics

Model	Coefficient of Multiple Correlation	*R*-square	*F*	*p*	*N*
1. Log-linear	0.907	0.823	309	0.000	203
2. Translog model	0.934	0.872	146	0.000	203
3. Log-linear (type and control)	0.910	0.827	189	0.000	203
4. Log-linear (all characteristics)	0.913	0.834	142	0.000	176

explain more than 90 percent of the variation in the number of faculty despite the variation in product mix (scope), scale, quality, and type of the doctoral universities (Table 2). All three regression coefficients of the products are statistically significant beyond the .0001 level in all four regression models (Tables 6 through 9). Each product provides a separate component of a university's increase in scale, which means (1) that the faculty cost of producing each of these products is primarily additive, (2) that the number of faculty members of any doctoral university can be predicted quite accurately with knowledge only of the number of undergraduate students, graduate students, and articles published, and (3) that their multiproduct gross productivity is quite similarly defined. The results reinforce beliefs about the multidimensionality of universities. All three indicators of gross productivity are statistically significant, meaning that faculty roles in doctoral universities vary in at least three dimensions. Undergraduate instruction, graduate instruction, and research have been properly conceptualized as different dimensions of faculty activity.

All three of the product variables had been transformed using the natural log. The statistically significant coefficients of the logs of the natural unit variables mean that the relationship between the products and faculty change with scale. Table 5 presents scale elasticities (or ray economies of scale) for the four re-

TABLE 5. Ray Economies of Scale of American Doctoral Universities (Percentage Increase in Academic Products from a 100% Increase in Faculty Size)

	Model 1	Model 2	Model 3	Model 4
Undergraduates	36.7	47.8	38.5	33.3
Graduate students	58.9	44.4	64.5	70.3
Articles published	21.3	17.2	21.7	24.3
Total	116.9	109.4	124.7	127.9
N	203	203	203	176

Note: Assumes percentages change from the means.

TABLE 6. Percentage Increase in Faculty Associated with 100% Increase in a Product or Characteristic of an American Doctoral University Model 1: Academic Products

Product/Characteristic	Percentage Change in Faculty	*SE*	*t*	*p*
Undergraduates	26.9	3.1	8.630	0.000
Graduate students	43.1	4.2	10.161	0.000
Articles published	15.6	1.8	8.539	0.000

F = 309
p = 0.000
R-square = 0.823
N = 203

gression models. All four are greater than one, which means that productivity increases with scale. For example, a scale elasticity of 1.17 means that a 10 percent increase in faculty members is associated with an increase in total product of 11.7 percent, the scale elasticity times 10 percent. The scale elasticities were computed by dividing one by the sum of the elasticities of each of the products (Jorgenson, 1986). These scale economies depend on the mix of products. Different combinations of undergraduate instruction, graduate instruction, and research can have different implications for economies of scale. The translog (log-linear quadratic) regression explored them.

The quadratic model reveals the effects of interactions between the products as their levels change. Table 7 presents the results of the quadratic model. The positive coefficient of the interaction term *undergraduates-squared* means that as universities have increasingly more undergraduates the rate of increase in faculty members accelerates. This gradually reduces the previously discussed increase in productivity from scale. The small and statistically insignificant coefficients of graduate-students-squared and articles-published-squared mean that the rate of increase in faculty associated with an increase in the number of graduate students or articles published remains unchanged with scale, leading to continually increasing faculty productivity within the present range of university operations for the same proportionate mix of academic products.

The results also support beliefs that product mix affects faculty gross productivity (Table 7). The negative coefficients of the interaction terms of undergraduate and graduate students and undergraduate students and articles published means a slowing of the rate of increase in faculty size associated with a simultaneous increase in undergraduate and graduate students and undergraduate students and published articles respectively, which means that faculty productivity is enhanced by increases in either of these combinations of products. Cohn, Rhine, and Santos (1989) and De Groot, McMahon, and Volkwein

TABLE 7. Percentage Increase in Faculty Associated with 100% Increase in a Product or Characteristic of an American Doctoral University Model 2: Quadratic Model of Academic Products

Product/Characteristic	Percentage Change in Faculty	*SE*	*t*	*p*
Undergraduates	39.9	3.6	11.06	0.000
Graduate students	37.1	4.2	8.79	0.000
Articles published	14.4	1.9	7.45	0.000
Undergraduates squared	8.0	1.5	5.31	0.000
Graduates squared	9.6	5.4	1.79	0.075
Articles squared	1.1	0.8	1.44	0.153
Graduates*undergraduates	−9.3	5.4	−3.60	0.000
Articles*undergraduates	−4.5	2.2	−2.03	0.044
Articles*graduates	6.1	3.2	1.89	0.061

F = 146.0
p = 0.000
R-square = 0.872
N = 203

(1989) found economies of scope for universities in total factor studies of productivity. On the other hand, the coefficient for the interaction of graduate students and articles published is negative, meaning that the rate of increase in faculty members accelerates for a simultaneous increase in the number of graduate students and articles published, decreasing productivity gains that would otherwise be expected from increasing these products.

The third and fourth regression models provide insights into the relationship between faculty productivity and several characteristics of the university (Tables 8 and 9). Both models include dichotomous variables for university type (Carnegie classification) and control, and Model 4 also includes science emphasis. Science emphasis was only available for a nonrandom subpopulation of 176 universities, so Model 3 was analyzed separately to provide information about the dichotomous variables for the full population. The results of Model 4 need to be examined cautiously. For example, the coefficient for research university is larger and more statistically significant than in Model 3 (compare Tables 8 and 9).

There is no statistically significant difference between universities associated with science emphasis. This occurs despite the use of articles published as the measurement of research activity rather than books or some other product more associated with the humanities or social sciences and despite the absence of any normalizing for (1) differences in the relative number of journals in the sciences

TABLE 8. Percentage Increase in Faculty Associated with 100% Increase in a Product or Characteristic of an American Doctoral University Model 3: Academic Products and University Type and Control

Product/Characteristic	Percentage Change in Faculty	*SE*	*t*	*p*
Undergraduates	24.7	3.7	6.66	0.000
Graduate students	41.5	4.6	8.94	0.000
Articles published	14.0	2.0	6.84	0.000
Research I or II	11.2*	6.6	1.70	0.092
Private control	−06.7*	5.7	−1.19	0.237

$F = 189$
$p = 0.000$
R-square = 0.827
$N = 203$
*Estimated at the means. Represents a shift in a dichotomous variable from 0 to 1.

TABLE 9. Percentage Increase in Faculty Associated with 100% Increase in a Product or Characteristic of an American Doctoral University Model 4: Academic Products and All Characteristic Variables

Product/Characteristic	Percentage Change in Faculty	*SE*	*t*	*p*
Undergraduates	20.4	4.1	4.989	0.000
Graduate students	43.0	4.8	8.974	0.000
Articles published	14.8	2.2	6.789	0.000
Science emphasis	−5.4	5.1	−1.072	0.286
Research I or II	17.8*	7.4	2.406	0.017
Private control	−8.0*	4.3	−1.841	0.067

$F = 142$
$p = 0.000$
R-square = 0.834
$N = 176$
*Estimated at the means. Represents a shift in a dichotomous variable from 0 to 1.

included in the counts or (2) the length of the articles. Tables 10 through 12 present results of regressions of each of the products on the other independent variables in the study. Here published articles increase with science emphasis as would be expected, but undergraduates decrease importantly. Apparently, increases in articles published that are associated with a science emphasis are offset by decreases in undergraduate enrollment to keep science emphasis from

TABLE 10. Percentage Increase in Undergraduates Associated with 100% Increase in Another Product or Characteristic of an American Doctoral University

Product/Characteristic	Percentage Change in Undergraduates	*SE*	*t*	*p*
Graduate students	44.8	8.3	5.388	0.000
Articles published	12.2	4.0	3.059	0.003
Science emphasis	−36.2	9.1	−3.976	0.000
Research I or II	03.3	13.9	0.239	0.811
Private control	−58.4	6.8	−8.574	0.000

$F = 40.9$
$p = 0.000$
R-square $= 0.546$
$N = 176$

TABLE 11. Percentage Increase in Graduate Students Associated with 100% Increase in Another Product or Characteristic of an American Doctoral University

Product/Characteristic	Percentage Change in Graduate Students	*SE*	*t*	*p*
Undergraduates	32.6	6.0	5.388	0.000
Articles published	11.9	3.4	3.521	0.001
Science emphasis	−3.1	8.1	−0.382	0.703
Research classification	51.5	11.1	4.616	0.000
Private control	22.4	6.7	3.330	0.001

$F = 43.0$
$p = 0.000$
R-square $= 0.559$
$N = 176$

making a statistically significant difference in faculty productivity. Graduate enrollment remains much the same. The findings for published articles and undergraduate enrollment are highly significant statistically (Tables 10 and 12).

Research universities differ from other universities in the products that they produce (Tables 10 through 12), producing more articles for publication and instructing more graduate students than other doctoral universities. Overall, their gross productivity is lower than that of other doctoral universities (Tables 8 and 9). It is possible that the differences in gross productivity result from differences in what might be called quality productivity. More faculty attention to the quality of production could result in lower gross productivity, but that

TABLE 12. Percentage Increase in Articles Published Associated with 100% Increase in Another Product or Characteristic of an American Doctoral University

Product/Characteristic	Percentage Change in Articles Published	*SE*	*t*	*p*
Undergraduates	42.6	13.9	3.059	0.003
Graduate students	57.1	16.2	3.521	0.001
Science emphasis	66.2	17.0	3.881	0.000
Research classification	16.9	24.3	4.814	0.000
Private control	1.3	15.2	0.084	0.933

$F = 48.3$
$p = 0.000$
R-square $= 0.587$
$N = 176$

does not mean that lower gross productivity is necessarily an indicator of quality. Research is needed that controls for differences in quality to test this conjecture.

Privately controlled universities do not differ importantly or statistically significantly from public universities in faculty gross productivity (Tables 8 and 9). They do enroll more undergraduate students, but apparently these increases are offset enough by reduced enrollment of undergraduates (Tables 10 and 11) to keep their multiproduct gross productivity about the same (Table 8). There is also little difference in publishing rates (Table 12).

DISCUSSION

While other results also merit discussion, our focus is on the high proportion of variation in faculty size that is explained by undergraduate and graduate enrollments and articles published. The acknowledged weakness of the measures makes the results even more interesting. That three gross measures of academic production statistically explain more than 90 percent of the variation in the scale of faculty means that universities conform quite closely to the same gross definitions of productivity. This suggests that American universities operate in a highly constrained space.

When a pattern fits an entire population of organizations, an environmental explanation should be sought rather than separate explanations of each university's behavior. It is very unlikely that all doctoral universities would simultaneously experience independent circumstances that lead to such a similar result. It is much more likely that the same set of environmental influences affects them all.

Economists (for example, Commons, 1934, reprinted 1959; Gordon, 1980; Veblen, 1918, reprinted 1957) and sociologists (for example, Meyer and Scott, 1983) have identified two major environmental dimensions that constrain organizational activities. Meyer and Scott (1983) refer to these dimensions as technical and institutional environments. Basically the technical dimension is the dimension of technical feasibility. It is the dimension with which neoclassical economists usually concern themselves. The institutional dimension is the dimension of social convention and expectation. It most concerns institutional economists and institutional theorists in sociology, although they also are concerned about the technical dimension. These dimensions provide a framework for discussing the high conformity of universities to similar definitions of gross faculty productivity.

If universities were not technically or institutionally constrained in the gross productivity of their faculties, there would be randomness in the relationship between the measurements of faculty and the academic products. Each university would act completely independently of the others. They would not arrive at similar relationships because they work well to produce the desired outcomes (the technical dimension) or as a result of imitation or professional norms (the institutional dimension). Completely independent action without technical or institutional constraints would result in a multiple correlation coefficient for our regression models of approximately zero. Coefficients exceeding 90 percent confirm the presence of constrained behavior, but what constraints are operating?

Are they technical constraints? For example, every university might be trying to maximize simultaneously the quality and quantity of instruction and research for the particular faculty, students, and other resources that they have. If all universities moved toward technical efficiency, pushing against the same production frontier, then the relationships might conform closely to each other as they do. It is unlikely that any of the universities would be perfectly efficient; some might err in producing too much quantity for the quality and others too much quality for the quantity, leading to some variation around a center, perhaps to results like ours. The differences in the characteristics of their faculties, students, other resources, and local environments might also result in differences in their performances, providing another explanation of the spread around a common center. But, tightly constrained activity resulting from technical efficiency would be very unexpected. Universities and other educational organizations are not widely believed to be technically efficient (Levin, 1974).

The constraints might also be institutional. For example, American society might have developed a common convention for university faculty-student ratios and publishing obligations that defines the gross productivity that is expected of a university faculty member. The conventions are loosely enough defined that none of the universities conforms completely to them, but none of them deviates dramatically either. These conventions could have developed through each university comparing itself to a group of peer institutions. These groupings might overlap, creating one interlocking set of similar relationships. It might also develop through common professional norms. These explanations are inconsistent with the beliefs of some authors about the absence of structure in American universities.

Scholars differ about how well defined is the structure of university-productive activities. For example, Clark (1983) and James (1990) say that universities are structured through complex social processes; but Froomkin (1990, p. 189) says that there is little if any consistency among universities in the structure of production, because there is no central governmental administration to define that structure. It also does not explain the nonlinear nature of the relationship between faculty size, undergraduate instruction, graduate instruction, and articles published. This study shows that as universities increase in size, the gross productivity of their faculties does not remain the same, which it probably would through strict imitation or professional norms; it increases consistently, which would be hard to achieve through simple imitative behavior. If universities were merely imitating each other, the relationships should be the same at all levels, not consistently increasing with the scale of the academic activities. The high statistical significance of the regression coefficients, exceeding .0001, underscores the consistency of these increases. This consistency is even more surprising because it varies across three different dimensions of academic activity, making simple imitation or professional norms less likely explanations of the results.

It is more likely that both technical and institutional constraints are operating. Universities might conform to social definitions of faculty teaching, administrative, and service loads; and then their faculty members research and publish as much as technically feasible given those loads. Decreases in enrollments would lead to increases in publishing. As universities increased in size, they would be able to increase the number of large courses and to implement other technological changes that would gradually increase faculty productivity, leading to higher gross productivity. Lighter teaching loads would permit heavier research loads.

CONCLUSIONS

The study results mean that universities cannot expect major productivity gains from their faculty without redefining their roles in research or teaching. They could increase their productivity in teaching, but at the expense of research. They could increase their productivity in research, but at the expense of teaching. Some gains would be possible through increasing the scale of activities (Tables 6 through 9), but these gains in gross productivity might not be gains in value or quality productivity (James, 1978). Some gains might also be possible through modifying the mix of resources (Table 7). Increasing undergraduate instruction and research (or undergraduate instruction and graduate instruction) brings economies of scope (Table 7), but these also are gains in gross productivity, not necessarily value productivity.

James (1978) warns that apparent gross cost gains (or productivity gains) from increasing undergraduate enrollments might result from losses in value productivity as class sizes increase. Rothschild and White (1993) counter that large enrollment programs continue to remain competitive in the marketplace with small enrollment programs, implying that value is not lost, at least not in the eyes of the product's consumers. But it is also possible that technical value might be lost in terms of less effective teaching, while prestige value remains from continuing acceptance of the credentials of the large enrollment programs. But this in turn raises questions about how a credential can maintain its prestige value despite loss of a program's technical value. One answer is that the prestige value of the credential depends at least partly on the research productivity of the faculty (for example, Garvin, 1980; James, 1978); increased research productivity leads to prestige that benefits both the university and the student, making students willing to attend universities with less effective instructional technologies.

As universities seek to become more productive, they confront the limitations on productivity that this study identifies. The better society understands these limitations, the more readily universities will overcome them and increase the cost-effectiveness of their activities. This paper empirically identifies the importance of the environmental constraint on faculty gross productivity, presents some of its implications for economies of scale and scope in faculty activities, and presents preliminarily some possible explanations of the sources of the constraint and the explanations' most obvious weaknesses. Further study and discussion is needed to determine the exact nature of the constraint and how it can be overcome to increase faculty productivity and effectiveness.

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