Jobs and Ph.D.'s in the Mathematical Sciences, II.

By R. D. Anderson

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3. JOB PROSPECTS FOR THE NEXT TWENTY YEARS

The academic employment prospects for the next twenty years are not good. There is now every reason to believe that the total national mathematics faculty will increase very little in the rest of the 1970s and will actually decrease somewhat in the 1980s. The prospects are dominated by four factors: (1) the annual size of the group of eighteen-year olds; (2) the percentage of eighteen-year olds enrolling each year for the first time in four-year colleges and universities; (3) the percentage of enrollments in mathematics courses by freshmen and sophomores; (4) the amount of money available for higher education. It should be pointed out that twenty-year projections are necessarily subject to considerable uncertainty. In particular, public priorities could change in favor of substantially more support for traditional higher education, although the author knows of no indication of that now.

(1) The following table gives the annual number of live births in the United States from 1950 to date. These data were obtained from Statistical Abstract of the United States and the Monthly Vital Statistical Report.

Year	Live Births (in thousands)	Year	Live Births (in thousands)
1950	3632	1961	4268
1951	3823	1962	4167
1952	3913	1963	4098
1953	3965	1964	4027
1954	4078	1965	3760
1955	4104	1966	3606
1956	4163	1967	3521
1957	4255	1968	3502
1958	4204	1969	3571*
1959	4245	1970	3718*
1960	4258	1971	3559*
		1972	3256*

The size of the group of eighteen-year olds is essentially determined through 1990: It increases at about 2% a year until 1975, is almost stable until 1979, and then decreases almost 25% until 1990. The figures for the first four months of 1973 show a further drop of forty-four thousand from 1972 levels but indicate a probable stabilizing trend.

*Preliminary or provisional from 1969 on.

(2) The number of students enrolling in four-year colleges and universities for the first time has dropped slightly for the past two years, showing a decrease in the percentage of the age group going on to four-year institutions, reversing a trend toward greater percentages that had been observed since 1945. With expected college enrollments indicating that the percentage will probably drop again this fall, an era of relative stability in the percentage of eighteen-year olds enrolling in four-year colleges and universities has presumably been reached, implying that the annual number of freshmen is likely to be closely tied to the size of this age group.

The percentage, however, will probably go up slightly in the 1980s, dampening the effect of the decreases in the size of the age group on college enrollments. Society probably has relatively stable numerical needs for college graduates over a period of years, and in the latter 1980s, when the number of twenty-one year olds is decreasing, society can be expected to need a greater percentage of this age group for jobs requiring college training. Thus, the economic demand probably has an inverse effect on the relationship of the size of the age group and the percentage of the age group going to college. Perhaps with a large number of eighteen-year olds, we are seeing that effect now.

(3) CBMS Survey data and AMS data do not give explicit percentages of the enrollment of freshmen and sophomores in mathematics courses, but the data do show that approximately 50% of all undergraduate enrollments in mathematics are in courses below the calculus level, 25% more are in analytic geometry—calculus courses, and, in addition, more than half the statistics and computer science course enrollments are in pre-calculus or introductory courses. The graduate course enrollments are only about 4% or 5% of the total. Since employment of mathematicians in academia is tied primarily to course enrollments, and since 75% of these enrollments are by freshmen and sophomores, we can make apparently reliable projections concerning the number of faculty members needed by considering items (1) and (2) above. In this respect, academic employment prospects for Ph. D. mathematicians are worse than those for some other potential academicians. The three potential "growth" areas in higher education: two-year colleges, adult or continuing education, and career or vocational education involve relatively few employment opportunities for Ph. D. mathematicians. There is now much evidence that two-year colleges do not and will not need or hire enough Ph. D.'s to affect the overall job

market, adult education programs are likely to be more culturally than scientifically oriented, and much so-called career education will involve little mathematics above the high school level.

Clearly, the mathematics community should try to increase the demand for mathematics courses by making both elementary and advanced mathematics more attractive and meaningful to more types of students; however, the community cannot expect to do more than make the best of a bad employment situation in this way. Such efforts cannot conceivably "solve" the unemployment problem.

(4) The observed annual increase in money for higher education that was a hallmark of the 60s has been sharply reduced over the last two or three years, virtually to that needed to meet increased costs with no increase in faculty. This phenomenon apparently stems both from the levelling off of the student population and from changed public priorities. It is observed in legislative appropriations for higher education in almost all states.

Obviously, if our society chose to do so, it could provide sufficient funds over the next twenty years to improve the quality of higher education significantly by greatly decreasing the student-faculty ratio. In the process, enough expansion of the faculty could occur to provide jobs for all deserving prospective Ph. D.'s. However, in terms of observable recent patterns (such as the pressures for educational accountability) and in terms of apparent societal priorities, there seems little likelihood that higher education in the traditional sense will get funds much in excess of those needed to maintain present student-faculty ratios and to meet cost-of-living increases. The following table (Office of Education figures) shows total expenditures by regular institutions of higher education in the public and private sectors in 1961 and 1971 and total degree credit (full- and part-time) students for those years.

		Expenditures in billions	Students in thousands
Public	1961	4.7	2,329
	1971	19.9	6,014
Private	1961	3.8	1,532
	1971	10.0	2,102

Clearly, the 1970s were a "golden age" for higher education. The implications of exponential growth make it explicitly clear that similar expansion in expenditures could not occur very much longer. In the 1960s, the national four-year college and university mathematics faculty rose by a factor of almost 2.8, whereas the student population rose by a factor of about 2.1. According to CBMS Survey figures, the ratio of undergraduate mathematics course enrollments to number of full-time faculty dropped from 99:1 to 81:1 in the five years from fall 1965 to fall 1970, the drop occurring almost uniformly in universities, public colleges, and private institutions.

In the public college and university sector, funds for faculty positions come primarily from state legislative appropriations and secondarily from tuition. In the past several years, as student enrollments have leveled off and as public priorities appear to have changed, additional state funds for traditional higher education have also leveled off. With the increasing demands for welfare and poverty programs, urban and transportation programs, pollution and environmental programs, vocational and career education, as well as for adjustment to inflation phenomena, there appears no basis for optimism that legislatures, or the public behind them, will increase funds for traditional higher education much in excess of that called for by student demand and inflation costs. Indeed, a number of states are developing formulas for educational appropriations specifically tied to enrollments.

Private colleges and universities, dependent largely on tuition for faculty salaries, are already greatly concerned with existing or potential reductions in numbers of students and have no basis for significant expansion of faculties.

There is a widely held hypothesis that the employment situation for Ph. D. mathematicians would be significantly improved by substantial increases in federal funds for education and research. The author seriously doubts that hypothesis unless there were major shifts in the uses of such funds.

Federal funds for education are used for special projects, impacted areas, minority groups, etc., primarily below the higher education level; relatively small amounts find their way into the salary budgets of mathematics departments. NDEA matching funds and teacher institute costs have been exceptions in some schools. Support for students, of course, does tend to increase student enrollments and, thus, the potential demand for mathematics. Interestingly, according to the Brookings Institution report on the proposed budget for the fiscal year 1974 (page 149), federal support for undergraduate students (as distinct from institutions) in higher education shows a major increase from \$2,814,000,000 in fiscal 1972 to \$3,722,000,000 in fiscal 1974, the current fiscal year. In spite of such funding increases, first-time students and mathematics course enrollments have both apparently been decreasing slightly in four-year colleges and universities. Unfortunately, as federal budgets for education have kept going up recently, the mathematics community seems to have gotten less than its share.

Federal money for research does have a more direct impact on jobs for mathematicians, but even here the effect is not massive. Obviously, some jobs are available in federally financed research projects themselves, but the number of Ph. D. mathematicians involved has apparently been modest, and the emphasis has been primarily on nonacademic mathematicians. The projects are customarily oriented toward equipment and engineering. There is some spin-off of overhead costs on research projects to those universities which get large grants. Substantially increased federal research budgets would create a few more temporary mathematics positions at some of the major private universities by easing their budgets, but the number of positions, concentrated at schools like NYU, MIT, Stanford, etc., would be a relative handlful.

Redistribution of Students. With a stable national student population, a slight increase in total mathematics faculty may still be anticipated due to the redistribution of students (and thus of faculty). This factor slightly increases the likelihood of new Ph. D.'s getting jobs but also probably increases the number of nonretained Ph. D.'s without jobs. Thus, some schools will increase in size and others will decrease, or even close. The changing geographical population patterns are partly responsible for this redistribution of students. It is difficult to assess the phenomenon numerically, or to be confident in any numbers assigned, since the patterns will depend on adjustment to a nongrowth situation for which there are few clear historical precedents. The realities of university financing, however, suggest that contraction is resisted even more strongly than expansion is pushed, and, thus, on a national basis, slight faculty growth should be expected even with a numerically stable student population.

Nonacademic Employment. There was a slight rise over the past year in the number of new Ph. D.'s reported getting nonacademic (professional) employment in the U. S. Also, the AMS faculty mobility survey shows that the number of faculty members who moved to nonacademic jobs this summer was somewhat higher than the number a year ago.

A slight improvement in nonacademic employment for Ph. D.'s should have been anticipated in an improving economy and a tight but stable academic market. Much further improvement is needed in the next several years, however, if we are to avoid serious unemployment. The AMS Committee on Employment and Educational Policy has been seeking financing from governmental and private agencies for a serious study of potential nonacademic employment for mathematicians. While initial reactions from possible funding agencies have been negative, the committee is continuing to explore possibilities. With the dismal prospects for long-range academic employment of young Ph. D.'s, the community must either cut back production drastically or develop extensive nonacademic employment opportunities. In this connection it should be pointed out that whereas current employment prospects are generally satisfactory for those in statistics and computer related areas, there is no proven or established nonacademic demand beyond current employment patterns. Young Ph. D.'s should be encouraged to develop competence in areas where there is a demand, but attempts should also be made to ascertain future demand before present programs are modified extensively.

4. TENURE, MORAL TENURE, AND JOB RETENTION

Almost certainly, the question of academic job retention has become the most critical and difficult aspect of the job market. A year ago, in the November 1972 *Notices*, the author wrote a brief analysis of the problem based on AMS data then available. Those data did not involve tenure information as such, but rather distributions of academic positions by rank over the past several years. This summer, the AMS collected data on the number of tenured positions by rank in the annual salary survey, on numbers of faculty members with newly acquired tenure in the faculty mobility survey, and some data on Ph. D.'s moving to positions with tenure. The data now available are "harder" data and are more discouraging.

The following table presents tenure data from the salary survey for Ph. D.-granting mathematics departments in the U. S. and for departments granting the master's and bachelor's degrees in the mathematical sciences in the U. S. and Canada, published originally in the October 1973 *Notices*. (The returns included from Canadian departments and from departments other than mathematics were relatively few and may be ignored.)

The figures on faculty size are the faculty totals reported for both doctorates and nondoctorates for the ranks of assistant professor, associate professor, and professor. Instructors are not included. Somewhat more complete figures, including data from departments whose salary data were not usable, show substantially the same percentages and percentage changes.

Professional Tenure Figures from Salary Survey Data

Type of department and number reporting	1972–1973 No. of Faculty	1972–1973 with tenure	1972–1973 % with tenure	1973–1974 No. of Faculty	1973–1974 with tenure	1973–1974 % with tenure	Rise in past year
ACE top rated, 15 of 27	784	605	77%	791	628	79%	2%
Other ACE rated, 27 of 38	1028	609	59%	1016	634	62%	3%
ACE non-rated doctorate producing, 55 of 89	1488	910	61%	1479	970	66%	5%
Master's level, 116 of 310	1563	987	63%	1624	1122	69%	6%
Bachelor's level, 325 of 1080	1648	897	54%	1673	955	57%	3%

It is clear from both the percentages and the recorded changes in percentages that the national mathematics faculty is rapidly approaching effectively fully tenured status. Except for replacement of those retiring or dying, there will shortly be very few nontemporary positions available for those not in positions having tenure or leading to tenure.

The basic question, however, is not who or how many faculty members have formal tenure but rather who or how many will, in fact, be retained by their departments on a permanent basis. For that we must consider moral tenure and attitudes of chairmen toward retention. The abolition of tenure would, by itself, probably have relatively little effect on retention policies—few departments or schools would drop colleagues after lengthy periods of conscientious or satisfactory service unless forced to do so by fiscal necessity.

A Small Scale Study of Moral Tenure. A study conducted this fall by the author in the states of Louisiana and Mississippi (which have 3% of the nation's population) suggests that the incidence of nonflexibility in the system is much more critical than is suggested by the national figures concerning tenure.

All chairmen of departments of mathematics and computer science at four-year colleges and universities in the two states were sent a questionnaire in September asking for the total number of faculty members presently in the various ranks, the number with tenure, the number with moral tenure, the number without tenure or moral tenure but expected to be retained indefinitely, and the number whose positions were regarded as definitely temporary. Moral tenure was defined to mean that a person having it would be regarded at the departmental level like a person with tenure in the sense that he or she would normally be automatically reappointed unless a budget crisis forced cutting off the position.

The table below includes data from twenty-one mathematics departments, all of those responding except for Tulane and LSU (Baton Rouge) which have had Ph. D. programs for the past twenty years and are not typical. Also omitted are data received from three computer science departments; these departments are newer, are presumably still growing, and are, therefore, somewhat atypical. It seems evident that moral tenure was interpreted differently by various chairmen, and that some of those listed as having moral tenure could have been in the "expected to be retained indefinitely" category. However, such consideration does not really alter the implications of the study for the employment market. Responses were received from about 65% of the mathematics department chairmen polled.

	Total Faculty	With Tenure	With Moral Tenure	Expected to be Retained Indefinitely	Temporary Positions
Instructor	42	9	19	4	6
Asst. Prof.	116	67	32	16	1
Assoc. Prof.	70	51	13	7	0
Professor	39	35	2	2	0
Total	269	162	66	29	7

There appear to be only five other prospectively permanent positions (or about one per year) available. Thus, in this sample, there appears to be almost no expectation of vacancies except for those resulting from death, retirement, or resignation. The percentage (60%) of tenured faculty is near the national average.

It would be a mistake to generalize too much from the small sample considered; it would also be a mistake not to be concerned with the evidence found. If the patterns of the sample are common in very many states, and if the national faculty does not grow, then almost immediately there is going to be a situation in which the annual number of vacancies in master- and bachelor-level departments or in newer Ph. D.-granting departments may be little more than the number needed for replacement due to death and retirement. In other words, whereas over the past three years, there have been annually perhaps four or five hundred Ph. D. mathematicians finding jobs in such departments, that number may soon drop to one or two hundred.

In the same questionnaire, the chairmen were asked to indicate the number of additional positions expected to be available for 1974–1975 and for 1975–1976. The twenty-one chairmen indicated perhaps five positions for 1974–1975 and three more for 1975–1976, or about 2% and 1% of the existing faculty. This is far less than similar surveys indicated in the past two or three years (and in that period the total faculty growth has been near zero.

In a sense, the results of this poll should have been expected, but they are, nevertheless, startlingly decisive. Over the past five or ten years, departments like those responding have had good choices of new faculty members from among a number applying. And, the departments and schools have a tradition of seeking to retain faculty members they consider good. In addition, the developing lack of mobility in the community has made many recent new faculty members regard their employment (hopefully) as permanent, and they have earnestly sought to be retained. The percentage of new faculty members retained can be expected to be higher than formerly except in those systems which arbitrarily regulate the percentage of those with tenure or of those they retain.

With about fifty-five hundred faculty members in Ph. D.-granting departments of mathematics and about ten thousand in master- and bachelor-level departments (and the rest in departments of statistics or computer science), we can shortly expect only about one thousand to fifteen hundred temporary positions in the Ph. D.-granting departments and not more than several hundred temporary positions in the other departments. From the assumption that replacements due to death and retirement over the next fifteen years will be two hundred per year (which was about the number for the past several years, and which conforms to prior estimates of age distribution), the author is led to the conclusion that if five or six hundred new Ph. D.'s enter mathematics departments per year (as would appear to have been the case this year and last), three or four hundred others will be forced out after an average stay of perhaps four years on temporary appointments. Of the two hundred staying, only about a third will be in research-oriented departments. This picture is grim and philosophically intolerable. It is made worse by the likelihood that the selection process for retention will be quite haphazard on a national basis. Many of those not retained will be among the most able researchers and even among the better teachers.

In the opinion of the author, the community should go to great lengths to avoid a continuing phenomenon of the type anticipated. The production of Ph. D.'s trained primarily for academic employment should be cut back to less than one-half of the present level, and the mathematical community should actively seek alternative satisfactory professional or quasi-professional employment opportunities for those forced out of academia.

Is This Doctoral Program Necessary?*

by Saunders Mac Lane

In the United States and Canada there were about 250 new Ph. D.'s in 1952 in the Mathematical Sciences. In 1972 there were about 1,400. This startling increase came about through a variety of causes: The reaction to Sputnik, the recommendations of government bodies, as in the notorious Gilliland report, the enthusiasm for training more scientists and engineers to support the thrust into outer space, the prediction, by COSRIMS and others, of an intense need for more teachers of Mathematics, the development grants offered by the National Science Foundation, and just plain unreasonable desire to start up new Ph. D. programs.

At present many of the new Ph. D.'s have great anguish and trouble in finding positions reasonably related to their training; there are some (150 this summer, by a reasonably careful estimate) who have searched for such positions with no success. In time the news of these difficulties will get back to the beginning graduate students and even to mid-course students: Some will not start and others will give up; still others will continue but with a clearer expectation, knowing that they are studying Mathematics for its great beauty without sure prospects of their own subsequent employability. Thus in time, as in other human affairs not subject to detailed planning, supply will probably adjust itself to demand—but only at the cost of considerable personal hardship. Under these circumstances, it is only appropriate that those responsible for Ph. D. programs—professors, directors of graduate study, chairmen, and deans—ask themselves some hard questions: Is <u>our</u> Ph. D. program necessary?

Here is a possible check list of specific questions.

1. The Ph. D. testifies that its holders have made an original contribution to knowledge; the degree is granted because of the hope that its recipients will go on to make additional and more fundamental contributions. Not all Ph. D.'s succeed in this, but any Ph. D. program, after 10 or 15 years, should have some graduates who have really done outstanding work. How many can you list for your program?

2. Outstanding research work is stimulated by visible previous outstanding work. Does the faculty of your program exhibit this? It is not hard to find out: Name the outstanding papers they have written and the reasons why they are outstanding, and specify the national and international invited addresses given by members of the faculty.

3. Adequate graduate work requires a multiplicity of prospects for research: Not just some long list of topics, but a real variety of promising fields of research, with enthusiastic faculty for each. Does your program provide this?

4. Sometimes graduate programs were established at prosperous times for what might now appear to be the wrong reasons. Were the following some of the reasons for your program?

(a) Graduate programs often provide teaching assistants to conduct undergraduate courses. How good are your teaching assistants? Are they chosen for their teaching ability or because they need the financial support? How much do they teach; can it be that they are exploited? Does your program exist in part in order to provide graduate assistants?

(b) Faculty members like to have graduate students, and this for a variety of reasons, some good, some bad. It is sometimes asserted that a research program will go well <u>only</u> if students are taking part. If this is really so, each tenured member of the faculty active in research would be likely to "turn out" a Ph. D. every three years

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or so. With a research career of 30 years, this means that five to ten new Mathematicians will grow for each present one. Does this make a case for population control? Is your program there chiefly in order to attract faculty? If so, are there alternatives?

(c) Innovation is the order of the day, and rightly so. Graduate training should be reformed to give the student a better feel for his future teaching, a wider grasp of Mathematics, and a better understanding of some of the applications. Sometimes Ph. D. programs are set up in order to make such a reform. Was your program the child of reform? Is this really an adequate reason for a new program?

(d) Was your program established for institutional prestige or for the economic advancement of your region of the country? If so, are these reasons adequate ones and are they really compelling?

5. Do your students know where they are going? Are they aware of the variety of other universities with graduate programs, of the multiplicity of fields of research, and of the uncertain prospects of professional employment? Do you help them to see the situation fully?

6. Mathematical research today is producing brilliant solutions of many basic problems. For example, just in one recent week I learned of three remarkable advances: Deligne's solution of the Weil conjectures (with a consequent solution of an old problem of Ramanujan), the Boone-Higman characterization of finitely generated groups with a solvable word problem, and Graeme Segal's elegant conceptual proof of the result of Nishida, that the stable homotopy ring is nilpotent.

Do your graduate students know enough to recognize these problems and so take part and pleasure in the advances of Mathematics? A real graduate training provides access to the beauty and wonders of Mathematical structures. Does your program do this? If there is doubt, . . .