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DETERMINANTS OF RESEARCH PRODUCTIVITY IN HIGHER EDUCATION

Halil Dundar and Darrell R. Lewis

As research expenditures have risen and as sources of research funding have changed, an increased emphasis on research performance has developed in U.S. research universities. Although much of the historical debate has centered around the individual attributes of faculty, several recent studies have begun to focus on the effect of program or organizational factors as powerful attributes for enhancing such productivity. This paper extends the findings of these recent studies by examining the relationship between academic research productivity and institutional factors from the most recent National Research Council data on the nation's research universities and their programs in the four broad fields of the biological sciences, engineering, the physical sciences and mathematics, and the social and behavioral sciences. Several findings are recommended for institutional policymakers.

What are the determinants of the research performance of doctoral programs in American research universities? Although this question appears to be relatively easy to answer, surprisingly it has not been fully examined. Fortunately, the most recent survey of the quality assessment of doctoral programs by the National Research Council (Goldberger et al., 1995) has provided us with a set of data that permits such examination. This paper estimates several regression models to examine the possible predictors and organizational factors influencing research performance in U.S. doctoral-level institutions.

Participants in American higher education have long been interested in uncovering those policy and institutional factors that not only associate with but also facilitate enhanced productivity in both research and instructional activities in research-level institutions. Although a large number of studies have been undertaken to rate and rank graduate-level programs, beginning with Hughes (1925) in his early study of graduate schools and continuing up through similar

Halil Dundar, Research Associate of Planning, University of Minnesota; Darrell R. Lewis, Professor of Educational Policy, University of Minnesota. Address correspondence to: Darrell R. Lewis, Department of Educational Policy and Administration, 310H Wulling Hall, University of Minnesota, Minneapolis, MN 55455; e-mail: lewis004@maroon.tc.umn.edu.

work by Cartter (1966), Roose and Anderson (1970), Jones, Lindzey, and Coggeshall (1982), and the most recent reviews by Goldberger, Maher, and Flattau (1995), none of these studies attempted to directly address and examine the predictors and factors influencing actual performances.

Although reputational studies have received a great deal of attention within higher education, debate continues as to how reliable they are as a measure of a program's actual productivity. Accordingly, a number of studies have searched for factors that correlated with program ratings (e.g., Hagstrom, 1971; Drew and Karpf, 1981; Laband, 1985; Saunier, 1985; Webster, 1986; Fairweather, 1988; Conrad and Blackburn, 1985; Young et al., 1987; Tan, 1990, 1992; Tautkoushian et al., in press). Even though there are some concerns about the methods and sample populations employed in these studies, most of the studies tend to confirm that program ratings are indeed highly correlated with only a few factors: The two most important appeared to be program size and the research productivity of individual faculty. Even though most of these studies have identified some correlates with program ratings, it is still largely an unanswered question as to what an institution can do to help increase its program quality and its research productivity. As a result, the purpose of this paper is to examine the research productivity of doctoral-granting universities as measured through the most recent survey sponsored by the National Research Council, and to explore those departmental and institutional factors that contribute to such measures of productivity.

Although productivity in higher education has an obvious multidimensional character as it relates to both knowledge production and knowledge dissemination through its various forms of research, teaching, and outreach activities, research productivity in particular has received a great amount of attention and concern. Research effort and output form a very distinguishing part of the definitional character of American research universities and, as a consequence, the public rankings of academic programs have become increasingly important. Spurred by college rankings in the popular press, numerous studies have rated the nation's colleges and universities based on several subjective (e.g., judgments about the quality of program faculty or the quality of their teaching) and objective measures (e.g., research performance, student selectivity, and the like). In 1995, for example, when the National Research Council released its latest comprehensive study examining the ratings of doctoral programs of the nation's research universities (Goldberger et al., 1995), several studies investigated the correlates of these ratings and found, as expected, that the research productivity of the academic programs was highly related to their favorable reputation (e.g., Ehrenberg and Hurst, 1996; Tautkoushian et al., in press). None of these recent studies attempted to directly infer causation, only association. It was noted that reputation for scholarly excellence can, in turn, result in an increased capacity for attracting research and high-ability graduate students to the program (Grunig, 1997).

On the other hand, some institutional administrators have complained that their small program size undoubtedly contributed to their low reputation, but that such measures did not accurately account for either their distinguishing high quality or the strength of their average faculty productivity. They argued that such reputational rankings were heavily influenced simply by the size of large programs independent of the quality of average faculty productivity. This view of the linkages between productivity, organizational size, and reputation is not well understood. In other words, the policy question becomes whether an increase in the number of faculty members will, by itself, result in an improvement in program productivity. If so, how and to what extent?

The present study adds to our knowledge about research productivity in higher education in several important ways that include both new data and new models with better model specification and better measurement of factors. First, the study uses the most recent 1995 NRC data and updates previous studies with an expanded and respecified model. It extends this previous work by introducing new measures of influencing factors. Second, it examines the data by field clusters (i.e., social sciences, engineering, biological sciences, physical sciences), rather than by departmental forms (i.e., economics, electrical engineering, chemistry) or institutional-level data. Such an aggregated data set of field-related clusters provides us with a stronger sample and greater confidence of predictability with our regression models.

THE LITERATURE ON RESEARCH PRODUCTIVITY

Productivity studies in higher education have been increasing in importance since the early 1970s. Numerous and differing types of studies have examined factors affecting the productivity of universities and their individual academic programs or their faculty (see, for example, Graves et al., 1982; Clark and Lewis, 1985; Creswell, 1985; Golden et al., 1986; John, 1994; Johnes, 1988b; Long, 1978; Levin and Stephan, 1989; Meador et al., 1992; Olson, 1994). Despite the proliferation of such studies, very few have addressed the particular problem that is related to the multiproduct nature of most universities—that is, the production and combination of teaching, research, and service/outreach activities. Only a few studies, for example, have addressed economies of scale and scope in the context of the multidimensional outcomes of universities (Cohn et al., 1989; Lewis and Dundar, 1995). As a consequence, most productivity studies in higher education have tended to focus on instruction and largely on undergraduate instruction. Nevertheless, several studies have attempted to examine those institutional factors that contribute to research productivity. Many have perceived that measuring research performance is a relatively easy task because of readily available measures such as published books, journal articles, or citation counts across universities. Despite the availability of such outcome measures, studies examining research productivity still have remained quite limited. This largely has been due to the measurement problems of both research inputs and outputs.

The unit of analysis for research productivity can be at individual, departmental or collegiate, and institutional levels. Yet most of the early productivity studies of faculty research performance focused on individual faculty rather than at the departmental or institutional levels.

Individual Attributes

Individual faculty productivity studies have examined a wide range of factors affecting faculty research productivity. Early work with these factors included the effects of age, gender, socioeconomic status, and educational background (Bell and Seater, 1980; Braxton and Bayer, 1986; Clark and Lewis, 1985; Creswell, 1986; Levin and Stephan, 1989; Lewis and Becker, 1979; Tien and Blackburn, 1996), along with several cultural and organizational dimensions (Conrad and Blackburn, 1986). A particular tracking relationship, for example, has been between age, experience, and productivity. Although there appears to be a strong age- and experience-productivity relationship in economic theory (i.e., as age and experience increase, productivity also increases up to a point and then appears to level off), this relationship has been found to be more mixed in higher education and varies by field (Clark and Lewis, 1985; Levin and Stephen, 1989). Nevertheless, it has also been noted that generally full and more senior professors (particularly at research universities) tend to have accumulative advantages over most assistant and associate professors that result in higher levels of productivity (Cole and Cole, 1972; Clark and Lewis, 1985; Long, 1978).

These factors generally have been introduced in several different ways. Most have included individual characteristics, for example, innate attributes such as ability, stamina, personality, gender, age, and years of experience (Creswell, 1986). Other individual attributes have been related to environmental location, including quality of graduate training, prestige of employing department or institution, communication networks, and freedom in the workplace (see, for example, Cole and Cole, 1972).

The culture of a department or institution also has been found to be an important factor determining research performance of individual faculty. Culture relates to shared attitudes and values in an academic unit. A research-oriented culture exists when all faculty and administrators are socialized to be strong researchers during their graduate training, value research, and maintain continuous internal and external communication with other researchers, and hire new faculty with strong research credentials (Creswell, 1986).

Departmental and Institutional Attributes

More useful for public and institutional policy purposes have been studies that focus largely on departmental and institutional attributes that might relate to enhanced research productivity. One critical dimension of departmental research productivity is its relationship to organizational and faculty size. A growing number of studies (e.g., Bell and Seater, 1980; Rushton and Meltzer, 1981; Baird, 1986, 1991; Crewe, 1988; Jordan et al., 1988, 1989; Golden et al., 1986, 1992a, 1992b, Johnson et al., 1995) have directly examined faculty size, most recently the study conducted by Kyvik (1995).

Kyvik identified several arguments in favor of larger departmental size for research productivity. First, larger departments can better facilitate collaborative research groups. In larger departments there are more likely to be several faculty with similar research interests, which may increase cooperation and collaboration for joint research products. Quite simply, research performance is likely to increase as a result of greater interaction between department members. This process has been referred to as "intellectual synergy" (Kyvik, 1995). Second, larger departments are more likely to attract higher-quality researchers. Finally, larger departments may have greater amounts of resources with more degrees of freedom in their use. Despite these potential advantages of large department sizes for research performance, it has also been argued that there are several disadvantages to large size. As a department's size increases, research performance can be hampered due to increasing difficulty in communication and more formal rules and routines that may hinder initiatives and innovativeness. Moreover, as emerging technologies provide more and more opportunities for faculty to collaborate with their colleagues at other universities worldwide, a large department may not provide the assumed benefit of collaborations for such research.

In fact, much of the research on faculty size is mixed. Some have argued that what many have measured or estimated is simply total departmental research production and not quality or average faculty productivity. In an early study of the determinants of research productivity, Blackburn and his colleagues (1978) reported that department size was a relatively poor predictor of research productivity as measured by the total number of publications per faculty member. It was estimated that beyond a departmental size of 11 to 15 faculty members, productivity remained relatively stable in their study.

Kyvik (1995) examined the relationship between size of departments and research productivity in Norway's four universities in five fields of study (i.e., in the humanities, social sciences, natural sciences, medical sciences, and technology). Research productivity was measured as the number of publications between 1989 and 1991. The publications were journal articles, articles in research books, textbooks and conference proceedings, research books published by book companies, and reports published in report series. A single index of research productivity was created using a weighting system. Using Pearson's correlation analysis, Kyvik reported no significant relationships between size and research productivity except in the natural sciences. Martin and Skea (1992) also found no relationship between size and productivity in a study of British university departments expressly in the natural sciences field. However, they did find a significant relationship with subfield groups within a department when the faculty were able to share some of the same research equipment or interact closely with each other.

Jordan and his colleagues (1988, 1989), on the other hand, examined the relationship between academic departmental size and publications in the United States and found a positive relationship. Departmental productivity was assumed to be measured by average faculty publication within a given department. They found that departmental research productivity was closely related to program size as measured by the number of program faculty, but that departmental research productivity increases only up to a point in size and then starts to decline as the number of faculty increases beyond some point of scale. Golden and Carstensen (1992a) reexamined the same data and reported that the effect of departmental size was even smaller and actually declines after controlling for several other factors. After several iterations between these two groups in the research literature, the results were still largely inconclusive due to problems in both the measurement of variables and in specifying the estimation model.

Crewe (1988) examined research productivity in the departments of politics in U.K. universities and found a large variation in departmental average publication rates. He suggested that these differences resulted from differences in resources and opportunities for research. Such possible factors as leave entitlements, travel money, teaching loads, the availability of research funds, and the research ethos in a department were all examined and offered as plausible explanations.

In short, departmental size often is seen as a critical factor in facilitating research. Large departments may simply become more powerful within a college or university and receive more facilitating resources for research activities—such as equipment, supplies, secretarial support, research assistants, travel funds, or teaching replacements for those on leave—and these resources may facilitate greater research performance. The accumulative effects of faculty size are important. In addition, departmental economies of scale may arise and lead to even more efficiency through shared use of such resources.

Institutional control (i.e., private versus public) also has been an area reporting mixed results in previous research. Jordan and his colleagues (1988, 1989) examined the effects of type of organizational influence and control (i.e., public or private) on departmental research productivity. They reportedly found strong evidence that private institutions were associated with greater academic research productivity. However, in a reanalysis of the same data set, Golden and Carstensen (1992b) reported that the effect of institutional control declines after controlling for both research support and the department's reputational rating. They argued that this finding is consistent with the view that departments in private institutions emphasize research over teaching and service activities, while departments in public universities give greater emphases to teaching, public service, and outreach. In their words, "Private institutions may not be more efficient in their resource use than are public universities; the latter may produce more teaching and service outputs per faculty member, provide fewer support facilities and pay lower salaries" (p. 160).

Beyond the size of faculties and organizational control, other departmental variables have been found to be at least correlated with departmental research performance. These factors have included the annual research spending of the department, the number of students in the department, and the percentage of departmental faculty holding research grants (see, for example, Grunig, 1997). In the context of British experiences with departmental research performance, Johnes (1988a) noted that the student–staff ratio, the quality of computing facilities, the size of the library, and the availability of secretarial, administrative, and teaching assistance were all factors that might influence the research performance of a department. He also noted that another possible explanation of differences in research output might be the quantity of nongovernment research funding acquired by the university. A number of other studies also have focused on the use of technology to enhance both instructional and research productivity (e.g., Massy and Wilger, 1995).

Institutions play a significant role in determining both individual and departmental productivity. Despite the importance of institutional factors on research performance, very few such studies exist due in part to the lack of appropriate output data at the institutional level and to measurement problems across institutions. Yet several attempts have been made to examine institutional research performance. Several studies indicated that publication patterns of the faculty may vary from institution to institution because of differences in institutional norms. Long (1978), for example, found that when natural scientists moved to a new institution, their production patterns soon reflected the publication norms of the new institution. Bentley and Blackburn (1990) analyzed changes in institutional research performance (publication and grant support) between 1979 and 1988 and found that there were substantial changes in institutional performance over time. They also noted that "accumulative advantage" and "resources and recognition" contribute to research support and in turn lead to greater research productivity.

In another institutional-level study, Rushton and Meltzer (1981) examined the number of publication citations across 169 universities in Canada, the U.S., and the U.K. They found that a strong association existed for individual universities in the number of its academic staff, the number of its research students, the number of its library books and journals, the level of its university revenue, and the number of its institutionally associated publications. A summary of all these individual and organizational attributes derived from past research can be seen in the profiles reported in Table 1.

An important issue to keep in mind as these studies are reviewed is the basic notion of causality. The above conceptual framework assumes that individual, departmental, and institutional characteristics are causally prior to the average publishing productivity levels of their faculty. There are, of course, notable exceptions. We can note, for example, the many cases where distinguished faculty have been recruited after their growth at other institutions, which is especially true in the hiring practices of strong private research universities. There are also the possible recursive effects relating to the associated and interactive relationships between faculty size and obtaining resources—for example, only with additional resources is a larger faculty cohort possible. Several studies have found that departmental structures, norms, and resources (i.e., the context in which faculty work and the facilities and assistants that are available) are important for enhanced scientific productivity. Long (1978), for example, advanced the earlier work of Cole and Cole (1972) on accumulative advantage

TABLE 1. Attributes Associated with Research Productivity

Individual Attributes
Innate abilities (i.e., IQ, personality, gender, and age)
Personal environmental influences (i.e., quality and culture of graduate training, and culture of employing department)
Institutional and Departmental Attributes
Institutional structure and leadership
Size of program and faculty
Control by private sector
Amount of university revenue
Availability of technology and computing facilities
Number of books and journals in library
Departmental culture and working conditions
Workload policies
Availability of leaves, travel, and institutional funds for research
Number of students on research support
Availability of "star" faculty
Availability of nongovernmental research funds

Sources: Past studies on research productivity.

and found strong effects of departmental location on subsequent research productivity. More recently, Tautkoushian, Dundar, and Becker (in press) also found that departmental research productivity was a significant predictor of its reputation and prestige, and this in turn often leads to more resources.

METHOD

The Data

Data in this study come from the latest 1993 National Research Council (NRC) study on research-doctorate programs in the United States (Goldberger et al., 1995). The original NRC study examined more than 3,600 doctoral programs in 41 fields in the biological sciences, the physical sciences and mathematics, the social and behavioral sciences, engineering, and the arts and humanities at 274 universities. The NRC study based its analysis on many objective and subjective measures that varied by discipline across 17 to 20 measures. The four reputational measures employed were (1) the rating of graduate faculty quality, (2) the rating of graduate program effectiveness in training researchers and scientists, (3) the improvement of the graduate program in the last 5 years, and (4) familiarity with the work of the program faculty. The objective measures were related to the achievements of faculty in each program (e.g., publications and citation counts) and the characteristics of the program's graduates.

In our current study addressing research productivity we attempted to cluster only on programs that had similar research output goals. Our final NRC sample included only a total of 30 program areas within four cluster fields identified as the biological sciences, the physical sciences and mathematics, the social and behavioral sciences, and the field of engineering from across the select 90 research classified universities in the U.S. (classified as Research I universities according to the Carnegie classification). These institutions all exhibit a strong orientation toward research and scholarly writing and focus heavily on graduate education with large numbers of graduate programs. Moreover, they are typically considered a homogeneous set of institutions with similar production technology (Braxton and Bayer, 1986, p. 26). In the final analysis of the current study, all of the field-related doctoral study programs in the 90 research universities in the U.S. were included in the study and these totaled 1,841 doctoral programs. We did not include several fields from the arts and humanities due to their differing performance indicators.

Beyond updating previous studies and introducing new measures for explanation and possible prediction, our study attempts a new and larger sample design based on clusters of departmental programs. Most past studies have attempted to examine research productivity by examining departmental profiles, typically in a single program area such as politics or economics. A few other research productivity studies have also tended to focus on the entire institution. The current study is the first comprehensive analysis of research productivity by field or clusters of related departments across universities. We included the departmental programs in our four fields by controlling differences among programs through the use of program-specific dummy variables. Our design technique permitted us to examine a larger sample of programs. With a larger sample size, our regression and statistical techniques were much more robust with higher degrees of reliability.

The Model

Research productivity is conventionally measured as the ratio of total publications to number of program faculty. Publication analysis of journal articles and books is clearly the most common measure of such research performance (Olson, 1994). The principal dependent variable for research productivity in the current study was the number of journal articles per average faculty member attributed to each of the programs between 1988 and 1992. Unfortunately, we were only able to include journal articles in the study since data were not available for books. Although an analysis of journal articles presents its own set of problems (relating to such matters as journal quality, types of publication, and multiple authorship), it has become the most common measure of research productivity largely because of the availability of such data from the Institute for Scientific Information (Braxton and Bayer, 1986).

Based on our review of the research literature and availability of data, several explanatory variables were included in our models for examination. We assumed that research productivity as a dependent variable was largely measured by journal publications and that this output measure was functionally related to those individual faculty and organizational attributes discussed and identified in Table 1. Unfortunately, several important dimensions that others have identified were missing from our data. We are missing appropriate measures for such attributes as individual faculty innate abilities and their personal environmental influences. Moreover, we are missing measures that relate to some important dimensions of departmental culture and working conditions that include workload and discretionary departmental funds, and the availability of nongovernmental research funds. In addition, we are missing data on other institutional attributes that measure the amount of university revenues and the availability of technology and computing facilities. Nevertheless, we do have measures for an important number of the relevant departmental and institutional variables that were uncovered in our review of the literature. In several of our models we included measures for size by controlling for numbers of faculty and ratios of graduate students to faculty. We also examined whether the institution was private or public, the amount of expenditures for library acquisitions, the age and seasoning of the faculty through percentage of faculty who were full professors, the scope of whether many faculty were publishing or whether only a few "stars" were contributing to the program's research productivity, the percentage of faculty under independent research support, and the degree to which graduate students were being supported as research assistants in the programs.

Program size was measured by the total number of faculty affiliated with each of the programs. It was used mainly for estimating average faculty productivity.

Concentration and percentage of faculty publishing were measured through the use of the National Research Council's Gini coefficient and a constructed measure for percentage of faculty publishing in each of the departments. We employed different regression models for both measures. For percentage of faculty publishing we included all of the program's faculty and used this second measure as a proxy for the Gini coefficient as to whether faculty publication distribution might be the source of the program's research productivity. It is expected that the larger the percentage of faculty publishing, the larger the number of faculty involved in research and scholarship activity. A program's research productivity is therefore expected to be positively related to the percentage of its publishing faculty.

Percentage of faculty who are full professors is intended to measure the degree of faculty maturity and experience within each of the program areas. It is assumed that more experienced faculty will be both more productive and publish more (see Levin and Stephan, 1989).

Institutional library expenditures was intended to serve as a proxy for institutional resources. It is expected that a strong and positive relationship between research productivity and library expenditures exists since library expenditures are likely to have a positive impact on the quality and quantity of such research output.

Ratio of graduate students to faculty is intended as a proxy for departmental workload. The number of graduate students is assumed to influence the time that faculty have to address their total workload. As the number of students increases, research time is likely to become scarcer, and it is expected that a high ratio will result in lower research performance. A higher ratio also suggests that faculty may be less accessible to students, which may result in reduced teaching effectiveness.

Percentage of faculty with research support measures whether faculty members are active with research funded from outside the department. It is assumed that the more active and successful a program's faculty is in obtaining externally sponsored research funding, the higher their research productivity and subsequent publication record.

Percentage of graduate students who hold research assistantships is assumed to positively affect a program's research performance. This proposition is alleged to be particularly true in the science and engineering fields. Such students often help faculty increase their research performance by directly contributing to project-related research.

Institutional control on research performance is directly examined through the use of a dummy variable that indicates whether the institution is a public university or a private school.

The General Statistical Model

The general model for this study can be expressed as follows:

$$P_i = a_0 + a_1 F_i + a_2 F_i^2 + \sum_{j=3}^{7} a_j X_{ji} + e_i$$

where P_i is the number of average research publications of each departmental cluster at institution i; F_i is the number of departmental faculty clusters at institution i; X_{ji} is the number of other explanatory variables assumed to influence departmental research productivity; e_i is a random error term; and a_j is the coefficient to be estimated.

The nature of the individual explanatory variables is derived from our review of past literature and is identified in Tables 1 and 2. The specific form in which these influencing factors is measured is taken or constructed from the data sets available to the study.

We can test whether the relationship between average publication and departmental size is nonlinear by examining the squared faculty size variable. Holding all other variables constant, if a_1 proves to be positive and a_2 proves to be negative, the average departmental publication will first increase as faculty size increases, but at a diminishing rate.

We also should note that department-specific dummy variables are included in all the models to control for differences among the departments. The model specified above was first estimated for all the departments combined and then run for each of the four fields (i.e., biology, engineering, physical sciences, and social and behavioral sciences). These five models are identified in Table 3. Several other models based on this general model were also estimated in the study and are identified in the following discussions.

It should be noted that we also attempted to examine the data with respect to each of the 30 individual departmental programs. However, the data appeared not to fit our models very well and resulted in very low R^2 and in several of the cases the model equations were not significant. This can be attributed to the small sample sizes in most of the departmental program areas. As a consequence, we used the cluster fields as our model of analysis by controlling for departmental differences with individual dummy variables.

RESULTS

By employing all of the program areas available in the four cluster fields, our final sample included 1,834 programs in the NRC data set. Programs included in the pooled sample were 534 in the biological sciences, 380 in engineering, 481 in the physical sciences and mathematics, and 438 in the social and behavioral sciences. From data supporting Table 2, we note that average program faculty size varied from 24 in engineering to 36 in the biological sciences. We also note that there were considerable differences between rates of productivity between fields as measured by the average publications of each program wherein they varied from 2.5 in the social and behavioral sciences to 9 in the biological sciences. Not surprisingly, a typical faculty member in the social sciences wrote 2.5 articles between 1988 and 1991, whereas a colleague in the biological sciences wrote about 9 articles during the same period. These differences may not reflect productivity differences between fields but may simply indicate differences in styles and types of publications between fields.

Employing our general model for estimating influences and associated factors with departmental research productivity, we framed five separate regressions. In Table 3 these five estimated regressions are presented. We first estimated results for the entire sample combined and then subsequently estimated separate models for each of the four cluster fields of research. Each of the models also includes department-specific dummy variables, but these are not reported in Table 3 due to their length and limited importance to our questions. Only 6 (i.e., molecular and general genetics, neurosciences, biomedical engineering, astrophysics and astronomy, physics, and statistics and biostatistics) of the 30 departments were found not to be significant in the full model estimation. The estimated and adjusted R^2 for the pooled model was a relatively high .67 and for the four fields the R^2 ranged from .50 for the biological sciences to .80 for the social and behavioral sciences, all indicating reasonably good fits between our models and the data set. It is important to note that all of the coefficients (except for the six departmental dummy variables identified above) for the full model are statistically significant at very high levels with all associations in the expected directions, indicating very high reliability for our estimates. Both the coefficient signs and degrees of significance appear to be consistent across the four cluster fields, only with some material differences in the social science fields.

With these models conceptually framed from our review of the past literature, we should now be better able to address some of the persisting policy

TABLE 2. Descriptive Statistics

	All Fields	Biological Sciences	Engineering	Physical Sciences and Mathematics	Social and Behavioral Sciences
	Mean (Std. Deviation)	Mean (Std. Deviation)	Mean (Std. Deviation)	Mean (Std. Deviation)	Mean (Std. Deviation)
Average faculty publications	6.65	9.03	7.14	7.32	2.57
	(4.76)	(4.12)	(5.18)	(4.64)	(1.80)
Faculty	29.85	36.58	24.27	28.32	28.07
	(21.82)	(31.19)	(15.53)	(16.94)	(13.72)
Faculty-squared	1366.75	2308.89	829.26	1088.80	975.50
	(2902.50)	(4818.92)	(1236.12)	(1564.34)	(1082.28)
Ratio of graduate students to faculty	2.37	1.29	3.01	2.72	2.77
	(1.95)	(1.18)	(2.36)	(2.26)	(1.29)
Percentage of graduate students who are RAs	30.57	26.53	50.68	37.80	10.23
	(26.18)	(22.86)	(21.94)	(27.44)	(12.22)
Library expenditures ($, 000)	15961.66	15500.00	15607.38	16228.20	16540.24
	(8190.55)	(8196.29)	(7157.63)	(8830.09)	(8272.81)
Public institutions (1 if public, 0 otherwise)	0.70	0.69	0.73	0.69	0.70
	(0.46)	(0.46)	(0.45)	(0.46)	(0.46)
Percentage of full professors	56.09	52.67	56.00	60.91	55.10
	(15.24)	(14.98)	(14.88)	(16.13)	(13.45)
Percentage of faculty publishing	78.80	86.99	79.27	82.43	64.31
	(15.52)	(9.13)	(12.70)	(11.53)	(17.78)
Percentage of faculty with research support	49.86	64.48	53.28	58.67	19.24
	(26.07)	(20.24)	(19.89)	(19.50)	(17.08)
Valid *N* (listwise)	1834	534	380	481	438

Source: Goldberger et al. (1995).

TABLE 3. Estimates of Regression Coefficients Explaining Average Faculty Publications

Variables	Full Model	Biological Sciences	Engineering	Physical Sciences and Mathematics	Social and Behavioral Sciences
	Coefficients (t-statistics)	Coefficients (t-statistics)	Coefficients (t-statistics)	Coefficients (t-statistics)	Coefficients (t-statistics)
Constant	−4.29	−10.63	−9.20	−3.93	0.19
	−(6.76)*	−(7.78)*	−(5.72)*	−(3.55)*	(.54)
Faculty	0.05	0.06	0.048	0.07	0.01
	−(5.99)*	(4.70)*	(1.21)	(3.07)*	(1.17)
Faculty-squared	−0.0002	−0.0003	−0.0003	−0.001	−0.0001
	−(3.50)*	−(3.51)*	−(.63)	−(2.27)*	−(.65)
Ratio of graduate students to faculty	0.16	0.19	0.17	0.26	−0.05
	(4.20)*	(1.59)	(2.12)**	(4.42)*	−(1.82)**
Percentage graduate students who are RAs	0.009	0.002	0.028	0.01	0.01
	(2.74)*	(.35)	(3.156)*	(2.00)*	(1.30)
Library expenditures	0.00004	0.0001	0.000001	0.0001	0.00001
	(4.84)*	(5.76)*	(.14)	(3.84)*	(.88)
Public Institution (1 if public, 0 otherwise)	−0.79	−1.62	0.04	−0.65	−0.15
	−(5.37)*	−(5.56)*	(.094)	−(2.39)*	−(1.57)
Percentage of full professors	0.029	0.05	0.06	0.02	−0.0005
	(6.07)*	(5.19)*	(4.22)*	(2.41)*	−(.151)
Percentage of faculty publishing	0.08	0.15	0.07	0.07	0.04
	(11.77)*	(9.47)*	(3.77)*	(5.46)*	(12.64)*
Percentage of faculty with research support	0.04	0.03	0.07	0.03	0.03
	(10.26)*	(4.49)*	(5.98)*	(4.18)*	(8.90)*
Adjusted R^2	0.68	0.51	0.57	0.71	0.79
F-statistic	102.79	37.79	32.6	75.12	110.72
Sample size	1,834	534	380	481	438

Note: All models include additional program specific dummy variables.
Tests of significance: $*p < 0.01$, $**p < 0.05$.

questions in higher education. Our results should be especially helpful with regard to departmental and institutional policy on how such institutions might enhance their research productivity.

Is a larger program with more faculty more productive? The pooled model included all academic programs from all four of our different field clusters: the social and behavioral sciences, the physical sciences and mathematics, engineering, and the biological sciences. The results indicate that program and departmental size in numbers of faculty is, indeed, a strong predictor of average departmental publication. However, the negative sign on our faculty-squared coefficient across all five of our models indicates that the effect of program size diminishes as size increases. With such results it is also logical to assume that beyond some large faculty size, such average productivity would not only fail to rise but would actually decline. Useful references to faculty sizes and their standard deviations across all the field clusters can be gained from data in Table 2.

Does the type of institutional control make a difference? We estimated for the effect of type of institutional control (i.e., public or private) by including a dummy variable in each of the models. We found in all our estimated regression models that if the institution was a public university this type of control associated negatively with departmental research production. In other words, average faculty research productivity in public universities tends to be significantly less than in private institutions, controlling for faculty size and the several other variables.

There might be several plausible explanations for why private institutions appear to have greater research productivity on the part of their faculty. First, this may be due to faculty in public institutions producing other products (e.g., producing other types of non-journal-related research products or focusing on teaching or more outreach rather than research). Moreover, as noted by Jordan and his colleagues (1989), public universities may be politically limited in their attempts to increase their research productivity because of their public nature and goals. Second, incentives for private research universities to maximize their research performances and reputations often are very strong because most private schools are heavily dependent on voluntary support and demand for their products in order to generate revenue. Since high research performance often results in significant reputational increase and thus additional resources, most private institutions attempt to recruit the most research-productive faculty. Jordan and his colleagues (1989) described this strategy as a “survival test” for private universities. Most private research universities generally have fewer but more highly research-productive faculty than those typically found in public schools. Finally, it is also likely that many private institutions may provide better organizational structure and performance incentives for faculty to enhance their research productivity. We do know that privates at least provide higher salaries (Clotfelter et al., 1991).

Does having more full professors make a department more productive in research performance? The effect of faculty rank on research productivity was found to have mixed results in past literature: Several studies found that rank was a significant predictor of faculty research productivity and several other studies found that rank had no effect (see Tien and Blackburn, 1996, p. 3). Although we do not have a variable measuring alternative forms of faculty rank, we do have a measure that indicates the percentage of departmental faculty who were full professors. We assume that full professors are tenured, experienced, and mature senior faculty. If a program has a large percentage of full professors, we can estimate the likely effect of this rank and seniority of program faculty. We found that having a higher percentage of faculty members who are full professors indeed does help to achieve higher research productivity in almost all fields. Except in the social and behavioral sciences, all the estimated coefficients are positive and statistically significant.

What is the effect of "star" faculty on research productivity? Some past research has found that the research productivity of a department can be influenced considerably by the presence or productivity of "star" faculty (Johnes, 1988a). Cole and Cole (1972) have reported, for example, that the most influential research being produced in many fields is being conducted only by a small number of all those engaged in research activity. We used a National Research Council constructed Gini coefficient for publications to test for the possible effect of "star" faculty on departmental average research productivity. The Gini coefficient here is used to measure the degree of publication concentration on a single or small number of program faculty during the period 1988–1992. As Goldberger and his colleagues (1995, p. 56) have noted:

> The higher the Gini coefficient, the less the dispersion. For example, consider three programs each having 20 faculty members who together publish 40 articles during a certain period of time. In program A, each of the 20 faculty members published 2 articles for a Gini coefficient of 5. In program B, 2 faculty members each produced 11 articles . . . and the remaining 18 faculty members each published one article; the Gini coefficient would be 16.3. In program C, one faculty member published 40 articles and the remainder published none; the Gini coefficient would be 100.

Such a measure can be used to test for the influence of "star" faculty in determining departmental research productivity. If a small number of faculty members are highly productive and the department also appears to be highly productive, then the recruitment of "star" faculty appears to be a rational and useful policy.

Fortunately, the 1995 NRC data set reported on such constructed Gini coefficients for each of the departmental programs in the total sample. This measure permitted us to test for this "star" faculty effect across the leading research universities in the United States. When this Gini coefficient was substituted for our measure of percentage of faculty who were publishing we found that it only was statistically significant and negative in our pooled and physical sciences and mathematics estimated models. These results indicate that very few university departments are relying on only a few "stars" to carry their efforts in research productivity.

What is the effect of distribution of faculty activity on research productivity? It is assumed that a large percentage of faculty publishing in a department is likely to have a statistically significant and positive influence on their departmental research productivity. Not surprisingly, this factor was found to be both highly significant and positive in all our models. A department that wants to increase such productivity ought to expect contribution from all of its members rather than from only a few "prolific" or "star" faculty.

What is the effect of faculty with financial research support? We also examined for the effect of faculty with nondepartmental financial research support on departmental research productivity. We assumed that the higher the percentage of faculty with such financial support, the higher would be their research performance. Not surprisingly, we found that this factor is closely related to departmental productivity in all four of the cluster fields.

What is the effect of institutional support on critical resources? Unfortunately, the only measure available for us to examine this question was institutional expenditure for their campus libraries. We found that in all cases, except engineering and the social sciences, institutional expenditures for libraries were significantly related to departmental research productivity. Beyond the indirect support of librarial holdings in support of departmental research, this positive effect also may suggest that institutions with more resources provide better resources in many other infrastructure ways as well. Most, if not all, of this infrastructure support should contribute to increasing their research productivity.

Does faculty teaching load with graduate students influence research productivity? The NRC data set permitted us to construct a measure for the ratio of graduate students to faculty and to examine whether such a high ratio might reduce average research productivity. One likely scenario resulting from a high ratio is that faculty members may have less time to do research since they might be required to teach more courses or advise more students. On the other hand, an alternative possible scenario resulting from a high ratio is that faculty and students can collaborate in projects and conduct joint research and subsequently publish their results. Large numbers of graduate students also might contribute to a richer mix of scholarship that might result from laboratories, seminars, and thesis projects. This may be particularly important in the science- and engineering-related fields as was noted by Lodahl and Gordon

(1972), wherein they found that high paradigm fields such as engineering and physical sciences do in fact use graduate students more effectively in both their teaching and research activities.

In our analysis of departmental research productivity, we found that a high ratio of graduate students to faculty is statistically and positively associated with departmental research productivity in the pooled model as well as in engineering and the physical sciences. Somewhat surprisingly, in the social and behavioral sciences we found that there was a significantly negative association between the ratio of graduate students to faculty and departmental research productivity. This latter effect undoubtedly results from workload effects and the prospective problems of communication for low-paradigm fields such as the social sciences (Lodahl and Gordon, 1972). It also indicates the differential effects that occur across the differing fields and clusters of departmental areas.

What is the effect of employing graduate students as research assistants? Across all of our models we found that the percentage of graduate students who held research assistantships was also positively associated with departmental research productivity. The estimated coefficients all had positive signs and were statistically significant in the pooled as well as in the engineering and physical sciences models.

It is important to note that we also ran all of the five models identified in Table 3 with research citations per average faculty member as the dependent variable in place of journal publications. In no case did any of our results change in either direction of signs or in significance of coefficients. The only material change was in the lower R^2 and degrees of significance found with the citations per faculty. In short, journal publication proved to be a better fit for our models and for our questions.

Limitations

The findings of this study provide some insight on research productivity in American higher education. Yet there are several caveats that need to be borne in mind in interpreting the results. First, it must be remembered that productivity in higher education is a multidimensional concept. While research production is an important dimension of productivity, it is only one of several major outputs (e.g., research along with teaching, public service, and outreach) in most research universities and some of these other outputs might have higher social or political priorities at times. An increase in the teaching load of a department, for example, is likely to lead to reduced research performance due to time constraints.

Second, even though research often appears to be the easiest of higher education's output to measure, there are still some serious difficulties in measuring research performance. Evaluating research performance is an inexact science since there is no precise measure of research output. There are multiple forms of research outputs such as journal articles, books, book chapters, monographs, unpublished conference presentations, and even computer software. This study was only able to use Institute of Scientific Information [ISI] journal articles as its main measure of research output since data related to the other forms were not readily available. Olson (1994) has noted, for example, that the faculty in a particular university can often appear more productive than faculty in another institution when only one product is analyzed, and this perceived result may be misleading due to the existence of an alternative form or measure of research productivity. The significance of article publication rates should not be exaggerated.

It also must be clearly acknowledged that the current study used only journal article counts that were obtained from the *Science Citation Index* and the *Social Science Citation Index* as its measure of output and articles. This source of data may have resulted in several biases. There are several problems relating to the use of publication and citation counts from these types of indexes (see Johnes, 1988b). It is important to note that journal articles not covered by those indexes were not included. Furthermore, no control was made for quality since no measure was available for such purposes. The ISI maintains a computer file consisting of bibliographic records of papers in the two citation indexes. From 1988 through 1992, the ISI matched its citation counts with institutional faculty lists from 1992 that were provided by the National Research Council. Thus, if faculty members moved during the 5-year period, they would only be counted in the receiving department and then only with citations from their tenure within the receiving department. This would not be a problem if faculty rarely changed departments, but academics in research departments are a mobile group in the labor force. Three types of departments are disadvantaged by these data-gathering procedures: those that experienced greater than average emigration; those that experienced greater than average immigration; and those that hired more new Ph.D.s than average because they would be adding to their staff with larger numbers of faculty with limited productivity. On the other hand, those departments that would benefit in articles per faculty ratio comparisons most likely would be in distinguished institutions with older professors (large proportions of full professors, who are less likely to move). It is clear that this prospective bias needs further examination. Nevertheless, although the use of journal publications as the sole indicator of departmental research productivity can be criticized, such a measure for publication is an important avenue for disseminating research results and this measure has strong acceptance across most academic peer groups. Such measures are also used for academic appointments, promotions, and other rewards.

Third, the data available for this study limit the development of a more comprehensive research productivity model. Cross-sectional data and designs often provide misleading results when compared with the employment of a more appropriate longitudinal design (Long, 1978). Moreover, there are several other measures related to individual faculty and departmental and institutional attributes that are likely to have an influence on and contribute to the research performance of departmental programs. Not only does some suggestive past literature and our own intuition suggest that the intelligence, aptitude, experience, and enthusiasm of the academic staff themselves should have some influence on research productivity but such reliable attributes are very difficult to measure and are missing from the current study. Moreover, the leadership of a department and its organizational and administrative effectiveness cannot be easily quantified and measured. Differences in productivity levels may reflect, for example, variations in teaching loads and the availability of other resources for research.

Finally, there also is evidence of the existence of economies of scope in higher education that result from the joint production of research and instructional activities, especially with regard to graduate education in research universities. Any analysis of research productivity without considering the additional effects of research production on teaching and learning is likely to underestimate the full effect of such research activity. The results of this study, along with all other similar work, need to be viewed with an appropriate amount of caution due to these limitations.

DISCUSSION AND POLICY RECOMMENDATIONS

In this paper we examined recent data from the NRC study on American doctorate-level research programs in order to investigate the relationships between departmental research productivity and institutional factors and policies. The findings from this study are important for U.S. research universities for several reasons. Most importantly, we found consistent with some previous studies that academic research productivity is closely associated with program faculty size, but usually at a diminishing rate. Programs will achieve increasing research performance as they increase the number of their program faculty, but at a certain level the marginal product of an additional faculty member will begin to decline. Previous studies noted that departmental faculty size affects research productivity to some extent as a result of critical mass. In order to have a highly productive research program, academic departments also need to have a significant number of faculty. This effect suggests that faculty size may have an influence on individual productivity resulting from enhanced opportunity for collaboration and reinforcement. Programs attempting to increase their research productivity (and thereby their reputation) should examine the marginal product of an additional faculty in their determination of an optimum program size.

The study was also useful in identifying other factors affecting research productivity. We found, not surprisingly, that departments located in private universities generally have higher research productivity. Public research universities need to identify those factors affecting this differential in their research productivity, especially those inhibiting productivity factors in public research universities. Attention needs to be given in the public institutions to removing these inhibiting factors and enhancing favorable policies. We also uncovered understandings that having more full professors and larger percentages of departmental faculty working on research, and having more "star" faculty, all contribute in material ways to enhancing departmental research productivity. Policies that hire more senior and "star" faculty and policies that induce more existing faculty to contribute to research will undoubtedly contribute to enhanced departmental productivity and subsequent reputations. Departmental and institutional policies that (1) induce faculty to solicit more grants and contracts outside of the university, (2) target institutional resources on research production such as library resources, technology, and graduate student research support, and (3) recruit a critical mass of graduate students will all enhance research productivity.

Additional studies are needed that examine the multiproduct nature of higher education and the interactive effects that result from the research, outreach, and teaching activities that frequently take place within many of our top research universities. Such information would be particularly helpful in our understanding of how different dimensions of output structures and productivity change with respect to different sets of inputs. A particularly useful attempt would be the identification of a full set of outputs and inputs in a relatively homogeneous set of academic departments to better understand productivity in these departments. Unfortunately, the departmental data sets in the NRC data were too small to permit this type of study.

Productivity in American higher education, despite many attempts to talk about it and a few attempts to measure it, is still a relatively uninvestigated area. Little is known about the factors affecting research productivity, particularly with respect to its interactive effects with teaching and learning. What, for example, is the likely contribution of graduate students to research productivity? Research productivity in particular needs a more comprehensive approach to identify factors affecting not only individual faculty but a department's productivity as a whole. How individual factors and departmental factors interact to result in a productive research environment is still not well understood. Studies examining, for example, the relationships between aging and research productivity are weak and in need of further investigation (Clark and Lewis, 1985). This latter question is particularly important given the expected graying effect of American higher education over the next decade. In short, future studies examining research productivity in our research universities must include better measures for specific individual, departmental, and institutional factors as they examine policy remedies for enhanced effectiveness.

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