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FUTURE JOB PROSPECTS FOR PH.D.'s IN THE MATHEMATICAL SCIENCES

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In this article we discuss employment prospects in the United States during the next ten years (1975–1985) for Ph.D.'s in the mathematical sciences. Students who begin a Ph.D. program in fall 1976 may expect to enter the job market during the middle of this period. Most tenure decisions regarding present junior faculty and those now in graduate school who will soon enter college teaching will be made before 1985.

The term "mathematical sciences" refers both to pure mathematics and to the areas of applied mathematics (operations research, statistics, computer science, physical applications, etc.). Currently about 1,200 new mathematical science Ph.D.'s per year are produced in the United States. Roughly half are in pure mathematics and half in an applied area. In this article the term "mathematician" will refer to a person trained in any of the mathematical sciences. We shall first discuss the academic job market in some detail. At the end of the article, job possibilities in industry, government, and in other countries will be discussed briefly.

Job prospects in mathematical science departments at four-year colleges and universities. For the last few years the total number of mathematics faculty has remained nearly constant, at between 17,000 and 18,000 following a period of rapid expansion during the 1960s. No appreciable increase in the total is expected during the rest of the 1970s; and some decrease is quite possible during the 1980s. A few departments will continue to expand, some will contract; and some specialties (probably in certain areas of applied mathematics) will be more in demand than others.

Attempts to predict numbers of future job openings, or of promotions to tenured faculty positions, face several uncertainties. Despite some hopeful signs, mentioned below, there are two predictable factors which will have a negative impact: (1) College age population numbers are leveling off, and will decline during the 1980s; (2) Mathematics faculties are heavily tenured, and relatively few faculty members will reach retirement age before 1985. Even under optimistic assumptions one must expect a difficult academic job market.

Until now around 80% of Ph.D. mathematicians in the United States have been employed by colleges and universities. The percentage in nonacademic employment is higher among recent Ph.D.'s, and this percentage is expected to increase further in years to come. If present rates of Ph.D. production continue, by the 1980s fewer than half the new Ph.D. mathematicians in the United States may expect long term academic positions. An increasing number will follow other careers either in kinds of employment in industry or government traditionally held by Ph.D.'s, or in new kinds of jobs which mathematicians can successfully fill.

The academic job market is strongly influenced on the one hand by mathematics course enrollments, and on the other by the amount of money available for higher education.

Course enrollments. The following table gives the annual number of live births in the United States from 1950 to 1973, according to the Statistical Abstract of the United States.

Year	Live Births (in thousands)	Year	Live Births (in thousands)
1950	3632	1962	4167
1951	3823	1963	4098
1952	3913	1964	4027
1953	3965	1965	3760
1954	4078	1966	3606
1955	4104	1967	3521
1956	4163	1968	3502
1957	4255	1969	3600
1958	4204	1970	3731
1959	4245	1971	3559*
1960	4258	1972	3256*
1961	4268	1973	3141*

These data give a close approximation to the size of the group of 18–19 year olds for the years 1968 through 1991. It increases at about 2% per year until 1975, is almost stable until 1979, then decreases by over 25% from 1980 to 1991.

According to a Census Bureau survey, college enrollments of full-time students were rather stable during 1971–1974. An increase in 1974 followed a decrease the previous year. Somewhat under half the 18–19 year age group are in college. During 1971–1974 the percentage of this group in college declined, with the most notable decreases among men and individuals from middle income families. The percentage of 18–19 year old women in college held steady. There has been considerable speculation whether this represents a permanent reversal of the long-term trend toward ever higher percentages of young people entering college. An argument in favor of this view is the apparent declining economic value of a college degree, since the gap between earnings of high school and college graduates is closing. On the other hand, a college education is still held to have great intrinsic value by a large segment of our society. Moreover, some young people will elect to continue their education if no reasonable job prospect is in sight.

In mathematics about 70% of all undergraduate enrollments are in elementary courses at the precalculus or calculus level. Fewer than 5% of mathematics course enrollments are at the graduate level. Mathematics course enrollments rose 4% nationwide from fall 1973 to fall 1974, after having changed little the two previous years. A number of departments have reported further increases for fall 1975. Freshman engineering enrollments were up 20% in fall 1974, reversing a nationwide drop for several previous years. Students in such fields as business, the social

*Preliminary or provisional from 1971 on.

sciences, and biology tend to take somewhat more mathematics. There are reports that among incoming college freshmen mathematical skills have fallen; an additional remedial course is often needed.

Mathematics enrollments overall should at least remain stable and perhaps continue some increase, for the next few years. The National Center for Educational Statistics has recently projected numbers of baccalaureate degrees in various fields through the early 1980s. The projected numbers of degrees are stable in the following scientific fields: mathematics and statistics, biological sciences, and social sciences. Definite increases are projected for computer and information sciences, engineering, and psychology, with a slight decline in the physical sciences.

Some departments seek aggressively to increase their share of undergraduate course enrollments, by designing courses which appeal to non-mathematics majors and recruiting faculty to teach them. A sizeable percentage of college graduates continue some form of postgraduate education, with a trend away from programs leading to careers in teaching and basic research. Mathematics may have either an increasing or decreasing share of graduate enrollments, depending on whether or not departments provide programs geared to the needs of students expecting to do applied work in industry or government.

Funding of higher education. Most colleges and universities in the United States are sorely pressed financially at this time. This makes more difficult the task of justifying new positions for mathematics faculty, even when course enrollments are up and highly qualified candidates for these positions are available. Some colleges and universities have cut the number of faculty. In particular, some private institutions have imposed a policy of retrenchment as a matter of continued institutional survival.

According to U.S. Office of Education estimates, expenditures for education in institutions of higher learning in the fiscal year 1974 were as follows:

Source of Funds	Amounts in Billions of Dollars		
	Public	Private	Total
U.S. Federal Government	3.1	1.9	5.0
State and Local Governments	10.6	0.3	10.9
All Other	9.3	9.5	18.8
Total	23.0	11.7	34.7

The total has increased by around 9% per year since 1970, following a dramatic increase during a period of rapidly rising enrollments in the 1960s. The 9% rate of increase has scarcely kept up with the overall inflation rate; and it is much less than the steep increases in such items as heat and electricity with which institutions have recently been faced. Expenditures for higher education by state and local governments have increased at a slightly higher rate. U.S. Federal Government expenditures for basic research and education in colleges and universities have actually fallen since 1972, excluding funds for student assistance which have substantially increased. Federal assistance to students does tend to increase enrollments, and thus indirectly increases the potential demand for mathematics. Federal money for research has a more direct effect, but its impact on numbers of regular faculty positions for mathematicians is not massive. Only a small percentage of total academic year salaries for mathematics faculty comes from such funds. Changes in the level or pattern of federal research funding might be expected to have a greater impact on numbers of postdoctoral and other temporary research positions for mathematicians, as well as on graduate student support.

It seems unlikely that amounts spent on higher education, measured in constant dollars, will increase much in the near future. State and local governments are themselves under severe budgetary pressures, with growing needs in many areas and strong public resistance to further tax increases. The federal government is running large deficits, trying to fund programs already in existence and trying to stimulate a lagging economy. The present situation of colleges and universities has been termed a "new depression in higher education". Its resolution is linked to the solution of broader economic and social problems facing the nation.

Tenure and job retention. The prospects of long term employment for junior faculty are closely related to their prospects for obtaining tenure, although tenure and job security are not identical concepts. While promotion to tenure has often been difficult lately, matters are likely to become worse in the years ahead. The basic reason is that nationwide the percentage of mathematics faculty with tenure has been rising two to three percent per year; and this percentage has reached quite high levels while total numbers of faculty have changed little. In some kinds of institutions there are also significant numbers of faculty without formal tenure, but expected to be retained indefinitely. This upward trend in the percentage tenured cannot continue for many more years; and in fact some leveling off was observed last year. From current AMS survey data it is estimated that between 500 and 600 Ph.D. mathematicians obtained tenure in mathematical science departments at four-year colleges and universities in the United States during the academic year 1974–1975. For 1973–1974 the number appears to have been higher by around 100. In almost all cases tenure was granted in the institution where the individual was already employed. New appointments which initially carry tenure are no longer common, even for established mathematicians.

By around 1980 we may expect neither the total number of faculty nor the percentage of tenured faculty to be increasing nationwide. Between 1980 and 1985 the number of tenured positions available will probably barely exceed the number of deaths and retirements, no more than 250 per year. Institutions are likely to be quite cautious about granting tenure in the face of almost certain declines in enrollments during the 1980s.

The situation regarding long term employment prospects varies somewhat according to type of department. We consider separately three categories: (1) Mathematics Departments which grant the Ph.D.; (2) Other mathematical sciences departments which grant the Ph.D.; and (3) Departments which grant at most master's degrees. There are about 150 departments in each of categories (1) and (2), and many more departments in (3). The percentages of total mathematical sciences faculty nationwide in the

three categories are roughly 30%, 10% and 60% respectively.

(1) Mathematics Departments which grant the Ph. D. These departments are over 70% tenured, if one counts full time faculty of the rank of assistant professor and above. AMS Survey data show that the departments ranked among the top twenty-seven in the ACE (American Council on Education) ratings have, as a group, already reached a nearly constant number of tenured positions. Prospects of permanency are generally poor for nontenured faculty currently being hired by these departments. On the other hand, nontenured faculty leaving the top twenty-seven rated departments have had, up to now, generally good success finding other positions.

There continues to be some increase in the number of tenured positions among lower ranked departments and those Ph. D. granting departments not rated by the ACE. However, when this increase ends one may expect for a period of several years no more than about 75 appointments to tenure per year, due to replacements, among about 150 Ph. D. granting mathematics departments altogether in the United States. This amounts to only one appointment to tenure every two years per department, on the average.

Percentages of faculty with tenure in the 80 to 85 percent range may not be unreasonable in a steady state situation. Tenure decisions normally occur from five to seven years after the Ph. D., and tenured faculty serve for some thirty years more before retirement. One needs a pool of assistant professors large enough to provide a continued flow of good young tenured faculty, but small enough to give assistant professors reasonable chances for permanency.

(2) Other mathematical sciences departments which grant the Ph. D. These departments are in the areas of statistics, computer and information science, operations research, and other applied mathematics. In statistics departments, both the total number of faculty and the percentage tenured (around 65%) have remained fairly stationary recently. On the other hand, statistics enrollments are increasing both at undergraduate and graduate levels; and nonacademic employment prospects for statisticians are good. There may be some expansion of statistics department faculties.

AMS survey data are less complete for other mathematical science departments. Our data collection is complicated by the fact that computer science and operations research sometimes are administratively part of an engineering division. These departments are generally younger with fewer than 60% of faculty being tenured. Enrollments have been steadily increasing. Some expansion in faculty sizes may be expected. On the other hand, the number of computer science Ph. D.'s per year has greatly expanded. Competition for Ph. D.-level jobs for computer scientists may become keen, despite a greater number of nonacademic opportunities in that field.

(3) Departments which grant at most master's degrees. Percentages of Ph. D.'s with tenure in these departments range from nearly 70% for those granting a master's degree down to around 55% for those granting only a bachelor's degree. However, in both cases there are substantial numbers of faculty formally without tenure who are expected to be retained indefinitely. Generally speaking, the tendency is to keep a young faculty member who performs well, unless budgetary restrictions mandate the elimination of his position. It is estimated that over 80% of all faculty in these departments of the rank of assistant professor or above are considered permanent. While these departments are an important part of the job market for Ph. D.'s, like other departments they are expected soon to reach a situation where the number of new permanent positions scarcely exceeds the number opened by death and retirements.

Other academic employment. It is estimated that last year nearly 100 Ph. D. mathematicians found positions in colleges or universities outside mathematical science departments. This includes in roughly equal proportions, both new Ph. D.'s and those already holding the Ph. D. and previously employed in a mathematical science department. These positions are sometimes in other academic departments. Other positions are, for instance, in computing or statistical laboratories. Another 50 or so were hired by two-year colleges or high schools. While these numbers may increase somewhat, they are too small to have a large impact on the overall job market for Ph. D.'s. Only about 10% of two-year college mathematics faculty have Ph. D.'s, a much lower figure than for example in biology. Adult or continuing education is an area of potential growth. However, such programs are likely to be more culturally than scientifically oriented. Relatively few jobs for Ph. D. mathematicians are likely to develop through them.

Nonacademic employment. Around 250 to 300 Ph. D. mathematicians per year take positions in government, industry, or nonprofit orgranizations. Somewhat over half of them are new Ph. D.'s. The majority, but by no means all, were trained in an area of applied mathematics. Manpower projections by the National Science Foundation and the Bureau of Labor Statistics predict a slow but steady increase in nonacademic employment by physical scientists, engineers and mathematicians. The increase is seen to be partly attributable to openings in traditional research and development types of work, and partly to new kinds of jobs. Such projections are subject to uncertainties about the future state of the economy and the pattern of research funding by the U. S. Federal Government. The number of openings for mathematicians also depends on the degree to which employers are willing to hire them in competition with applicants trained in such fields as physics, electrical engineering, or economics.

Future growth of nonacademic employment for mathematicians is likely to be selective. Probable areas of growth include computing, operations research, energy-related or health care-related research, and actuarial work. Most of those hired may expect to do applied work directly related to current projects. Openings in long-range basic research will be few. The job applicant must be prepared to convince the employer that he can fill a specific need in the organization. For some jobs, preference will be given to those whose background identifies them with a particular field of application.

Employment outside the United States. Currently about one-fourth of those receiving a Ph. D. in the mathematical sciences in the United States are citizens of other countries. Most of them are expected to return to positions at home, or in other foreign countries. In addition, a few Ph. D.'s

who are U.S. citizens have taken positions outside the U.S. Several countries in South America and the Middle East are intensively developing higher education and have openings.

As part of the annual AMS Survey, data are collected from doctorate granting departments in Canadian universities. The situation in Canada resembles in many ways the one described above for the U.S. Numbers of faculty and course enrollments have remained stable. Canadian departments are nearly 80% tenured. Canada produces about 90 Ph.D.'s in the mathematical sciences per year, somewhat more than the number of new mathematical science Ph.D.'s per year hired by Canadian institutions.

A final note. Further perspective about the employment situation may be found in a series of articles by Richard D. Anderson in these *Notices*, November and December 1973, November 1974, and November 1975. In preparing the present article the author has drawn freely upon this material, together with analyses of AMS Survey data and other sources. An article by John Jewett regarding two-year college employment appears in the October 1974 *Notices*. A lengthier commentary on the nonacademic job market appears in the April 1975 *Notices*.