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ABSTRACT

The effects of evolving federal research policies and programs on nongovernmental academic medical centers are examined. Medical schools, teaching hospitals, and research institutes are included. The major problem of analysis in this report is to sort out the effects of federally-supported biomedical research from other influences on academic medical centers. The analysis addresses the question of the status of the academic medical community on a number of levels. It examines how centers appear to have adjusted their educational programs, their organizational structures, their scientific activity, and their budgets as a result of their involvement in federal biomedical research. The measurable effects of federal research on the educational programs of centers appear to be limited largely to those components most involved in research. In general, the academic medical community is responsive to the influence of federal biomedical research programs. The analysis reported here confirms the interdependence between the federal agencies that sponsor research and the academic institutions performing it. Important characteristics of academic medical centers--Ph.D. programs, faculty size, budgets, and scientific activity--are directly related to the federal funding received by individual departments; and overall financial stability is often substantially affected by the stability of federal research funding. (Author/LBH)

THE EFFECT OF FEDERAL BIOMEDICAL RESEARCH PROGRAMS ON ACADEMIC MEDICAL CENTERS

PREPARED FOR THE PRESIDENT'S BIOMEDICAL RESEARCH PANEL

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PREFACE

This report was prepared for the President's Biomedical Research Panel under contract from the National Institutes of Health of the Department of Health, Education, and Welfare (NO 1-PP-5-2159). The contract was administered by the American Council on Education (ACE) and provided for research by a consortium of that organization, the Association of American Medical Colleges, and The Rand Corporation.

The purpose of the research was to assess the effects of federal biomedical and behavioral research programs on institutions of higher education. This report, which examines the effects of those programs on academic medical centers, is one of four basic components of the research effort. The other three reports are:

Lyle H. Lanier and Ivars Zageris, *A Study of Financial and Educational Trends in Research Universities, in Relation to Federal Funding of Health-Related Research—1964-1974*, American Council on Education, 1976.

T. E. Morgan and D. D. Jones, *Trends and Dimensions of Biomedical and Behavioral Research Funding in Academic Medical Centers: 1964-1974*, Association of American Medical Colleges, January 1976.

David E. Drew and John G. Wirt, *The Effects of Federal Funds upon Selected Health-Related Disciplines*, The Rand Corporation, R-1944-PBRP, 1976.

A fifth component of the research, prepared jointly by the research staff of ACE, AAMC, and Rand, summarizes the major findings of the four basic reports. This summary appears as an appendix to the report of the President's Biomedical Research Panel to the President and the Congress. The portions of this summary that relate to the Rand analysis of academic medical centers appear in the Summary to this report. Since the body of this report describes the methods of analysis in some detail, we recommend that the Summary be read prior to the major substantive sections (II through V).

Although this study was performed for the President's Biomedical Research Panel, it draws heavily on data collected for an earlier study of academic medical centers for the Health Resources Administration and the Office of the Assistant Secretary for Planning and Evaluation, Department of Health, Education, and Welfare (NO 1-MB-24196). It also uses material from a concurrent study for the Office of the Director, NIH (NO 1-OD-5-2127).

This report should be of interest to those concerned with federal biomedical research policy and higher education as well as to those involved in policy research and evaluation.

SUMMARY

This report examines the effects of evolving federal research policies and programs on the nongovernment institutions we call academic medical centers. Academic medical centers include, in addition to medical schools, at least one but usually several major teaching hospitals, and often one or more semi-autonomous research institutes. The implementation of federal biomedical research programs is affected by all organizational components of a center.

Just as it is necessary to consider the larger organizational complex, the academic medical center, in assessing research program effects, so it is necessary to take account of the instructional and patient-care functions of centers in examining their research activities. Very simply, this is because education, research, and patient care are conducted jointly within every center. Furthermore, some of the same resources are used in producing the three classes of outputs of education, research, and care. In some instances, all three are produced simultaneously, but in very few instances is the production of one irrelevant to the production of at least one of the others. Most important to the federal government and the institutions, the cost of producing any one class of outputs depends on the amounts of the others that are being produced.

Naturally, the mix of educational, research, and patient-care functions that are conducted by a center depends in substantial part on the incentives provided by external funding sources. In many cases, the most important of these is the federal government, which has programs concerned with all three classes of functions and their products.

The major problem of analysis in this report is to sort out the effects of federally supported biomedical research from other influences on academic medical centers. We use multivariate analysis to assess the simultaneous effects of multiple factors—including federal research programs—that affect academic medical centers.

Conceptual models of medical center activities have been developed to consider the effects of NIH research programs, and several statistical techniques permit the effects of other factors to be considered simultaneously. However, the models are in every case oversimplifications of complex processes, and the data are often only proxies for what one would wish to measure. Notwithstanding these limitations, the results of the analyses in most cases are strong enough and plausible enough for one to be confident of the direction, though not precisely of the magnitude, of the effects observed.

Many federal research and research-training programs were directed at the basic medical sciences. Using individual departments as the unit of analysis, we examined the effects of various federal programs on enrollment and doctorate production. Although the general trend is one of doubling of size, there are, as one might expect, significant differences among institutions and across disciplines. Taking these into account, the effects of federal programs are still quite strong. Among federal programs, research-training funds received by a department appear to have the strongest effects on its enrollment and Ph.D. production. The amount of a center's general research support grants (formula grants based on a school's overall research funding) also significantly affected enrollment, and this probably reflected

the overall research intensity of a center. After these two federal funding effects were controlled for, research funds to the individual departments had only a very small positive effect on educational program size.

Our analysis indicated that the growth of basic science education programs may be attributed mainly to federal training programs that included student stipends. This raised questions regarding the likely effects of cutbacks in such funding. Preliminary analysis of trends and plans of department chairmen at ten medical schools suggests that the size of graduate programs in the basic science departments will be significantly related to the availability of funds expressly dedicated for student support. There appear to be only limited opportunities to build graduate programs with "self-supported" students. Since federal training funds are an important source of student support, cutbacks are likely to lead to changes in enrollment in the short run. Departments with substantial research funding have some limited capacity to support graduate students as research assistants in laboratory work.

The role models of research faculty are thought by some to influence M.D. graduates of research-intensive medical schools to choose nonprimary-care specialties. An examination of the graduates of ten medical schools indicated that the specialty choices of medical school graduates are affected very little by the intensity of research in particular departments or in the medical school as a whole, and there is no evidence at all to suggest that research intensity discourages a school's graduates from entering primary care specialties. However, it is possible to predict with limited accuracy the choices of careers among broad categories of practice (internal medicine, other primary care, surgical specialties, other nonprimary-care specialties) using characteristics of individual graduates (e.g., sex, undergraduate grade-point average, class standing in medical school).

A research-intensive medical school environment positively affects the likelihood of a graduate's entering a research or academic career. However, only a small proportion of graduates of even the most research-intensive schools enter academic or research careers. Analysis of data on individual graduates of the ten sample medical schools indicates that research funding of the school where M.D.s received their undergraduate medical education was positively related to these choices, but the funding effects were much less important than individual characteristics such as class standing.

It has been suggested that the research intensity of a medical center affects the size of its graduate medical education programs in various ways, in particular that high research funding encourages medical centers to expand the number of interns and residents beyond levels appropriate to the availability of patients for teaching purposes. Analysis of cross-section data for internal medicine yields no evidence to support this suggestion. Instead, it appears that the numbers of faculty and patients largely determine the numbers of interns and residents in the majority of departments of medicine.

We examined data on individual department size to determine the separate effects of research and educational programs. At the level of the departments (e.g., biochemistry), differences in faculty size across schools are related to differences in NIH research funding in a statistically consistent manner. In contrast, only for certain kinds of departments do teaching responsibilities appear to explain faculty size. However, where differences in numbers of faculty are related to teaching loads, the magnitude of the effect is much larger than that for research funding. That is, although for all departments the relationship between research program size and faculty size follows a more consistent pattern than the relationship between education program size and faculty size, the total effect of education programs on department size is greater than that of research.

Analysis of data on departments of medicine in all institutions does not indicate that research funding significantly affects the clinical-care activities of departments. However, the limitations of the data and the models used for the analysis may explain the absence of observed effects.

The dependence on federal biomedical research funds for faculty salaries varies greatly across institutions. Not surprisingly, those centers that have been most consistently successful in competing for research funds have tended to rely more heavily on this source of support.

The only consistent trend in sources of support for faculty salaries is the increased reliance on practice earnings for the compensation of clinical faculty. However, part of this change may be more apparent than real. It may result from the reclassification of some faculty from part-time or volunteer status to full time and from increased institutional accountability for practice fees. The real increase in revenue from this source due to expansion in the patient-care functions of academic medical centers and public-health insurance programs for the aged and needy is probably a one-time phenomenon. It does not represent a readily expandable source to replace research funds currently used for faculty salaries.

Analysis of sources of support for individual faculty salaries does not reveal any consistent pattern of vulnerability to cutbacks in research and research-training funds that applies to all institutions. Although the proportion of faculty salaries funded from these sources does vary somewhat by the department (e.g., internal medicine, biochemistry) and the academic rank (e.g., full professor, assistant professor) of the individual faculty member, most of the variation is accounted for by other factors. This does not confirm but is consistent with the hypothesis that differences in individual faculty, including, among other things, involvement in research, account for most of the differences in their dependence on soft funds for salary.

By far the most important determinants of average departmental faculty salary levels appear to be the type of department (anatomy, medicine, surgery, etc.), the region of the country in which the school is located, and the relative cost of living in the surrounding area. Taking these into account, there is a significant negative relation between NIH funding and faculty salaries. In departments with high levels of NIH funding, salaries tend to be lower, with this effect more pronounced for junior faculty than for senior faculty. Salaries of department chairmen, however, are positively related to levels of NIH funding.

When changes in faculty salaries are related to changes in NIH funding, the results are not as clear. In clinical departments there appears to be a positive relationship between increases in grants and increases in full professors' salaries. This relationship does not seem to hold, however, for associate or assistant professors. Salary increases for assistant professors appear to be very vulnerable to decreases in NIH training grants. In basic science departments, no interpretable pattern emerges.

Federal research programs may vary in size over time and medical centers may be more or less successful in competing for them from one year to the next. We analyzed data on institutional budgets to determine the effects of such changes from year to year. Changes in NIH funding seem to have only mild effects on funding from other sources. Where consistent effects are observed, they seem to be associated with increases rather than decreases in NIH funding. This suggests that other funding sources are not generally available to compensate for shortfalls in NIH funding. Neither is there any evidence of significant "multiplier" effects; increases in NIH funding do not seem to attract substantial funds from other sources. In general, the models relating changes in various categories of funding for the institution to changes in another single category (the effects of revenue from tuition, patient fees, NIH support, etc. on revenue from foundations) are not of much predictive value. In most cases, they explain no more than 25 percent of the variance.

Analysis of data on the allocation of institutionally controlled funds (tuition, capitation grants, etc.) does not indicate that such funds are treated as substitutes for funds generated by individual departments (e.g., research and training grants, patient fees). These results indicate that academic medical-center departments act as entrepreneurial units whose functions depend in substantial part on their ability to generate funds from outside sources. NIH and other public and private research funding agencies are important sources of department-generated funds, and practice earnings are of growing importance to all clinical departments (particularly those of the high-earning specialties).

The central administration of a medical center appears to exercise only limited control over total department budgets, at least in the short term. There may be some asymmetry in the central administration's budget behavior with respect to increases and decreases in departmental research and research-training funds, but the asymmetry is different from what one might expect. That is, it appears that in most institutions in our sample, a department may obtain more institutional funds by increasing its research support. However, a department's loss of research funds does not appear to have a significant effect on its allocation of institutional funds. This indicates that individual departments may be quite vulnerable to research funding cutbacks because the institution has little flexibility to compensate departments for such losses.

Another inference that may be drawn from our analysis relates to the question of whether research funds "subsidize" the education programs of medical centers. No evidence has been found that research funds supplant institutional funds that are generated by, or that would normally be used exclusively for, the training of undergraduate M.D.s. That is not to say that the *character* of M.D. education programs is not influenced by the presence of a research effort.

From the point of view of the federal government, an important attribute of the research being performed in an academic setting under NIH and ADAMHA sponsorship is the Institute, or program within the Institute, that sponsors the research. The sponsor describes, at least in part, the disease entity or normal process that will be better understood as a result of the research. Budget allocations among programs are made on the basis of the health problem being studied. The review processes for NIH and ADAMHA are administered separately. Differences among the federal programs may have different effects on the different parts of the university.

Federal programs also affect the research activity of individual scientists. To assess the effects of federal programs on scientific activity, it is necessary to examine changes over time in that activity; and the sponsoring agency is not an adequate description of research for this purpose. There is not enough detail to detect many kinds of changes that may have occurred. In some areas of science, research that is very similar in its methods, knowledge base, and scientific goals is sponsored through programs of different Institutes. Changes over time in the sponsoring agency do not always signal real changes in scientific activity because there have been changes in the perception of the areas of basic research that are relevant to certain diseases. In addition, it might be possible for an investigator to influence the assignment of his application to an Institute by adding a disease-oriented window dressing to his application, without changing the scientific content of his work. To avoid these problems, scientific activity has been classified solely on the basis of its scientific content as described in the NIH IMPAC file.

Changes in the relative funding levels of the various federal programs will have a greater effect on the parts of the university that are most heavily involved in the programs being enlarged or cut back. The analysis shows significant differences in the academic settings of research among institutes of NIH and ADAMHA.

Applications assigned to the National Institute of General Medical Sciences (NIGMS) are much more frequently from a university science department than from a basic science department of a medical school. Applications for the National Heart and Lung Institute (NHLI) and the National Institute for Arthritis, Metabolism, and Digestive Diseases (NIAMDD) are most frequently from clinical departments of medical schools and, in addition, applications from basic science departments are much more frequently from the medical school side of the university. The situation for basic science at the National Institute of Child Health and Human Development (NICHD) is reversed, probably because of population and psychology studies. However, applications come to the National Cancer Institute (NCI) from each component of the university in the same proportion as total NIH applications.

ADAMHA receives 75 percent of psychiatry department applications but only 10 percent of applications from the rest of university and medical school departments. Within ADAMHA, departments of the medical school other than psychiatry have a higher than expected proportion of their applications going to NIAAA and NIDA, while university departments are more likely to apply to NIMH. Applications from departments of psychiatry and health professions schools go to each of the three Institutes of ADAMHA in the same proportion as the total number of applications.

Applications to ADAMHA were disapproved at a much higher rate than applications to NIH. ADAMHA disapproved 52 percent of new applications and 22 percent of renewal applications, while NIH disapproved 33 percent of new applications and 22 percent of renewal applications. The rate of approval of NIH applications increased slightly during the 1971-1975 time period, while no trend is observable for ADAMHA.

Applications to NIH from basic science departments of medical schools and graduate departments have a higher approval rate than applications from the rest of the university. Applications to ADAMHA from the basic science departments of medical schools also have a higher approval rate than those from the rest of the university, although the university graduate departments do not.

The percent of approved NIH applications that are funded is the same for each component of the university. Approved applications to ADAMHA from graduate departments have a slightly smaller chance of being funded than approved applications from the rest of the university.

The scientific classification system from the IMPAC file describes NIH proposals for research project grants along four axes: Discipline and Field, Body System, Research Materials, and whether or not the project is drug-related. This system permits construction of a typology of biomedical science by grouping applications that have similar descriptions in the scientific classification system into clusters that constitute subfields of biomedical research. Since each grant may receive several codes from each axis, the detailed descriptions of most projects are unique. Nevertheless, some sequences of codes appear repeatedly on different applications and describe the research subfield to which the application can be assigned.

A set of 50 clusters has been identified by a new clustering algorithm developed for this purpose. Most of these clusters may be easily classified as a subarea of one of the interdisciplinary cluster panels assembled by the President's Panel for Biomedical Research.

An examination of the applications in these clusters shows that each component of the university performs a unique role in the spectrum of biomedical research. Clinical studies are performed almost solely by members of the clinical science departments of medical schools. The exception is clinical developmental studies that are performed in all components of the university except for the basic science departments of the medical school. The research performed in basic science departments of medical schools differs significantly from research performed in graduate schools; the former is more likely to be drug-related, based on a body system, or related to a medical specialty. Some fields of biomedical research within chemistry are performed in university departments but hardly ever in medical schools. The medical school's clinical departments and the university graduate departments are involved in behavioral research, but this is almost totally absent from the basic science departments of medical schools.

Federal program priorities affect the scientific activity being performed under research project grants by funding some fields at a higher rate than others. One way to examine this effect is to compare actual funding rates with what would have happened if the study-section priority scores were the *only* criteria used in awarding applications in each year. On the average, 16 percent of total decisions made between 1971 and 1975 to fund or not to fund applications were different from what they would have been if scientific merit were the only criterion.

Federal programs might have an additional effect on research by influencing the kinds of research that scientists propose in their applications—i.e., a scientist with an opportunity to work on several problems might write a proposal for the one that he believed had the highest chance of funding. Changes over time in the number of competing applications in each cluster is one way to describe the demand for research support in the scientific field. In addition to the perceived likelihood of obtaining research support, demand for research support in an area depends on the scientific opportunities available in that area and on the number of available scientists who possess the training and ability to work in that area. There is no way of directly measuring any of these quantities, so surrogates are used for each one.

The proxy for funding levels due to governmental priorities is the difference between actual grants awarded in a cluster and the number of grants that would have been funded if the priority score had been the sole determinant of funding. The proxy for the scientific opportunities available in a field is developed from the distribution of priority scores in each cluster. For the supply of manpower, the data are the number of scientists working on grants in a cluster. The analysis provides some evidence of a response by the scientific community to availability of funding. For every application awarded beyond the nominal cutoff line in a research subfield in 1971 and 1972, two additional applications were received in 1974 or 1975. However, the variable that appears to dominate in year-to-year changes is the availability of manpower.

ACKNOWLEDGMENTS

This study would not have been possible without the cooperation of the administrators and faculty of ten academic medical centers that served as the sample institutions for this and our earlier research on federal program effects. They have in all instances been generous with their time, candid with their comments, patient in explaining the operations of their centers, and trusting in granting us access to sensitive data that were essential to thorough analysis.

The active cooperation of the Association of American Medical Colleges (AAMC) has been vital to our research on the academic medical community over the past four years, of which this study is but one part. We are particularly grateful to John A. D. Cooper, President of the AAMC, for his continued interest in and constructive criticism of our research. Paul Jolly and Jesse Darnell were instrumental in helping us to understand and use data from the AAMC's Institutional Profile System, which was very valuable to this study. The American Medical Association provided data on the careers of medical school graduates from their Master File of Physicians. Solomon Eskenazi and William B. Casey of NIH and David F. Kefauver of ADAMHA were instrumental in providing and helping us to interpret data on extramural grants of those two organizations.

Our close working relationship with Lyle H. Lanier of ACE and Thomas E. Morgan of AAMC, the project leaders for the ACE and AAMC components of the research for the Panel, was invaluable throughout the course of the study. We also benefited greatly from the assistance of the study advisory committee: Steven Muller (chairman), Alfred J. Bollett, Stuart Bondurant, John R. Hogeness, Doris Merritt, Leslie T. Webster, and John T. Wilson.

Throughout the study, we have benefited from our interaction with Charles Lowe, Jarold Kieffer, and Charles McKay, the Executive Secretary, Staff Director, and our project monitor of the Panel. The comments and questions of Panel members during our briefings to them helped to sharpen the focus of our final report.

Performing a study of this magnitude in a short time has required the collection, management, and processing of large quantities of data from diverse sources. In this area the efforts of Kent Brown, Henry Corona, Misako Fugisaki, Heather Hanunian, and Clara Lai were crucial to our analysis. Kenneth Barker, Bruce Bennett, Douglas Campbell, Dolph Hatch, John Lema, and Esther Uyehara provided valuable programming and other assistance in our research. Our final report has also benefited from the comments and criticism of Stephen Klein and Tom Lincoln who reviewed an earlier draft.

The editing and coordination efforts of Helen Turin have been invaluable. Marilyn La Prell maintained an up-to-date computer-based version of our report through dozens of separate revisions by the various authors, and Beverly Westlund coordinated the final production process.

While the success of this project owes much to those mentioned above, the authors bear full responsibility for any errors of commission and omission that remain in the analysis.

CONTENTS

GLOSSARY

ADAMHA	ALCOHOL, DRUG ABUSE, AND MENTAL HEALTH ADMINISTRATION
NIAAA	National Institute on Alcohol Abuse and Alcoholism
NIDA	National Institute on Drug Abuse
NIMH	National Institute on Mental Health
NIH	NATIONAL INSTITUTES OF HEALTH
NCI	National Cancer Institute
NEI	National Eye Institute
NHLI	National Heart and Lung Institute
NIA	National Institute on Aging
NIAID	National Institute of Allergy and Infectious Diseases
NIAMDD	National Institute of Arthritis, Metabolism, and Digestive Diseases
NICHD	National Institute of Child Health and Human Development
NIDR	National Institute of Dental Research
NIEHS	National Institute of Environmental Health Sciences
NIGMS	National Institute of General Medical Sciences
NINCDS	National Institute of Neurological and Communicative Disorders and Stroke

I. INTRODUCTION

The federal government relies heavily on nongovernmental institutions to carry out its policies in biomedical research. Although the first federal extramural research grants date back to 1918, the scope of present day involvement with universities, medical schools, and teaching hospitals is the result of the rapid growth in federal biomedical research expenditures that began in the early 1950s.

From this growth an interdependency has developed between the federal government and the institutions that perform its research. On the one hand, the institutions have developed along lines that make them responsive to and reliant upon federal research funding. On the other hand, the federal government has designed programs on the assumption that these institutions will both perform the bulk of the research it seeks and train the scientists that federal programs will need in the future. As a result, the efficiency of federal government programs in biomedical research depends in substantial part on the efficiency of these nongovernment institutions.

The purpose of this study is to assess the effects of evolving federal research policies and programs on the nongovernment institutions that must carry them out. The particular focus of this report is on the institutions we call academic medical centers, each of which contains a medical school. The treatment of medical schools in a report separate from one dealing with "universities" is explained in part by the greater interdependency between federal biomedical research organizations and medical schools than between those organizations and universities as a whole. The separate treatment can also be attributed to the broader range of functions and greater organizational complexity of academic medical centers, of which medical schools are only one component.

It is the presence of the joint functions of education, research, and patient care, rather than any particular formal organizational relationships, that determines the existence of an academic medical center. A medical school is the core component of every center, but the school often bears exclusive responsibility for only the undergraduate medical education programs. Sometimes several (but at least one) teaching hospitals share the responsibility with the M.D. degree-granting medical school for the clinical portion of medical education and have major responsibility for graduate medical education. The corporate relationships between medical schools and their teaching hospitals vary from outright ownership of the hospital by the medical school to a purely informal relationship between two totally separate corporate entities. The biomedical research functions of academic medical centers may be under the administrative purview of the medical school, its teaching hospitals, an affiliated but corporately distinct research organization, or some combination of the three.

Whatever the organizational peculiarities of any academic medical center, the factors affecting the implementation of federal biomedical research projects are not confined to the medical school. Similarly, the effects of federal programs are not confined to any single organizational component of a center, no matter who bears the responsibility for administration of the federal research funds. Thus, it is appropriate to focus an examination of the effects of evolving federal biomedical research policies and programs on the entire academic medical center. It is also necessary to take account of the education and patient care functions of centers in examining their research activities. Very simply, this is because education, research, and patient care are produced jointly within every center. Some of the same resources are used in producing the three outputs of education, research, and patient care. In some instances, all three are produced simultaneously, but in very few instances is the production of one totally irrelevant to the production of at least one of the others.[1] Most important to the federal government and the institutions, the cost of producing any one group of outputs depends on the amounts of the others that are being produced.[2]

The mix of outputs of education, research, and patient care that are produced by a center depends heavily on the incentives provided by external funding sources. In many cases, the most important of these is the federal government, which has programs concerned with all three classes of outputs.

The focus of this report on the effects of research programs does not imply any normative view about how much, where, or for what the federal government should spend research dollars. We are attempting to (1) provide an objective analytic description of what has happened as a result of past federal research funding, and (2) present the analysis clearly enough that the reader may judge whether it is reasonable to extrapolate from the past effects to future ones.

DATA SOURCES

To analyze the effects of federal biomedical programs on academic medical centers, it is necessary to use data that range from strictly quantitative to highly subjective. The more subjective data (e.g., interviews with deans and department chairmen) are used to generate the hypotheses and develop the models of program effects, and the more quantitative data (e.g., federal expenditures, enrollment) are used in the actual hypothesis testing.

Some important limitations on the analyses of the questions this report addresses are imposed by the nature of the data that can be used. Although specific discussion of data constraints is best left for the sections that address separate analytic questions, the reader should have, at the outset, a general understanding of the data sources that were used in the overall report.

The major source of *subjective data* on the operations of academic medical centers is an in-depth study of ten institutions done by The Rand Corporation from mid-1972 to mid-1974. That study was aimed at developing an understanding of the effects of a wide range of federal programs involving education, research, and patient care on the internal operations and output of academic medical centers.[3]

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[1] An example of simultaneous joint production would be a case in which a patient is being treated with a new drug in a teaching hospital: The attending faculty physician is using the case to instruct house staff and medical students in clinical medicine, he is providing therapeutic treatment to the patient (with the assistance of house staff), and he is collecting data for clinical research on the effects of the new drug.

[2] A more complete discussion of the implications of joint production is presented below.

[3] The final report of that study is presented in G. M. Carter, D. S. C. Chu, J. E. Koehler, and A. P. Williams, ~~The~~ *Federal Government and Academic Medicine*, R-1814-HEW, The Rand Corporation (forthcoming). This report contains a description of the procedure used to select these ten cases.

Although this earlier study was concerned with many of the same questions as the present one, the focus was much broader. That is, federal research program effects were not the only matters of concern. To deal with the research programs more exclusively and to update our information on these institutions, we have revisited each in the course of this study.

Detailed data on *educational programs and graduates* were obtained from the ten sample institutions. These include information on graduate programs in the basic sciences, including funding for students, and information on the background and medical school experience of the classes of 1955, 1960, 1965, 1969, and 1972, which we use (in conjunction with AMA data) to assess NIH research program effects on the careers of M.D. graduates.

Data on the *postmedical school education and career characteristics* of graduates of the sample classes from the ten medical schools were obtained from the American Medical Association. These data are maintained from annual questionnaires sent to all M.D.s whether or not they are AMA members.

Data on *departmental budgets* were obtained from the financial offices of the ten sample medical schools. These data were broken down by sources of support (e.g., NIH, NSF, foundation, hospital) and designated use of funds (e.g., research, graduate training, patient care).

Data on research and research training grants from NIH and ADAMHA for all institutions were obtained from the IMPAC file maintained by the Division of Research Grants. Data for each academic medical center were compiled by aggregating grants to the medical school and its major teaching hospitals.

Data on the patient care and graduate medical education activities of centers and selected clinical departments were obtained from the various issues of the *Directory of Approved Internships and Residencies.* For purposes of our analysis, we drew the boundary to include information on only "major teaching hospitals," as listed in the Directory.

Data on educational programs of all centers were obtained from the various medical education supplements of the *Journal of the American Medical Association.* The data were originally extracted from the annual questionnaires of the Longitudinal Committee on Medical Education (LCME).

Data on faculty size of medical school departments were obtained from the Institutional Profile System (IPS) maintained by the Association of American Medical Colleges (AAMC). These data also came originally from the LCME questionnaire.

Data on sources of funding for medical schools were also obtained from the IPS. To protect the security of these data, we performed the analysis using the computational facilities of the AAMC. In all cases, we have taken care to protect the confidentiality of sensitive data on individuals and institutions. We report the analytic results without identifying the subjects, whether the population is the departments of an individual center, centers from our sample of ten, all centers on which we have data, or M.D. graduates of the ten sample centers.

ANALYSIS

All the questions addressed in this report have one thing in common: They call for sorting out the effects of federal research funding from other effects on the activities and outputs of academic medical centers. Conceptually, this requires a set of behavioral models of medical center processes and a large body of data on the funding, functions, and outputs of the centers. As a practical matter, the models used in the analysis are extremely simplifed representations of the complex processes that determine centers' behavior. In many cases, the available data are only crude proxies for the functions and outputs of interest. Even in the case of funding data, which are among the more precise, budgeting units and accounting conventions change over time so as to confound longitudinal comparisons.

The analysis uses a number of multivariate statistical techniques that yield results understandable to laymen. In almost every case, the analytical approach to a question necessarily assumes a direction of causality by relating a group of independent variables, including NIH funding, to a dependent variable that is the particular outcome (such as enrollment or faculty size) being examined. Such analysis cannot capture some complex interactions that occur in the real world. However, it does permit the assessment of NIH program effects while controlling for some other factors that are hypothesized to influence the outcome being examined. In some cases, such as the relations between enrollment and faculty size, we examine influence in both directions.

In spite of the limitations of our models, we believe the results of the analysis provide appropriate bases for cautious inferences about the effects of federal biomedical research programs on academic medical centers. However, if the nature of the inference is to match the structure of the analysis, it is essential to distinguish between analyses that use longitudinal or time series data and those that use only cross-sectional data.

Time series data conceptually provide the soundest basis for inferences about the effects of programs on particular institutions. These data permit one to analyze the relationship between, say, enrollment in a particular institution and that institution's levels of NIH research and training grant funding over time. Since the time span of these data is usually limited, a number of institutions or subunits of an institution, such as academic departments, are analyzed together. Such analysis assumes that the pattern of relationships between the independent variables and the dependent variable is the same for all organizational units being analyzed, and remain the same over the time period being considered.

Cross-sectional data analysis is appropriate for explaining sources of differences among institutions at a particular point in time—for example, why some institutions produce more Ph.D.s than others. It does not directly address questions about the effects of changes in a program on an institution, and, consequently, inferences about such effects should be made with considerable caution. Analysis of cross-sectional data, in contrast to that of time series data, assumes nothing about a constant pattern of relationships over time but instead assumes that the pattern of relationships is the same for all institutions being analyzed at the particular point in time that the data were collected.

The explanatory power of the models will vary according to the structure of the model and the quality of the data used in the analysis, but it is important to recognize that overall prediction is not the most important criterion for judging the quality of the models used. Instead, our major concern is to develop models that are likely to be most sensitive to the effects of federal biomedical research programs. It is simplest to explain the difference between these two criteria by example. If the objective is to maximize overall explanatory power of a model, one can introduce independent variables that capture the continuity of the system being observed—earlier year's enrollment to explain the current year's Ph.D. production or last year's faculty size to explain the current year's faculty size. However, if the objective is to make the analysis most sensitive to year-to-year changes in funding, a model that relates only differences in independent variables over time to differences in the dependent variable is more appropriate. The resulting difference equations would exclude from consideration all factors related to the continuity of the system of, for example, faculty salaries, and examine only the effects of, say, year-to-year changes in NIH funding and the cost of living. Although the overall explanatory power of a difference model is usually small because of the unaccounted-for short term perturbations, the results are sometimes less subject to misinterpretation.

In most cases, we tried more than one analytic approach in addressing the questions in this report. In most cases, there is no simple correct choice of a best model because all require assumptions. The most obvious cases are the assumptions about stability of structure in time series models and the assumptions about the homogeneity of structure in cross-sectional models. Where we have restricted our analysis to the latter class of model, it was usually because of data constraints. In the report, we describe the results of all analysis other than the purely exploratory. However, in drawing our conclusions, we place most weight on the results of quantitative analysis that we can easily interpret based on our overall understanding of academic medical centers.

ORGANIZATION OF THE REPORT

This report is organized into four substantive sections and a brief conclusion. Each of the substantive sections contains subsections that treat a category of questions about the effects of federal biomedical research programs. In each subsection, which deals with a separate analytic task, we describe the conceptual model, the data used in the analysis, and the results. Then we offer conclusions regarding the federal funding effects on the particular activity or output being examined.

Section II is an examination of the effects of federal research funding on the educational programs of centers. We consider basic science department graduate programs, student financial support, graduate medical education, and career decisions of M.D. graduates. In Section III we examine federal research program effects on the characteristics of medical school departments: the determinants of department size, factors that explain faculty involvement in patient care, the use of NIH research funds for faculty salary support, and the effects of research intensity on faculty salary levels. In Section IV we look at federal research support in the context of the total funding for academic medical centers. We deal first with the apparent relationship between NIH funding and funding from other sources at the level of total center resources and then describe factors that influence allocation of institutional resources to individual departments.

Section V examines the scientific content of proposals to NIH for research project grants from all components of the university, not just academic medical centers. The proposals are grouped into clusters representing subfields of biomedical research. We then examine the effects of the level of funding of a research area on subsequent applications for support in that area, and the parts of the university that perform different types of biomedical research. Section VI summarizes the findings of the other sections. Although we make no recommendations, this section contains a synthesis of our analyses that focuses on policy-relevant findings.

II. FEDERAL BIOMEDICAL RESEARCH FUNDING AND THE EDUCATIONAL PROGRAMS OF ACADEMIC MEDICAL CENTERS

The federal government is concerned about both positive and negative effects of its biomedical research funding on academic medical center educational programs. On the positive side, there should be adequate numbers and a satisfactory mix of biomedical researchers for the future. On the negative side, it is important to avoid possible adverse effects on educational programs outside the research sphere.

Academic medical centers are a major source of graduate training for basic biomedical research. The medical school basic science departments train many of the Ph.D.s who will pursue biomedical research careers in academic and other settings. Of course, the vast majority of the country's research-oriented M.D.s receive their undergraduate and graduate medical education in academic medical centers in the United States. Moreover, they almost always receive their research training as clinical fellows in major teaching hospitals or as postdoctoral fellows in medical school basic science departments.

The mechanisms for federal influence on the centers' production of biomedical research manpower are its various grants for research and research training—the common research project grants, center grants, training grants, fellowships, general research support, and so on. Federal policy must be concerned with the response of centers to both increased and decreased funding in each of these areas. Apart from the direct effects of particular programs, the government needs to take account of the effect on research career education of overall changes in research funding to a center.

Concern over adverse effects of research generally focuses on both undergraduate and graduate M.D. training. In the case of undergraduate medical education, research-intensive centers are thought to influence their graduates toward nonprimary care fields of the medical profession. In the case of graduate medical education, research is thought to increase the size of house staff programs above levels that can be justified by their contributions to patient care.

In this section, we examine both the positive and the negative sides of the alleged effects of biomedical research funding. First, we analyze the effects of various classes of NIH funding on basic science department enrollments and Ph.D. production. Second, we examine effects of changing NIH policies toward training grants on the enrollment of and funding for graduate students in the basic sciences. Third, we examine the effects of research funding on the size of graduate medical education programs in medicine. Finally, we analyze data on physician specialties and career types to find evidence of the effects of the research intensity of the center in which they received their undergraduate medical education.

BASIC SCIENCE DEPARTMENT ENROLLMENT

Basic science departments of medical schools fill a multiple role. They contribute to medical education by teaching a portion of the undergraduate medical students' program, and they train masters and doctoral students in the sciences themselves. They undertake research on their own and in conjunction with private corporations. Basic science faculty members do not, as a rule, engage in direct patient care.

There are six main basic science departments: anatomy, biochemistry, microbiology, pathology, pharmacology, and physiology. In recent years, biophysics, cell biology, and genetics have also become important enough in some medical schools to warrant separate department status. The department of pathology is somewhat special because it is also a clinical department; that is, it is directly related to patient care. Pharmacology also has some clinical aspects.

The Ph.D. graduates of basic science departments pursue a wide range of careers in industry, medical laboratories, higher education, and elsewhere. We have not attempted to examine the market for graduates in detail but we have found some evidence of an appropriate balance between supply and demand. The number of budgeted but unfilled full-time faculty positions in medical school basic science departments has stayed in the 3-6 percent range, an indication that departments are interested in hiring new faculty if they are good enough, but not a sign of critical demand. The number of postgraduate fellowships has been rising slowly, but in approximate proportion to the number of Ph.D.s produced. Field trips to several medical school basic science departments, undertaken as part of an earlier study, indicated that the departments usually placed their graduates after some effort. To a certain extent the department of pathology is an exception; there seems to be a continuing shortage of pathologists.

Maintenance of the market for basic medical scientists constitutes an important motive for studying the role of federally funded biomedical research in the determination of student enrollment. At the same time, it should be kept in mind that research funds influence other department characteristics, such as the size and quality of the faculty, the quality of the students, and the research itself. On the basis of historical records we have examined, it would be improper to draw conclusions about the desirability of increasing or decreasing research funding for the purpose of influencing enrollment. Also, it is difficult for us to say what might happen if the levels or distribution of funding were drastically changed. What we can do is provide some insight into how the existing institutions have been working.

The basic instrument through which federal biomedical research funding affects enrollment is the department budget. As described in Carter et al.,[1] budgetary inputs consist of department gifts and endowments, medical school deans' funds, private research grants and contracts, federal training grants, federal research grants and contracts, and university controlled funds. Competing claims on the budget include faculty salaries, administrative costs, research expenses, and student stipends.

There are (at least) three theories on how basic science department enrollments are affected by available funds. The first is that departments base their admissions or cutbacks on whatever funding is supplied to them. Under this hypothesis, only funding in the current and immediate past year matters. The second hypothesis is that departments admit whom they please and provide support as best they can for

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[1] Grace M. Carter, David S. C. Chu, John E. Koehler, Robert L. Slighton, and Albert P. Williams, *Federal Manpower Legislation and the Academic Health Centers: An Interim Report*, The Rand Corporation, R-1814-HEW, April 1974.

those who enroll. The third hypothesis is that admissions are determined by such a mechanism as the central administration or the anticipated market conditions. In all probability a combination of these factors is at work, with the situation differing from school to school.

Site visits to ten medical schools, as reported in Carter et al., provide some clues to what basic science department chairmen and medical school deans think happens. That report says,

> The size of the basic science program is largely determined on a department by department basis, subject to little control bv central medical school or university administration. The determination of size tends to follow the research strength of the departments closely since the reputation of the department determines the number of applicants who will apply and the availability of research grant funding for the support of graduate students. The number of places offered by departments is closely related in general to the student aid available.

Data Sources

Two main data sources were available for research. First, the Longitudinal Committee on Medical Education of the American Medical Association and the American Association of Medical Colleges conducts an annual survey of medical schools. Many of the results are published in the annual JAMA Supplement on Medical Education. From these we obtained for the years 1963-1974 (i.e., 1962-63 to 1973-74) counts of enrollment in masters, doctoral, and postdoctoral training, and degrees granted in the important basic sciences departments (the six listed at the beginning of this section), as well as a total over all departments. This information was coded on a school-by-school basis. Although this survey is the best source of enrollment data that is readily available, it is not particularly well checked for accuracy and consistency from year to year. In the sample of ten schools that we surveyed in a previous Rand study, we found several discrepancies. However, the total number of errors seems to be small enough that the net effect on our results is negligible.

The other main data source is the IMPAC file supplied by NIH. This contains all awards distributed in fiscal years 1967 through 1975. For the purposes of this research, we aggregated the awards by grant type within school, department, and year. We also recorded grants that were awarded to hospitals affiliated with each medical school department.

For each of the departments, 16 types of funding totals were available to us. These were:

(1) Research project funds (code R). These are usually small grants (less than $50,000) generally awarded to one faculty member (principal investigator) for a specific research project. The funds usually pay a part of the faculty member's salary and may partially support some graduate students who serve as research assistants.

(2) Training grants (code T). Awarded directly to the institution for the support of graduate students.

(3) General Research Support grants (code S). Awarded directly to the

controlling institution according to a formula applied to all research grants obtained by that institution. These have been phased out since 1974.

(4) Fellowship grants (code F). Awarded directly to students for their education. For the most part, these students have just earned their degrees and wish to pursue independent research.

(5) Career development awards (code K). Awarded to junior faculty members who show unusual promise in research, giving them an individual means of support.

(6) Program project (code P). Awarded to several faculty members for their research project.

(7) Clinical research center (code M). Pays for bed costs and staff in a clinical research project.

(8) Other.

(9) to (16) correspond to (1) to (8) except that they apply to hospitals that are affiliated with the medical schools. In cases where a hospital was affiliated with more than one school, funds were divided in the same ratio as the research funds that were awarded to the medical schools directly. The formula was applied within individual departments.

We have combined R, K, P, and M grants into a single category, which we call research. We also made calculations separately with similar results. Since the two data sources overlap for the years 1967-74, our results apply to that period only. All funding levels are reported in units of a thousand 1964 constant dollars, with Halstead's Higher Education Price Index used as the conversion factor.

Trends

Table 1 shows the overall trends for enrollment and funding per 1974 medical school department. Only the six major departments are included. Enrollment has remained almost steady with some increase in microbiology, pathology, and pharmacology. Ph.D. production has increased steadily, reflecting the large increases in enrollment that took place immediately before 1967. In constant dollar terms, research funds have increased, but training grants and General Research Support grants have decreased, although some funds were restored in 1974. Hospital grants are small compared with other money. In most cases, they probably differ little from grants to clinical departments except that they generally go to faculty members who are primarily attached to the recipient hospital that has decided to maintain a research program administratively separate from the medical school.

Further Analysis

The enrollment data described above are listed by year, school, and department, which may be viewed as three factors that explain differences in enrollment, Ph.D. production, etc. The effects of these factors can be examined in an analysis-of-variance framework to determine their relative influence as well as interactions

Table 1

TRENDS IN BASIC SCIENCE DEPARTMENTS
(Average Per Unit)

	Students			$1000's (1964 dollars)			
Year	Ph.D.s	Enrollment	Postgraduate Students	Research	Training	Hospital	GRS
1967	0.80	9.7	1.98	124	32.7	6.06	170
1968	1.23	10.5	1.99	125	30.8	5.51	189
1969	1.22	10.3	1.60	122	31.5	5.14	178
1970	1.31	9.6	2.24	110	26.7	4.12	158
1971	1.33	10.7	2.16	114	25.2	3.64	143
1972	1.41	10.6	2.94	130	25.3	3.64	131
1973	1.34	11.1	2.63	127	18.4	3.71	47
1974	1.45	11.5	2.62	148	27.1	3.60	174

NOTE: "Units" are all departments at 1974 medical schools, so totals are (114 x 6) times values shown. The one exception is GRS units, which are schools. A given department is entitled to a small fraction of GRS funds only.

among them on dependent variables of interest (e.g., enrollment, research funding). A school by department interaction, for example, means the extent to which departments within schools differ in enrollments depending on the schools. Such a difference might arise if the anatomy department was strongest (or largest) at one school and the biochemistry department was strongest at another. Table 2 shows an analysis of variance breakdown for enrollments, Ph.D. production, research, training, and GRS funds.

The interpretation of Table 2 is that most of the differences observed are differences between schools. Some schools are large and rich in every respect, others are small and poor. The dominance of this status quo prevents a decisive statistical investigation into the effect of funding on institutional quality. There are also large effects due to the tendency for some departments to be large in some schools but small in other schools. Frequently, the school by department interaction in enrollments is due to large (small) biochemistry and microbiology departments and small (large) anatomy, pathology, and pharmacology departments at the same school. However, this phenomenon did not carry over to research funding.

We also noticed that time trends account for a substantial portion of the school by department by year interaction variance. Such trends describe the changes in the relative standing of departments within the school and the relative standing of the school within a basic science field.

Another analysis we performed involves regressing enrollments (masters plus doctorate degree candidates) on the various funding types available in the same year. The departments were considered individually as well as collectively. Forty variables were available for the regression (30 in the case of departments considered collectively). The 40 variables arise from taking five funding types (research, training, fellowship, GRS, and other) by two routes (school and affiliated hospital) by four department types (the department itself, the rest of the basic science departments, the clinical science departments, and other departments). In the collective analysis

Table 2

ANALYSIS OF VARIANCE RESULTS FOR BASIC SCIENCE DEPARTMENTS 1967-74

		% Variance Explained				
Term	df	Enrollment	Ph.Ds	Res. Funding	Training Grants	GRS
School	113	44.3	28.3	50.5	44.4	67.0
Department	5	9.9	7.6	2.6	1.1	--
Year	7	0.0	0.0	0.0	0.0	12.5
Slope	1	0.0	0.0	0.0	0.0	3.6
Residual	6	0.0	0.0	0.0	0.0	8.8
School x Department	565	22.9	20.2	31.7	34.1	--
School x Year	791	8.9	11.2	3.0	4.4	20.5
Slope	113	2.5	2.4	1.6	2.1	9.3
Residuals	678	6.4	8.8	1.4	2.3	11.2
Department x Year	35	0.1	0.2	0.4	0.2	--
Slope	5	0.0	0.0	0.0	0.0	--
Residuals	30	0.1	0.2	0.4	0.2	--
School x Department x Year	3,955	13.8	32.5	11.8	15.8	--
Slope	565	4.8	5.8	6.6	7.0	--
Residuals	3,390	9.1	26.7	5.2	8.8	--

there are only three department types, since basic science department funding covers both the department and its complement.

It is not reasonable to include all 40 variables in the same equation because almost half the funding types are moderately and positively related to enrollment and most are not physically relevant. Nevertheless, one can draw some conclusions about the relative influences of the different funding types. The overall conclusion, based on regressing basic science enrollments as a total on the 30 relevant variables, is that the training grants to the basic sciences, research funds to the clinical sciences, and school funds are the most important quantities. Once these variables are controlled for, basic science research funding has little additional effect.

Within the departments, we list the selected variables by decreasing significance (and order of entry). For anatomy, the significant variables were training grants and GRS grants. For biochemistry, GRS grants, training grants, and training grants in the other basic science departments were significant. For microbiology, research in the clinical sciences and training grants were important. Other limiting factors than money on enrollment in pathology reduce the explanatory power of the regression, but training grants are still significant. In pharmacology, training and GRS grants are the most significant, but research in the hospital and the school seems to play a part, as do training grants in hospitals of the clinical science departments. The last result may be a statistical aberration or it may describe a tendency for clinical hospital programs to draw resources away from pharmacology in a basic science setting. In the physiology departments, GRS grants, training grants, and research in the school and hospital physiology department were significant. The r^2 levels for these regressions range from 0.25 to 0.6.

A similar set of regressions was run for Ph.D. production. However, the results generally parallel the enrollment results, so they are not discussed here.

When we control for training grants and school funds, research funds have a small but positive effect on enrollment in every basic science department studied and are statistically significant in two of the six departments. We conclude that although research funds may be important to the existence of a department that can train people, it is the training grants and school funds that actually determine how many are to be trained. Since this analysis establishes only a relationship and not a cause, we must caution that the effect could go in either or both ways: Training grants may cause enrollment or enrollment may cause grants, or institutional characteristics may give rise to both simultaneously. We explored the reasons for the regression results by regressing effects calculated in the analysis of variance tables on quantities obtained for similar units. For example, one of these regressions sought to explain the changes over time in enrollment at each of the schools as a function of school averages for enrollment, funding of various types, and funding change. One striking finding was that levels of enrollment are well explained by levels of funding, but changes over time are not. However, these changes are reasonably well explained by basic levels of both funding and enrollment: The larger departments have added more students and Ph.D.s than the smaller departments. These conclusions apply to the individual departments and averages across departments (within schools). Although this tendency may be an artifact of growth at equal rates across schools, it does indicate where most of the extra graduates are being trained. Since the technical theory supporting the regressing of analysis of variance effects is poorly developed, we caution against placing too much emphasis on these results; however, they suggest that the major features of enrollment differences across schools and departments are imbedded in long term characteristics of the institutions.

We performed several regressions with 1973 enrollment as the dependent variable, with previous years' funding levels and enrollment levels as predictors. Each department was considered separately. The results are similar for all departments. One or perhaps two of the previous years' enrollments explain the current year better than any of the research, training, or general research support award levels. The r^2 values for regressions on the last two years of enrollment alone range from 0.47 (pharmacology) to 0.91 (biochemistry). With funding variables included in the regression, training grants contribute the most in additional explanatory power, although the contribution is only marginally significant and 1973 training grants are generally more important than those of previous years. Similar regressions using 1969 to 1972 enrollments as the dependent variables indicate somewhat stronger effects of research and training grants in the earlier years. The contribution of funds to the change in department size is not statistically overwhelming. Because only about 100 schools are available for any given department and year, effects large enough to be policy relevant may not be statistically detected.

For the earlier years we cannot tell whether the strong relationship between enrollments from year to year represents funding sources missing from these equations or a tendency for departments to manage support for the students they want to have. We suspect that growth was erratic, depending on the availability of such scarce resources as staff, students, and money. The year 1973 marks a turning point, since in that year schools were hard pressed to support the students they had. However, it appears they were able to find the money and have continued to expand, perhaps on a more conservative basis. New funding and enrollment figures should be consulted when available for an appreciation of more recent trends.

Summary of Findings

Many federal research and research training programs were directed at the basic medical sciences. Using individual departments as the unit of analysis, we examined the effects of various federal programs on enrollment and doctorate production. Although the general trend is one of doubling of size, there are, as one might expect, significant differences among institutions and across disciplines. Taking these into account, the effects of federal programs are still quite strong. Among federal programs, research training funds received by a department appear to have the strongest effects on its enrollment and Ph.D. production. The amount of a center's general research support grants (formula grants based on a school's overall research funding) also significantly affected enrollment and probably reflected the overall research intensity of a center. After these two federal funding effects were controlled for, research funds to the individual departments had only a very small positive effect on educational program size.

We also found that the graduate enrollments and Ph.D. production of the centers respond to the long term levels of federal support but do not appear to be very sensitive to short term fluctuations.

CHANGES IN STUDENT FINANCIAL SUPPORT

Conceptual Model and Policy Questions

The National Institutes of Health have supported research training in the biomedical sciences since 1938 as part of their mandate to study the physical and mental diseases of man. Since World War II, much of this support has been in the form of training grants to institutions, paying both the salaries of the faculty and the stipends of the students. Training grants were awarded for three types of activity: pre-Ph.D. training in the basic sciences (e.g., anatomy, physiology); postdoctoral training of Ph.D.s; and postdoctoral training of M.D.s, often combining both laboratory and clinical study.

As the general level of NIH activity reached a plateau in the late 1960s, so did appropriations for research training. Some members of the executive branch began to ask whether federal support is needed to assure an adequate supply of high quality manpower in these areas. Secretary of HEW Weinberger attempted to reformulate the nature of federal support for research training, but before his programs could get off the ground, Congress passed the National Research Act of 1974. The act repealed all existing authorities for NIH support of research training and created a new program of National Research Service Awards. These awards may be fellowships given directly to individuals by the federal government, or grants to institutions who in turn select the recipients. Congress and the executive branch are still engaged in dialogue about how this act should be implemented. It is clear, however, that as a result of these discussions there may be significant changes in assistance for training in the basic biomedical sciences. It is therefore of interest to examine how changes in this support might affect the number of Ph.D.s trained.

To better understand what the effects of changes in federal support might be on Ph.D. training, it is useful first to ask why the basic science departments in academic medical centers have Ph.D. programs. First, and perhaps most important, is that the training of Ph.D. students is viewed as one of the principal activities of such a department. Second, it is widely believed that it is necessary to have a strong Ph.D. program to attract good faculty. Third, Ph.D. students play an important role in the research program of the institution by serving as junior professionals in a larger research team. Finally, in some of the basic sciences—such as anatomy—the students assist in the teaching program by instructing M.D. students.

The number of graduate student positions that a department offers depends on the age of the department, its perceptions about long run demands for trained people in the field, the size of its faculty, the size and nature of its research effort, the amount and nature of its M.D. teaching responsibilities, and the number and quality of applicants for graduate positions in that field of study. The number of applicants, in turn, is a function of job opportunities for graduates in the field, and of the amount of scholarship support available. A large part of that scholarship support currently comes from the federal government, and changes in such support will obviously have an effect on the number of students trained. Changes in federal funding of departmental expenses, through their influence on faculty size, will also affect the number of trainees.

Data Sources

We are currently gathering the data on enrollment and sources of student support with which to investigate how large the effects of any particular change in federal support will be. Until we have enough of these data, we do have an alternative way of gaining some understanding of how changes in federal support for Ph.D. training in the biomedical sciences would affect enrollment in those programs. That alternative consists of information provided by a "natural experiment" that occurred in 1973, when the executive branch attempted to cut back on training grant funds. During the fall of 1973 we collected data from the departments of anatomy, biochemistry, microbiology, pathology, pharmacology, and physiology in the ten medical schools with which we were working closely. These data focused on graduate student enrollments. They were collected after the termination of the traditional training grant programs and the inception of the so-called Weinberger fellowships had been announced, but before the court cases on impounded funds had been decided, and before Congress had passed the National Research Act of 1974. Thus departmental decisions were taking place in an environment in which department chairmen *thought* that future federal support for graduate training might be substantially reduced. Moreover, most departments could not use their FY 1973 training grant funds to appoint new trainees at the first-year level.

We asked the departments to provide us the actual numbers of Ph.D. students in FY 1971 through 1974, the likely number for first-year students for FY 1975 if training grants continued, and the likely number if training grants were terminated. Responses are tabulated in Tables 3 and 4. The tabulations include both departments with training grants and those without such federal support.

Data Interpretation

It might be argued that we should confine our attention to departments currently receiving federal funds (28 of 54 departments when these data were collected).

Table 3

ACTUAL PH.D. MATRICULATION

Field	Number of Departments Responding	Number of First-Year Students FY71	FY73	FY74
Anatomy	7	15	17	17
Biochemistry	9	35	42	49
Microbiology	6	31	43	15
Pathology	4	8	17	8
Pharmacology	5	14	19	11
Physiology	6	38	27	44
TOTAL		141	165	144

Table 4

PROSPECTIVE PH.D. MATRICULATION

Field	Number of Departments Responding	FY74 Actual	FY75 with Training Grants	FY75 without Training Grants
Anatomy	6	17	17	14
Biochemistry	8	47	49	33
Microbiology	5	14	36	14
Pathology	4	8	20	6
Pharmacology	5	11	21	10
TOTAL		134	191	105

However, there are two reasons for believing the effects of the change of policy will not be limited to the departments directly concerned. First, our interviews with the department chairmen indicated that the prospect of federal funding provides a significant incentive to start or improve a Ph.D. training program. Thus, the reduction of the federal training grants would affect both departments currently receiving training money and those without such support. Second, each school has a limited amount of funds available from its own resources to support the Ph.D. program. Reductions of federal support for one department may mean that this "dean's money" must be spread over more departments. Thus, cutbacks in one area can affect other departments within the school.

It is important to recall that students matriculating in FY 1974 (see Table 3) could be covered only if the program had made the commitment before January

1973. Thus the effects of withdrawing federal support are visible in FY 1974 behavior of basic science departments.

For the departments as a group, the cutback reduced first year enrollment by 13 percent (see Table 3), returning enrollment to the FY 1971 level. However, much of the reduction was concentrated in departments of microbiology, pathology, and pharmacology; enrollments in biochemistry and physiology actually increased.

Assuming the restoration of training grant funds was not to occur, the department chairmen predicted a further 22 percent decline in matriculation in 1975 (see Table 4). In contrast to Table 3, declines now occur in biochemistry and physiology.

If these forecasts can be believed, and if these departments are typical of departments in all academic medical centers, withdrawal of federal training funds would lead to a short run reduction of approximately 30 percent of Ph.D. matriculation. This reduction would not be spread uniformly among the various basic sciences. This natural experiment suggests that the steepest declines would occur in microbiology, pathology, and pharmacology, and the departments of anatomy, biochemistry, and physiology would be less affected.

HOUSE STAFF SIZE

In contrast with education in the basic sciences, clinical education fundamentally involves patient care. Treating patients in affiliated hospitals provides the experience necessary to a medical school's clinical training, while clinical faculty, house staff, and medical students together contribute substantially to serving patients' health care needs.

With patient care rather than research occupying the core of clinical education, it is unclear whether the role of research funding in determining house staff size would be similar to its role in determining basic science enrollments. It might be argued that the constraints and responsibilities imposed by patient-care activities limit the effects of research funding. For example, even if increased research funding contributed to a desire to expand house staff size, expansion might be inhibited by a lack of adequate numbers (or kinds) of teaching patients in affiliated hospitals.

Alternatively, it might be argued that despite the need for teaching patients, house staff size remains subject to discretion: When research funding is high, major teaching hospitals in particular may expand house staff, increasing staff-patient and perhaps even staff-faculty ratios but exposing house staff to broader experiences in clinical research. A concern reflected in this hypothesis is that high research funding may cause house staff size to expand beyond levels appropriate to the availability of teaching patients.

This study examines the hypothesis that higher levels of research funding are associated with larger house staffs than would otherwise be found given the availability of teaching patients. Data available for this study permit us to examine relationships between house staff size and measures of both patient availability and NIH research funding for six yearly cross-section samples of departments of medicine; measures of faculty size can also be included as control variables for three of the years.

Although the analysis does not provide a test of the hypothesis that house staff size is constrained by patient availability, the possibility that institutions are constrained has important implications for interpreting the results presented here. Therefore, we begin with a discussion of the possible role of patient availability constraints. Then we describe the data, the empirical methods, and the results of the analysis.

Implications of Patient Availability Constraints

A number of factors may be taken into account by a clinical department, its medical school, and its affiliated hospitals in reaching a decision concerning house staff size. House staff provide valuable services in patient care, in research, and in undergraduate clinical training; a large and high-ranking house staff training program may even help attract respected clinical faculty. At the same time, house staff must be given adequate experience in treating various health conditions, they must have adequate access to faculty, and they must be supported financially. Future expectations, historical background, and other characteristics specific to individual institutions may also affect house staff size.

The view that many factors affect house staff size is not necessarily inconsistent with the argument that patient availability imposes a constraint on house staff size. As shown in a highly simplified fashion by the solid line in Fig. 1, there may be a maximum acceptable house staff size that is consistent with each level of patient availability, but below which house staff size might vary among institutions. For example, suppose H_A, H_B, and H_C are alternative levels of house staff size that would be desired, depending on research funding, faculty size, or other factors. An institution with patient availability P* could choose house staff size H_A (at point A) or H_B (at point B), but could not achieve level H_C because point C lies above the constraint.

Although institutions that are not constrained by patient availability could be very responsive to effects of research funding, a constrained institution would not increase house staff size regardless of changes in funding, and might reduce house staff size only in response to a major change in funding. For example, even if funding

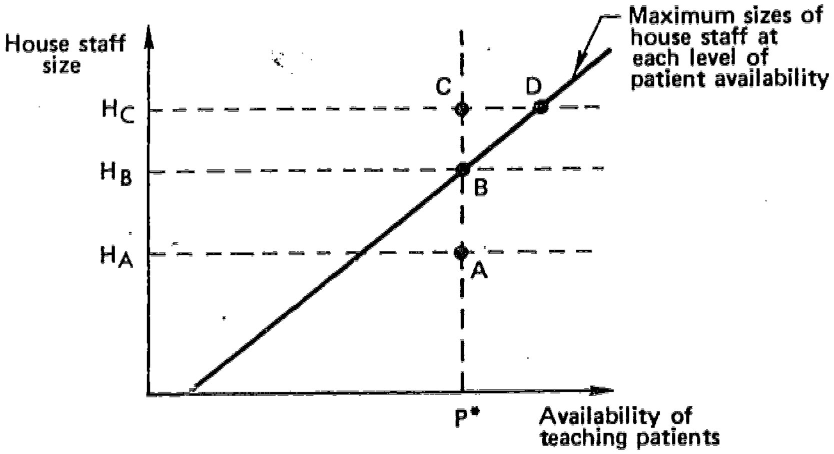

Fig. 1—Patient availability constraints on house staff size

changes caused desired house staff size to shift back and forth between H_B and H_C, the institution at point B in Fig. 1 would not make any change in house staff size; the institution would respond only to a change in funding sufficient to make the desired house staff size smaller than level H_B.

In principle, patient availability constraints are a short term phenomenon: Over time, staff size might be expanded by extending affiliation arrangements. For example, the institution in Fig. 1 might eventually achieve level H_C by expanding patient availability and moving to point D. In reality, however, patient availability constraints may also prove to be a longer-term phenomenon. Many institutions have largely exhausted their locally available affiliation opportunities and many affiliated hospitals are experiencing declining patient loads. In some specialties (e.g., OB/GYN) declining patient availability is a trend expected to continue for some time into the future.[2]

The present study does not address longer-term responsiveness to research funding. To do so, we would require more detailed time-series data on affiliation behavior than are available to us. In any case, our primary interest is in whether high research funding causes larger house staff size than would otherwise be found, *given patient availability.* The analysis examines research funding effects among cross-section samples of institutions, each of which faces a currently fixed availability of patients and some of which may face current constraints on house staff size because of patient availability.

In our cross-section data, we observe many different combinations of house staff size and patient availability. As shown below, the data consistently reveal a tendency for house staff size to be larger in institutions with larger patient loads, but the data do not provide a means of determining whether any of the institutions in our samples have been constrained by patient availability. Therefore, our estimates of the effects of research funding may be based on behavior of an unknown mixture of constrained and unconstrained institutions.

A consequence of using a mixed sample is that the results might underestimate funding effects in unconstrained departments and overestimate funding effects in constrained departments. The results are best interpreted as a general statement about "average" behavior for the nationwide set of institutions. However, even this interpretation would be relevant only to the particular mix of constrained and unconstrained institutions reflected in our data. If patient availability does impose constraints on house staff size, the number of institutions facing constraints can be expected to increase over the next several years, and the "average" responsiveness to such factors as research funding would be expected to decline from levels that might be observed in our data.

Data Sources

Measures of house staff size and patient care activities by department were obtained from the American Medical Association, *Directory of Approved Internships and Residencies* (Green Book). The time required to prepare these data (as described below) necessitated a decision to focus on a single clinical department for analysis. We have chosen to analyze medicine because of its importance in the clinical train-

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[2] It is observed that major teaching hospitals have been increasing their share of the market-wide availability of beds. This also is a trend that cannot continue indefinitely.

ing curriculum and the fairly close correspondence in scope of activities between the hospital service (internal medicine) and the medical school department.

To allow for analysis of several recent years of data, we obtained data from the Green Books for academic years 1967-68 through 1969-70, but excluding 1970-71 because the Green Book was not published that year. The sampling frame for the analysis consisted of medical schools in the list of Medical School Affiliations from each issue of the Green Book. For each such school, we prepared a list of hospitals with major affiliations (as defined by the Green Book) in each year as indicated in the Consolidated List of Hospitals. Then we obtained data on the annual admissions, average daily census, and annual out-patient visits for internal medicine in each affiliated hospital from the List of Approved Residencies. The last also provided data on the total number of residency positions available in the hospital, while the List of Approved Internships provided the total number of internships available. Finally, each of these variables was summed over all the hospitals affiliated with each school. This process yielded six yearly samples, each covering roughly 70 to 80 departments of medicine.

Note that the numbers of residencies or internships refer to positions available for the year addressed by each Green Book, whereas the patient load data reflect conditions in each hospital two years earlier. (For example, admissions data from 1970-71 would be obtained during 1971-72 for publication of the 1972-73 issue of the Green Book.) It is assumed here that the patient load data reported in a particular issue are those that were relevant to the choice of the number of house staff positions offered in that issue. Further, we assume that each school and hospital in the sample expected to fill all available positions.[3]

Data on faculty size in departments of medicine were obtained from the Information Profile System of the Association of American Medical Colleges. These data were available by category of faculty (e.g., full-time, associate professors) but could be matched with Green Book data only for academic years 1971-72, 1972-73, and 1973-74. NIH research funding data were obtained, by category of grant, from the IMPAC file.[4] If a grant was made to a hospital, we included the funding data for the school with which the hospital was currently affiliated. These funding data are available for all the years for which house staff size data were collected.

Of the three data sources, the Green Book seems most likely to contain reporting or coding errors; to eliminate the most egregious, we calculated average lengths of stay (based on admissions and daily census data) and omitted any observation that yielded values greater than 30. Moreover, we examined the time-series of data for each school and deleted observations where the value of a variable was not within a plausible range of variation. Similar cleaning procedures were applied to the remaining data sources, but always with due caution to avoid biasing results in the research.

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[3] The National Intern and Resident Matching Program reports that approximately 72 percent of *all* available positions in 1975 were filled by the program and has informed us that this has been typical of earlier years; hospitals with major affiliations (such as those in our sample) have a better-than-average chance of filling positions through the program, and some additional positions are filled by nonparticipants.

[4] We used the grant description to assign funding to departments by matching each grant title with department titles and codes in the Faculty Roster File. The file is maintained by the Association of American Medical Colleges. Faculty data are collected by surveying individual institutions, and the AAMC assigns department codes to the department titles submitted in the surveys.

Problems with Proxies

The data used in the analysis do not necessarily reflect the variables most desired for study. In some cases, the analysis was modified to accept the kinds of variables on which data were available, while in other cases we assume that the data provide approximate measures (proxies) for the variables of interest. For example, although we assume that current house staff size reflects expectations about the availability of teaching patients (among other factors), our data measure the total availability of patients in a previous period. In the analysis we assume that previous patient loads are a measure of current expectations and that the availability of teaching patients is approximately proportional to the total availability of patients.

The measures of house staff size pose somewhat more difficult problems. First, the designation of internships and residencies may vary among schools and over time; in at least some cases, internships and residencies may not differ in any substantive way. Therefore, we consider the hypothesis that total house staff size, rather than internships and residencies separately, is the variable of interest.

A second problem is that the data used here measure positions to be filled rather than total house staff size though the analysis is concerned with determination of the latter. We treat positions offered as a proxy for program size, according to the following reasoning:[5] In each year, the number of available positions reflects replacement of losses due to attrition or completion of training, plus a factor (positive or negative) reflecting the desired change in overall program size. If the desired overall change is zero, then number of positions offered is a proxy for program size. If most schools are at their desired program size in a given year, schools with larger numbers of offered positions are those with larger program sizes. If most schools were, say, expanding by roughly the same proportions, then positions offered would continue to reflect cross-sectional differences in program size. However, in comparison with years in which most schools were not expanding, positions offered would be larger, across the board.

Finally, measures of total faculty size may not be appropriate proxies for the variables of interest here. We might suppose that house staff size is affected by faculty time available for the joint activities, teaching and patient care. Total faculty time, as measured by faculty size, includes time devoted to other activities—research in particular. Thus, faculty size variables may act as proxies for research funding as well as for the variable (time for patient care and teaching) we wish to measure. The implications of this for the empirical analysis are discussed in more detail in the section on empirical methodology, below, and in Appendix A to this section.

Patterns and Trends

Table 5 presents the means and standard deviations of house staff positions and patient load data among medical schools for the six annual samples. Certain patterns are apparent in the data, though it should be emphasized that none of the variable means differ in a statistically significant manner among the six samples.

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[5] We have considered alternative hypotheses about the relationship between positions available and program size. In particular, we tried alternative specifications reflecting the hypotheses that positions available include replacement of losses from the program in the preceding year plus the desired change (positive or negative) in current program size. The resulting specifications did not yield new information, so in the results presented here, positions available are used simply as direct proxies for house staff size.

Table 5

MEANS OF HOUSE STAFF SIZE AND PATIENT LOADS, SIX ANNUAL SAMPLES[a]

VARIABLE	YEARS 1967-1968	1968-1969	1969-1970	1971-1972	1972-1973	1973-1974	COMBINED 1967-1970	COMBINED 1971-1974
RESIDENCIES (RES)	52.8 (27.5)	55.2 (27.8)	45.5 (27.7)	58.2 (39.2)	55.8 (37.5)	57.8 (35.3)	44.5 (27.7)	57.2 (37.4)
INTERNSHIPS (INT)	45.1 (27.4)	36.3 (25.0)	35.1 (25.5)	42.4 (27.9)	38.9 (22.5)	36.7 (23.1)	37.5 (25.7)	39.3 (24.7)
ANNUAL ADMISSIONS[b] (ADM)	8841 (6012)	8520 (5178)	8558 (5663)	10,602 (7783)	10,592 (6816)	10,877 (6563)	8605 (5624)	10,687 (7070)
AVERAGE DAILY CENSUS[b] (ADC)	371 (240)	383 (245)	352 (239)	388 (276)	403 (269)	372 (252)	371 (244)	388 (266)
OUTPATIENT VISITS[b] (OPV)	52,654 (30,597)	58,910 (42,911)	53,503 (36,847)	57,216 (60,131)	60,419 (49,028)	71,061 (59,492)	48,163 (40,358)	62,787 (56,546)
AVERAGE LENGTH OF STAY[b] (ALS)	15.7 (4.4)	16.5 (5.1)	15.2 (3.8)	13.9 (3.5)	14.1 (4.3)	12.6 (2.9)	15.8 (4.1)	13.5 (3.7)
RES/ADM	.006 (.003)	.006 (.004)	.006 (.003)	.006 (.003)	.006 (.003)	.006 (.003)	.006 (.003)	.006 (.003)
RES/ADC[c]	.15 (.09)	.15 (.09)	.16 (.09)	.17 (.08)	.17 (.10)	.18 (.08)	.15 (.09)	.17 (.09)
INT/ADM	.005 (.003)	.005 (.004)	.005 (.004)	.005 (.003)	.004 (.003)	.004 (.002)	.005 (.003)	.004 (.003)
INT/ADC[c]	.13 (.11)	.12 (.09)	.13 (.08)	.13 (.08)	.13 (.11)	.11 (.06)	.13 (.09)	.12 (.09)
SAMPLE SIZE	69	72	69	72	78	73	210	221

[a] Standard deviations in parentheses.

[b] Patient load measures for Internal Medicine Services of hospitals having major affiliations with each school.

[c] When divided by 365, yields a measure of house staff per patient day.

The patterns in the data are most apparent when the first three years are compared with the last three. Between the two periods, there seem to have been increases in numbers of residencies, in annual admissions, in outpatient visits, and in residencies per patient day (as indicated by the ratio of residencies to average daily census). Average length of stay seems to have declined between the two periods; this may reflect a changing patient composition either within hospitals or through changes in the nature of affiliation arrangements.

Aside from the general features of the two periods, there are noticeable peaks for 1971-72 in residencies, internships, and annual admissions; and there is a sizable step up in annual admissions, average daily census, and out-patient visits between 1969-70 and 1971-72. Since the data measure available house staff positions rather than total house staff levels, the peaks for residencies and internships may indicate that schools were moving to a higher level of house staffing in 1971-72. A second upward movement in residencies appears to have occurred in 1973-74.

Since the patient load data are lagged (as noted above), the higher patient loads listed for 1971-72 and 1973-74 could have been responsible for an increase in house staff positions. Notably, the number of residencies and internships available per patient episode (residencies or internships per annual admission) do not vary much between 1971-72 and the other years. These observations are consistent with the hypothesis that house staff size is importantly affected by the availability of patients.

Table 6 lists average NIH funding by category of grant for the same annual samples described by Table 5. For funding, there are few cases in which the two three-year periods exhibit distinctive patterns; instead, there are fluctuations throughout the six years. Research, training, fellowships, and career development grants seem to have declined substantially in 1972-73, but grants labeled "Other" more than compensated, yielding an overall grant level second only to that for

Table 6

MEANS OF NIH RESEARCH FUNDING VARIABLES, SIX ANNUAL SAMPLES[a]

GRANT CATEGORY	YEARS 1967-1968	1968-1969	1969-1970	1971-1972	1972-1973	1973-1974	COMBINED 1967-1970	COMBINED 1971-1974
RESEARCH	$636.6 (645.1)	$575.4 (568.7)	$545.2 (487.8)	$635.1 (551.0)	$577.7 (517.5)	$746.2 (671.1)	$585.6 (302.5)	$650.5 (585.6)
TRAINING	333.0 (280.3)	332.6 (306.3)	311.2 (318.7)	287.6 (238.2)	218.8 (237.0)	311.2 (353.8)	325.7 (302.5)	270.9 (283.0)
FELLOWSHIPS	29.4 (56.9)	26.4 (94.8)	17.3 (41.5)	15.9 (28.2)	9.1 (17.7)	29.2 (47.2)	24.4 (91.7)	17.8 (34.0)
CAREER DEVELOPMENT	69.4 (81.7)	71.8 (94.8)	72.7 (97.5)	62.0 (63.5)	57.3 (65.3)	58.5 (63.7)	71.3 (61.3)	59.2 (64.2)
PROGRAM PROJECT	330.0 (628.7)	316.1 (611.4)	302.6 (315.2)	389.2 (661.7)	492.0 (871.3)	636.9 (969.6	316.2 (321.3)	505.1 (850.1)
CLINICAL RESEARCH CENTER	171.2 (333.7)	153.9 (314.4)	148.3 (315.2)	137.6 (273.0)	140.1 (287.2)	158.5 (293.7)	157.7 (321.3)	145.2 (284.9)
OTHER	--	--	--	--	223.5 (371.0)	--	--	78.9 (244.9)
TOTAL	1,569.5 (1,739.2)	1,476.3 (1,706.0)	1,397.3 (1,620.4)	1,527.4 (1,286.6)	1,718.5 (1,803.5)	1,940.6 (2,007.4)	1,481.0 (1,691.0)	1,727.6 (1,734.8)
SAMPLE SIZE:	69			72	78	71		221

Standard Deviations in parentheses.

1973-74. Average NIH funding over all categories reached its lowest point in 1969-70 for departments in our samples.

The initial analysis of house staff size, reported below, uses the data to which Tables 5 and 6 refer. To include faculty data, the sample was reduced to years 1971-72, 1972-73, and 1973-74. Table 7 presents descriptive data concerning the resulting sample.

Table 7

MEANS OF HOUSE STAFF AND FACULTY SIZE: THREE ANNUAL SAMPLES[a]

VARIABLE	1971-1972	1972-1973	1973-1974	COMBINED YEARS
HOUSE STAFF:				
RESIDENTS	58.2 (39.2)	55.8 (37.5)	57.8 (35.3)	57.2 (37.4)
INTERNS	42.4 (27.9)	38.9 (22.5)	36.7 (23.1)	39.3 (24.7)
FACULTY:[b] FULL-TIME (FACFT)	54.4 (35.0	55.9 (39.6)	60.1 (40.1)	56.7 (38.4)
PART-TIME (FACPT)	12.2 (18.1)	9.2 (9.3)	8.6 (9.3)	10.0 (13.0)
VOLUNTEER (FACVOL.)	139.2 (120.0)	122.6 (85.8)	111.9 (78.9)	124.6 (97.0)
SAMPLE SIZE:	72	78	71	221

[a] Standard deviations in parentheses.

[b] Faculties of departments of Medicine.

Since the same annual samples are used in constructing all the tables, the means and standard deviations of the house staff variables in Table 7 do not differ from the corresponding values in Table 5. The faculty size variables suggest that numbers of part-time and volunteer faculty may have declined slightly between 1971-72 and 1973-74; average full-time faculty size appears to have increased somewhat. These results, together with those in the earlier tables, suggest that there was neither substantial growth nor substantial decline in teaching, patient care, or research activities associated with major teaching hospitals over the period 1971-1974.

Further information about the data is yielded by examining plots of house staff size against measures of patient availability and against NIH research funding. Figure 2 plots the sum of residencies and internships available in each institution against a measure of patient availability that reflects total inpatient days but weights days near the end of an average episode less heavily than days near the beginning.[6] Figure 3 plots the same measure of house staff size against total NIH research funding for each institution. Both figures use data for the academic year 1971-72 (patient data lagged as noted above), but the plots are representative of those for other years.

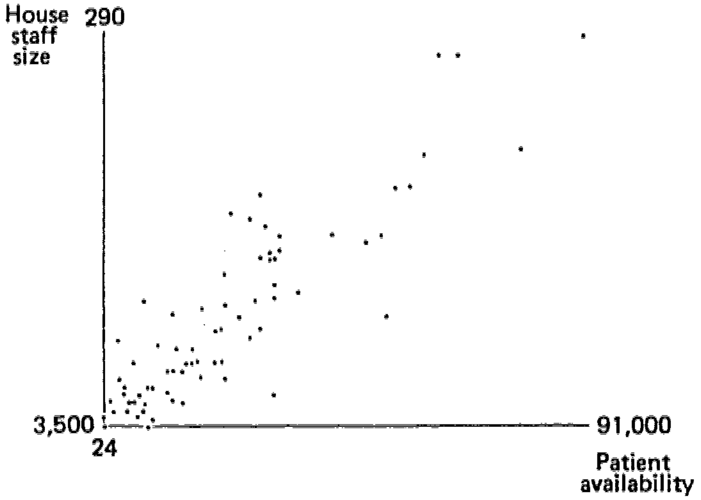

Fig. 2—Plot of data for academic year 1971-72: House staff size and patient availability

In Fig. 2, the observations occupy a fairly narrow band, suggesting that house staff size tends to be larger in institutions with larger patient availability. There also appears to be substantial variation in house staff size among institutions with very similar patient availability. At face value, the figure seems to indicate that there is considerable discretion in setting house staff size and that few—if any—institutions are operating on the kind of constraint line postulated in Fig. 1, above. However,

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[6] The measure is actually defined as the product of annual admissions and the natural logarithm of average length of stay. The conceptual basis for the measure is described below.

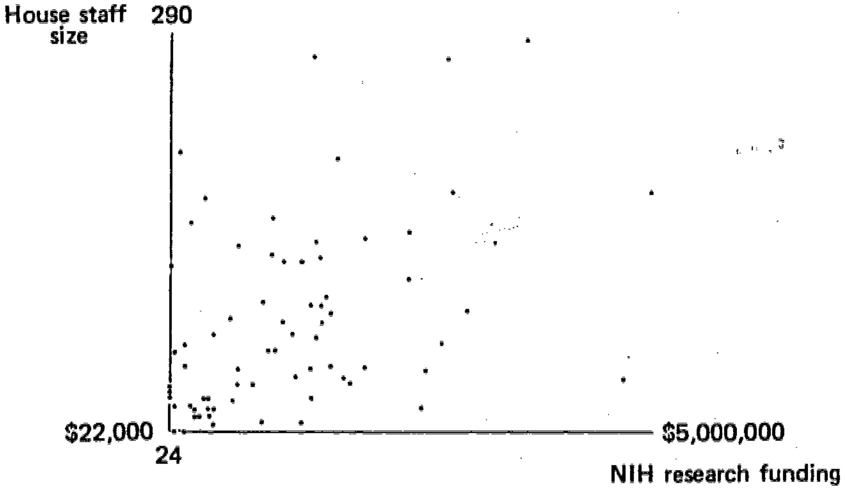

Fig. 3—Plot of data for academic year 1971–72: House staff size and NIH research funding

our measures of house staff size and patient availability are sufficiently crude that we cannot be sure that the "scattering" of points in the figure does not merely represent error. For the same reason, we do not use the data to speculate about which institutions are actually constrained.

In contrast, Fig. 3 shows no obvious relationship between house staff size and the more accurate measure of NIH funding. Although institutions do cluster in the lower left-hand quadrant of the figure, every quadrant contains some observations.

Neither Fig. 2 nor Fig. 3 addresses the possibility that research funding affects house staff size once patient availability is taken into account. To achieve this objective, we turn to multivariate statistical techniques that permit us to relate house staff size simultaneously to both patient loads and research funding.

Empirical Technique

If we used regression analysis to relate house staff size to patient availability, the regression would fit a line through the points illustrated in Fig. 2. Multiple regression allows us to include research funding as an additional explanatory variable. Heuristically, the estimated coefficients of research funding describe whether the vertical distances between observations and the line are systematically related to levels of research funding. For example, a positive coefficient on research funding would mean that an institution with less than average funding would tend to lie below the line, and an institution with higher than average funding would tend to lie above the line.

The results would not tell us, however, whether research funding *causes* an institution to lie on or off the line. An institution may lie on or off the line for a variety of reasons, and it may be true that some other factor that is simply correlated with research funding is actually responsible for variations in house staff size.

Faculty size might be one such factor. We know that faculty tends to be larger in institutions with higher research funding.[7] It is plausible also to suppose that house staff size might tend to be higher (even relative to patient loads) in institutions that have more faculty. If so, faculty size should be included in the equations as a control variable so that the funding coefficient would measure only the effect of funding *net* of faculty size effects. However, there are models of house staff determination that suggest that faculty size should be omitted from the analysis. In particular, if: (1) only the portion of faculty time devoted to teaching and patient care is relevant to house staff size, and (2) faculty time for teaching and patient care is independent of research funding, then *including* total faculty size can yield biased estimates of funding effects.

Appendix A to this section describes several alternative models of house staff determination and lists the empirical implications of including or excluding faculty size variables under each model. This analysis suggests that each equation should be run both with faculty variables and without them. The differences in results between the two specifications can be used to generate additional tentative inferences about house staff determination and the role of research funding.

Analysis and Results

Setting aside, for the moment, the effects of faculty size and research funding, consider the specification of a relationship between patient load and house staff size. Our data provide a crude means of describing both the duration of patient care (average length of stay) and the number of patients treated. Although there may be differences in diagnostic case mix or complexity among hospitals, we have no means of measuring such differences except through their influence on lengths of stay.

To specify the relationship, we initially considered two hypotheses: First, we postulated that each resident or intern spends a certain amount of time, on average, with each patient for each postadmission day of stay; according to this hypothesis, house staff input is a simple function of total inpatient days. Second, we postulated that the amount of house staff involvement with a patient declines continuously (though perhaps slowly) from the first day of stay to the last. A simple means of specifying the second hypothesis is to form a measure of patient days that weights days near the end of an episode less heavily than days near the beginning. One such measure is given by the product of annual admissions and the natural logarithm of average length of stay; this measure was used in Fig. 2, above. A disadvantage of the measure is that it does not offer a very satisfactory means of testing the hypothesis on which it is based.

A second specification is derived as follows: The amount of house staff time devoted to each patient is the sum of the amounts of involvement on each day of an inpatient episode. Using a straight line to describe how daily involvement declines over the length of stay, the basic equation is:

$$\text{HOUSE STAFF INPUT ON iTH DAY} = \alpha + \beta\,(\text{iTH DAY OF STAY}) \qquad (1)$$

where β is expected to be negative to reflect declining daily inputs. Therefore, the

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[7] Evidence on this point is shown in another study in this report. A further variable of potential importance is the number of graduate fellows in an institution. Data on this group are unavailable.

total input for an episode with a given length of stay (LOS) is the integral of Eq. (1) from zero to the value of LOS:

$$\text{HOUSE STAFF INPUT PER EPISODE} = \alpha\ \text{LOS} + \beta\ (\text{LOS}^2/2) \tag{2}$$

where β is still expected to be negative. To get the total house staff input over all patients, Eq. (2) should be summed over all patients. Since we have data only on average lengths of stay and annual admissions, we must approximate the desired sum by multiplying the right-hand side of Eq. (2) by the total number of admissions per year (AA).

The final specification of inpatient load includes two variables, the first of which is annual admissions multiplied by average length of stay (AA × LOS); this variable is equivalent to total annual patient days. If house staff daily input is constant over the length of stay, then only the first variable would have a nonzero coefficient. A test of the hypothesis that staff inputs decline during an inpatient episode is whether the estimated coefficient of the second variable ($\text{LOS}^2/2 \times \text{AA}$) is negative; the coefficient of the second variable is equivalent (by derivation) to the β in Eq. (1).

To complete the specification of patient loads, we include outpatient visits (OPV) as an additional explanatory variable. Then we add funding variables to the equations. There were too few observations in each sample to include separate variables for all the categories on NIH funding. Therefore, in preliminary analysis we used subsets of the categories in alternative specifications, hoping to determine whether any particular categories of funding are especially relevant to determining house staff size. Since there was no clear evidence that certain kinds of funding are particularly relevant, the results shown here use only total NIH funding, FUND.

The equations to be estimated describe residencies (RES), internships (INT), and total house staff positions (HSTAFF = RES + INT) as follows:

$$\begin{aligned}
\text{RES} &= \text{INTERCEPT}_R + \alpha_R(\text{LOS} \times \text{AA}) + \beta_R(\text{LOS}^2/2 \times \text{AA}) + \\
&\quad \gamma_R\text{OPV} + \delta_R\text{FUND} + \epsilon_R, & (3)\\
\text{INT} &= \text{INTERCEPT}_I + \alpha_I(\text{LOS} \times \text{AA}) + \beta_I(\text{LOS}^2/2 \times \text{AA}) + \\
&\quad \gamma_I\text{OPV} + \delta_I\text{FUND} + \epsilon_I, & (4)\\
\text{HSTAFF} &= \text{INTERCEPT}_H + \alpha_H(\text{LOS} \times \text{AA}) + \beta_H(\text{LOS}^2/2 \times \text{AA}) + \\
&\quad \gamma_H\text{OPV} + \delta_H\text{FUND} + \epsilon_H. & (5)
\end{aligned}$$

We expect the estimates of α and γ to be positive and the estimates of β to be negative or zero. The error terms (ϵ_R, ϵ_I, ϵ_H) reflect random factors affecting house staff size, possibly including faculty size. The INTERCEPT terms would measure the average effects of any omitted variables.

Results from this analysis are presented in Appendix B, Table B.1; only coefficients that are statistically different from zero with at least 95 percent confidence are reported. The coefficients in the HSTAFF equations are equal (with some rounding error) to the sum of the corresponding coefficients in the RES and INT equations. In general, the RES and INT equations perform quite well individually and differ in their coefficient estimates. For these reasons, we rely primarily on the separate RES and INT equations in the remainder of this discussion.

Coefficients of determination ($\bar{R}^2$, corrected for degrees of freedom) measure the proportion of variance (i.e., dispersion) in the dependent variable that is "explained" by the variables in the equation. For RES, patient load and funding variables together explain 61 to 72 percent of the variation in house staff size among institutions; for INT, the equations explain 42 to 68 percent. These figures are unusually high for any cross-section analysis, and are surprisingly high given the crudeness of the data and the simplicity of the models used here.

In all cases for which the patient load variables yield statistically significant coefficients, the signs are those we expected. Interestingly, outpatient visits rarely yield significant coefficients in the RES equations; this may reflect a larger role of residents in outpatient care.

As noted above, a significant negative estimate for β may be interpreted as evidence that house staff input declines during the length of stay. Obtaining a significant coefficient is difficult because we had to use average lengths of stay for each institution, because there is relatively little variation in length of stay among institutions in the sample (particularly in 1973-74, as shown in Table 5), and because the variable used to estimate β is highly correlated with the variable used to estimate α.[8] Nevertheless, the estimate of β manages to be significant in four of the INT equations and two of the RES equations. The results seem to support the hypothesis that house staff input declines during an inpatient episode.

The coefficients of the patient load variables appear to differ substantially from year to year. We do not offer any particular interpretation of this fact. The measures of house staff used here are not necessarily comparable from year to year (as noted above) and none of the coefficient estimates differ from year to year in a statistically significant manner.

The funding coefficients are almost never statistically significant. Even when they are significant (for RES in 1968-69 and 1969-70), the estimated values are very small. For example, for 1969-70 the results show that funding would have had to differ by over $300,000 to generate a difference of one in the number of residents. At the sample means for that year, the results imply that a difference of 24 percent in NIH funding might have generated only little more than a 2 percent difference in residencies.

Now let us consider how the funding effect estimates are affected by including faculty size variables in the analysis. This can be done only for the last three annual samples. To simplify the analysis, we obtained only one coefficient for inpatient loads by using the logarithmic patient load variable described above; preliminary analyses showed that similar results are obtained using the pair of inpatient variables. Although preliminary analyses used several different measures of faculty size, the measure used here performs as well as any of the combinations of separate variables we tried. The measure is FAC = full-time faculty plus part-time faculty plus 1/10 of volunteers.

For purposes of comparison, Table B.2 in Appendix B presents pairs of otherwise identical equations for each of the three annual samples for which faculty data are available; the only difference within a pair of equations is that FAC is first excluded and then included. The equations for interns differ from those for residents in that OPV is omitted; similar results are obtained when OPV is included, and the coefficients of OPV are almost never statistically significant.

Except for the intercept terms, the coefficients in residents equations are strikingly similar among the three years; considerable similarity is also observed for the interns equations. Therefore, it seems reasonable to combine the three years of data

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[8] A regression cannot obtain a precise estimate of the coefficient of a variable unless the variable varies in the sample and varies independently of other variables in the equation.

in equations that include year dummy variables (YR73 and YR74) to allow the intercepts to vary by year. Results for the combined years are:

$$\begin{aligned} RES = {} & \underset{(3.53)^{**}}{10.29} - \underset{(3.58)}{3.72}\ YR73 - \underset{(3.70)}{2.93}\ YR74 \\ & + \underset{(.0001)^{**}}{.0014}\ AA \cdot LOG(ALS) + \underset{(.00003)^{**}}{.00012}\ OPV \\ & + \underset{(.0009)}{.0013}\ FUND \qquad \bar{R}^2 = .66 \end{aligned} \tag{6}$$

$$\begin{aligned} RES = {} & \underset{(3.65)}{3.44} - \underset{(3.42)}{2.55}\ YR73 - \underset{(3.54)}{1.63}\ YR74 \\ & + \underset{(.0001)^{**}}{.0013}\ AA \cdot LOG(ALS) + \underset{(.00003)^{**}}{.00012}\ OPV \\ & - \underset{(.0010)}{.0013}\ FUND + \underset{(.039)^{**}}{.186}\ FAC \qquad \bar{R}^2 = .69 \end{aligned} \tag{7}$$

$$\begin{aligned} INT = {} & \underset{(2.45)^{**}}{11.81} - \underset{(2.49)^{*}}{4.20}\ YR73 - \underset{(2.56)^{**}}{6.24}\ YR74 \\ & + \underset{(.0001)^{**}}{.0011}\ AA \cdot LOG(ALS) + \underset{(.0006)}{.0009}\ FUND \qquad \bar{R}^2 = .62 \end{aligned} \tag{8}$$

$$\begin{aligned} INT = {} & \underset{(2.58)^{**}}{7.91} - \underset{(2.42)}{3.54}\ YR73 - \underset{(2.48)^{**}}{5.55}\ YR74 \\ & + \underset{(.0001)^{**}}{.0010}\ AA \cdot LOG(ALS) - \underset{(.0007)}{.0005}\ FUND \\ & + \underset{(.028)^{**}}{.105}\ FAC \qquad \bar{R}^2 = .64 \end{aligned} \tag{9}$$

In these equations, the figures in parentheses are standard errors, one asterisk denotes a coefficient that is statistically nonzero with at least 90 percent confidence; two asterisks denote 95 percent confidence. Funding is measured in thousands of dollars.

The consistency of the negative signs on YR73 and YR74 suggests that residencies and internships were fewer after 1972, net of effects of changing patient loads, faculty size, and funding. If so, 1972 may have been a year of expansion in house staff size.

The patient load variables always yield significant coefficients with the expected signs. These variables alone explain over 50 percent of the variance in house staff size.

When included, the faculty size coefficients are statistically significant and positive. At the means of the variables, the coefficients imply that a 10 percent difference in faculty size implies about a 3 percent difference in residencies and about a 2 percent difference in internships among institutions.

The coefficients of funding are statistically nonzero with better than 80 percent confidence in both of the residency equations—but change sign from positive to negative when faculty size is included. For interns, the funding coefficient is significantly nonzero at 80 percent confidence only when faculty size is excluded.

Referring to the chart in Appendix A, the results are clearly inconsistent with models II, IV, V, and VIII. The results for residencies also seem to rule out model I. The three remaining models (III, VI, and VII) all suggest that house staff size is based not on total faculty size but on faculty time available for teaching and patient care. Moreover, the plausible models do *not* suggest that faculty time available for patient care and teaching declines with research funding; two of the models assume that available time for teaching is *higher* when research funding is high (perhaps suggesting that faculty expands by more than the amount directly involved in research).

One of the three plausible models suggests that despite apparently nonzero coefficients, funding has no effect on house staff size. The other two models suggest that the estimates are an upper bound on the true effect. Assuming that our results are an upper bound, we find that any direct effects of funding are at most very small: a difference of one million dollars would imply at most a difference of about 1.2 in residencies and a little less than one in internships.

Summary of Results

The analysis presented here possesses several shortcomings, most due to lack of detailed, accurate data on the variables of interest. Nevertheless, the data yield plausible and statistically meaningful results when applied to the models used in this study. We find that patient loads explain much of the variation among institutions in house staff size and that the data reveal a plausible decline in daily house staff input during an episode of inpatient care.

In general, the results do not show strong statistical significance for coefficients of research funding and the coefficients are very small. The results simply yield no evidence of a strong or consistent direct effect of research funding on house staff size. The results also fail to show that research competes with teaching for faculty time.

As we argued above, the reason that research funding effects appear to be so weak may be that patient-availability constraints overwhelm research funding in affecting decisions with regard to house staff size. If so, and if the constraints continue in the future, prospective research funding policies may be expected to have little effect on house staff size.

CAREER OUTCOMES OF GRADUATES

In recent years, a broad national concern over a general shortage of physicians has given way to more specific concern over shortages of particular types of physicians, particularly those in the primary care specialties. Since primary care involves responsibility for a patient's overall health care—treatment of the "whole patient"

—it is not surprising that some have inferred that a center's biomedical research activities, which are usually highly focused on details of a particular health problem or body function, are at odds with a center's primary care training functions.

The supposed mechanism of a center's influencing students to choose nonprimary care specialties is the role model of the biomedical research "superstar" on the faculty. Because these individuals enjoy prestige in academic medicine, it is presumed that medical students seek to model their careers after these specialists. An extension of this logic is that the more research intensive an institution or a department, the less likely its graduates are to enter primary care specialties.

The questions we address in this section are, what influence does a medical school's federal research funding have on the professional career paths of its M.D. graduates, in terms of both the specialty chosen and the type of practice? For the purposes of this section, we define four specialty groups: internal medicine, all other primary care specialties (general practice, family practice, pediatrics, obstetrics and gynecology), surgical specialties, and other nonprimary care specialties.[9] By type of practice, we are referring to whether the physician chooses patient care, administration, teaching, or research.

To investigate these questions, we model these two aspects of career choice as a function of federal research funding and individual characteristics of physicians.

The Data

We have three data files relevant to the questions being considered. One is the AMA Master File of Physicians, which contains extensive information on postgraduate medical education and practice characteristics of all M.D.s. The second file was compiled by Rand in connection with its three-year study of federal program effects. This file contains background data on individual students from ten academic medical centers, including age, sex, medical school grade-point average, selectivity index for undergraduate (premedical school) college, standardized test scores, and other variables.[10] The third data file is the IMPAC file created and maintained by the Division of Research Grants of the NIH. This file includes information on the amounts of federal funding to medical schools by department over the period 1967 through 1975.

Our data on practice characteristics of physicians from the AMA master file are as of December 1974. Our data on student characteristics in ten medical schools are for the classes of 1955, 1960, 1965, 1969, and 1972. Since the funding data cover 1967 to 1975, we eliminate the 1955 and 1960 classes from our analysis. We thus analyze data for the 1965, 1969, and 1972 classes from ten medical schools.

The Analysis

Our objective is to discover what factors influence the types of medical careers

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[9] Both the specialty of practice and the type of practice are defined by the physician who fills out the AMA survey. Hence "internal medicine," for example, does not signify board certification or even level of training but rather what the physician has designated as his type of practice.

[10] A selectivity index of undergraduate schools was developed on the basis of material in the "College Admissions Selector." The scale runs from 9 points for colleges with the most competitive admissions policies to 1 point for a special category of colleges for which admissions is not based primarily on academic criteria. See *Barron's Profiles of American Colleges*, Barron's Educational Series, Woodbury, N.Y., 1972, pp. xxii-xxix.

that physicians chose. For purposes of this analysis we consider two aspects of these careers: (1) the medical specialty (e.g., surgery, pediatrics) in which the physician is trained, and (2) the primary activity in which the physician is engaged (patient care, administration, teaching, or research). We have data on these two aspects of the careers of the graduates of sample classes from ten medical schools, and we are seeking to determine, after the fact, what factors appear to explain the career choices of these graduates.

Discriminant analysis is an appropriate statistical technique to use in such a retrospective analysis. It uses a set of independent or explanatory variables to statistically distinguish *categories* on some dependent variables. The model is somewhat similar to a regression model except that the dependent variable is categorical. Linear combinations of the independent variables, called discriminant functions, are formed. The coefficients in these discriminant functions are chosen to maximize the separation of the groups: to maximize the differences in the discriminant scores (the value of a discriminant function for a particular individual and the sample) of the groups. These discriminant functions can be analyzed directly and can also be used to estimate the relative *probabilities* of membership, called the classification functions, in each of the groups. (The difference between the discriminant scores of two groups equals the natural logarithm of the odds that the individual is from one group rather than the other.)

We use four specialty groups: internal medicine, other primary care specialties, surgical specialties, and other nonprimary care specialties. Among the 1965, 1969, and 1972 graduates from these ten schools, 20.0 percent are in internal medicine (IM), 20.3 percent are in other primary care (OPC) specialties, 25.5 percent in surgical specialties (SS), and 34.2 percent in other nonprimary care (ONPC) specialties. Among these same graduates, 87.8 percent are in patient care, 2.5 percent in administration, and 9.7 percent are in teaching or research.

The independent variables we use in the discriminant analysis are shown in Table 8.

Findings and Conclusions

We consider the discriminant analysis results for specialty choice, and whether the physician is in patient care or academic medicine. For both cases, we distinguish the effects of research funding by department to the medical schools where the physicians received their medical degrees, from the effects of research funding by department to medical schools and their affiliated hospitals where the physicians did their first residencies.

For all four discriminant analyses, the background characteristics of physicians, especially rank in medical school class, are the principal determinants of career choice. The research intensity of institutions is of less importance and adds very little to our ability to predict career choices.

In the case of specialty choice, sex and rank are the first two variables to enter the discriminant analysis, with proportionately more males choosing internal medicine and the surgical specialties and with physicians who ranked higher in their medical school classes more frequently choosing internal medicine and to a lesser degree the surgical specialties. These results hold both for research funding associated with the institution where the physician's undergraduate medical education took

Table 8

THE VARIABLES USED IN THE DISCRIMINANT ANALYSIS

Variables	Definitions	Mean Values
SELINDX	Selectivity index[a] of the undergraduate college (a 1 to 9 scale)	5.40
MCATV	MCAT[b] verbal score	552.70
MCATQ	MCAT quantitative score	565.92
MCATS	MCAT science score	565.53
MCATG	MCAT general score	555.46
GPATOTAL	Total grade-point average in medical school	3.10
GPASCI	Grade-point average for science	3.10
RANK	Rank in medical school class, transformed to approximate mean and standard deviation of 500 and 100, and with higher values representing higher rank in class	510.84
Sex	Dummy variable for sex (male - 0, female = 1)	.07
FDIM	Federal research funding[c] for internal medicine departments	3.68
FDOPC	Federal research funding for other primary care departments	.48
FDSS	Federal research funding for surgical specialties departments	.55
FDONPC	Federal research funding for other nonprimary care departments	.84
FDCST	Total federal funding for clinical science departments	5.78
FDBST	Total federal funding for basic science departments	2.75

[a] The measure of selectivity of undergraduate schools is based on the evaluation of *Barron's Profiles of American Colleges*. We assigned a value of 9 to *Barron's* "Most Competitive" category, 7 to "Highly Competitive," 5 to "Very Competitive," and so on. Most schools in the country rank 3 or lower on this scale. The mean for the applicant groups at the sample medical school ranges between 4.5 and 5.3. See *Barron's Profiles of American Colleges*, Barron's Educational Series, Inc., Woodbury, N.Y., 1972, pp. xxii-xxix.

[b] Medical College Aptitude Test.

[c] The funding variables are all average annual funding figures in millions of dollars for the period 1967 to 1975. The funding variables by departments include research grants, teaching grants, research support grants, fellowship grants, career development awards, program project grants and clinical research center grants.

place and for research funding associated with the institution where the first residency took place. See Tables 9 and 10. Funding for the primary care specialties other than internal medicine during a physician's undergraduate medical education is significantly associated with the eventual choice of one of those specialties, and total research funding for all clinical science departments is significantly associated with a choice of internal medicine and surgical specialties. Research funding for internal medicine during a physician's residency is significantly associated with the eventual choice of internal medicine as a specialty.

All of the funding variables together add very little to our ability to predict specialty choice in the discriminant analysis. In the case of research funding to the medical school (and its affiliated hospitals) where the physician received his M.D., the discriminant analysis correctly classified 35.9 percent of the physicians into the four specialty groups, and was able to correctly classify 35.6 percent using only the background variables and no funding variables. Similarly, for funding to the medical school and its affiliated hospitals where the first residency was taken, the discriminant analysis correctly classified 36.3 percent (and the same 35.6 percent without the funding variables). We would expect to classify 25 percent correctly with random assignment.

For the choice between academic medicine and patient care, the first two variables to enter the discriminant analysis for both cases (i.e., funding to undergraduate medical institution and funding to institution associated with the physician's first residency) are RANK and MCATQ. Higher rank in class and higher MCAT quantitative scores are both associated with a choice of medical education or research careers. These two variables are the only variables in the analysis significantly related to the choice between academic medicine and patient care when we consider federal research funding to the physician's undergraduate medical institution. One other variable, research funding for the surgical specialties, is significantly related to this choice when we consider funding to the institution associated with the physician's first residency. And this variable (funding for the surgical specialties) is also associated with a choice of a teaching or research career. See Tables 11 and 12.

Table 9

DISCRIMINANT ANALYSIS RESULTS FOR EFFECT ON TYPE OF PRACTICE[a] OF FEDERAL RESEARCH FUNDING TO THE INSTITUTION WHERE THE M.D. WAS TAKEN

		Classification Function Coefficients[b]		
Variables[c]	Significance Level[d]	Patient Care	Administration	Medical Teaching or Research
RANK	<.001	.044	.045	.050
MCATQ	.019	.067	.063	.072
Sex	.109	-1.781	-2.152	-.547
MCATV	.172	.064	.070	.066
Constant		-46.508	-48.407	-53.549
(Other variables not entered)[e]				

[a] The F-ratio for the difference between groups as distinguished by the discriminant analysis is significant at the .001 level for the difference between patient care and teaching plus research. The F-ratios for the differences between administration and either of the other two practice types are not significant at the .05 level.

[b] Differences between the coefficients across groups for a given variable represent the estimated effect of that variable on the relative probabilities of membership in those groups.

[c] The variables are listed in the order in which they entered the discriminant analysis.

[d] The significance level for each variable is the statistical significance of that variable's contribution to separating the groups.

[e] No funding variables enter this discriminant analysis.

Table 10

DISCRIMINANT ANALYSIS RESULTS FOR EFFECT ON TYPE OF PRACTICE[a] OF FEDERAL RESEARCH FUNDING TO THE INSTITUTION WHERE THE FIRST RESIDENCY WAS TAKEN

		Classification Function Coefficients[b]		
Variables[c]	Significance level[d]	Patient Care	Administration	Medical Teaching or Research
RANK	<.001	.044	.044	.048
MCATQ	.019	.070	.066	.076
FDSS	.035	1.264	1.351	2.010
SEX	.062	-1.632	-1.827	-.096
FDCST	.202	-.140	-.142	-.211
MCATV	.235	.066	.071	.068
Constant		-47.379	-49.018	-54.999
(Other variables not entered)				

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[a] The F-ratio for the difference between groups as distinguished by the discriminant analysis is significant at the .001 level for the difference between patient care and teaching/research. The F-ratios for the differences between administration and either of the other two practice types are not significant at the .05 level.

[b] Differences between the coefficients across groups for a given variable represent the estimated effect of that variable on the relative probabilities of membership in those groups.

[c] The variables are listed in the order in which they entered the discriminant analysis.

[d] The significance level for each variable given in the second column is the statistical significance of that variable's contribution to separating the groups.

With no funding variables included, the discriminant analysis correctly classified 46.7 percent of the physicians into the three types of practice groups (patient care, administration, and teaching plus research). With funding associated with the physician's undergraduate institution added, the discriminant analysis correctly classified 49.4 percent; and with funding associated with the institution of the first residency added, the discriminant analysis correctly classified 50.4 percent of the physicians. We would expect to classify 33.3 percent correctly with random assignment. And although only about 10 percent of the physicians in the sample are in teaching or research, the discriminant analysis correctly classified about 60 percent of the physicians in that category.

If we do the discriminant analysis using only the funding variables without the background variables, only 26 percent of the physicians are correctly classified into the four specialty groups. And no variables even enter the discriminant analysis in the case of predicting type of practice from funding to the undergraduate medical institution.

In sum, federal research funding is to a slight degree related to choices among four broad categories of medical specialties, but personal characteristics appear to be the principal determinants of these specialty choices. There is no apparent rela-

Table 11

DISCRIMINANT ANALYSIS RESULTS FOR EFFECT ON SPECIALTY CHOICE[a] OF FEDERAL RESEARCH FUNDING TO THE INSTITUTION WHERE THE M.D. WAS TAKEN

		Classification Function Coefficients[b]			
Variables[c]	Significance level[d]	Internal Medicine	Other Primary Care	Surgical Specialties	Other Non-primary care
Sex	.005	-14.298	-13.261	-14.707	-14.071
RANK	.021	.029	.026	.028	.027
FDOPC	.038	-151.228	-144.629	-152.705	-151.241
FDCST	.001	8.193	7.864	8.365	8.212
GPATOTAL	.009	42.455	42.354	41.146	42.000
MCATG	.028	.049	.048	.045	.048
GPASCI	.127	-1.624	-2.114	-.986	-1.270
MCATV	.093	.008	.008	.011	.009
MCATQ	.133	.082	.082	.081	.080
FDSS	.277	99.168	95.521	100.299	100.020
FDONPC	.156	-26.870	-26.445	-27.747	-27.539
SELINDX	.279	3.256	3.238	3.286	3.333
AGE	.316	11.662	11.669	11.712	11.624
Constant		-276.246	-272.072	-273.687	-273.490
(Other variables not entered)					

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[a] The F-ratios for the differences between groups as distinguished by the discriminant analysis are all significant at the .025 level.

[b] Differences between the coefficients across groups for a given variable represent the estimated effect of that variable on the relative probabilities of membership in those groups.

[c] The variables are listed in the order in which they entered the discriminant analysis.

[d] The significance level for each variable is the statistical significance of that variable's contribution to separating the groups.

tionship between research funding and the choice between primary care and nonprimary care specialties. Indeed this dichotomy is not a useful one in examining factors that influence specialty choices because the characteristics of individuals in different specialties *within* these broad categories differ almost as much as those in specialties *between* the categories. In the choice of a career in medical training or research as in the case of specialty choice, personal characteristics of physicians seem to be the principal determinants of a career in academic medicine or research.

Table 12

DISCRIMINANT ANALYSIS RESULTS FOR EFFECT ON SPECIALTY CHOICE[a] OF FEDERAL RESEARCH FUNDING TO THE INSTITUTION WHERE THE FIRST RESIDENCY WAS TAKEN

		Classification Function Coefficients[b]			
Variables[c]	Significance level[d]	Internal Medicine	Other Primary Care	Surgical Specialties	Other Non-primary Care
Sex	.004	-8.239	-7.246	-8.607	-8.043
RANK	.018	.034	.032	.033	.032
SELINDX	.135	1.567	1.476	1.532	1.558
GPATOTAL	.046	23.864	24.093	22.725	23.865
GPASCI	.121	.931	.484	1.572	1.156
MCATG	.113	.059	.059	.056	.060
MCATV	.068	.035	.035	.039	.036
FDONPC	.113	-.802	-1.134	-1.231	-.917
FDIM	.020	-.552	-.727	-.695	-.824
FDCST	.307	.209	.356	.370	.393
Constant		-76.494	-73.584	-73.742	-76.470
(Other variables not entered)					

[a] The F-ratios for the differences between groups as distinguished by the discriminant analysis are all significant at the .005 level.

[b] Differences between the coefficients across groups for a given variable represent the estimated effect on the relative probabilities of membership in those groups.

[c] The variables are listed in the order in which they entered the discriminant analysis.

[d] The significance level for each variable is the statistical significance of that variable's contribution to separating the groups.

APPENDIX A

The appropriateness of including or excluding faculty size measures as control variables in house staff regressions depends greatly on our model of house staff determination. Specifically, depending on the model, the coefficient of research funding might be biased either by including or by excluding faculty. Here we show that pairs of results with faculty included and excluded can help distinguish among alternative models. This is shown by working through some simple deterministic models and then by summarizing some additional models by means of a simple chart.

Consider a simple deterministic model:

$$H = a_1P + b_1F, \tag{i}$$

where H = house staff size, P = patient load, F = faculty size, and both a_1 and b_1 are positive parameters. The model says that research funding does not affect house staff size, but faculty size does. However, suppose that there is a relationship between faculty size and research funding, R:

$$F = c_1 + d_1R, \tag{ii}$$

where c_1 and d_1 are positive parameters.

If we related house staff to patient loads and research funding, we would observe the relationship:

$$H = \tilde{a}P + \tilde{b}R + \tilde{c} \tag{iii}$$

where $\tilde{a}$, $\tilde{b}$, and $\tilde{c}$ are estimated parameters. By substituting Eq. (ii) in Eq. (i) we find that:

$$\begin{aligned} H &= a_1P + b_1 F \\ &= a_1P + b_1(c_1 + d_1R) \\ &= a_1P + b_1c_1 + b_1d_1R. \end{aligned} \tag{iv}$$

Therefore, in our estimates of Eq. (iii), we would find that:

$$\tilde{a} = a_1,\ \tilde{b} = b_1d_1 \text{ and } \tilde{c} = b_1c_1. \tag{v}$$

The results would yield a positive coefficient ($\tilde{b}$) for research funding even if research funding has no effect on house staff size. Complex, stochastic models based on the same relationships as the foregoing equations yield the same kind of result: Omitting faculty size might generate biased estimates of the effects of research funding.

If the preceding model were essentially correct, the problem could be corrected by including faculty size as an additional variable. If we estimated:

$$H = \hat{a}P + \hat{b}F + \hat{f}R + \hat{c}, \tag{vi}$$

we would correctly obtain a zero value for $\hat{f}$, where $\hat{a}$, $\hat{b}$, $\hat{f}$, and $\hat{c}$ are estimated coefficients.

However, if the foregoing model is not correct, including faculty size variables may not generate appropriate results. For example, suppose that house staff size is affected by faculty time available for teaching and patient care activities, T, rather than by total faculty time (as measured by F); that is, suppose that:

$$H = a_2P + b_2T, \tag{vii}$$

and

$$F = T + S, \tag{viii}$$

where S = time spent in research. Suppose further that T and S are determined independently (i.e., T and S are determined and these in turn determine total faculty size) and only S is affected by research funding:

$$S = d_2R. \tag{ix}$$

Substituting (ix) and (viii) into (vii), we have:

$$\begin{aligned} H &= a_2P + b_2T \\ &= a_2P + b_2(F - S) \\ &= a_2P + b_2F - b_2d_2R. \end{aligned} \tag{x}$$

Therefore, if we estimated Eq. (vi), we would find that:

$$\hat{a} = a_2, \hat{b} = b_2, \text{ and } \hat{f} = -b_2d_2. \qquad \text{(xi)}$$

Including faculty size variables would cause the estimated equation to generate a negative coefficient for a research funding variable even though the model (Eq. vii) says that funding doesn't affect house staff size. In this case, it would be more appropriate to omit faculty size from the empirical analysis.

The characteristic of the second model that is essential to obtain this result is the assumption that research funding does not affect the component of faculty time that influences house staff size. Alternatively, if T were a function of R (if research funding affected the allocation of faculty time to teaching and patient care), then we would get a biased estimate of the funding coefficient regardless of whether faculty size is included in the analysis. Specifically, suppose:

$$T = g_3R. \qquad \text{(xii)}$$

Then, from the model in Eq. (vii), we have:

$$\begin{aligned} H &= a_2P + b_2T \\ &= a_2P + b_2g_3R \end{aligned} \qquad \text{(xiii)}$$

$$\begin{aligned} \text{and } H &= a_2P + b_2(g_3(F - S)) \\ &= a_2P + b_2g_3F - b_2g_3d_2R. \end{aligned} \qquad \text{(xiv)}$$

If g_3 is positive (T increases with R), then Eq. (xiii) shows that we would get a positive coefficient for R when faculty size is omitted and Eq. (xiv) shows that we would get a negative coefficient when faculty size is included. Opposite results would be obtained if g_3 were negative.

Figure A-1 summarizes the implications of various models when faculty size is included or excluded from analysis. The chart includes not only the results from the foregoing models that assume research has no direct effect on house staff size, but also includes results for corresponding models that assume research funding has an effect on house staff size.

Note that the chart describes results for deterministic models. If the models were stochastic, empirical results would not be as clear-cut as the chart implies. For example, instead of obtaining a zero coefficient in case 2, we might obtain a positive coefficient that is not statistically different from zero.

Of the pairs of results shown in the chart, only the pair for Model number II is distinctive; at least two different models could produce any of the other pairs of outcomes. Thus, the chart illustrates the difficulty of using the empirical results of this study to generate precise conclusions about how house staff size is determined. At the same time, the chart shows that when data permit, models should be estimated with faculty variables both included and excluded; the pair of results so obtained can at least focus attention on a small subset of the models in the chart.

Model	Faculty Formation Assumption	Model Number	Case Number	Estimating Equation	Resulting Coefficient of Funding	Status
$H = a_1P + b_1F$	$F = c_1 + d_1R$	(I)	(1)	Exclude Faculty	Positive	Should be zero
			(2)	Include Faculty	Zero	Correct result
$H = a_2P + b_2T$	$F = T + S$ $S = d_2R$ T independent of R	(II)	(3)	Exclude Faculty	Zero	Correct result
			(4)	Include Faculty	Negative	Should be zero
	$F = T + S$ $S = d_2R$ $T = g_3R$ $g_3 > 0$	(III)	(5)	Exclude Faculty	Positive	Should be zero
			(6)	Include Faculty	Negative	Should be zero
	$F = T + S$ $S = d_2R$ $T = g_4R$ $g_4 < 0$	(IV)	(7)	Exclude Faculty	Negative	Should be zero
			(8)	Include Faculty	Positive	Should be zero
$H = a_4P + b_4F$ $+ f_yR$ $f_4 > 0$	$F = c_1 + d_1R$	(V)	(9)	Exclude Faculty	Positive (Larger than Case (10))	Biased up
			(10)	Include Faculty	Positive	Correct result
$H = a_5P + b_5T$ $+ f_5R$ $f_5 > 0$	$F = T + S$ $S = d_2R$ T independent of R	(VI)	(11)	Exclude Faculty	Positive (Larger than Case (12))	Correct result
			(12)	Include Faculty	Positive or Negative (Possibly zero)	Biased down
	$F = T + S$ $S = d_2R$ $T = g_3R$ $g_3 > 0$	(VII)	(13)	Exclude Faculty	Positive (Larger than Case (14))	Biased up
			(14)	Include Faculty	Positive or Negative (Possibly zero)	Biased down
	$F = T + S$ $S = d_2R$ $T = g_3R$ $g_3 < 0$	(VIII)	(15)	Exclude Faculty	Positive or Negative (Possibly zero)	Biased down
			(16)	Include Faculty	Positive	Biased up

Fig. A-1—Chart of theoretical outcomes

APPENDIX B

Appendix B

Table B-1

STATISTICALLY SIGNIFICANT COEFFICIENTS FROM REGRESSIONS OF HOUSE STAFF SIZE ON PATIENT LOAD AND NIH FUNDING: SIX SAMPLES[a]

Dependent Variable	Year	Intercept	Estimate of: w	ε	Coefficient Estimate for: OPV	FUND[b]	$\bar{R}^2$
RESIDENTS	1967-1968	--	.00019 (.00006)	--	.00021 (.00006)	--	.64
	1968-1969	8.20 (4.00)	.00027 (.00008)	--	.00020 (.00006)	.0023 (.0013)	.62
	1969-1970	11.15 (4.03)	--	--	.00026 (.00007)	.0030 (.0014)	.61
	1971-1972	8.35 (4.62)	.00054 (.00007)	-.000035 (.000008)	.00013 (.00005)	--	.72
	1972-1973	--	.00046 (.00007)	-.000022 (.000006)	--	--	.66
	1973-1974	13.62 (5.33)	--	--	.00014 (.00005)	--	.62
INTERNS	1967-1968	--	.00029 (.00007)	--	--	--	.52
	1968-1969	9.36 (4.25)	.00027 (.00008)	-.000015 (.000008)	.00012 (.00006)	--	.42
	1969-1970	9.64 (4.10)	.00055 (.00009)	-.000039 (.000009)	--	--	.52
	1971-1972	11.84 (4.07)	.00042 (.00006)	-.000026 (.000007)	--	--	.57
	1972-1973	10.10 (3.33)	.00033 (.00004)	-.000018 (.000004)	--	--	.58
	1973-1974	5.50 (3.24)	.00027 (.00007)	--	--	--	.68
TOTAL HOUSE STAFF	1967-1968	12.00 (7.08)	.00049 (.00012)	--	.00028 (.00011)	--	.66
	1968-1969	17.56 (6.93)	.00054 (.00013)	-.000026 (.000013)	.00032 (.00010)	--	.61
	1969-1970	20.99 (7.21)	.00067 (.00016)	-.000035 (.000016)	--	--	.60
	1971-1972	20.19 (6.38)	.00096 (.00010)	-.000061 (.000010)	.00013 (.00007)	--	.78
	1972-1973	14.70 (7.37)	.00079 (.00010)	-.000040 (.000008)	--	--	.68
	1973-1974	19.12 (7.06)	.00043 (.00015)	--	.00015 (.00007)	--	.72

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[a] Standard Errors in parentheses; all reported coefficients are significantly nonzero with at least 90 percent confidence (using a two-tailed test).

[b] Funding in $1,000.

Table B-2

REGRESSION RESULTS: HOUSE STAFF SIZE ON PATIENT LOADS, FACULTY SIZE AND NIH FUNDING; THREE SAMPLES[a]

Dependent Variable	Year	Intercept	Coefficient of AA · LOG(ALS)	OPV	FAC	FUND[b]	$\bar{R}^2$
RESIDENTS	1971-1972	8.39 * (4.67)	.0015 ** (.0002)	.00013 ** (.00005)	--	.0017 (.0022)	.71
	1971-1972	1.00 (5.02)	.0013 ** (.0002)	.00014 ** (.00005)	.188 ** (.061)	-.0011 (.0023)	.74
	1972-1973	4.56 (5.13)	.0015 ** (.0002)	.00012 * (.00007)	--	.0019 (.0014)	.65
	1972-1973	-1.71 (5.36)	.0014 ** (.0002)	.00010 (.00007)	.194 ** (.068)	-.0011 (.0018)	.68
	1973-1974	11.74 ** (5.53)	.0013 ** (.0002)	.00012 ** (.00005)	--	.0005 (.0014)	.59
	1973-1974	7.26 (5.67)	.0012 ** (.0002)	.00010 * (.00004)	.195 ** (.081)	-.0019 (.0016)	.62
INTERNS	1971-1972	11.44 ** (3.94)	.0012 ** (.0001)	--	--	-.0008 (.0018)	.60
	1971-1972	5.90 (4.28)	.0011 ** (.0001)	--	.142 ** (.052)	-.0028 (.0019)	.63
	1972-1973	9.16 ** (3.28)	.0011 ** (.0001)	--	--	.0016 * (.0009)	.60
	1972-1973	7.02 ** (3.57)	.0009 ** (.0001)	--	.066 (.045)	.0006 (.0011)	.60
	1973-1974	5.04 (3.14)	.0011 ** (.0001)	--	--	.0009 (.0008)	.68
	1973-1974	2.34 (3.27)	.0010 ** (.0001)	--	.105 ** (.047)	-.0004 (.0001)	.70

[a] Standard errors in parentheses; one asterisk denotes statistically nonzero coefficient, 90 percent confidence; two asterisks denote 95 percent confidence. Two-tailed tests.

[b] Funding in $1,000.

III. THE EFFECTS OF FEDERAL BIOMEDICAL RESEARCH PROGRAMS ON THE CHARACTERISTICS OF DEPARTMENTS

The medical center activities of education, research, and patient care are to a large extent organized along academic departmental lines, although interdisciplinary research is common. Basic science departments have responsibility for Ph.D. programs in their fields and for specific portions of the undergraduate medical education curriculum. Clinical departments have responsibility for specific components, "rotations" in the clinical training of undergraduate M.D. students, for the training of interns, residents, and fellows in their medical fields, and for the supervision of the various inpatient services in major teaching hospitals.

In this section, we examine the effects of federal biomedical research programs on important characteristics of academic departments. First, we examine determinants of department size, including education, research, and patient care programs. Second, we examine evidence of the effects of research programs on faculty involvement in patient care activity. Third, we examine changes in patterns of support for faculty salaries; and, finally, we examine the effects of a department's research activity on the salary levels of its faculty members.

DETERMINANTS OF DEPARTMENT SIZE

The Model

The number of full-time faculty has grown with exceptional rapidity since World War II. The research responsibility assumed by medical schools—and the availability of federal funding for research—is the most frequently cited explanation for this development. To test this hypothesis, we need to develop a model of the determinants of department size that takes account of research as well as other factors that might affect the number of faculty members in a department.

For a basic science department, such a model might have the following specification:

$$F = b_0 + b_1S + b_2R + b_3G + b_4SR + b_5SF + b_6RG + b_7SRG \qquad (1)$$

where F = the number of full-time faculty
b_0 = a constant term
b_1 through b_7 = the regression coefficients
S = total medical student enrollment
R = NIH awards for research
G = graduate student enrollment

Equation (1) relates the number of full-time faculty to the number of medical students, the amount of NIH research funding received, and the number of basic science students. If, in fact, teaching and research are joint outputs, then the coefficients on the interaction terms (b_4 through b_7) should be negative and statistically significant.

The model might be modified for a clinical department by substituting house staff for graduate students and adding an explanatory variable P to account for the patient care load of the clinical faculty. The additional interaction terms need to be added to account for joint production. The clinical department model would then have the following specification:

$$F = b_8P + b_9PS + b_{10}PR + b_{11}PH + b_{12}PRS + b_{13}PHR + b_{14}PHS + b_{15}PHSR. \qquad (2)$$

The coefficients on the interaction terms (b_4 through b_7) and (b_9 through b_{15}) take account of the clinical department joint production process that includes patient care (P).

Data and Results

To estimate the model we use data for FY 1973[1] from the AAMC faculty roster, the AMA Directory of Approved Internships and Residencies, the *Journal of the American Medical Association,* and the NIH IMPAC file. Equation (1) is applied separately for each major type of basic science department; thus F, R, and G refer to faculty, research awards, and graduate students specific to a department. Equation (2) is applied to data from the department of medicine using patient load data from the internal medicine services of major teaching hospitals.[2] Unfortunately, technical problems prevent us from providing estimates of the coefficients on the interaction terms.[3]

The results of estimating the truncated equation are presented in Table 13. They indicate strong support for the notion that both M.D. enrollment and research awards play a statistically significant role in the determination of faculty strength in the basic science departments; the role of graduate student enrollment is less consistent.

A better idea of the *magnitude* of these effects (as opposed to their statistical significance) is given in Table 14, which presents elasticity of faculty strength with respect to each of the explanatory variables—that is, the percentage change in faculty strength that can be expected for each 1 percent change in the explanatory variable. In general, a 1 percent change in medical student enrollment has about twice the effect of a 1 percent change in research funding. Both elasticities, however, are usually much less than one. Thus, changes in funding would have an appreciable but less than proportionate effect on faculty strength.

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[1] This is the latest year for which complete data were available at the time of writing. Complete data are now available for FY1974 and will be used in the final report.

[2] We construct a patient load variable that is total annual admissions times the natural log of average length of stay. The log of length of stay is used because the physician inputs per day of hospitalization are believed to be less the longer the stay.

[3] There is strong multicollinearity between the interaction terms and the other independent variables. While the estimated coefficients usually had the right signs, their standard errors were unacceptably large.

Table 13

CROSS-SECTION REGRESSION ANALYSIS OF DEPARTMENT SIZE
(Standard errors in parentheses)

Department[e]	Number	Constant Term	Regression coefficients Medical Student Enrollment	NIH Research and Training Grants to Departments	Numbers of Graduate Students	Patient Load[c]	R^2
Anatomy	105	3.65	.016[a] (.002)	9.9[a] (1.8)	.10 (.06)	d	.60
Biochemistry	101	3.77	.012[a] (.003)	11.6[a] (2.1)	.03 (.04)	d	.42
Microbiology	98	4.35	.006[a] (.002)	4.4[a] (1.7)	.15[a] (.03)	d	.51
Pharmacology	97	5.9	.001 (.002)	8.3[a] (1.3)	.23[a] (.05)	d	.54
Physiology	83	4.8	.009[a] (.002)	9.8[a] (2.2)	.10[b] (.05)	d	.47
Medicine	79	15.7	.018 (.024)	13.8[a] (2.81)	.11[a] (.063)	22.4 (19.05)	.37

[a] Significant at 1%.

[b] Significant at 5%.

[c] Total annual admissions times the natural log of average length of stay.

[d] Applicable only to department of medicine.

[e] Data for all departments except medicine are for FY 1973; medicine department data are for FY 1972.

Table 14

ELASTICITIES, 1974

	S	R	G
Anatomy	.54	.10	-
Biochemistry	.40	.27	-
Microbiology	.26	.08	.24
Pharmacology	-	.17	.23
Physiology	.33	.18	.10
Medicine	-	.29	.21

We have also tried a modified version of Eq. (2) for medicine departments in FY 1972, introducing a variable describing the patient load (annual admissions times the log of the average length of stay; for a justification of patient load variables of this kind, see the discussion of the determinants of house staff size, above). The results are similar to those for basic science departments: NIH research funding is positively and significantly related to faculty size, as is number of house staff, but the number of medical students is not. The number of faculty is positively associated with the patient load variable, but not in a statistically significant fashion. This may reflect the omission of volunteer faculty in our counts of department members. Volunteer faculty provide a limited amount of teaching; they also admit patients to the teaching hospital. Thus, a school with large numbers of volunteer faculty will have a higher value for its patient load variable but no corresponding increase in its (observed) faculty strength.

These results pertain to a cross section of data for FY 1973. Relationships observed in the cross section may not, in fact, predict actual changes over time. To examine this possibility we ran Eq. (1) using changes in faculty strength in basic science departments between FY 1971 and 1974; and changes in the number of medical students, amount of research funding (in constant dollars), and number of graduate students. The results generally confirm what is presented in Table 13: that is, changes in research funding are the most consistent predictor of changes in faculty strength, while changes in student load are less frequently associated with changes in faculty size.

FACULTY INVOLVEMENT IN CLINICAL CARE

Objectives and Limitations

In principle, there are two potential effects of research funding on faculty involvement in clinical patient care: (1) A change in research funding may lead to a change in faculty size with consequent effects on both teaching and patient care; and (2) a change in funding for research may lead to a change in the allocation of a given amount of faculty time among teaching, research, and patient care. The preceding subsection examined the first of these potential effects. Here, we consider the effects of research funding on patient care when faculty size has already been determined. Therefore, to determine the overall effects, results from this and the preceding subsection should be considered jointly.

Availability of data places certain important limitations on this analysis: First, we do not have data that reflect actual involvement in patient care by faculty or, for that matter, by house staff. Instead, the patient care data measure only the total patient loads and average lengths of stay for all hospitals affiliated with each medical school in the sample; faculty involvement may be limited to some share of such patients, and the share may vary among medical schools, but we cannot test these hypotheses. Second, the analysis deals only with internal medicine services; behavior might differ in other hospital services. Third, the variables used in the analysis could be brought together only for a single year (academic and fiscal year 1971-72).

Therefore, the analysis describes cross-sectional behavior rather than responses over time, and the cross-sectional results may not be representative of behavior in other years.

Data Sources and Variables

The variables used in the analysis are:

(1) Annual admissions to all internal medicine services in hospitals affiliated with each medical school (AA);
(2) Average daily census in all internal medicine services of hospitals affiliated with each school (ADC);
(3) Outpatient visits in internal medicine (OPV);
(4) Numbers of full-time faculty in the department of medicine in each school (FACFT);
(5) Numbers of part-time faculty in each department of medicine (FACPT);
(6) Numbers of volunteer faculty in each department of medicine (FACVOL);
(7) Research funding received by faculty in each department of medicine (DFUND);
(8) Research funding of internal medicine services of affiliated hospitals (HFUND);
(9) Residency positions available, as a proxy for program size (RES);
(10) Internships available, as a proxy for program size (INT).

These variables are the same as those used in Section II to analyze effects of research funding on house staff size—but with an important distinction: In Section II, we assumed that current house staff size in each year is determined in part by patient loads in a previous year. Thus, the patient load variables used to analyze house staff size in 1971-72 reflect patient loads actually encountered in 1969-70. In contrast, here we analyze the relationships between current patient care outputs and current faculty and house staff inputs.

To do this, we had to identify one or more years of data for which current patient load, faculty size, funding, and house staff data were available. Faculty data were available for 1970-71, 1971-72, 1972-73, and 1973-74; funding data were available for 1966-67 through 1973-74; house staff data were for 1967-68 through 1973-74, but omit 1970-71; patient load data were for 1965-66 through 1971-72, but omit 1968-69. The only year for which all of the kinds of data are currently available is 1971-72. The means and standard deviations of variables in the file are listed in tables in Section II.

Analysis and Results

Although not fully specified, the model used in this analysis is a production model: We postulate that patient care is an output of a production process using faculty and house staff as inputs. Research funding enters the model as follows: We postulate that the faculty input to patient care is a function of both faculty size and time devoted to research, with research funding used as a proxy for the latter. This reasoning leads to a specification of the following general form:

$$\text{PATIENT CARE INPUT} = f(\text{FACULTY, RESEARCH FUNDING, RESIDENTS, INTERNS}), \tag{1}$$

where f denotes a general functional relationship.

We are interested in whether the coefficients of research funding variables are nonzero and, if so, whether they are positive or negative. If positive, the coefficients would suggest that, given faculty and house staff size, research contributes to patient care output; and if negative, the coefficients would suggest that research competes with patient care as a production activity.

A number of specific forms of Eq. (1) were used in preliminary analysis. For example, we initially used three categories of faculty (FACFT, FACPT, and FAC-VOL). However, given the high correlations among the categories within such a small sample, attempts to introduce greater detail into the specification produced high standard errors for the coefficients and, therefore, little basis on which to evaluate the results. In obtaining the results reported below, we use a single measure of faculty size (FAC = FACFT + FACPT + .1 VOL) and a single measure of funding per faculty member (FUND/FAC).

The measurement of patient care output leads to some alternative specifications. The regression techniques used here allow for only a single dependent variable, yet we have three measures of patient care output (admissions, total days of care, and outpatient visits). Initial analysis suggested that the number of outpatient visits is not highly correlated with either faculty size or funding, although it is highly correlated with the remaining measures of patient care output. The results reported here either omit outpatient visits or treat it as an explanatory variable; by placing outpatient visits among the explanatory variables, we control for the use of some share of faculty and house staff inputs in outpatient care, assuming that the provision of such care is not affected by research funding or by faculty size.

Both annual admissions and average length of stay do reveal some correlation with faculty size. Since total days of care reflect both admissions and length of stay, we initially used total days as the measure of patient care output. However, the coefficient of faculty size proved to be negative when days was the dependent variable. On balance, the negative correlation between length of stay and faculty size appears to outweigh the positive correlation between admissions and faculty size.

A negative coefficient for an input in a production relation violates common sense and suggests specification error. Moreover, the specification of days as the dependent variable is inconsistent with the model used in analyzing house staff size, which suggests that fewer inputs are used in providing care on days near the end of stay than on days near the beginning of stay.

A measure of output that places less weight on days at the end of stay can be specified by taking the natural log of length of stay. Multiplying this by the total number of admissions results in a measure of total patient output that weights patient-days more heavily in hospitals with shorter lengths of stay. Replacing days with this new variable improved the properties of the regression equation without any substantive change in the conclusions regarding effects of research funding.

Despite the large number of alternative specifications considered, we found little evidence of a statistically significant relationship between research funding and patient care output for the 1971-72 cross-section sample. The following results are generally illustrative of those found in equations whose specifications satisfied in general criteria developed above:[4]

$$\mathrm{AA} \cdot \mathrm{LN(ALS)} = \underset{(4040)}{3164)} + \underset{(41.73)}{61.85)}\ \mathrm{FAC} + \underset{(61.23)^{**}}{203.01}\ \mathrm{RES}$$

$$+ \underset{(84.63)^{**}}{262.89}\ \mathrm{INT} - \underset{(.1234)}{.0252}\ \frac{\mathrm{FUND}}{\mathrm{FAC}}\ . \qquad (2)$$

$$\bar{\bar{R}}^2 = .60$$

The values in parentheses are the standard errors for the corresponding coefficients; double asterisks denote significance at 95 percent or better (using two-tailed tests). The standard errors indicate that the coefficient of funding (measured in $1,000) is not statistically nonzero at any of the usually accepted confidence levels. Moreover, the FAC variable also fails to yield a statistically significant coefficient. Therefore, there is little basis on which to calculate how patient care might be affected by research funding even through its effect on faculty size.

Limitations

This analysis was based on a small sample of medical school departments of medicine for a single year and uses crude measures of patient care output. For these reasons, the results of the analysis are potentially subject to considerable error and do not offer a strong foundation for predicting the future implications of changes in NIH funding policy. What can be said of the results is that they do not reveal a strong relationship between research funding and patient care output, holding faculty size constant, for 1971-21. However, the results also reveal little relationship between patient care output and faculty size. Thus it appears that the variables, the observations, or the empirical methods are inadequate for proper analysis of this issue.

RELIANCE ON NIH FUNDS FOR FACULTY SALARY SUPPORT

Our analysis has shown that NIH funds have strongly influenced the faculty size of medical school basic science departments, and that training grants have affected enrollment in Ph.D. programs. Thus there is little doubt that the characteristics of individual departments have been determined in substantial part by federal biomedical research and training programs. This indicates that academic medical centers have responded to federal program influence by changing their internal structure, but it does not provide clear evidence of how vulnerable centers are to changes in federal programs. Perhaps the best indicator of departmental vulnerability to changes in federal programs is their reliance on these programs for faculty

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[4] The variables whose codes are not defined elsewhere: AA × LN(ALS) = annual admissions times the log of average length of stay; FAC = FACFT + FACPT + .1 VOL.

salary support. The hiring of a faculty member implies a commitment by a center of at least several years' duration; in the case of tenured faculty, the commitment is of much longer duration.[5]

To the extent that uncertain sources of support from outside organizations, such as NIH—so-called soft money—are used to meet a center's firm commitments to faculty salaries, the center is vulnerable to changes over which it has little control, and it must find other sources of funding to cover its commitments if soft funding is cut back.

We hypothesize that the reliance on soft money for faculty salaries may vary within an institution by departments, by faculty rank, and over time. We might also expect to find differences between centers depending on their success in obtaining research and other soft funding and on whether they are private or state-owned institutions. Our analysis examines data on department budgets to determine whether consistent patterns exist in the reliance on soft funds for faculty salaries.

Data Sources

Analysis of the dependence on soft funds for faculty salaries can be performed using both data on sources of support for individual faculty members and aggregate data on funding sources for department salaries. The latter are easier to obtain, but they may mask differences among departments in their treatment of faculty of different rank. Both types of data must be obtained from individual centers because there is no central source of such data, and if there were, differences in accounting definitions would make them suspect.

The data used in the analysis reported below were obtained from the ten academic medical centers in the earlier Rand study and updated for recent years.[6] In the results reported, the data are in most cases drawn from individual faculty sources of support, and department data are aggregations of individual salary support data. In several cases, however, the sources of funds for faculty salaries were not available on an individual basis and total department salary data were provided by the school.

Analysis and Results

It is possible to obtain a broad picture of sources of support for faculty salaries and differences across institutions and departments from simple tabulations from medical center budget data. Such tabulations require no statistical analysis. They do require extensive examination of medical center financial accounts and the development of a common framework for making cross-school comparisons. Aggregation of multiple categories of funds (e.g., NIH research grants, program project grants, center grants, career development awards, etc.) into broad classes of funds (e.g., HEW research) also facilitates comparisons.

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[5] In general, tenure is of less significance in academic medical center departments than in university departments, and this is particularly true of clinical departments. Even so, centers consider commitments to senior faculty as being of a longer term nature than those to junior faculty.

[6] Data are not available for all ten institutions because the responsibility for faculty compensation is in some cases divided among center components—the medical school, teaching hospitals, research foundations, departmental group practices partnerships—such that it is impossible to obtain unambiguous data on total compensation for some individuals.

The percentages of faculty salaries supported from seven broad classes of funds in eight medical schools are presented in Tables 15 and 16 for departments of medicine and biochemistry. It is apparent that there is substantial variation across schools and between these two types of departments. Such variation exists in the data for other departments and institutions.

It is difficult to observe consistent trends over the time in the data. The only clear trend is the increased reliance on patient care revenue for faculty salary support in all clinical departments. This same trend is apparent in the aggregate data on medical school budgets, and it can be explained by several important interrelated changes in recent years. First, Medicare and Medicaid programs have turned many of the pre-1965 charity patients of medical centers into "paying" patients, thus generating revenue for academic physicians. Second, the full time clinical faculties of medical centers have grown substantially in recent years, and part of this growth has been more apparent than real, the result of a change in status of physicians who in earlier years practiced in academic medical centers but volunteered their teaching services. Third, the institutional control over practice income has increased in most centers during the past eight years. Taken together, these factors account for some apparent and some real increase in reliance on practice fees for clinical faculty compensation.

Apart from the increased reliance on practice income, our data show no clear pattern among schools, across departments, or over time in the reliance on NIH

Table 15

SOURCES OF SUPPORT FOR FACULTY SALARIES:
DEPARTMENT OF MEDICINE
FY 1973-74
(Percent)

Source	School A	School B	School C	School D[b]	School E	School F	School G[b]	School H[b]
General funds[a]	36.5	38.7	38.3	7.4	26.2	50.5	7.2	55.0
Federal research grants	25.6	5.2	20.5	29.6	17.2	11.8	32.7[c]	2.6
Federal training grants	3.0	4.1	5.5	1.1	7.8	17.8	0.0	0.0
Other federal funds	0.0	0.0	5.0	1.2	0.0	0.0	0.0	0.0
Foundation grants	1.7	1.4	3.2	6.0	20.0	1.5	5.2	0.0
Patient care revenue	30.3	50.5	26.2	46.4	28.8	17.0	55.9	42.4
Other sources	2.9	0.1	1.1	8.3	0.0	1.4	0.0	0.0

Sources: budget data provided by individual medical schools.

[a] General funds include state appropriations, university general funds, endowment, tuition and federal and state capitation payments.

[b] Private medical schools.

[c] Includes some federal training grant funds.

Table 16

SOURCES OF SUPPORT FOR FACULTY SALARIES:
DEPARTMENT OF BIOCHEMISTRY
FY 1973-74
(Percent)

Source	School A	School B	School C	School D[b]	School E	School F	School G[b]	School H[b]
General funds[a]	72.6	70.7	81.0	81.2	46.0	60.6	44.4	95.2
Federal research grants	21.1	24.6	17.8	15.7	13.3	31.6	47.8[c]	2.8
Federal training grants	0.0	4.3	0.0	0.0	30.8	6.1	0.0	0.0
Other federal funds	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Foundation grants	0.0	0.0	0.9	3.1	9.8	0.0	6.0	0.0
Patient care revenue	4.3	0.4	0.0	0.0	0.0	1.5	1.8	0.0
Other sources	0.0	0.0	0.3	0.0	0.0	0.2	0.0	0.2

Sources: budget data provided by individual medical schools.

[a] General funds include state appropriations, university general funds, endowment, tuition and federal and state capitation payments.

[b] Private medical schools.

[c] Includes some federal training grant funds.

research and training funds for faculty salary support. However, institutional policies appear to be changing in this area. In general, institutions that have been able to retain or increase their NIH research support in the face of tighter federal budgets have urged their faculty to apply for more salary support on their grants. This trend is most pronounced in the state institutions in our sample. Schools that have done less well in recent years competing for NIH research funds have tried to shift faculty salaries from this funding source to another in order to reduce their vulnerability to federal funding cutbacks in the future.

We have analyzed data on sources of support for individual faculty salaries to determine if there are consistent patterns of support for faculty of different ranks, departments, and over time. The statistical technique used was analysis of variance (with interactions). The dependent variable in all cases was the percent of faculty salary on "soft" funds, where soft funds were defined as federal and nonfederal research and research training funds.[7] The categorical explanatory variables were faculty rank, academic year, and department type. Departments were classified as basic science departments, procedurally oriented departments (all surgical special-

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[7] We also analyzed the salary source data using an alternative definition of soft funds that included federal capitation and other federal program terms. The results were uninteresting in that we could explain less of the variance in the proportion of faculty salaries from soft sources using this broader definition than the one restricted to research and research training.

ties, anesthesiology, radiology, ophthalmology, and otolaryngology), and all other clinical departments.[8]

The analysis of variances results are presented for five medical schools in Tables 17 and 18. Table 17 gives data for salary sources of all faculty members including those that receive no money from soft sources. From that table one can estimate the average proportion of soft salary funding that faculty members of a particular rank in a given school would receive in a particular class of department in a given year.

Table 17

ANALYSIS OF VARIANCE
FACTORS AFFECTING PERCENTAGE OF FACULTY
SALARIES PROVIDED FROM SOFT SOURCES[a]
(Including all faculty)

	School A	School B	School C	School D	School E
Grand Mean	37.3	37.3	8.9	26.6	28.4
Year effects[b,c]					
Statistical significance[d]	NS	NS	NS	.078	NS
1966				-5.4	
1967				-3.2	
1968	-4.5	3.7		-0.3	
1969	1.2	0.8		-0.6	
1970	4.7	-1.2		0.1	
1971	3.0	1.8		2.7	
1972	-0.2	-1.6		3.0	2.7
1973	0.0	-3.0	-.2	-0.4	-1.4
1974	-4.9	1.2	.2		-0.9
1975					0.0
Department and rank effects[b]					
Statistical significance[d]	.001	.001	.001	.001	.001
Basic Science					
Professor	-20.7	-26.0	15.4	-5.6	-11.8
Associate Professor	31.0	-7.1	1.2	1.9	13.2
Assistant Professor	5.8	-18.6	14.5	9.2	11.9
Instructor	15.1	-9.9	34.2	-10.6	-7.8
Procedural Specialty					
Professor	-22.9	-14.1	-5.2	-15.3	-18.2
Associate Professor	-26.5	-11.3	-5.4	-6.3	-3.4
Assistant Professor	-23.2	-14.2	-7.0	-1.8	1.1
Instructor	-9.4	-2.0	2.5	-23.8	-20.9
Other Specialties					
Professor	-7.9	-15.2	-1.1	-10.6	2.1
Associate Professor	8.8	5.4	-3.2	3.4	1.4
Assistant Professor	13.2	16.2	2.1	16.6	7.0
Instructor	33.0	17.2	-4.9	20.6	72.8
Proportion of variance explained	.21	.09	.12	.10	.07

[a] Soft sources include federal and nonfederal research and research training funds.

[b] The numbers in the columns are deviations from the grand mean, adjusted for the other independent variables. They are analogous to the coefficients in a multiple regression that uses only categorical data as the explanatory variables.

[c] Blank spaces in year columns indicate no data available for that year.

[d] Main effects that are not significant at the .10 level are noted as "NS"; significance levels beyond .001 are listed as .001.

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[8] The analysis was performed separately with pathology classified as a basic science department and as a procedural specialty. Results were not very sensitive to changes in this classification.

Table 18

ANALYSIS OF VARIANCE
FACTORS AFFECTING PERCENTAGE OF FACULTY
SALARIES PROVIDED FROM SOFT SOURCES[a]
(Excludes faculty with no soft funds)

	School A	School B	School C	School D	School E
Grand mean	59.9	75.0	33.8	53.2	47.7
Year effects[b,c]					
Statistical significance[d]	NS	.085	NS	NS	NS
1966				-4.4	
1967				-2.8	
1968	4.6	0.1		-3.3	
1969	.6	-0.7		-1.9	
1970	3.0	1.0		-1.2	
1971	0.4	8.5		1.3	
1972	-4.0	0.2		3.3	3.0
1973	-0.3	-2.4	-1.1	2.8	0.2
1974	-2.1	-6.5	1.1		-1.0
1975					-1.7
Department and rank effects[b]					
Statistical significance[d]	.001	.001	.001	.001	.001
Basic Science					
Professor	-31.5	-23.1	0.2	-26.2	25.5
Associate Professor	14.5	-7.5	-12.4	-21.6	-1.5
Assistant Professor	0.7	-23.4	2.8	-11.5	-5.8
Instructor	17.1	16.0	26.9	27.4	34.0
Procedural Specialty					
Professor	-16.9	-16.5	-18.3	4.3	10.0
Associate Professor	-32.9	-4.9	-13.9	15.9	16.8
Assistant Professor	-14.8	0.0	-10.8	18.3	23.4
Instructor	-2.8	16.2	34.8	24.3	53.6
Other Specialties					
Professor	-5.5	-15.0	-8.0	-14.7	-1.4
Associate Professor	-0.1	-5.1	-10.4	5.7	5.9
Assistant Professor	10.2	3.1	20.7	17.9	6.6
Instructor	24.4	16.7	17.9	32.2	52.7
Proportion of variance explained	.21	.07	.22	.27	.16

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[a] Soft sources include federal and nonfederal research and research training funds.

[b] The numbers in the columns are deviations from the grand mean, adjusted for the other independent variables. They are analogous to the coefficients in a multiple regression that uses only categorical data as the explanatory variables.

[c] Blank spaces in year columns indicate no data available for that year.

[d] Main effects that are not significant at the .10 level are noted as "NS"; significance levels beyond .001 are listed as .001.

For example, an assistant professor in a basic science department in school A in 1974 would receive an average 38.2 percent of his salary from soft sources (37.3 − 4.9 + 5.8). Table 18 uses data for only those members who received some salary support from soft funds. Thus, from Table 18 we would estimate that *given he were to receive soft fund salary support,* the same assistant professor would be expected to receive 58.5 percent of his salary from soft funds (59.9 − 2.1 + 0.7).

In general, the results indicate that the junior faculty are somewhat more heavily supported with soft money than senior faculty, and this differs among the three classes of departments. Year to year differences are not significantly different in most schools but one school (D) shows a slight trend that is marginally significant.

The most striking thing about the analysis is not the existence of statistically significant relationships but that these factors do not account for much of the differences in soft money support for individual faculty. In none of the cases have we been able to explain more than 27 percent of the total variance (R^2) in the proportion of individuals' salaries supported by soft funds, and the average R^2s are 13 percent for all faculty and 19 percent for those receiving some soft salary support.

Conclusions

There is little apparent validity to broad generalizations about the dependence of academic medical centers on federal biomedical research funds for faculty salaries. This dependence varies greatly across institutions, and not surprisingly those that have been most consistently successful in competing for research funds have tended to rely more heavily on this source of support. Although as a matter of policy, some state schools have tried to draw more heavily on soft funds in recent years, the data show no strong trend in this direction.

The only consistent trend in sources of support for faculty salaries is the increased reliance on practice earnings to pay clinical faculty salaries. However, part of this change is more apparent than real, resulting from the reclassification of some faculty from volunteer to full time and the increased accountability for practice fees. The real increase in revenue from this source due to expansion in the patient care functions of academic medical centers and public health insurance programs for the aged and needy is probably a one-time phenomenon. It does not represent a readily expandable source to replace research funds currently used for faculty salaries.

Analysis of data on individual faculty salaries does not reveal any consistently strong pattern of vulnerability to soft funding cutbacks by rank or department type. This does not confirm but is consistent with the hypothesis that individual faculty differences—among other things, success in research grants competition—account for variation in the dependence on soft funds for salary.

NIH FUNDING AND FACULTY SALARY LEVELS

We have seen that the importance of federal research funds as a source of support for faculty salaries varies across institutions. This variation can be attributed in part to differences in the research intensity of the institutions, but it is also influenced by other institutional factors—in particular, whether the institution is public or private. The variation in dependence on research funds for faculty salaries begs questions about the effects of research involvement on salary levels. For example, one might hypothesize that the availability of research funds for faculty salaries might lead to inflated salaries in research-intensive institutions.

The analysis in this section is in two parts. The first is an attempt to describe the way in which faculty salaries in a particular department are related to the level of NIH funding in that department. The second deals with how these salary levels change when NIH funding levels change.

The Data

The data for both parts of the analysis were derived from the same sources. Salary data came from the AAMC Faculty Salary Surveys for academic years 1973-74 and 1974-75. From these surveys we extracted average salaries by rank of strict full-time professors in 13 departments of each of the 117 medical schools for which the AAMC keeps data.[9] Because of the sensitive nature of the raw data, the analysis was actually performed at the computation facilities of the AAMC. Grant data by department were from the NIH IMPAC file and included data on all types of NIH grants. For convenience in this analysis we grouped all grants into two categories: Research grants include individual research grants, research support grants, program-project grants, and clinical research center grants; training grants include training grants, fellowship grants, and career development awards. Grant data are from fiscal years 1973 and 1974. Missing data for some departments reduced actual sample sizes well below the maximum possible size.

Analysis of Salary Levels

For this analysis average salary level for each professorial rank was regressed on the amount of NIH funding *per professor,* a measure of the relative cost of living[10] in the locale of the school, a dummy variable indicating whether the school was publicly or privately controlled, dummy variables denoting the region of the country (northeast, south, midwest, or west) where the school was located, and dummy variables indicating the kind of department (anatomy, biochemistry, etc.). Table 19 gives the description of the variables. Each equation was estimated twice, once using NIH research funding and once using NIH training funding.[11] The complete results of these regressions are given in Tables 20 and 21.

By far the largest part of the explained variance in salaries at all ranks is accounted for by the department and region dummies and the cost of living index. The coefficients of the region and department dummies can be interpreted as deviations from the average salary of a medicine department in the western region. In almost all cases, however, there is also a significant effect due to NIH funding that reveals an interesting pattern. For all ranks of professors a larger amount of funding per faculty member is associated with a lower average salary. For department chairmen the relationship is reversed.

A possible explanation of this pattern is that in "prestige" departments—those with large grants—professors receive some nonmonetary remuneration in the form of career advancement, improved reputation, association with stimulating col-

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[9] The departments were anatomy, biochemistry, microbiology, pathology, pharmacology, physiology, medicine, obstetrics, pediatrics, psychiatry, radiology, surgery, and orthopedic surgery.

[10] This measure was the Consumer Price Index for the city in which the medical school is located when such an index was computed, or the CPI for the nearest city. For schools not located near major cities the U.S. urban average CPI was used. It should be noted that these CPI measures give only an imperfect comparison among cities, since they are constructed primarily to show difference from one year to the next within the same city. They are, however, the best measure of relative cost of living available, and that is why we used them.

[11] It was not useful to include both types of funding in the same equation because two variables are highly collinear. (The correlation coefficient between them is in the neighborhood of 0.8.) By estimating two equations, we run the risk of attributing to each some of the effect of the other. It will be seen, however, that the estimated coefficients for both are similar and the general picture that emerges is not highly sensitive to the specification. Regressions with both variables included were run and the results did not vary significantly.

Table 19

DESCRIPTION OF VARIABLES

PUBLIC	-	1 for publicly controlled schools; 0 for privately controlled schools.
RSRH	-	Amount of NIH research funding per professor.
TECH	-	Amount of NIH training funding per professor.
IRSRH	-	Increase in NIH research funding per professor.
ORSRH	-	Decrease in NIH research funding per professor.
ITECH	-	Increase in NIH training funding per professor.
DTECH	-	Decrease in NIH training funding per professor.
CPI	-	Consumer Price Index in area of medical school.
ΔCPI	-	Change in Consumer Price Index in area of medical school.
Northeast, South, Midwest	-	Dummy variables for region.
Anatomy, Biochemistry, Etc.	-	Dummy variables for type of department.

leagues, etc. and are thus willing to work for a lower monetary income. Chairmen, however, act as entrepreneurs in building and managing such "prestige" departments and in attracting grants. They are paid according to their success. It is interesting to note that associate professors give up more in monetary terms than do full professors in order to be associated with departments receiving high levels of grants. Assistant professors give up still more.

A fairly high level of grants is associated with a fairly high level of average salary for all ranks of professors. To be consistent with the results reported above, this implies a different seniority structure in these departments, with the faculty being somewhat more "top-heavy" in departments receiving high NIH funding.[12]

Training grants seem to have a slightly more pronounced effect on salary levels than do research grants, but because of the closely collinear nature of research and training grants, not much should be made of this difference.

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[12] Another study, *The Federal Government and Academic Medicine: The Effect of Federal Programs on Activities and Output*, by Grace M. Carter et al., The Rand Corporation, R-1814-HEW (forthcoming), reports that the rapidity of promotion of a medical school faculty is not related to the success of that faculty member in obtaining NIH research grants. This study did not address the issue of how the level of grants in a particular department influenced promotion.

Table 20

RESEARCH GRANTS AND FACULTY SALARIES

Variables	Full Professor	Associate Professor	Assistant Professor	Chairman	All Professors
Public	-1638^b (375)	-418 (333)	-909^b (258)	-1978^b (543)	1.518 (387)
RSRH	$-.003^b$ (.001)	$-.012^b$ (.002)	$-.012^b$ (.001)	$.003^b$ (.002)	$.003^a$ (.001)
CPI	29^b (7)	27^b (6)	26^b (5.0)	54^b (10.6)	15^a (7)
Northeast	-316^b (762)	-2864^b (657)	-3006^b (501)	-3115^b (1063)	-3095^b (792)
South	-3621^b (552)	-3143^b (482)	-2469^b (370)	-1781^b (800)	-3661^b (576)
Midwest	-4220^b (515)	-3070^b (455)	-1765^b (359)	-1146^a (771)	-2698^b (544)
Anatomy	-11628^b (739)	-11076^b (651)	-9365^b (523)	-15401^b (1132)	-10273^b (770)
Biochemistry	-11051^b (738)	-10574^b (651)	-8550^b (523)	-14456^b (1131)	-9712^b (784)
Microbiology	-11084^b (732)	-10347^b (649)	-8840^b (523)	-14331^b (1129)	-9341^b (780)
Pathology	-1250^a (757)	-1236^a (672)	-1226^b (539)	-890 (1228)	63 (807)
Pharmacology	-10280^b (755)	-9944^b (669)	-8428^b (531)	-14299^b (1140)	-8912^b (806)
Physiology	-10357^b (731)	-9858^b (643)	-8714^b (524)	-13829^b (1125)	-9045^b (772)
Obstetrics	248 (894)	932 (764)	-461 (577)	1215 (1352)	1466 (968)
Pediatrics	-1807^a (803)	-2900^b (724)	-2509^b (565)	-3574^b (1289)	-3017^b (868)
Psychiatry	-3068^b (794)	-2524^b (712)	-2830^b (559)	-781 (1303)	-1681^a (842)
Radiology	4761^b (835)	4923^b (750)	4445^b (580)	5135^b (1327)	4204^b (896)
Surgery	4760^b (137)	2785^b (724)	2017^b (569)	5913^b (1380)	3436^b (876)
Orthopedic Surgery	-	-	-	-43161^b (1211)	-31415^b (825)
Constant	328	-4924	-10003	-26895	11242
R^2	$.537^b$	$.543^b$	$.542^b$	$.661^b$	$.693^b$

[a] Significant at the .05 level.

[b] Significant at the .01 level.

Table 21

TRAINING GRANTS AND FACULTY SALARIES

Variables	Full Professor	Associate Professor	Assistant Professor	Chairman	All Professors
Public	-1668^b (375)	-383 (337)	-988^b (262)	-1985^b (545)	33 (388)
TECH	$-.016^b$ (.004)	$-.021^b$ (.007)	$-.003^b$ (.005)	.008 (.009)	$.001^a$ (.008)
CPI	28^b (7)	28^b (6)	27^b (5)	55^b (10)	15^a (7)
Northeast	-3110^b (761)	-2918^b (664)	-3076^b (506)	-3139^b (1064)	-3087^b (793)
South	-3611^b (552)	-3117^b (486)	-2436^b (374)	-1831^a (800)	-3654^b (577)
Midwest	-4208^b (515)	-3028^b (459)	-1760^b (363)	-1176 (771)	-2696^b (544)
Anatomy	-11638^b (736)	-10542^b (648)	-9137^b (528)	-15543^b (1130)	-10309^b (769)
Biochemistry	-11076^b (736)	-10234^b (654)	-8494^b (531)	-14543^b (1131)	-9735^b (783)
Microbiology	-11085^b (729)	-9917^b (649)	-8669^b (529)	-14437^b (1127)	-9395^b (778)
Pathology	-1245^a (754)	-740 (670)	-1112^a (545)	-1025 (1225)	-36 (804)
Pharmacology	-10218^b (749)	-9497^b (669)	-8197^b (535)	-14407^b (1139)	-8988^b (803)
Physiology	-10345^b (727)	-9498^b (645)	-8521^b (529)	-13940^b (1123)	-9097^b (770)
Obstetrics	220 (892)	1425^a (766)	-258 (583)	1064 (1350)	1440 (968)
Pediatrics	-1845^a (803)	-2392^b (724)	-2326^b (571)	-3705^b (1287)	-3055^b (867)
Psychiatry	-3083^b (791)	-1941^b (710)	-2579^b (565)	-942 (1301)	-1709^a (842)
Radiology	4789^b (830)	5494^b (748)	4617^b (585)	4983^b (1324)	4121^b (893)
Surgery	4788^b (812)	2851^b (730)	1873^b (576)	5781^b (1378)	3361^b (874)
Orthopedic Surgery	-	-	-	-43330^b (1208)	-31448^b (824)
Constant	1688	-6935	-10965	-27538	10974
R^2	$.538^b$	$.536^b$	$.533^b$	$.660^b$	$.693^b$

[a] Significant at the .05 level.

[b] Significant at the .01 level.

Analysis of Changes in Salary Levels

Although the preceding analysis of salary levels gives some indication of how faculty salaries and NIH funding are related at present, it tells us nothing directly about what would happen to salaries if NIH funding levels were to change. To explore this question, we regressed changes in average salaries from one year to the next on changes in NIH funding, the level of NIH funding, changes in the cost of living, dummy variables to indicate region of the country, and a dummy variable to indicate public or private control. As in the analysis of salary levels, all funding data were computed on a per faculty member basis.

Because only two years of salary data were available, we were able to compute only one observation for each department. This limited sample size requires that these results be viewed as quite tentative. Some patterns do emerge. As always, data on changes are subject to wide variation caused by factors not included in our model. We have not, therefore, been able to explain very much of the variance in changes in salaries.

We found in preliminary analyses that patterns of change in salaries differ from clinical departments to basic science departments. Complete results of the regressions for clinical departments can be found in Table 22 and those for basic science departments in Table 23. In clinical departments there appears to be a positive relation between increases in research grants and increases in full professors' salaries. This relationship does not seem to hold, however, for associate or assistant professors. Assistant professors appear to be highly vulnerable to decreases in training grants. For each dollar reduction in the amount of training grants per faculty member, increases in assistant professors' salaries are reduced 26 cents. In departments with high levels of research grants per faculty member, full professors' salaries have risen less and associate professors' more than in departments with lower grant levels. In departments with high levels of training grants, salaries of both full and assistant professors have risen more than those in departments with lower levels of training grants. Levels of neither type of grant appear to affect the size of changes in assistant professors' salaries.

Very few coefficients fitted for basic science departments are statistically different from zero. Perhaps with more years of data some patterns would emerge, but on the basis of what was available for this study there is simply no interpretable pattern for basic science departments.

Table 22

CHANGES IN FACULTY SALARIES IN CLINICAL DEPARTMENTS

Variables	Full Professors	Associate Professors	Assistant Professors	Chairman
Public	1380[a]	-1082	-206	-2846
	(701)	(745)	(620)	(2737)
RSRH	-.010[b]	-.010	-.007	-016
	(.003)	(.011)	(.005)	(065)
TECH	.089[b]	.069	.017	-.227
	(.028)	(.045)	(.031)	(.313)
IRSRH	.023[a]	-.018	.009	-.116
	(.011)	(.018)	(.013)	(.141)
DRSRH	.115[a]	.012	.015	.197
	(.058)	(.014)	(.011)	(.294)
ITECH	-.175[b]	-.007	-.011	.140
	(.051)	(.083)	(.058)	(.579)
DTECH	.144	.069	.268[a]	.340
	(.158)	(.134)	(.135)	(.567)
ACPI	64[a]	17	37	166
	(38)	(38)	(33)	(141)
Northeast	1230	-786	721	-6504
	(1105)	(1132)	(953)	(4152)
South	-1147	-1189	-715	-4044
	(897)	(924)	(771)	(3315)
Midwest	-573	-853	-1002	-4156
	(889)	(901)	(802)	(3314)
Constant	-7206	1290	-3120	-8264
R^2	.238[b]	.059	.080[a]	.051

[a] Significant at the .05 level.

[b] Significant at the .01 level.

Table 23

CHANGES IN FACULTY SALARIES IN BASIC SCIENCE DEPARTMENTS

Variables	Full Professors	Associate Professors	Assistant Professors	Chairman
Public	-11.9 (290)	487[a] (269)	385 (250)	531[a] (267)
RSRH	.003 (.005)	.011[a] (.005)	-.010[a] (.004)	.005 (.005)
TECH	-.031[a] (.016)	-.000 .001	.026[a] (.015)	.013 (.021)
IRSRH	-.008 (.012)	-.010 (.008)	.008 (.005)	-.006 (.006)
DRSRH	.000 (.023)	-.025 .021	-.029 (.019)	.032 (.022)
ITECH	.028 (.026)	-.026 .028	-.029 (.023)	-.058[a] (.028)
DTECH	.016 (.056)	-.004 (.054)	.078 (.069)	.008 (.055)
ΔCPI	9.3 (16.1)	-3.1 (15.2)	10.1 (13.5)	13.1 (14.9)
Northeast	659 (469)	774[a] (435)	451 (386)	1145[b] (414)
South	95.6 (411)	-136 (398)	-370 (347)	243 (384)
Midwest	240 (383)	556 (382)	-197 (341)	610 (371)
Constant	494	1333	-493	-105
R^2	.032	.045	.042	.068[a]

[a] Significant at the .05 level.

[b] Significant at the .01 level.

IV. THE EFFECTS OF FEDERAL BIOMEDICAL RESEARCH PROGRAMS ON INSTITUTIONAL FUNDING

Federal biomedical research funds are an important source of revenue for academic medical centers. However, the importance of biomedical research funding has declined relative to other sources. In 1974, federal research funds accounted for approximately 21 percent of the total of operating budgets of all centers; ten years earlier, the comparable figure was 36 percent. Obviously, the financial structure of academic medical centers must have changed substantially in this period, but highly aggregated data can provide very few insights into the effects of funding changes on particular institutions.

This section analyzes the effects of funding changes on academic medical centers at two levels. The first is the total operating budget of a center exclusive of teaching hospitals—the effects of changes in NIH funding on funding from other sources (e.g., state appropriations, foundations) for the center as a whole. The second level is the internal budget process within a particular center—the effects of changes in funding from outside the center (e.g., NIH research, patient fees) on the allocation of funds that are under the discretionary control of the dean or vice-president.

ALTERNATIVE SOURCES OF REVENUE FOR MEDICAL SCHOOLS

The Model

Recently questions have arisen about what effect the receipt of NIH funding has on the efforts and ability of medical schools to find and exploit other sources of revenue. For example, are losses in federal funding likely to be made up by increased revenues from state governments and foundations? Are losses in federal training funds passed on to students in the form of higher tuition? Do other sources of revenue view the receipt of NIH awards as an indication of merit and make their own awards accordingly, thus multiplying the effect of NIH awards? These are the types of questions addressed in this section.

Inasmuch as this is an exploratory analysis, the conceptual model used here is quite simple. The analysis is both cross-sectional and time series, in that we have followed the pattern of revenues from nonfederal sources for all medical schools over a seven-year period. The principal aim of our analysis is to determine by what amount revenues from these sources rose or fell as a result of changes in levels of various types of NIH funding.

For each of 15 alternative sources of funding a regression equation was fitted. All equations had the same form, regressing yearly changes in revenues from the source in question on several types of variables. Of principal interest are the coefficients associated with changes in NIH funding in the current and previous years. These coefficients are a measure of the extent to which funds from the alternative sources matched or replaced NIH funds over the time period covered by our sample. For example, a coefficient of 140 indicates that a $1000 increase in NIH funds brought with it an additional $140 of revenue from the alternative source in question, all other things being equal. A negative coefficient indicates that NIH funding replaces or is replaced by funds from the alternative source.

It is possible that medical schools may respond differently to decreases in NIH funding than they do to increases due, perhaps, to long-term commitments of the schools or other institutional rigidities that make it difficult for schools to respond to some stimuli. To allow for this type of behavior, changes in NIH funding have been decomposed into two variables, one representing increases in such funding and the other decreases. Only one of these variables can be nonzero in a particular observation. It is possible that the size of a medical school might affect its behavior in seeking money from nonfederal sources. Larger schools may be better able to absorb losses or may have more extensive experience in raising funds from a wide variety of sources. In an effort to control for these effects, two measures of the financial size of a school have been included in the regression, total revenue and total NIH grants of a given type.

Growth in the size of the undergraduate student body and of the faculty should also be taken into account. To the extent that increased revenues from tuition may reflect only the growth of the student body or rising revenues from the professional activities of the faculty may reflect faculty growth, these changes are not of concern in this section of the study. We have therefore included in the regressions terms for changes in number of students and faculty. Like NIH grants, these have been divided into increases and decreases. Finally, dummy variables have been included to reflect the differing financial environments faced by public and private schools and by accredited and provisionally accredited institutions.

The equations estimated have the following form.(ΔR is the change in revenue from a particular source. For a discussion of the sources considered, see below.)

$$\begin{aligned}\Delta R = a_1 + a_2\mathrm{ACRDT} + a_3\mathrm{NIH} + a_4\mathrm{INIH} + a_5\mathrm{DNIH} + a_6\mathrm{INIHL} \\ + a_7\mathrm{DNIHL} + a_8\mathrm{IUG} + a_9\mathrm{DUG} + a_{10}\mathrm{IFAC} + a_{11}\mathrm{DFAC} \\ + a_{12}\mathrm{TREV} + a_{13}\mathrm{PUBLIC}.\end{aligned}$$

A description of each of the variables used in this equation is found in Table 24.

The Data

All data except NIH grant data are from surveys taken by the Liaison Committee on Medical Education (LCME) of the Council on Medical Education, American Medical Association and the Association of American Medical Colleges. Most of the data for this analysis were drawn from the Institutional Profile System (IPS) file. The results of the LCME questionnaire were available for the seven academic years 1967-68 through 1973-74, allowing nine sources of revenue to be followed through this period. For the last three of these years, a richer set of responses was available, allowing an additional six sources to be considered for this shorter period. Although all data in the IPS are kept for the 117 medical schools in operation during the 1974-75 academic year, some schools were not in operation during the early portion of the period covered by the study and there are often data missing from the survey responses. Because the regression equations fitted involve differences and lagged differences, it is possible to produce a maximum of five observations per school out of seven years of data. The missing data reduce the actual sample sizes to considerably less than the 585 theoretically possible.

Table 24

DESCRIPTIONS OF VARIABLES

ACRDT	-	Dummy variable; 1 if school is accredited, 0 if provisionally accredited.
NIH	-	Amount of NIH grants. (Various formulations of this variable were used. See discussion of data below.)
INIH	-	Increase in NIH grants from one year to next, if any.
DNIH	-	Decrease in NIH grants, if any.
INIHL	-	Increase in NIH grants, lagged one year.
DNIHL	-	Decrease in NIH grants, lagged one year.
IUG	-	Increase in number of undergraduates, if any.
DUG	-	Decrease in number of undergraduates, if any.
IFAC	-	Increase in faculty size, if any (full time).
DFAC	-	Decrease in faculty size, if any (full time).
TREV	-	Total revenue.
PUBLIC	-	Dummy variable; 1 if school is public or state related, 0 if private.

Data on NIH grants were of three types. The IPS contains data on NIH funding for program projects and center grants, and for research grants received by schools during a given *academic* year. These data are available for academic years 1967-68 through 1973-74. The amounts of grants awarded by NIH to institutions during a given *fiscal* year are available from the NIH IMPAC file for FY 1967 through FY 1973. This file contains data on program project, center, and research grants, and on training grants. Also in this file are data on grants made to hospitals associated with medical schools. Each regression equation was fitted three times: once using AAMC research grant data, once using IMPAC file research grant data, and once using IMPAC file training grant data. Since the IMPAC file data are for grants awarded in a given fiscal year, the effects of these grants will most likely show up most strongly in the academic year immediately following when most of this money is spent. Thus, an effect that appears with a lag with the AAMC data should appear to be a current effect with the IMPAC data. (This, in fact, is what is observed.)

Analysis

Of the 15 sources of revenue considered in this study, six appear to show patterns of response (or nonresponse) to changes in NIH funding of sufficient interest to be reported in detail here. Each of these will be dealt with briefly. The complete results of the regressions are given in Tables 25-31. The remaining nine[1] seem to exhibit no relationship to NIH funding. Great care must be taken when attributing changes in revenues from nonfederal sources to a causal relation with NIH funding. What is revealed by this analysis is only that during the time period of our study revenues from some appeared to change with some relation to changes in NIH funding. The inference of a causal relationship must rest on other evidence. In some of the cases cited below, the relations that appear are probably spurious. In many cases, the most that can be said is that the data either are or are not consistent with a causal relation among funding sources.

It should also be stressed that the results reported here are based on a first analysis of the data. In a few cases, which will be noted, we see apparently anomalous results. These are probably statistical artifacts and could perhaps be explained by a more extensive examination than was possible in the present study. In any case, they provide useful cautionary tales about interpreting these results too finely. Despite these blemishes, the picture that emerges is broadly interpretable.

State Sponsored Research. The level of state sponsored research appears to respond to changes in NIH funding in the ways one might expect. Both the AAMC data and the IMPAC data on research grants show a negative relation between increases in NIH funding and state sponsored research. The AAMC data suggest that an increase of $1000 in NIH research replaces about $149 of state research money. The figure implied by the IMPAC data is $175. Decreases in NIH funding seem to have no noticeable effect. As one might expect, there is no effect due to changes in NIH training grants.

The situation depicted by these results seems to be one in which large amounts of NIH money replace small amounts of state money, but not vice versa. Perhaps state research funds are used as "seed money" to get particular programs started. This possibility should be explored in more depth.[2]

Nongovernment Sponsored Research. Research sponsored by nongovernmental sources shows behavior similar to that of total gift revenue. In the short run there appears to be a negative relation between this type of research support and NIH research funding, but in the longer term money from these sources follows NIH money. With AAMC data, an *increase* in current NIH research of $1000 funding brings about a drop of $57 in nongovernment research money. A lagged increase in NIH funding of the same size brings a gain of $124. Once again, as in many of the cases above, decreases in NIH funding seem not to have an effect.

This pattern is consistent with the IMPAC data. The early negative effect is not observed because when using this data set we observe funding only after a lag. The

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[1] These are public and state related appropriations, alumni gifts, business and industry gifts, private school subsidies from state and local governments, revenues from intrastate and interstate compacts, city-county government appropriations, foundation gifts, state and local multipurpose funds, and nongovernment multipurpose funds.

[2] This equation is the only one in which there seems to be evidence of serially correlated residuals produced by the regression. The serial correlation appears to be positive, and thus it is likely that the errors in this equation have been understated and the significance of some effects overstated. Unfortunately, we were not able to reestimate this equation to eliminate this bias.

Table 25

STATE SPONSORED RESEARCH

Variable	Research (IPS Data)	Research (IMPAC Data)	Training (IMPAC Data)
NIH	-.803	15.6[a]	.768
	(11.6)	(9.3)	(26.9)
INIH	13.1	-175.0[b]	-32.1
	(26.9)	(36.2)	(216.0)
DNIH	-69.3	-69.0	-189.8
	(104.2)	(71.5)	(135.2)
INIHL	-149.1[b]	-22.0	16.6
	(37.8)	(34.7)	(169.3)
DNIHL	-93.1	-21.2	244.1
	(91.7)	(85.3)	(251.7)
IUG	-665.8	-395.6	-507.9
	(854.1)	(808.5)	845.9
DUG	-1122.7	-887.3	-1293.3
	(2275.8)	(2227.1)	2327.4
IFAC	-1558.2[b]	-1395.0[b]	-1495.2[b]
	(436.8)	(422.1)	438.5
DFAC	1382.3[a]	1294.4	1359.4[a]
	(649.0)	(658.7)	659.7
TREV	5.0[a]	.002	7.0
	(2.9)	(.002)	(2.3)
ACRDT	-100985.0	-22561.9	17292.2
	(320122.3)	(180312.5)	190042.4
PUBLIC	21369.1	28654.6	19969.1
	(43571.1)	(40625.6)	(42700.6)
CONSTANT	105995.9	12131.2	20154.5
R^2	.160[b]	.174[b]	.084[a]

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[a] Significant at the .05 level.

[b] Significant at the .01 level.

Table 26

NONGOVERNMENT SPONSORED RESEARCH

Variable	Research (IPS Data)	Research (IMPAC Data)	Training (IMPAC Data)
NIH	14.3	5.8	3.5
	(11.6)	(9.4)	(25.5)
INIH	-57.0[a]	98.9[b]	134.1
	(28.4)	(35.8)	(199.8)
DNIH	94.2	16.4	38.1
	(109.5)	(73.9)	(133.9)
INIHL	124.1[b]	89.1[b]	132.9
	(38.4)	(35.2)	(164.0)
DNIHL	-4.9	-81.7	74.3
	(94.4)	(78.2)	(235.8)
IUG	391.1	269.0	356.3
	(726.6)	(691.0)	708.1
DUG	1660.7	1727.3	1878.5
	(2059.6)	(2003.9)	(2055.3)
IFAC	-757.8[a]	-947.3[a]	-675.8
	(441.8)	(427.1)	(436.1)
DFAC	-362.5	21.5	-491.8
	(705.2)	(707.0)	(702.8)
TREV	.002	.001	.006[b]
	.002	.002	(.002)
ACRDT	-41314.7	-10292.8	-26620.9
	(370326.0)	(162970.7)	(167735.1)
PUBLIC	40818.2	47566.9	43485.5
	(38153.2)	(36234.3)	(37244.4)
CONSTANT	-4428.7	-37391.6	-43017.33
R^2	.112[b]	.115[b]	.065[b]

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[a] Significant at the .05 level.

[b] Significant at the .01 level.

Table 27

NONFEDERAL TEACHING AND TRAINING FUNDS

Variable	Research (IPS Data)	Research (IMPAC Data)	Training (IMPAC Data)
NIH	22.3 (23.6)	24.6 (19.6)	83.9[a] (49.3)
INIH	.767 (55.9)	18.4 (82.6)	-565.2 (380.4)
DNIH	10.7 (209.7)	238.0[a] (139.0)	-772.8[b] (8506.7)
INIHL	13.7 (81.7)	-47.5 (71.4)	-349.2 (1371.4)
DNIHL	254.9 (173.7)	37.6 (147.0)	-396.6 (452.2)
IUG	2687.1[a] (1375.2)	2686.3[a] (1319.6)	2694.3[a] (1292.6)
DUG	-691.2 (3596.7)	-1398.1 (3509.0)	-616.6 (3433.1)
IFAC	704.5 (1080.2)	683.6 (1053.3)	618.9 (980.8)
DFAC	97.2 (1445.7)	136.5 (1462.6)	581.6 (1358.4)
TREV	-.000 (.005)	.000 (.005)	-.002 (.004)
ACRDT	(7.2)	-46237.2 (441765.3)	-55482.9 (433679.8)
PUBLIC	29427.0 (78713.6)	37616.0 (74672.6)	49564.4 (73322.8)
CONSTANT	-85603.5	-42265.1	-64943.2
R^2	.042	.047	.083[b]

[a] Significant at the .05 level.

[b] Significant at the .01 level.

Table 28

TUITION (PRIVATE SCHOOLS)

Variable	Research (IPS Data)	Research (IMPAC Data)	Training (IMPAC Data)
NIH	-8.0 (8.1)	-4.5 (5.7)	17.5 (16.0)
INIH	3.5 (15.4)	50.1[a] (20.2)	-513.8[b] (140.2)
DNIH	235.9[b] (78.0)	1.06 (47.4)	121.8 (77.0)
INIHL	66.3[b] (21.3)	-24.0 (20.3)	-69.2 (99.9)
DNIHL	-.919 (54.3)	48.7 (55.2)	127.9 (148.8)
IUG	1925.0[b] (695.5)	1913.7[b] (687.3)	2087.7[b] (679.5)
DUG	2142.8 (4065.6)	1652.3 (4095.9)	2128.1 (4035.4)
IFAC	-282.5 (228.2)	-210.2 (232.2)	-121.6 (228.2)
DFAC	-1385.9[b] (418.9)	-1614.4[b] (475.3)	-1296.8[b] 423.4
TREV	.001 (.001)	1.46 (1.47)	1.8 (1.3)
ACRDT	-	-	-
PUBLIC			
CONSTANT	131585.9	114703.1	11558.9
R^2	.21310[b]	.171[b]	.194[b]

[a] Significant at the .05 level.

[b] Significant at the .01 level.

Table 29

TUITION (PUBLIC SCHOOLS)

Variable	Research (IPS Data)	Research (IMPAC Data)	Training (IMPAC Data)
NIH	-3.7 (5.5)	5.8 (4.8)	3.23 (12.4)
INIH	-1.1 (17.8)	4.9 (20.3)	20.2 (86.8)
DNIH	46.7 (56.8)	28.8 (39.2)	65.3 (69.8)
INIHL	5.8 (21.9)	-98.9^{b} (22.5)	-156.7^{a} (82.1)
DNIHL	128.4^{a} (58.5)	3.7 (38.2)	-312.0^{b} (109.6)
IUG	479.7 (293.0)	534.6^{a} (273.3)	426.9 273.6
DUG	-501.0 (724.5)	-1122.6 (695.4)	-803.8 (693.8)
IFAC	371.0 (538.8)	-13.9 (301.0)	106.6 (298.8)
DFAC	-267.0 (354.6)	-46.4 (335.3)	-61.4 (333.0)
TREV	$.004^{b}$ (.001)	4.5^{b} (1.2)	$.003^{b}$ (.001)
ACRDT	16825.7 (124367.5)	-51856.5 (68593.0)	-55606.2 (69012.7)
PUBLIC			
CONSTANT	-15032.5	37987.0	42658.5
R^2	$.131^{b}$	$.193^{b}$	$.183^{b}$

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[a] Significant at the .05 level.

[b] Significant at the .01 level.

Table 30

PROFESSIONAL FEES

Variable	Research (IPS Data)	Research (IMPAC Data)	Training (IMPAC Data)
NIH	-10.8 (26.5)	7.8 (22.5)	6.9 (57.9)
INIH	64.8 (79.9)	-129.1 (86.6)	-190.1 (432.6)
DNIH	-230.7 (264.3)	339.2[a] (165.0)	-148.2 (304.3)
INIHL	-75.5 (89.2)	.073 (79.1)	-1.3 (349.4)
DNIHL	339.4 (206.9)	49.7 (171.6)	-105.1 (531.6)
IUG	-2177.8 (2041.0)	-1773.7 (1986.3)	-1737.5 (1990.0)
DUG	10901.4[b] (4169.1)	10428.4[a] (4127.4)	10744.5[a] (4140.8)
IFAC	645.6 (1228.7)	882.2 (1205.7)	300.8 (1168.0)
DFAC	2162.5 (1664.1)	1863.5 (1698.4)	2314.5 (1648.5)
TREV	.010 (.007)	10.6[a] (6.3)	7.9 (5.5)
ACRDT	158335.7 (742291.3)	166663.6 (731234.9)	147443.0 (736562.6)
PUBLIC	8982.3 (93496.3)	46795.4 (89647.1)	40642.6 (90025.4)
CONSTANT	130158.2	80596.4	91120.0
R^2	.066	.069[a]	.056

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[a] Significant at the .05 level.

[b] Significant at the .01 level.

Table 31

TOTAL GIFT REVENUE

Variable	Research (IPS Data)	Research (IMPAC Data)	Training (IMPAC Data)
NIH	-3.0 (14.7)	-12.8 (10.9)	-41.8 (29.8)
INIH	4.6 (32.8)	-115.8[b] (43.2)	403.8[a] (227.3)
DNIH	110.2 (133.9)	-27.7 (82.2)	-315.7[a] (166.9)
INIHL	-155.0[b] (47.1)	143.7[b] (40.9)	-290.7 (185.1)
DNIHL	-23.6 (106.2)	39.7 (96.9)	196.0 (276.2)
IUG	-10.2 (972.2)	-396.2 (923.2)	-148.5 (944.4)
DUG	741.7 (2825.1	2093.2 (2726.8)	928.7 (2782.4)
IFAC	607.0 (506.7)	586.9 (488.0)	504.7 (486.1)
DFAC	-4335.1[b] (864.5)	-3964.8[b] (887.9)	-4014.6[b] (853.4)
TREV	7.2[a] (3.4)	.005[a] (.002)	.005[a] (.002)
ACRDT	-	-58726.6 (194092.7)	-61549.5 (199616.0)
PUBLIC	30371.8 (46970.8)	29007.2 (44167.6)	31975.7 (45479.6)
CONSTANT	-103259.2	-32221.98	-37993.3
R^2	.151[b]	.177[b]	.131[b]

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[a] Significant at the .05 level.

[b] Significant at the .01 level.

positive effects show up as they should, associated with increases in NIH funding. Current (that is, for the just ended fiscal year) NIH funding increases of $1000 bring an additional $98 in nongovernment research money. The figure for a similar lagged increase is $89.

Changes in training grants have no discernible effect.

The picture presented here appears to be one of NIH funding in the previous year being regarded as an indication of merit by other research funding organizations as they make their own grant decisions. There is some evidence that to a small degree these sources also make up for short-run decreases in NIH funding.

Nonfederal Teaching and Training Funds. As might be expected, changes in NIH research funding seem to have little effect on the availability of nonfederal training funds. The situation is very different, however, when we consider the effect of NIH training grants. An increase of $1000 in NIH training grants replaces about $596 of funds from other sources in the current year. A loss of $1000 is replaced by about $772 from other sources. These same patterns (of a magnitude of about $400 per $1000 of NIH funds) appear with respect to lagged NIH funding, although the variance of these latter estimates is very high and they are in fact not statistically significant.

The pattern that emerges is clearly one of major substitution of NIH funds for other training funds and vice versa.

Total Revenues from Student Tuition

Tuition revenue is the only source of funding studied that shows markedly different behavior for public and private schools. Private schools increased their total tuition revenues by about $100,000 more per year than did public schools and the patterns of increases are markedly different.

Changes in NIH research funding appear to be *positively* related to changes in total tuition revenue. Rises in NIH funding seem to have brought with them small *increases* in tuition revenues, and conversely for a fall in NIH funding. When we use AAMC data, public schools decreased their total tuition by $128 for each $1000 lost in NIH research grants the previous year. Private schools decreased their tuition revenues by $235 for each $1000 in NIH money lost during that year and added $66 per $1000 gained the previous year. When we use IMPAC research grant data, these relations are somewhat less marked. An increase of $1000 in NIH funding brought a $50 increase in tuition revenue for private schools in the same year and a $99 increase for public schools the following year.

When we use IMPAC training grant data, negative effects appear, but curiously only for public schools. An increase in NIH funds of $1000 reduces total tuition by $156 after a delay of a year and a similar decrease raises tuition revenues by $312. For private schools, the relation has been positive with a $1000 decrease in NIH training funds being associated with a decrease in tuition of $128 in the same year.

The picture that emerges, then, is cloudy. There seems to be a small positive effect associated with NIH research funding, with public schools taking longer to respond than private schools. We have no explanation for these apparent patterns of behavior. The results associated with training grants are difficult to understand and should probably be attributed to anomalies in the time period in question until further study permits a more satisfactory explanation.

Revenue from Professional Fees. There is a positive relationship between revenues from the professional services of the faculty of a medical school and lagged losses in NIH research funding. Results are similar with both types of NIH data: A loss of $1000 in NIH research funding is followed by a loss of $339 in revenue from professional services. It is curious that in spite of such a large effect of decreases in NIH funding there seems to be no effect due to increases in such funding. Changes in training grants seem to have no effect.

It is difficult to know what to make of these results. Historically, revenues from professional services have been underreported by medical schools. The trend, however, has been for these reports to become more accurate in recent years. It is possible, then, that gains in revenues from this source are randomly reported as better accounting procedures are adopted. Losses, a much smaller subset of the sample than gains, might be reported quite accurately, thus giving the observed result. This explanation is *ad hoc;* a better one will have to await more detailed study.

Total Revenue from Gifts. Gift revenue seems to substitute for NIH research funding to a small degree in the current period. Over the longer run, however, gifts seem to come with NIH funding, suggesting that to some degree NIH funding is looked upon as an indication of merit by other donors. With AAMC data, an increase in lagged NIH research funding of $1000 brings a drop in gift revenue of about $155. Decreases in NIH funding have no discernible effect.

When we use IMPAC data, this negative relationship continues to hold (now in the current period, because of the nature of the data). An increase in NIH research funding of $1000 brings a loss of gifts of about $115. Once again a loss in NIH funding seems to have no effect. A lagged NIH funding increase of $1000 brings $143 in additional gift income. Lagged decreases seem to have no effect.

Changes in NIH training grants show the curious behavior of seeming to promote higher gift revenue no matter in which direction the change is. An increase of $1000 brings in $403 in extra gifts and a decrease of similar size brings $315 in extra gifts.

The picture seems to be one of institutional action in the face of changed circumstances. When research grants decrease, gifts are sought, but in the long run gifts are attracted by the same qualities that attract NIH grants. Any change in teaching funds appears to encourage the seeking of new gift income: attempting to make up for shortfalls and being encouraged by increases. Perhaps in unchanging circumstances medical schools become complacent in seeking gifts, but it is more likely that this finding is a peculiarity of the data used.

Conclusions

It is difficult to summarize the results briefly presented above in any convenient way. Changes in NIH research grants seem to exert only a mild influence on revenues received from other sources, and the effects are usually the result of increases in NIH funding. Revenues from sources other than NIH apparently do not make up very much for shortfalls in NIH funding and respond only slightly to increases in NIH funding. With training grants the picture is somewhat different. NIH funds apparently are being substituted for by funds from nonfederal sources.

In all cases the ratio of changes in funds from alternative sources to changes in

NIH funds is far less than one to one. There is simply no evidence that changes in NIH funding have a major effect on funding from other sources.

Two caveats should be kept in mind. First, none of the equations estimated fits very well. In no case have we been able to explain more than 25 percent of the variance in funding from other sources. Given the widely divergent natures of medical schools in the United States, it is unlikely that any model could accurately characterize such a disparate group of institutions, particularly since we examined data on changes from one year to the next. These data are influenced by many factors beyond those considered in this simple model. Even with the poor fit of the equations, some patterns of behavior stand out. All results presented here, unless otherwise noted, are statistically significant at the 5 percent level. Relationships not reported may in fact exist, but they cannot be established with the data available.

The second caveat is that inasmuch as there is a large cross-sectional component to this analysis, one must be careful in extending these results to a situation very different from that of the last seven years. To be more specific, medical schools often compete for revenue from many of the sources considered here. In many cases if one school receives money, another does not. A cut in NIH funding to a particular school could have very different effects depending on whether similar cuts were also being experienced by other schools. The unraveling of this interrelationship among schools will have to await a more elaborate analysis.

RESOURCE ALLOCATION DECISIONS WITHIN ACADEMIC MEDICAL CENTERS

The Model

The preceding part of this section examines the relationships among the various sources that support a medical school, but it would be incorrect to infer from that discussion of aggregate funding that all or even most of the school's resources, much less the center's, are under the control of the central administration. To be sure, the individual with the broadest responsibility for budget, program, and policy decisions is the medical school dean or vice-president. The parent university, as well as most outsider organizations and agencies, provides support to the center, at least nominally, through the dean's office. However, as any medical school dean would hasten to point out, having broad policy responsibility and having money pass through his hands do not mean that he controls the programs to which the money is allocated. Real control of resources is highly decentralized.

Control over programs stems in part from control over the use of funds that are available to a center. This control, in turn, depends on the dean's relationship to the provider of money. The continuum of relationships runs from those in which the dean's office serves merely as a conduit through which predetermined amounts of money are passed to predesignated recipients (e.g., research project grants), to those in which the dean acts as the agent of the provider in deciding how money is to be used (e.g., general research support grants).

Control over programs also depends on the dean's obligation to potential recipients of the resources he controls. In some instances it is implicitly, if not explicitly, the dean's responsibility to provide the resources necessary to meet specific requirements, independently of program action. An example is the base salary for tenured faculty. In other cases the dean's responsibility is directly limited to the recipient's participation in a program that is the subject of an agreement between the medical school and the outside funding agency. An example is a research associate (a term employee of the center) whose work is funded by a grant from the Health Resources Administration. At the other end of the continuum of obligations is the situation where someone in the center requests some money over which the dean has complete control for the purpose of starting a new program or, in the case of a department chairman, hiring a new faculty member.

The dean's resource allocation process may be viewed as a system for mixing funds from different providers to support activities that each approves to meet the dean's obligations. He seeks a funding mix that will promote the programs of the center that are consistent with his policy. The mixing process provides a means for the dean to meet prior obligations, to use funds for purposes specified by the providers, and to exercise some marginal control over programs with his scarce institutional funds—that is, the funds a provider has not already earmarked for a particular center function or individual. (Examples include university general funds and federal capitation grants.)

Our description of the dean's budget suggests that many factors influence his decisions on how to allocate the scarce resources that are not already earmarked by funding organizations for particular medical center activities. It is not feasible to specify a mathematical model that takes account of all these factors since many of them are not easily measured. However, by means of simple models it is possible to describe some budget outcomes that the dean influences. The most easily interpretable of these relate to individual department budgets. The department is probably the most useful organizational unit to analyze in terms of the effects of federal biomedical research funding because many center activities are organized along departmental lines. Examples are the graduate programs in the basic sciences, the intern and residency programs, the major services of the teaching hospitals, and much of the biomedical research outside the large centers or research institutes.

A question of great significance to federal research policy is the effect of receiving research grants on a department allocation of institutional funds. The answer is important from several standpoints:

- If the dean reduces institutional funds when a department receives more money from NIH or offsets reductions in NIH funding with institutional funds, the effect of earmarking federal funds for research is mitigated.
- If the dean increases a department's allotment of institutional funds when it gets increased NIH funding, then the federal government may be getting more for its money than it spends, and it is almost certain that research funds are not "subsidizing" medical education, at least at the margin.
- If a dean does not compensate for losses in NIH money with institutional funds or even cuts back on those allocations, then departments are extremely vulnerable to changes in NIH support.

To analyze the effects of research funding on the dean's allocation of institutional funds to a department, a regression equation is fitted for each department of nine medical schools in our sample of ten. The data used are both cross-section and time series, in that the observation is a department budget year. The dependent variable is that year's allocation of institutional funds. The explanatory variables include last year's allocation of institutional funds (both because we expect that a chairman will use that as a point of departure for bargaining with the dean and because we expect that real commitments to tenured faculty will impose year to year continuity in the institutional budget. The other explanatory variables are year to year changes in earmarked funding from outside resources (e.g., NIH research grants) and clinical department generated funds from patient care activities. Since we expect that a dean would treat a department's gain in outside funding differently from its losses, we have decomposed earmarked funding into two variables, one for year to year increases and the other for year to year decreases.

The data for the analysis were collected from the financial offices of the individual medical schools. We have based our analysis on two kinds of department budget data: (1) the total department budget as defined by the medical school business office, and (2) the total department budget for faculty compensation as extracted from individual faculty compensation records. Where they are available, we chose to use the latter kinds of data. The data for total department budgets present problems because the financial boundaries of departments vary across departments within an individual school, across schools, and over time.

The number of years of comparable department budget data varied across the schools in our sample. In all of the examples for which results are reported, we had data for at least four consecutive years through the academic year 1974-1975.

Our fund source data were in most cases collected in very disaggregated form—that is, by account number. We then developed a common accounting framework to fit all institutions' data and mapped the new data into that framework. Each resulting category specified the source of funds, the designated use, and the funding instrument. For example, NPG signified an NIH (N) program-project (P) grant (G). However, because the sample size for a regression is limited by the product of the number of departments in a school and the number of years of data less one (for differences), we had to aggregate budget data into broad classes, which became the variables for our equation. These are shown in Table 32.

Analysis and Results

The results of the multiple linear regression analysis for nine academic medical centers are presented in Table 33. The dependent variable is the amount of institutionally controlled funds (university general funds and federal institutional support etc.) allocated to a particular department in a particular year. The coefficients for each of the explanatory variables are presented in the table. Since the first variable, LGNFNDPY, is the department's allocation of institutionally controlled funds in the previous year and the remaining variables, RF[illegible]TRNINC etc., are year to year differences in categories of funding, coefficients for these two classes of variables require different interpretations.

The coefficients for LGNFNDPY may be interpreted as the base budget for institutionally controlled funds as a proportion of last year's level. That is, a department chairman in School C may be viewed as starting with 93 cents on the dollar from his last year's budget of general funds. Changes from this base depend on his department's or the school's success in generating other funds and on factors not accounted for in our model.

Table 32

VARIABLES FOR INSTITUTIONAL BUDGET ANALYSIS

Variable in Regression	Funding Sources Included
Institutional Funds (LGNFND, LGNFNDPY)[a]	University general funds, tuition state appropriations, endowment, capitation, etc.
Federal Research and Training Funds (RESTRNINC, RESTRNDEC)[b]	HEW, NSF, and other federal agency funds for biomedical and behavioral research and research training.
Year-to-year difference in nonfederal research and research training funds (NFRESTRND)	Foundations, industry, other private grants and gifts.
Year-to-year difference in other HEW earmarked funds (HEWPGMD)	Special project grants, Regional Medical Programs, and other HEW programs that are not directly related to biomedical research.
Year-to-year difference in patient care revenue (PATCARD)	Revenue from individual and clinical faculty group practice, contracts with hospitals, VA hospitals, and other patient care activities.
Year-to-year differences in other funds (OTHERD)	Sources not otherwise specified.

[a] LGNFND is the current year allocation and is the dependent variable in all regressions. LGNFNDPY is the corresponding amount for the previous year and is an independent variable in all regressions.

[b] Federal research and research training funds are decomposed into two variables; RESTRNINC and RESTRNDEC. RESTRNINC is used when there is an increase in amounts between two successive years; when there is a year-to-year decrease, it takes the value of zero. RESTRNDEC is used when there is a year-to-year decrease, and it takes the value of zero for increases.

The coefficients on the variables (RESTRNINC, RESTRNDEC, NFRESTRND, PATCARD, HEWPGMD, and OTHERD) are conceptually more easily interpreted. They are the estimated effect of a change in each category of support between two years on a particular department's allocation of institutional funds. However, in most cases they are not statistically significant at the .05 level. For an example where the regression coefficient is statistically significant, see School D. A department in that school may expect to get $.36 more in institutional support for faculty salaries for every dollar increase in research and training grant dollars it applies to faculty salaries.

The regression results showing coefficients very close to 1.0 for LGNFNDPY and highly significant statistical relationships were expected and reflect the strong year to year continuity in institutional budget allocations to departments and in budgets more generally. Last year's budget is almost always an excellent predictor of next year's budget, no matter what the setting. What is perhaps surprising is that the variable LGNFNDPY alone is not sufficient to explain more of the variance in these budget allocations than our entire model explains.

Although there is a significant positive coefficient for RESTRNINC in only one school, the fact that the signs are positive indicates that increases in NIH and other

Table 33

FACTORS AFFECTING ALLOCATION OF INSTITUTIONAL FUNDS TO DEPARTMENTS

		Regression Coefficients for Variables								
Schools	Number of Department Years	Institutional Funds Previous Years	Federal Research and Training Increase	Federal Research and Training Decrease	Difference in Nonfederal Research and Training	Difference in Other HEW Earmarked Funds	Difference in Patient Care Revenue	Difference in Other Funds	Constant Term	R^2
A	56	1.06[b] (.08)	0.55 (0.30)	0.94[a] (0.42)	-0.05 (.34)	0.74 (1.19)	0.00 (.05)	-.72[b] (.18)	7388	.92
B	36	1.04[b] (.06)	0.32 (.47)	-1.01 (1.07)	0.08 (.63)	c	0.02 (.05)	1.01 (2.43)	17995	.98
C	200	.93[b] (.04)	0.41 (.22)	0.33 (.28)	3.09[b] (.74)	-1.52 (1.05)	.18 (.10)	0.72[a] (0.31)	19363	.86
D	119	0.91[b] (.04)	0.36[b] (.09)	0.02 (.09)	0.04 (.04)	-0.42 (.10)	-0.07 (.03)	0.02 (.13)	9606	.82
E	113[e]	0.94[b] (.06)	0.11 (.12)	-0.01 (.35)	d	-0.06 (.10)	.18[b] (.07)	0.16 (.29)	12223	.76
F	76	0.98[b] (.06)	0.17 (.14)	-0.26 (.21)	-0.43 (.57)	c	0.21[a] (.11)	-0.19 (.15)	18147	.88
G	53	1.02[b] (.05)	0.20 (.13)	0.03 (.06)	d	c	-0.01 (.02)	f	-2672	.69
H	72	0.96[b] (.06)	-0.54 (.34)	-0.26 (.31)	d	c	-0.30 (.16)	f	21359	.79
J	69	1.03[b] (.04)	0.00 (.01)	0.00 (.01)	d	c	-0.03 (.02)	0.05 (0.04)	16135	.93

Sources: Budget data from each individual school.

[a] Indicates that coefficient is statistically significant at the .05 level.

[b] Indicates that coefficient is statistically significant at the .01 level or better.

[c] Funding from this category was either not received or has been included with general funds.

[d] Non-federal research and training funds for this school are included in federal research and training funds.

[e] Data are for years through 1972-73; a change in accounting for Veterans Administration funds make the two most recent years not comparable for earlier years. All other school data include most recent years 1974-1975.

[f] All sources of funds are classified in one of the specific categories; hence, there is no "other" category.

research funds are matched by these medical centers' own funds, that it may cost the institution something to participate in research programs. (A sign test shows the effect to be positive and significant at the .05 level.) These results tend to contradict claims that institutions use research funds to "free up" their own resources for other purposes. Only in School H is there evidence (a minus sign) of such budget behavior and this is not statistically significant.

The absence of significant negative coefficients for RESTRNDEC indicates that institutional funds are *not* used consistently to replace a department's loss of research funds. Indeed, School A appears to reduce the allocation of institutional funds substantially when a department loses research funds. This suggests that departments are left to fend for themselves in the face of cutbacks in research support and probably reflects a general shortage of institutional resources.

There is no consistent pattern among the coefficients for other categories of funds. The significant positive coefficients for patient care revenue in Schools E and F probably reflect recycling of department-generated practice revenue through a "dean's fund" (institutional funds) back to the department.

Conclusions

The results of our analysis indicate that academic medical center departments function as entrepreneurial units whose fortunes depend in substantial part on their ability to generate funds from outside sources. NIH and other public and private research funding agencies are important sources of department-generated funds, and practice earnings are of growing importance to all clinical departments, particularly those of high-earning specialties.

The central administration of a medical center appears to exercise only limited control over total department budgets, at least in the short term. There may be some asymmetry in the central administration's budget behavior with respect to increases and decreases in department research and research training funds, but the asymmetry is different from what one might expect. That is, it appears that in most institutions, a department may obtain more institutional funds by increasing its research support. However, a department's loss of research funds does not appear to have a significant effect on its allocation of institutional funds. This indicates that individual departments may be quite vulnerable to research funding cutbacks.

Another inference that may be drawn from our analysis relates to the question of whether research funds "subsidize" the education programs of medical centers. There is no evidence of such subsidies in our analysis. It appears that in most of the schools in our sample a department's research success may enable it to attract matching institutional funds. We find no evidence that research funds supplant institutional funds that are generated by, or would normally be used exclusively for, the training of undergraduate M.D.s. That is not to say that the *character* of M.D. education programs is not influenced by the presence of a research effort.

V. THE INFLUENCE OF FEDERAL BIOMEDICAL RESEARCH FUNDING ON RESEARCH AT UNIVERSITIES

This section examines the characteristics of the biomedical and behavioral research funded by NIH and ADAMHA and performed in an academic setting: graduate departments of universities, colleges of arts and sciences, schools of medicine and affiliated hospitals, and other health professions schools. The analyses described in the previous sections have sought to differentiate the effects of the research program from the effects of other factors that combine to shape the institutional characteristics (e.g., education programs, budget decisions) of the academic medical centers. This section focuses only on the research programs, ignoring the possible effects of education and health career programs on the research activities of the universities. We examine the relationships among federal research programs (e.g., ADAMHA, NIH, NIMH, NCI), the various segments of the university community that receive funds from each program, and the scientific content of the research that has been funded.

Our first step is to describe the research that is being performed under federal sponsorship. From the point of view of the federal government, an important attribute of biomedical and behavioral research is the agency, Institute, or program within the Institute that sponsors the research. Identifying the sponsor enables us to describe, at least roughly, the disease entity or normal process that will be better understood as a result of the research. Budget allocations among programs are made on the basis of the health problem being studied. The review processes for NIH and ADAMHA are administered separately. Differences among the federal programs may have different effects on the different parts of the university.

From the scientist's point of view, scientific activity is described less by the sponsoring agency than by the content and methods of the research. Although some sponsoring agencies do consistently fund certain kinds of research, the agency alone is not an adequate description of the research. There is not enough detail to describe the variety of biomedical research. In some areas of science, research that is very similar in its methods, knowledge base, and scientific goals is sponsored through programs of different institutes. Changes over time in the sponsoring agency do not always signal real changes in scientific activity because there have been changes in the perception of the areas of basic research that are relevant to certain diseases. In addition, it might be possible for an investigator to influence the assignment of his application to an Institute by adding a disease-oriented window dressing to his application, without changing the scientific content of his work. To avoid these problems, scientific activity has been classified based only on its scientific content, and not in any way on the structure of federal programs. This classification permits exploration of the effects federal program decisions have had on scientific activity.

The data consist of all applications in FY 1971 to 1975 for traditional single investigator research project grants[1] from educational institutions: medical schools, affiliated hospitals, other health professions schools, graduate departments, and colleges of arts and sciences.

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[1] Coded R01 on the IMPAC file.

Federal program characteristics are used to present the effect of current review practices and funding levels for NIH and ADAMHA on support of the different components of the university. Then the typology of the scientific activity performed under NIH research project grants is used to describe how federal funding priorities affect the scientific characteristics of research performed in institutions of higher education.

FEDERAL PROGRAM CHARACTERISTICS

Assignment of Applications to Institutes

Changes in the relative funding levels of the various federal programs will have a greater effect on the parts of the university that are most heavily involved in the programs being enlarged or cut back. There are significant differences in the academic settings of research among the institutes of NIH and ADAMHA (see Table 34).

Applications assigned to NIGMS are much more frequently from a university science department than from a medical school basic science department. Applications for NHLI and NIAMDD are most frequently from clinical departments of medical schools, and applications from basic science departments are frequently from the medical school side of the university. The situation for basic science at NICHD is reversed, probably because of population and psychology studies. However, applications come to NCI from each component of the university in the same proportion as total NIH applications.

ADAMHA receives 75 percent of psychiatry department applications but only 10 percent of applications from the rest of the university and medical school departments. Within ADAMHA, departments of the medical school other than psychiatry have a higher than expected proportion of their applications going to NIAA and NIDA, while university departments are more likely to apply to NIMH. Applications from departments of psychiatry and health professions schools go to each of the three Institutes of ADAMHA in the same proportion as the total number of applications.

Rate of Disapproval of Applications

In general, ADAMHA disapproved a larger proportion of applications than NIH. NIH disapproved 33 percent of new applications and 11 percent of renewal applications, while ADAMHA disapproved 52 percent of new applications, 22 percent of renewal applications (see Tables 35 and 36). Aside from graduate schools, we find that in both NIH and ADAMHA, the rate of disapproval of applications follows the same pattern by source, with basic science departments having fewest of their applications disapproved. However, in all these cases, ADAMHA applications are disapproved much more frequently than NIH applications. The difference in the rate of disapproval of applications from graduate schools relative to all applications for each agency *may* be because applications to NIH are likely to be from basic science departments, which have a higher approval rate, and applications to ADAMHA are likely to be from behavioral sciences departments, which have a lower approval rate.

The rate of disapproval of applications varies among the study sections in both

Table 34

PERCENTAGE OF COMPETING RESEARCH PROJECT GRANT APPLICATIONS
FROM COMPONENTS OF UNIVERSITIES BY INSTITUTES
OF NIH AND ADAMHA

	Basic Science Departments of Medical Schools	Clinical Science Departments of Medical Schools	Psychiatry Departments of Medical Schools	Health Professions Schools	Graduate Departments and Schools of Arts and Sciences
Institute of NIH					
NAI	28.4	18.8	2.0	9.6	41.1
NIAID	34.1	30.0	0	6.9	29.1
NIAMDD	29.8	51.3	0.1	4.0	14.8
NCI	33.0	37.5	0.3	5.9	23.2
NIDR	13.8	7.6	0	70.0	8.7
NIESH	30.2	23.1	0.4	14.5	31.9
NEI	13.2	54.1	0.6	4.2	28.0
NIGMS	26.1	13.0	0.3	4.2	56.4
NICHD	19.6	32.2	3.3	8.3	36.7
NHLI	32.1	52.2	0.5	5.1	10.1
NLM	13.9	26.8	5.2	12.1	42.0
NINCDS	34.6	33.6	3.7	4.4	23.8
DRR	14.8	51.9	0	11.1	22.2
Total NIH	28.6	35.6	1.1	7.4	27.4
Number of NIH Applications	8747	10878	324	2274	8375
Institute of ADAMHA					
NIAA	17.6	24.8	24.5	6.0	27.1
NIDA	25.6	20.3	27.9	6.5	19.7
NIMH	6.1	7.0	20.8	6.4	59.7
Total ADAMHA	9.5	10.1	21.9	6.4	52.1
Number of ADAMHA Applications	424	450	975	283	2313

Table 35

DISAPPROVAL RATE FOR RESEARCH PROJECT GRANT APPLICATIONS TO NIH BY COMPONENTS OF THE UNIVERSITY[a]

	New Applications		Renewal Applications	
	Number of Applications	Percentage Disapproved	Number of Applications	Percentage Disapproved
Basic Science Department of Medical School	5664	28.1	2894	9.8
Clinical Science Department of Medical School	7636	37.2	3008	14.2
Psychiatry Department of Medical School	258	52.3	59	10.2
Health Professions Schools	1739	41.9	502	15.1
Graduate Departments and Schools of Arts and Sciences	5882	30.2	2319	7.1
TOTAL	21179	33.4	8782	10.9

a) Competing R01 applications from IMPAC file fiscal years 1971-1975. When amended applications appear on the IMPAC tape, only the last amendment is counted.

Table 36

DISAPPROVAL RATE FOR RESEARCH PROJECT GRANT APPLICATIONS TO ADAMHA BY COMPONENTS OF THE UNIVERSITY[a]

	New Applications		Renewal Applications	
	Number of Applications	Percentage Disapproved	Number of Applications	Percentage Disapproved
Basic Science Department of Medical School	299	41.1	120	17.5
Clinical Science Department of Medical School	331	46.2	100	27.0
Psychiatry Department of Medical School	734	52.6	206	23.8
Health Professions Schools	227	52.4	42	23.8
Graduate Departments and Schools of Arts and Sciences	1772	54.2	474	21.9
TOTAL	3363	51.8	942	22.4

[a] Competing R01 applications from IMPAC file, fiscal years 1971-1975. When amended applications appear on the IMPAC file, only the last amendment is counted.

NIH and ADAMHA. However, no meaningful grouping of the study sections has been found to explain the pattern in disapproval rates.

Over the time period of FY 1971 to FY 1975, NIH study sections approved more applications, both new and renewal, in the later years than in the earlier ones; in FY 1971 and FY 1972, an average of 37 percent of new applications and 14 percent of renewal applications were disapproved; in FY 1974 and FY 1975, an average of 29 percent of new applications and 9 percent of renewal applications were disapproved. No trend is observable in the rate of disapproval of ADAMHA applications.

Rate of Funding of Applications

The rate of funding of approved NIH applications is the same for applications from all of the university components; about 59 percent of approved applications are funded. This is not true in ADAMHA. Once approved, ADAMHA applications from all parts of the medical and other health professions schools are funded about 80 percent of the time, while approved applications from the university departments and schools of arts and sciences are funded only 66 percent of the time. The disposition of applications is summarized in Table 37.

Table 37

DISPOSITION OF RESEARCH PROJECT GRANT APPLICATIONS[a]

	Percent of Applications That Were Disapproved			Percent of Approved Applications That Were Funded			Percent of All Applications That Were Funded		
	NIH	ADAMHA	TOTAL	NIH	ADAMHA	TOTAL	NIH	ADAMHA	TOTAL
Basic Science Departments of Medical Schools	22	34	23	60	81	61	47	53	47
Clinical Science Departments of Medical Schools	31	42	31	59	82	59	41	48	41
Psychiatry Departments of Medical Schools	45	46	46	52	79	72	29	42	39
Health Professions Schools	36	48	37	59	82	61	38	43	39
Graduate Departments and Schools of Arts and Sciences	24	47	29	59	66	60	45	35	43
Total	27	45	29	59	73	60	43	40	43

[a] Competing R01 applications from IMPAC file, FY 1971-1975. When amended applications appear on the IMPAC Tape, only the last amendment is counted.

SCIENTIFIC CHARACTERISTICS

Data Base

We have chosen to use the scientific classification codes assigned to approved applications to NIH for traditional research project grants (R01) from the IMPAC file to develop a typology of biomedical science that would describe the subfields within this broad field. Unfortunately, no similar classification system is available for applications to ADAMHA.

The scientific classification system describes the research to be performed along four axes. The first axis gives up to three codes for discipline and field such as biochemistry, physiology, etc. The complete list of codes is found in Table 38. The second axis gives up to two codes for the body system or systems under consideration; allowable codes are enumerated in Table 39. The third axis describes the research materials used for the research. Each code in the third axis describes both the source of the research material (e.g., humans, animal), the stage of development being studied or used as a source (e.g., infancy, childhood), and whether the research has developmental aspects (i.e., the study concerns changes over time or events at one stage that cause changes at a later stage). A research material code consists of a code from each section of Table 40 (a special code is used when stage of development is not applicable—e.g., with research materials or computer) with a binary indicator for the existence of developmental aspects. For simplicity in the analysis, we have separated the components of each research material code into its three parts and used them as if they were separate codes. This should not be a major problem, but it does mean that we will treat a grant that studied the infancy period of animals and the childhood period of humans the same as one that studied the infancy period of humans and the childhood period of animals. The fourth axis is a binary code that tells whether the project is drug related.

It may be worth discussing several available indicators of the kind of research that we have chosen not to use. The disease category to which the work is applicable is of course a policy-relevant indicator of the kind of research, and the Institute assignment of the application gives information about that category. However, an investigator may succeed in influencing the Institute to which an application is assigned by orienting a basic research proposal toward a specific disease when his proposal is applicable to the charter of more than one Institute. Insofar as this is true, the Institute assignment of the application reflects not the scientific content of the work but rather only the content of the proposal. Another problem with using Institute assignment has to do with changes over time in the perception of the disease category to which certain fields of basic research are relevant. For example, the Cancer Institute supported 37.4 percent of competitive renewals in immunology in 1974, whereas it had supported only 11.6 percent of these grants in 1971. In 1974 NCI took over 68 immunology grants that had previously been funded by NIAID.[2]

Another indicator of the kind of research is the Initial Review Group for the application. Here the case is not so clear for either inclusion or exclusion, since the study section assignment should reflect the broad category of the research. However, the charters of some study sections overlap because of the large numbers of appli-

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[2] Herman N. Eisen et al., Final Report of the Immunology and Microbiology Interdisciplinary Cluster, October 8, 1975.

Table 38

DISCIPLINE AND FIELD CODES ASSIGNED TO APPROVED COMPETING APPLICATIONS FOR RESEARCH PROJECT GRANTS (AXIS I)

	1971	1972	1973	1974	1975	Total
SCIENTIFIC DISCIPLINE						
1100 Physics	9	7	13	17	10	56
1200 Chemistry	366	409	314	453	459	2001
1240 Structural Chemistry of Biopolymers	351	286	188	223	247	1295
1300 Biochemistry	1436	1741	1655	2224	2376	9432
1500 Pharmacology	393	492	513	641	697	2736
1600 Toxicology	75	79	77	91	123	445
1700 Physiology	912	1064	1105	1455	1529	6065
1900 Nutrition	97	100	94	124	142	557
2000 Microbiology, Excluding Virology	108	159	175	218	271	931
2100 Parasitology	42	64	67	59	72	304
2210 Immunogenetics	27	48	49	61	74	259
2215 Immunochemistry	145	189	189	237	254	1014
2220 Immunopathology	128	160	220	257	295	1060
2225 Hypersensitivity	38	45	38	64	55	240
2230 Immunotherapy	6	33	47	63	91	240
2299 Immunology, Other	143	177	178	224	296	1018
2300 Genetics	374	424	452	530	581	2361
2400 Cell Biology	331	380	366	441	510	2028
2500 Virology	123	153	154	186	230	846
2600 Anatomy	169	217	194	265	329	1174
2700 Pathology	299	353	437	503	552	2144
2900 Biology, Not Elsehwere Classified	88	66	84	112	96	446
3100 Social Sciences	70	88	79	126	111	474
3200 Psychology	184	199	193	273	219	1068
3400 Reproduction, Growth & Dev.	195	300	287	405	423	1610
3500 Epidemiology	16	42	33	64	57	212
3600 Mathematics	73	73	83	95	79	403
3700 Information and Communication Sciences	39	39	34	39	32	183
3800 Bioengineering and Instrumentation	117	166	177	209	194	863
3900 Biomaterials	14	20	14	12	28	88
4100 Environmental Health Sciences	17	19	16	20	29	101
4200 Health Sciences and Services	11	11	14	15	20	71
4310 Biological Resources	6	3	2	5	5	21
4320 Animal Production & Facilities	6	3	4	4	4	21
4400 Clinical Medicine, General	32	96	93	81	96	398
4505 Anesthesiology	5	10	12	12	15	54
4510 Oncology	53	57	93	122	161	486
4514 Radiology	15	42	62	89	85	293
4515 Transplantation, Other Than Transplantation Immunology	64	68	53	75	75	335
4520 Surgery	63	138	144	174	139	658
4521 Trauma	20	34	41	30	41	166
4525 Denistry	19	21	16	10	45	111
4530 Hematology	83	88	70	89	92	422
4550 Opthalmology	37	24	17	19	21	118

Table 39

BODY SYSTEM CODES ASSIGNED TO APPROVED COMPETING APPLICATIONS FOR RESEARCH PROJECT GRANTS (AXIS II)

		1971	1972	1973	1974	1975	Total
100	Whole Body	355	346	340	411	457	1909
110	Oral and Dental	51	94	62	80	113	400
120	Body Caviries and Fluids	551	632	627	831	922	3563
130	Lymphatic, Hematopoietic and Reticuloendothelial Systems	181	200	217	271	327	1196
140	Skin and Membrane	79	163	159	225	212	838
150	Connective Tissues	98	147	120	142	159	666
160	Muscle	131	124	124	198	217	794
170	Nervous System	362	425	423	619	659	2488
190	Sensory Systems, Other than Visual Systems	96	100	77	150	118	541
200	Eye and Visual Systems	127	160	182	240	202	911
220	Endocrine & Exocrine Systems	160	237	270	340	400	1407
240	Circulatory System	338	349	424	449	494	2054
260	Respiratory System	103	134	130	189	176	732
270	Gastrointestinal System	308	439	354	472	496	2069
290	Urinary System	192	227	213	293	258	1183
300	Reproductive System	160	189	188	268	319	1124

Table 40

RESEARCH MATERIAL CODES ASSIGNED TO COMPETING APPLICATIONS FOR RESEARCH PROJECT GRANTS (AXIS III)

		1971	1972	1973	1974	1975	Total
STAGES OF DEVELOPMENT							
11	Preconception	13	14	15	16	16	74
12	Prenatal	112	125	112	143	131	623
13	Perinatal	59	70	74	76	81	360
14	Infancy (First Year of Life)	44	47	43	72	56	262
15	Childhood	91	72	73	88	70	394
16	Adolescence	17	20	18	22	20	97
17	Adult	244	265	262	367	352	1490
18	Aged	13	22	11	31	38	115
19	Combination of 3 or More	152	253	268	326	345	1344
20	Life Span	57	39	43	41	59	239
21	Pregnancy	9	40	22	28	41	140
RESEARCH MATERIALS							
1	Individuals, Human	387	516	600	668	677	2848
2	Individuals, Human & Animal	255	313	222	334	362	1486
3	Individuals, Animals	1555	1809	1795	2376	2506	10041
56	Microorganisms, Including Virus and Protozoa	544	693	636	763	847	3483
60	Plant	65	54	53	64	72	308
85	Computers	94	105	121	161	133	614
90	Other	341	451	378	499	523	2192
98*	Biological Subsystems: Tissues, Organs, Tumors, Body Fluids, Cells and Cell Lines	1522	1727	1912	2582	2889	10632
TOTAL NUMBER OF APPLICATIONS		3273	3882	3711	5103	5358	21327

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[*] Temporary category summarizes all codes which cannot be uniquely mapped between systems used in different time periods.

cations in a field. Study sections have been added and deleted over time. In addition, the content of the work reviewed by a study section might gradually change over time without a change in the title of a study section. A minor problem is that study section members' applications are not assigned to their own study sections, even though in many cases that would be the most scientifically appropriate selection. We produced two sets of clusters one including study section data and one without it. Unfortunately, when the study section was included, this variable appeared to dominate the clustering assignment, leading to fears that changes in the procedures used for study section assignment might overwhelm our analysis of changes in scientific content. Consequently, we have used the set of clusters without study section data in all our analyses.

Tables 38-40 list the number of competing R01 applications from selected components of institutions of higher education that received each code in fiscal years 1971 through 1975. When amended applications appeared on the IMPAC tape, only the last amendment was included in these tables and all subsequent analysis. In general, codes are not assigned for disapproved applications, so the population consists of only approved applications—i.e., those with enough scientific merit to be funded if the money is available. Unfortunately, in FY 1971 codes were not assigned to 189 approved applications, and in FY 1975 they were not assigned to 314 applications. However, this should not be much of a problem as it is less than 6 percent of the applications in each of these two years, and the grants without codes appear to be spread randomly over Institute and IRG.

Some trends are evident in these three tables and in Table 41, which shows the study section assignments for the same set of applications. One example is in the increasing assignment of the Immunology codes (2210-2299); they were assigned only 487 times in 1971, but 1065 times in 1975. This 119 percent increase is quite large compared with the 64 percent increase in number of approved applications. However, as we shall show, looking at research one attribute at a time does not provide enough information to enable us to pinpoint the changes that are taking place.

Methodology

We have attempted to relate each grant to an identifiable subfield of biomedical research. Using one code or one axis is not sufficient for this purpose; it is necessary to use the entire combination of codes assigned to each grant. For example, the biochemistry code appears on about 44 percent of applications, but one would clearly want to distinguish two grants that received the biochemistry code as belonging to separate subfields if one grant received the codes for pharmacology and nervous system along with biochemistry, and the other received the codes for physiology and the reproductive system.

Using the entire set of codes assigned to each application presents the opposite problem from the use of just a single code. Since each grant may receive as many as three codes for discipline and field, two codes for body system, two 5-digit codes for research materials, and a code for whether it was drug related, there is such a detailed description of each project that most are unique and therefore not amenable to analysis. Out of our file of 21,000 competing applications, there are over 11,000 unique descriptions when all the codes are considered. Nevertheless, some sequences

Table 41

INITIAL REVIEW GROUPS FOR COMPETING APPLICATIONS
FOR RESEARCH PROJECT GRANTS

		1971	1972	1973	1974	1975	Total
AFY	Applied Physiology and Bioengineering	7	11	13	30	42	103
ALY	Allergy and Immunology	87	109	111	128	142	577
BBCA	Biophysics & Biophysical Chemistry A	111	119	112	130	166	638
BBCB	Biophysics & Biophysical Chemistry B	104	107	105	138	166	620
BCM	Biomedical Communications	8	4	9	6	7	34
BIO	Biochemistry	154	158	145	199	228	884
BM	Bacteriology & Mycology	65	79	101	109	157	511
CBY	Cell Biology	81	113	95	123	92	504
CMS	Communicative Sciences	64	81	58	115	89	407
COM	Computer & Biomathematical Sciences	29	29	40	42	31	171
CVA	Cardiovascular & Pulmonary	60	76	80	115	119	450
CVB	Cardiovascular & Renal	63	65	70	98	129	425
DBR	Developmental Behavioral Sciences	29	32	30	29	33	153
DEN	Oral Biology & Medicine	46	73	55	59	92	325
EDC	Epidemiology & Disease Control	22	32	25	42	44	165
END	Endocrinology	93	119	125	153	170	660
ET	Experimental Therapeutics	47	76	90	91	103	407
EXP	Experimental Psychology	67	76	54	88	75	360
GEN	Genetics	106	145	162	167	175	755
GMA	General Medicine A	47	76	64	83	94	364
GMB	General Medicine B	65	90	77	110	82	424
HED	Human Embryology & Development	50	61	72	71	72	326
HEM	Hematology	94	109	97	102	107	509
IMB	Immunobiology	88	95	102	149	178	612
MBC	Microbial Chemistry	123	117	113	161	176	690
MBY	Molecular Biology	80	100	83	123	128	514
MCHA	Medicinal Chemistry A	55	93	86	105	97	436
MCHB	Medicinal Chemistry B	79	93	71	129	90	462
MET	Metabolism	115	125	106	132	146	624
NEUA	Neurology A	71	64	72	97	107	411
NEUB	Neurology B	65	89	80	156	141	531
NTN	Nutrition	33	34	26	29	63	185
PC	Physiological Chemistry	146	157	146	199	199	847
PHRA	Pharmacology	69	66	78	98	99	410
PHY	Physiology	112	102	97	145	153	609
POP	Population Research	20	43	57	86	82	288
PTHA	Pathology A	85	70	72	132	86	445
PTHB	Pathology B	68	71	87	96	91	413
RAD	Radiation	44	55	79	95	107	380
REB	Reproductive Biology	53	75	76	108	138	450
SGYA	Surgery A	40	67	55	64	62	288
SGYB	Surgery B	63	72	68	74	59	336
TEC	Clinical Trials Review (NHLI)	0	6	22	21	5	54
TMP	Tropical Medicine and Parasitology	39	60	60	53	65	277
TOX	Toxicology	38	31	35	50	70	224
VIS	Visual Sciences	75	107	126	170	162	640
VR	Virology	99	137	123	145	176	680

of codes appear repeatedly on different applications; and, although these sequences may not completely describe any single project because additional codes were attached to each application, they describe the research subfield to which the application can be assigned. For example, the sequence of codes for anatomy, physiology, the nervous system, and animals as a research material source occurs frequently and describes a subfield within the neurosciences.

We start with the hypothesis that projects having many of the same codes are more similar than projects having only one or no codes in common. We wish to group our set of applications into clusters such that each application is more like the set of grants in its own cluster than it is like the set of grants in any other cluster. To do this we define a function that describes the distance between any two applications as the total number of codes that describe either application but do not describe the other application. Thus two grants with identical descriptions have distance zero between them, and two grants that have all the same codes except for one each have distance two between them. We then assign each grant to the cluster that has the minimum distance between itself and the other grants in the cluster.

Most conventional clustering programs require a matrix of the distances between each pair of objects to be clustered. Such algorithms are well suited to data bases of 50 to 200 data points; but they become quite cumbersome, if not impossible, to handle when the data points are as large as even a thousand. Since we must cluster at least several thousand applications in order to get a rich description of scientific content, we had to develop a new clustering algorithm. To make the problem manageable, we calculate and store only distances from object to cluster center, not distances from object to object.

Clusters of Applications by Scientific Field

Table 42 describes 50 clusters that were produced by our algorithm. Each cluster represents a research area that contains at least several hundred research projects. To name these clusters, we took advantage of a detailed IMPAC coding system that was used on our IMPAC file in 1971 through 1973. For example, most projects with the body fluid code use the blood system, and most of the circulatory system codes refer to the cardiovascular system. In Table 42 we list only the codes from the scientific classification system that appear on at least one-third of the grants in the cluster. Most of the clusters can be neatly classified as a subset of one of the research areas of the interdisciplinary cluster panels convened by the President's Panel for Biomedical Research. Clusters 1-3 are subsets of the neurosciences; clusters 4 through 10 are from microbiology and immunology; clusters 11-13 are from developmental biology; clusters 14-22 are from the tissue and organ system; clusters 23-27 are from the pharmacology, substance abuse, and toxicology cluster; cluster 28 is within social and behavioral development; clusters 29-31 are in the behavioral sciences; clusters 32-47 are within biochemistry, molecular genetics, and cell biology; cluster 48 is within the epidemiology, biostatistics, and bioengineering cluster. The last two clusters are miscellaneous and contain grants that don't fit neatly anywhere else. The two interdisciplinary panels that do not emerge with separate clusters are nutrition and communicative sciences. There are few applications in these areas relative to many of the other panels. Their applications are scattered among several of our clusters.

When we used the study section assignment as an additional input to the cluster-

Table 42

CLASSIFICATION OF APPROVED RESEARCH GRANT APPLICATIONS

	Cluster	Number of Applications	Distance to Center	Scientific Classification Codes (Percent of Grants in Cluster with Code is Given in Parentheses)						Institute	Initial Review Group
				Discipline and Field	Body Systems	Research Materials	Stages of Development	Percent Developmental	Percent Drug Related		
1.	Drug Related Physiology of Nervous System	482	2.34	1700(90) 1500(49)	170(81)	13(100)	---	---	(84)	NINCDS(63)	---
2.	Psychology-Physiology of Nervous System	352	2.14	3200(70) 1700(68)	170(62)	13(98)	17(74)	---	---	NINCDS(61)	EXP(40)
3.	Anatomy-Physiology of Nervous System (Neuroanatomy)	552	2.32	2600(92) 1700(69)	170(76)	13(86) 98(51)	---	---	---	NINCDS(76)	NEUA + NEUB (48)
4.	Immunochemistry of Blood	443	3.01	2200(100) 2215(83) 2299(51)	120(89)	13(73) 98(61)	---	---	---	NIAID(61)	ALY(54)
5.	Clinical Studies of Immunopathology of Blood	319	3.68	2200(100) 2220(66)	120(73)	11(100) 98(54)	---	---	---	NIAID(30) NCI(26) NIAMDD(24)	ALY(31)
6.	Nonclinical Immunopathology	507	2.52	2200(100) 2220(98) 2215(30)	120(58) 130(33)	13(62) 98(82)	---	---	(32)	NCI(40)	IMB(31)
7.	Immunology of Microorganisms and Virology	213	3.59	2200(97) 2220(71) 2500(62)	120(39)	56(97) 13(64)	---	---	---	NIAID(54)	VR(53)
8.	Microbiology-Immunology	286	2.81	2200(100) 2000(92) 2299(85)	100(44)	13(49) 56(83)	---	---	---	NIAID(83)	BM(75)
9.	Immunology (Lymphatic System of Animals)	361	2.94	2200(100) 2299(85)	130(87)	13(80) 98(75)	---	---	---	NIAID(61)	IMB(60)
10.	Bacteriology	324	2.52	2000(99)	---	56(84)	---	---	---	NIAID(62)	BM(51)
11.	Embryology	487	3.04	3400(90)	---	13(94) 98(57)	12(71)	(100)	---	NICHD(51)	HED(30)
12.	Clinical Studies of Development	185	3.88	3400(91) 1700(43)	300(36)	11(68)	13(49)	(97)	(45)	NICHD(79)	HED(62)

	Cluster	Number of Appli-cations	Distance to Center	Scientific Classification Codes (Percent of Grants in Cluster with Code is Given in Parentheses)						Institute	Initial Review Group
				Discipline and Field	Body Systems	Research Materials	Stages of Development	Percent Developmental	Percent Drug Related		
13.	Animal Studies of Reproductive System	527	1.51	3400(97) 1700(70)	300(85) 220(43)	13(97)	---	---	---	NICHD(91)	REB(81)
14.	Biochemistry-Physiology of Endocrine System Using Animals	751	1.73	1700(91) 1300(97)	220(60)	13(100) 98(92)	---	---	---	NIAMDD(59)	END(45)
15.	Biochemistry-Physiology of Endocrine System, Clinical and Other	337	1.89	1700(99) 1300(96)	220(91)	98(95) 11(41)	---	---	---	NIAMDD(53)	END(73)
16.	Drug Related Physiology of Cardiovascular System	478	2.04	1700(92) 1500(77)	240(81)	13(92) 98(77)	---	---	(97)	NHLI(76)	CVA + CVB(49)
17.	Nondrug Related Physiology of Cardiovascular System	593	2.54	1700(97) 2700(37)	240(75)	13(99) 98(46)	---	---	---	NHLI(67)	CVA + CVB (37)
18.	Surgery (Mostly Cardiovascular)	344	2.29	4520(92) 1700(39) 3800(34)	240(66)	13(99)	---	---	(36)	NHLI(54)	SGYB + SGYA(56)
19.	Biochemistry of GI System	426	1.81	1300(95)	270(100)	13(96)	---	---	---	NIAMDD(46)	BIO(31)
20.	Hematology	279	3.44	4530(100) 1300(79)	120(97)	98(78)	---	---	---	NHLI(38) NIAMDD(37)	HEM(87)
21.	Other Clinical Physiological Studies	511	3.17	1700(80)	---	11(100)	---	---	---	NHLI(34)	---
22.	Clinical Physiological Studies Using Animals	315	3.42	1700(82)	240(45)	12(100)	---	---	(64)	NHLI(51)	---
23.	Drug Related Human Clinical Studies	420	3.16	1700(63) 1500(58)	240(35)	11(100)	---	---	(99)	NHLI(41)	---
24.	Chemistry-Pharmacology	563	0.96	1200(94) 1500(84)	---	90(93)	---	---	(97)	NCI(49)	MCHA + MCHB(87)

	Cluster	Number of Appli- cations	Distance to Center	Scientific Classification Codes (Percent of Grants in Cluster with Code is Given in Parentheses)						Institute	Initial Review Group
				Discipline and Field	Body Systems	Research Materials	Stages of Development	Percent Developmental	Percent Drug Related		
25.	Biochemistry-Pharmacology	604	2.43	1300(100) 1500(73)	---	98(90)	---	---	(100)	---	---
26.	Toxicology	192	2.44	1600(98) 1500(86) 1300(65)	100(51) 270(36)	13(95) 98(90)	17(84)	---	---	NIEHS(75)	TOX(93)
27.	Other Pharmacology	428	2.91	1500(95)	---	98(92) 13(53)	---	---	(97)	NCI(34)	ET(30)
28.	Clinical Behavioral Developmental Studies--Mostly Childhood Psychology	328	2.76	3200(70)	---	11(99)	15(43)	(95)	---	NICHD(56)	DBR(44)
29.	Population Studies	211	1.40	3100(96) 3200(63)	---	11(83)	17(95)	---	---	NICHD(92)	POP(79)
30.	Nonclincal Psychology	232	2.57	3200(85)	---	98(98)	---	(49)	---	NINCDS(32) NICHD(33)	EXP(48)
31.	Social Sciences	350	2.15	3100(47)	---	90(85)	---	---	---	NICHD(37)	POP(33)
32.	Biochemistry and Genetics of Microorganisms	736	2.07	1300(87) 2300(43)	---	56(99)	---	---	---	NIGMS(59)	---
33.	Biochemical Studies of Individuals	384	2.93	1300(88)	120(48)	12(100) 98(87)	---	---	---	NIAMDD(45)	MET(37)
34.	Biochemical Studies Using Both Animals and Other	645	2.32	1300(97)	270(47)	13(100) 98(100)	---	---	---	NIAMDD(30)	---
35.	Biochemistry and Animals	643	2.29	1300(100)	---	13(100)	---	---	---	---	---
36.	Chemistry of Biopolymers--Using Animals	369	2.20	1240(100) 1300(77)	---	13(100) 98(42)	---	---	---	NIAMDD(30) NIGMS(31)	BBCA + BBCB(48)

	Cluster	Number of Applications	Distance to Center	Scientific Classification Codes (Percent of Grants in Cluster with Code is Given in Parentheses)						Institute	Initial Review Group
				Discipline and Field	Body Systems	Research Materials	Stages of Development	Percent Developmental	Percent Drug Related		
37.	Chemistry of Biopolymers--Other	335	2.04	1240(81) 1200(100) 1300(78)	120(42)	98(93)	---	---	---	---	BBCA + BBCB(50)
38.	Animal Genetics	319	2.47	2300(70)	---	13(99)	---	---	---	NIGMS(40)	GEN(42)
39.	Biochemical Genetics on Microorganisms	947	1.03	2300(47) 1300(99)	---	56(100) 98(100)	---	---	---	NIAID(42) NIGMS(31)	MBC(55)
40.	Chemistry of Biopolymers--Using Microorganisms	341	1.22	1240(92) 1300(97)	---	56(100) 98(61)	---	---	---	NIGMS(53)	BBCA + BBCB(39)
41.	Other Chemistry	492	2.02	1200(100)	---	90(97)	---	---	---	NIGMS(67)	BBCA + BBCB([illegible]) MCHA + MCHB([illegible])
42.	Chemistry-Biochemistry	489	1.47	1300(100) 1200(88)	---	90(93)	---	---	---	NIGMS(55)	BBCA + BBCB([illegible]) MCHA + MCHB([illegible])
43.	Other Biochemistry	789	1.94	1300(92)	---	98(92)	---	---	---	---	---
44.	Cell Biology and Biochemistry	457	1.90	2400(100) 1300(100)	---	98(98)	---	---	---	---	---
45.	Molecular Genetics	389	2.20	2300(97)	---	98(90) 56(38)	---	---	---	NCI(35) NIGMS(33)	GEN(38)
46.	Other Cell Biology	451	2.39	2400(100)	---	98(76) 13(47)	---	---	---	---	---
47.	Radiation Biology	171	3.17	4514(74) 4510(46) 2900(58)	---	12(46)	19(82)	---	---	NCI(69)	RAD(96)
48.	Biomathematics and Bioengineering	244	2.27	3600(68) 3800(35) 1700(30)	---	85(96)	---	---	---	NIGMS(54)	COM(55)

	Cluster	Number of Appli-cations	Distance to Center	Scientific Classification Codes (Percent of Grants in Cluster with Code is Given in Parentheses)							
				Discipline and Field	Body Systems	Research Materials	Stages of Development	Percent Developmental	Percent Drug Related	Institute	Initial Review Group
49.	Pathology--Often Oncology	309	3.69	2700(97) 4510(51)	---	13(80) 98(47)	19(64)	(90)	---	NCI(67)	PTHB(77)
50.	Other Developmental Studies	414	3.50	1300(53)	---	13(82) 98(57)	19(100)	(100)	---	---	---

ing algorithm, several of the clusters were similar to those shown here. However, many of the clusters came to be defined almost exclusively by the study section to which applications were assigned and were much less homogeneous with respect to the codes of the scientific classification system. Several times grants that were identical in all attributes but study section were assigned to different clusters. One of the advantages of the clusters with study section assignment was that two separate clusters emerged for the communication sciences area, one for visual research, another for sensory perception. In our current system, these grants are linked with other grants based on their discipline and research materials (i.e., biochemistry or physiology or psychology; clinical studies or animal studies), rather than on the body system (eye or other sensory system) as in the alternative set of clusters.

Our clusters show very clearly the interdisciplinary nature of most biomedical research. Much research is taking place at the boundaries of two of the traditional fields of bioscience: 31 of these 50 clusters require at least two discipline and field codes to describe them. For example, a large part of the surgical research over this time period involved the circulatory system (mostly cardiovascular surgery).

The Initial Review Groups to which most of the applications in each cluster were assigned are also shown in Table 42, although they were not used as attributes to cluster the grants. Although there is a one to one relationship between a few clusters and IRGs, applications in other clusters were split among several IRGs.

The Institute assignment of the largest fraction of applications in each cluster also is shown in Table 42. Only a few of the clusters are clearly related to only one Institute, with many of the scientific fields being supported by several Institutes. Applications to the Eye Institute and the Dental Institute are small portions of several clusters and do not emerge from this analysis as separate research areas.

Trends in the Content of Biomedical Research

One straightforward application of our typology of biomedical research is an examination of trends in the content of biomedical research over the five-year period 1971-1975. Most knowledgeable observers of biomedical research in the United States agree that it has been changing rapidly as the nation's health priorities have changed, as new methods of research have developed, and as new links have been found between basic life processes and the nation's identified health priorities. Our research clusters provide an objective confirmation of this opinion. Some types of biomedical research have grown at a dramatic rate during the five-year period being studied, while others have grown slowly or even declined in size during the same period. Table 43 identifies 16 of the 50 research clusters that have grown at an annual rate of 10 percent or more during 1971-75. Cluster size here is defined as the number of projects in the cluster being supported by NIH each year (i.e., number of competing or continuation grants awarded). Radiation biology (cluster 47) heads the list, growing at an average rate of 28 percent per year. Population and social science studies (clusters 29 and 31) have experienced growth rates near 20 percent annually. Three immunology clusters (6, 7, and 9) have grown between 12 and 14 percent annually. Two genetics clusters (39 and 45) also appear on the high-growth list.

Table 44 shows seven clusters that have declined in size by 2 percent or more per year. These clusters seem to have little in common. The small number of clusters

Table 43

CLUSTERS WHICH HAVE BEEN GROWING BY
10 PERCENT OR MORE PER YEAR
DURING 1971-75

Cluster		Growth Rate[a] Per Year
47	Radiation Biology	28
29	Population Studies	22
31	Social Sciences	19
45	Molecular Genetics	17
43	Biochemistry Using Biological Subsystems	16
6	Nonclinical Immunopathology	14
7	Immunology of Microorganisms	12
9	Immunology (Lymphatic System of Animals)	12
13	Animal Studies of Reproductive System	12
27	Pharmacology Using Biological Subsystems	12
39	Biochemical Genetics of Microorganisms	12
42	Chemistry-Biochemistry	11
44	Cell Biology and Biochemistry	11
18	Surgery (Mostly Cardiovascular)	10
26	Toxicology	10
48	Biomathematics and Bioengineering	10

[a] Based on the regression:

$\ell n(\text{competing grants} + \text{continuation grants}) = a + b*\text{year}$

Table 44

CLUSTERS WHICH HAVE BEEN GROWING SMALLER
BY 2 PERCENT OR MORE PER YEAR
DURING 1971-75

Cluster		Growth Rate[a] Per Year
17	Nondrug Related Physiology of the Cardiovascular System	-8%
41	"Other" Chemistry	-4
21	Clinical Physiological Studies	-4
23	Drug Related Human Clinical Studies	-3
20	Hematology	-2
36	Chemistry of Biopolymers Using Animals	-2
22	Clinical Physiological Studies Using Animals	-2

[a] Based on the regression:

$\ell n(\text{competing grants} + \text{continuation grants}) = a + b*\text{year}$

on this list and the small rates of change reflect the fact that the total number of research projects funded by NIH has been growing during the 1971-75 period. When the 50 clusters are ranked by their rate of growth or decline over this period, the median cluster grew at a 6 percent annual rate.

National Health Priorities and the Content of Biomedical Research

Why have some types of biomedical research grown much more rapidly than average since 1971 while other types of research have declined? At least two competing explanations can be proposed. One is that changes in the content of biomedical research reflect changes in the scientific opportunity for work in different fields. In some fields, it could be argued, research is stalled for lack of appropriate research methods, lack of theory, or the need for more basic information from other fields before advances can be expected. In other fields, it might be argued, the potential for scientific advance is much greater than average because of recent advances in theory or methodology.

A second explanation for the greater growth of certain types of biomedical research is that the Congress, through differential funding of the Institutes of NIH, has established its own priorities for biomedical research based not on scientific criteria alone but also on the basis of the nation's health needs. The extent to which criteria other than scientific merit should be used in choosing among competing research applications has been, of course, a matter of considerable debate within the biomedical research community. Our present task is not to pass judgment on this question, but rather to ask some empirical questions that may clarify the debate. First, to what extent do priorities other than scientific merit actually play a part in research funding decisions? Second, is there any evidence that funding decisions based on national health priorities can influence the amount of high-quality work being done in a particular field?

Each competing approved research application receives a priority score as part of its review by an NIH Initial Review Group (sometimes referred to as a study section). This group consists of approximately 12 to 15 scientists who are knowledgeable in the scientific area of the application. Each study section member assigns a score between 1 and 5 based on the scientific merit of the application. These scores are averaged to produce the priority score for the application.

Suppose NIH were not NIH, but rather a different federal agency whose *only* concern was to fund biomedical research of the highest possible scientific merit without regard to its relevance to any specific disease problem. It might use the identical review procedure used by our current NIH and place all applications in a single list ordered by priority score—which is the only indicator of scientific merit available to the agency. It would then go down the list funding all applications until it had spent its budget authorization.

How different would this system be from the way NIH operates now? We found that 84 percent of the decisions to fund or not to fund applications would have been the same if priority score alone had been the basis for funding. Going further, we calculated how many applications in each cluster would have been funded if a uniform priority score cutoff had been applied across all the Institutes. Six of the 50 clusters have consistently received funds above what they would have received under a "priority score only" system, and seven of the 50 have consistently received funds below what they would have received under a "priority score only" system. These clusters are shown in Tables 45 and 46.

With the exception of social sciences (cluster 31) and pathology-oncology (cluster 49), the minimum support level for research clusters that consistently received extra funding has been only modestly above the expected level. For most of the clusters that have been consistently underfunded (that is, clusters receiving fewer grants than would be predicted from scientific priority scores alone), the maximum support level has been only modestly below the expected level. An exception has been cluster 39 (biochemical genetics with microorganisms), which, in its best year, received only 89 percent of the grants it would have received if priority score had been the sole basis for grant decisions.

The data in Tables 45 and 46 enable us to check, in a crude way, whether national health priorities (as reflected in consistently high or low funding levels for research clusters) have caused the amount of research in heavily funded clusters to increase or the amount of research in underfunded clusters to decrease. The cluster labeled "social sciences" has consistently been blessed with a high level of funding (relative to the priority scores on applications), and research in this area has grown dramatically during the 1971-75 time period. However, another heavily funded cluster (pathology-oncology) has grown only at a 3 percent annual rate, below the median; and most of the rapidly growing clusters in Table 43 have not consistently received heavy funding by NIH (again, relative to the priority scores on applications).

The same mixed pattern emerges when we look at clusters that have consistently received less funding than would be expected on the basis of scientific priorities. Two of the consistently underfunded clusters (chemistry of biopolymers using animals and chemistry of biopolymers using microorganisms) have also been declining in size over the 1971-75 period. A plausible interpretation is that the shortage

Table 45

CLUSTERS WHICH HAVE CONSISTENTLY RECEIVED
HIGH PRIORITY FUNDING

Cluster		Minimum Support Level[a]
49	Pathology-Oncology	1.27
31	Social Sciences	1.17[b]
24	Chemistry-Pharmacology	1.07
6	Other Immunopathology	1.03[b]
27	Other Pharmacology	1.03
21	Clinical Physiological Studies	1.03

[a] Ratio of actual number of grants to expected number based on priority score.

[b] This has been a rapidly growing cluster.

Table 46

CLUSTERS WHICH HAVE CONSISTENTLY RECEIVED LOW PRIORITY FUNDING

Cluster		Maximum Support Level[a]
39	Biochemical Genetics with Microorganisms	.89[b]
32	Biochemistry and Genetics of Microorganisms	.91
40	Chemistry of Biopolymers Using Microorganisms	.92[c]
48	Biomathematics and Bioengineering	.94[b]
9	Immunology, Other	.97[b]
4	Immunochemistry of Blood	.98
36	Chemistry of Biopolymers Using Animals	.98[c]

[a] Ratio of actual number of grants to expected number based on priority score.

[b] This has been a rapidly growing cluster.

[c] This has been a declining cluster.

of funds for research in biopolymers has depressed investigators' interest. However, three of the consistently underfunded clusters ("other" immunology, biochemical genetics with microorganisms, and biomathematics and bioengineering) have been growing rapidly. This suggests that the demand for research funding in these areas is pushing the supply, and that the supply of funds for these clusters, while growing, has never quite caught up with the increasing demand.

This examination of the clusters that have grown most and have grown least does not provide a definitive answer to the question of whether the level of funding of research attracts or discourages researchers. We hypothesize that demand for research support in an area would depend on the scientific opportunities available in that area, the number of available scientists who possess the training and ability to work in that area, and the perceived likelihood of obtaining research support. We do not have any way of directly measuring any of these quantities, so we have attempted to develop surrogates for each one.

It should be possible to develop a proxy for the kind of scientific opportunities available in an area from the distribution of the priority scores received by applications in the cluster. The priority score is a measure of the scientific merit of an application and one would expect that in an area with many exciting opportunities for research projects, there would be more applications with better than average scores. We tried using the average priority score awarded to applications in the cluster, as well as the proportion of applications in the cluster with scores among the best 10 percent and 20 percent of all scores. However, these variables were never significant in our regression equations. It may be true that when new scientific opportunities arise, they attract new projects that are of low scientific quality in the same proportion as those of the highest quality. In any case, we were unable to develop a proxy for scientific opportunity that was correlated with the growth in applications. We present our regression results without the variable from priority scores. Including this variable in the regression leads to identical conclusions.

Since we are considering only a five-year time span, the number of qualified scientists in any one field probably has not changed too much over this period. However, the availability of that manpower may change with changes in support levels. If many grants are awarded in an area in one year, then at least those people are unlikely to reapply the next year. Thus we have also counted the number of continuation grants awarded in each cluster in each year. We expect changes in this variable to be negatively correlated with changes in number of competing applications.

For a proxy of the perceived likelihood of funding in a cluster, we use the difference between the actual number of grants awarded in the cluster and the number of applications with scores better than our hypothetical priority score pay line—i.e., the number of grants that would have been awarded if scientific merit as measured by priority score had been the only criterion used to fund applications. We would expect that if a larger number of grants is awarded in a research subfield than would be expected by priority score alone, then the number of applications for research support in this area would increase sometime later.

To specify our model completely, we need to describe the lag structure. Table 47 shows a regression of the number of applications in each year on the number of applications in the previous year, the change in number of continuations between the two years and the difference between the number of grants awarded in the

Table 47

REGRESSION OF APPLICATIONS PER CLUSTER BY YEAR

	1972	1973	1974	1975
R^2	0.72	0.66	0.82	0.89
Applications in year t-1	0.83^a	0.85^a	1.29^a	1.02^a
	(8.7)	(8.9)	(13.1)	(15.6)
Changes in continuations	-0.58^a	-0.52^a	-0.60^b	-0.35
	(3.7)	(2.8)	(2.5)	(2.0)
Preference given to cluster in year t-1	-0.08	-0.18	-0.39	-0.35
	(0.2)	(0.4)	(0.8)	(1.0)
Constant term	19.8	13.5	2.32	4.33

t-statistics given in parentheses

[a] significant at 0.01 level

[b] significant at 0.05 level

previous year, and the number of grants above our hypothetical pay line in the same year. The change in continuations has the expected negative sign, but the variable for program priorities is never significantly different from zero. It would appear that federal program priorities cannot affect the receipt of applications in just a single year.

In order to look at the longer term effect of federal program priorities, we examined the number of applications in fiscal years 1974 and 1975 as a function of what happened in the cluster in 1971 and 1972. For the manpower working in the field, and therefore not likely to apply for a competing application in the two-year period (t, t + 1), we use continuation applications in year (t + 1) minus grants awarded on a competitive basis in year t. The other independent variables are the number of applications received in 1971 and 1972, the number of grants awarded in 1971 and 1972 minus the expected number of grants in that period. There is evidence here of a response by the scientific community to availability of funding. For every application awarded beyond the nominal cutoff line in a research subfield in 1971 or 1972, two applications were received in 1974 or 1975. Thus it would appear that although program priorities cannot affect requests for support in the very short term, they can affect requests for support over a longer period.

Research Content by Institutional Setting

The scientific content of the research that is performed in different parts of the university is another question that we can address. We consider four parts of the university: (1) basic science departments of medical schools, (2) clinical science departments of medical schools and hospitals with a major affiliation with a medical school, (3) graduate schools and schools of arts and science, (4) the other health professions schools of dentistry, public health, pharmacy, and nursing. The last category is aggregated because each component receives very few NIH grants. The entire category accounts for only 6.5 percent of the competing research project applications in our files.

An analysis of the relationship between scientific subfield based on the clusters of applications and the components of the university shows that each component of the university plays a unique role in the spectrum of biomedical research.

Most of the clusters of clinical studies are performed almost solely by members of the clinical science departments of medical schools (these clusters are 5, 9, 21, 22, 23, 33). The exception to this rule is cluster 28, which is clinical development studies that are performed in all components of the university except for the basic science departments of the medical school.

Two of the clusters identified by a medical specialty (surgery and radiology) are also performed almost entirely within the clinical department of the medical school.

One can also identify several subfields that are performed almost solely within the medical school but in both basic science and clinical departments. These are: drug-related studies of the nervous system (cluster 1), drug-related pharmacology (27), drug-related biochemistry (25), drug-related physiology of the cardiovascular system (16), pathology, immunology, other (9), microbiology and immunology (8), immunopathology (6), biochemistry and physiology of the endocrine system (14), physiology of the cardiovascular system (17), and hematology (20). Thus it would seem that some of the research performed in basic science departments of medical schools is sytematically different from research performed in graduate schools in being either drug-related, based on a body system, or related to a medical specialty.

Much of the basic research within departments of medical schools is also performed within graduate schools but not often within clinical departments. These areas are several of the biochemistry, molecular genetics, and cell biology clusters (32, 36, 39, 40). One can also identify fields of biomedical research that are performed in the university departments and hardly ever in medical schools. These areas are the chemistry clusters (24, 41, 42). Only the chemistry and pharmacology cluster is drug related.

Clinical departments of medical schools and university departments perform research not performed in basic science departments of medical schools only in the clusters within the behavioral sciences (28, 29, and 30).

Figure 4 summarizes the research areas in which each of the components of the university specializes. The clusters that have not been mentioned above receive applications from each part of the university approximately in proportion to total applications.

CONCLUSION

It is possible to use the scientific classification code system developed by the Division of Research Grants to produce a detailed typology of biomedical research projects. We have produced a preliminary set of clusters of applications for traditional NIH research project grants from institutions of higher education.

The rate of funding of approved NIH applications varies depending on the area of research of the application but does not vary by component of the university. On the average, applications for research support in a scientific field will increase for several years following an influx of NIH support for that area, but will not respond to year-to-year changes. The typology of research projects has also been used to describe differences in the research performed in different components of the university.

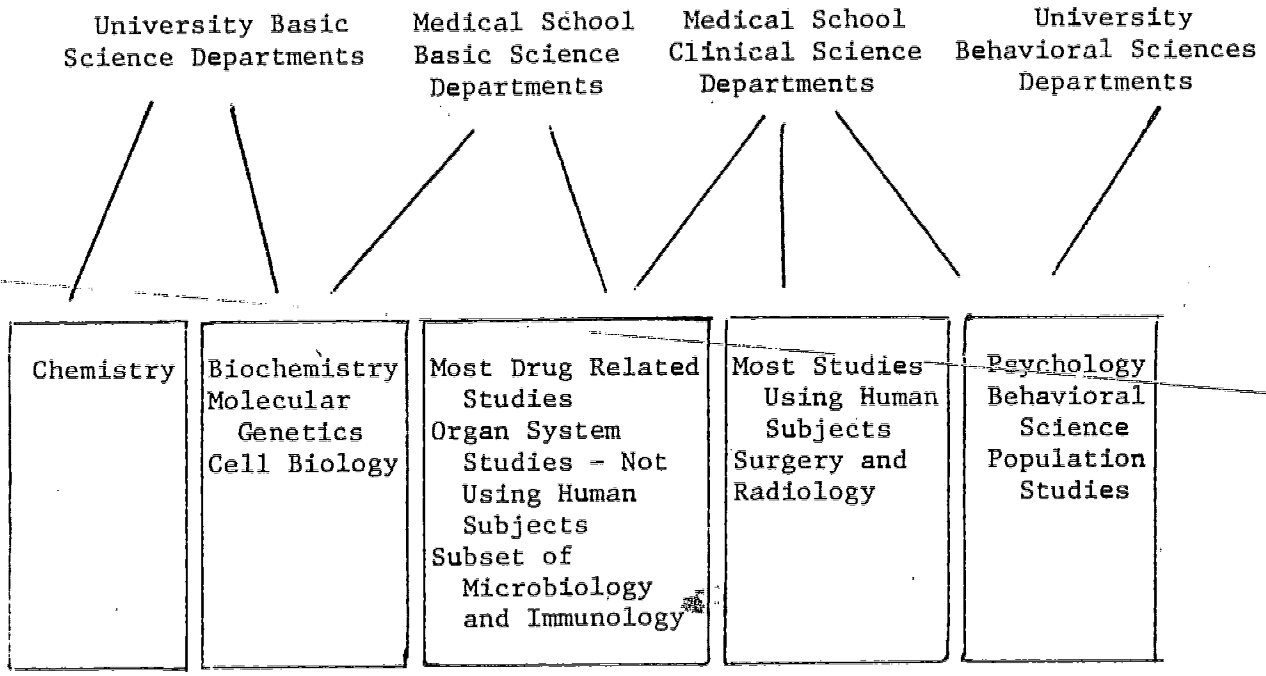

Fig. 4— Research specialization by institutional setting

VI. GENERAL CONCLUSIONS

Our analysis has focused on specific questions regarding the effects of federal biomedical research programs on academic medical centers. However, the purpose of the overall study is to provide a broader understanding of the degree and the determinants of the interdependency between the federal agencies that sponsor biomedical research and the academic institutions that perform it. Because the efficiency of federal biomedical research programs greatly depends on the efficiency of these nongovernmental institutions, this interdependency makes the status of these academic institutions a matter of federal concern.

Our analysis addresses the question of the status of the academic medical community on a number of levels. It examines how centers appear to have adjusted their educational programs, their organizational structures, their scientific activity, and their budgets as a result of their involvement in federal biomedical research.

The measurable effects of federal research on the educational programs of centers appear to be limited largely to those components most involved in research. We observe that federal research training programs specific to a scientific field and the overall research intensity of the institution are the factors that seem best to explain the size of Ph.D. programs in the basic science departments. Moreover, there is limited evidence to suggest that these departments significantly reduce enrollments when training grant funds are cut back, but the effects of these cutbacks may be mitigated in departments with substantial research funding.

By contrast to the situation in basic science departments, we do not observe strong effects of federal biomedical research on the major educational programs of clinical departments, and this is consistent with their major involvement in the delivery of patient care in conjunction with education. Our analysis of the size of graduate medical education programs in internal medicine suggests that the numbers of interns and residents are determined largely by the patient loads in teaching hospitals and by the size of the clinical faculty. The intensity of a clinical department's research activities does not appear to have a significant effect on the size of its house staff programs. We also find that the research intensity of a medical school has very little or no effect on the specialty choices of its graduates. Not surprisingly, M.D. graduates with the best academic records are the most likely to enter academic or research careers, and this likelihood is increased if they attended a research-intensive medical school. However, only a small proportion of the graduates of even the most research-intensive medical schools enter academic and research careers.

Departments are the most important organizational units of academic medical centers, and our analysis indicates that their success in the competition for federal research funds has an important effect on their size. This effect is most apparent in the case of basic science departments. The less strong apparent effects of research on clinical departments may be due to the limitations of data to account for patient care activities.

The total budgets of all departments appear to be quite sensitive to the rise and fall of their federal research funding. Moreover, substantial proportions of the salaries of research oriented faculty come from federal grants, indicating they may be vulnerable to federal funding cutbacks. Although the research funds are important to many departments, the research intensity of a department is negatively related to salary levels of its members, when local economic conditions are controlled for.

If an academic medical center is substantially involved in biomedical research, it must depend heavily on federal funds for budget stability. Our analysis of all funding sources indicates that federal research funds do not appear to attract substantial funds from other sources. Similarly, centers have little flexibility to compensate for federal research funding cutbacks with funds from other sources. This is consistent with our observation that deans generally do not use institution funds to "bail out" departments that lose research funding.

In examining the scientific characteristics of federally sponsored biomedical research in academic institutions, we find strong evidence of specialization along both federal program and scientific lines. The different Institutes of NIH and ADAMHA depend on different organizational components of medical centers and universities. This means that a particular set of departments, or a particular class of institutions, may be quite vulnerable to funding cutbacks by a single Institute, while many others may be hardly affected at all. Similarly, the success of the research programs of a particular Institute may be quite sensitive to the situation of a particular segment of higher education.

An individual investigator's research area is largely determined by his training and prior experience. However, there is clear evidence that the true scientific characteristics of research proposals are influenced by federal program emphasis as measured by the likelihood of funding among scientific groups. This suggests that the federal government has the capacity to affect not only the level but the nature of scientific activity within the biomedical research community.

In the most general terms, the results of our analyses appear to describe an academic medical community that is responsive to the influence of federal biomedical research programs. They tend to confirm the interdependence between the federal agencies that sponsor research and the academic institutions that perform it. Important characteristics of academic medical centers—Ph.D. programs, faculty size, budgets, scientific activity—are directly related to the federal funding received by individual departments; and the overall financial stability of research-intensive centers is substantially affected by the stability of federal research funding.

It is significant that centers must make long term commitments—hire new faculty, alter research directions, admit students—in order to respond to federal research policy that appears increasingly subject to short term shifts. In the past, centers have undertaken long term commitments to respond to federal programs, only to have the particular programs deemphasized by the government. However, in recent years, the accommodation to these unexpected changes in federal program emphasis has been eased because the centers have been able to devote these resources to other activities that were part of the growing federal program involvement in academic medicine—expanded M.D. enrollment, Medicaid, cancer research, family practice training, allied health professional education, and so on. We see little evidence in recent policy debates to suggest that the federal program involvement with academic medical centers will continue to grow at rates approaching those of the past. Hence, we would expect that any future short term shifts in federal biomedical research policy will have much more adverse effects on the academic medical community than such shifts have had in the past.