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Trends in Mathematical and Statistical Sciences in the United States

Lawrence H. Cox, Therese A. Hart, and James A. Voytuk[1]

Abstract: Mathematics and statistics have similar characteristics from an academic perspective, but different images from a professional point of view. While strong independent departments of statistics or statistical sciences exist, mathematics or mathematical sciences departments offer statistics, sometimes as a regular degree program, but usually as a sub-discipline of mathematics or as a collection of service courses. Both disciplines of mathematics and statistics are subject to some of the same forces and display some similar trends in the people who study and teach in these areas. These trends include under-representations of women and certain minority groups, increasing lower-level enrollment, a slow growing or static faculty size with a large anticipated retirement rate, and static (or declining) number of new degree holders at all levels. The demand for mathematically and statistically prepared people has increased remarkably in the last ten years – a trend that is projected to continue into the next century. An investigation of the academic preparation and socioeconomic backgrounds of students now in the educational "pipeline", and the changing demographics of the population reveal a serious problem in meeting the demands, both for professionally trained people and for a broad, high level of quantitative literacy.

Key words: Demographics of the statistical profession; statistical education; teaching.

1. Introduction

For many years mathematics, statistics, operations research, and computer science were considered to be the sub-disciplines that formed the base of the mathematical sciences. Computer sciences with its rapid growth and wide range of applications has in many respects decoupled itself and now is recognized as a separate field. Mathematics and statistics are still considered by many to be similar disciplines and as such are subject to the same forces and display some similar trends in the people who study and teach in these areas. Nonetheless, the emerging statistical sciences encompass several non-mathematical areas, and there are indications that statistics may in some ways be in the process of decoupling itself from mathematics.

The purpose of this paper is to serve as a resource document, detailing information on the mathematical and statistical sciences. In many cases information on the two disciplines is aggregated, since many view mathematics and statistics as similar fields.

[1] National Research Council. The opinions expressed here are solely those of the authors and are not intended to reflect opinions, conclusions, or positions of the National Research Council, its boards, or committees. Mailing address: Lawrence H. Cox, Board on Mathematical Sciences, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, D.C. 20418, U.S.A.

It is our intent to point out observable trends concerning the status of the professions, rather than to advance a thesis in support of any particular view or emerging trend. However, it was the differences between computer science and the mathematical sciences that lead to their separation, and as we demonstrate, there are now striking differences between the mathematical and statistical sciences. These differences can be seen in professional employment, salary, and areas of applications, but it is most visible in changes in the way these programs are administered in academic institutions.

Within mathematics or mathematical sciences departments, statistics is often a concentration or minor within the mathematics degree program, whereas it is offered as a degree program in established and emerging independent departments of statistics. This amalgamation of subject matter tends to create similar conditions with respect to the staffing and teaching of courses. As a result there are similar characteristics such as the under-representation of women and certain minority groups, increasing lower-level enrollment, slow growing or static faculty size with a high anticipated retirement rate, and static or declining number of degree holders at all levels. However, the opportunities available to mathematics and statistics graduates are different. There are also pedagogical differences. With the advent of low cost computing there is now the capability for more data manipulation and a greater emphasis is placed on the teaching of statistical concepts through the understanding of models that reflect actual conditions. Statistics has long emphasized laboratory teaching, while mathematics is only beginning to employ the use of computers in the classrooms.

Commonality in the disciplines exists in that the demand for mathematically and statistically prepared people has increased remarkably in the last ten years – a trend that is expected to continue into the next century. Public alarm has recently been aroused by the current inadequate levels of quantitative and statistical literacy of the general work force. An investigation of the academic preparation and socioeconomic background of the students now in the educational system and the changing demographics of the population reveal a serious problem in meeting the demands, both for a large number of professionally trained people and for a broad, high level of quantitative literacy.

The issues addressed in this paper are among those being investigated in a major study at the National Research Council (NRC), called Mathematical Sciences in the Year 2000 (MS 2000). The charge of MS 2000 is to identify concerns in the mathematical sciences in the areas of human resources, curriculum, and support resources at colleges and universities and to develop a strategy to remedy problems in these areas. The human resource information from this study is published in a report (National Research Council 1990).

2. U.S. Labor Force and Numeracy

". . . [P]rogress in science, in technology, in health, and public policy depends critically upon the level of our abilities to discover, or at least approach, truth from incomplete information" (National Research Council 1989a, p.2).

Mathematical literacy or numeracy, as either a critical basic skill or as an underpinning of science and technology, is needed to some extent by all individuals in the labor force. Problem solving and numerical reasoning are becoming part of an increasing number of jobs, and higher levels of mathematical and statistical competency and required of those involved in technological development and implementation. Decision-making in advertising, forecasting, and public policy is frequently based on data analysis which requires a competency and ease with statistics. Developments within the mathematical sciences and expanding applications demand a specialized mathematical knowledge which is a prerequisite to mathematics related professions.

The growing U.S. economy will add 21 million new jobs between 1986 and 2000, most of which will require some college education. The science and engineering work force is projected to grow faster than the general labor force during this period; 36% for scientists and engineers compared with 19% for the general labor force. The science and engineering work force (4.6 million persons) is only 4% of the total 120 million person labor force and mathematical scientists comprise less than 3% of this science and engineering work force.

In the decade ending in 1986 the number of mathematical scientists has increased remarkably (see Table 1). Who will be the mathematical scientists of the future is a shared concern of both mathematicians and statisticians. Because this small specialized work force has a great effect, the concern is reaching a much larger audience than the mathematical sciences community alone.

We have entered what some have called an information age – a time of an ever-increasing need "to understand how information is processed and translated into usable knowledge" (National Council of Teachers of Mathematics 1989, p. 8). At this same time of ever-increasing need is an ever-ringing alarm at the current state of mathematics education and the level of mathematical literacy. "Innumeracy, an inability to deal comfortably with the fundamental notions of number and chance, plagues far too many otherwise knowledgeable citizens" (Paulos 1988, p. 3).

3. Pre-College Preparation and the Changing Pool of Students

American students' pre-college mathematics preparation does not compare well internationally. On the most recent International Assessment of Mathematics and Science, U.S. students placed last in mathematics performance overall among 13-year old students in five countries and four Canadian provinces. On the six topics measured, including two statistics related (measurement and data organization and interpretation), U.S. students scored 10 to 20 percentage points below the top scorers (Lapointe, Mead, and Phillips 1989). Furthermore and more importantly, students are not learning enough mathematics in high school to prepare themselves for college level courses or for the future U.S. workplace.

Certain pre-college indicators and scores – National Assessment of Educational Progress (NAEP), American College Test (ACT), and Scholastic Aptitude Test (SAT)

Table 1. Mathematicians and Statisticians in the Work Force, 1976 and 1986

	1976	1986	Percent Increase
Total	48,600	131,000	170
Mathematicians	43,400	110,700	155
Statisticians	5,200	20,300	290

Source: National Science Foundation (1988c, pp. 81 and 85).

– have all shown some recent encouraging and upward trends after years of steady declines. But the major progress appears to have been in lower level skills, the higher problem solving abilities are not improving. The most recent NAEP assessment showed significant gains by blacks and Hispanics, but noted that only half of all 17-year olds in the assessment reached a junior high level of proficiency and thus lacked a breadth and depth of mathematics proficiency needed for advanced high school study of mathematics (Dossey, Mullis, Lindquist, and Chambers 1988).

The growing importance of data organization and interpretation is reflected in the recently released National Council of Teachers of Mathematics Standards, which recommends the exploration of statistics in practical situations from the earliest grades (National Council of Teachers of Mathematics 1989). Although an important topic in mathematics education, statistics emerges as a separate field of study only at the graduate level and prior to that is a sub-field or strand of mathematics. Thus the pool of potential statisticians prior to, and a certain extent during, the undergraduate years, is the same as the pool of potential mathematicians, and is subject to the same shifts in the popular college majors and changing demographics.

Women, blacks and Hispanics are under-represented in natural science and engineering fields. This under-representation is most severe in the mathematics intensive fields and worsens while climbing the academic and professional ladders, but is prevalent at lower levels of the educational process. High school students taking the necessary mathematics courses, college freshmen interested and prepared to pursue mathematics related majors, college seniors who have majored in a mathematics intensive field, graduate students with the necessary mathematics background, mathematicians and statisticians in the work place; each of these stages in the process needs full representation of women and minorities, but this is far from the case. The pipeline is long and leaky with women and minority students dropping out at higher rates than white men.

Table 2. Enrollments and Degrees by Ethnicity

	Total	Whites	Blacks	Hispanics
		Percent		
High School Graduates who Enroll in Institutions of Higher Education (1986)	34	35	29	29
Undergraduate Enrollment in Institutions of Higher Education (1986)	100	79	9	5
Bachelor's Degrees Awarded (1985)				
All Fields	100	88.0	6.1	2.8
Mathematical Sciences	100	86.1	5.4	1.8

Source: U.S. Department of Education (1988).

The fastest growing segments of the 18- to 24-year old population are least likely to finish high school, enroll in college, and pursue mathematics related majors (see Table 2). In 1985 minorities comprised one-quarter of the college age population (18- to 24-year olds); this will increase to almost one-third in the year 2000. Retention and recruitment in the educational, particularly the mathematics based, system are becoming more critical not only from the viewpoint of an educated populace, but also merely to sustain and maintain the current system which supplies high school teachers, college faculty, researchers, and technological specialists.

4. College Undergraduates

In the last twenty years, a fairly dramatic shift in students' interests in academic majors has taken place. The job-oriented majors are more popular than traditional liberal arts subjects. Business, engineering, and computer science majors have increased as a distribution of all majors, while majors in mathematics, education, English, and social sciences have decreased. Physical sciences, fine arts, life sciences, and agriculture show either mixed or fairly constant distribution of degree production.

Although mathematics is not unique in its loss of appeal as a major, the drop in interest has been steep in the last twenty years. In 1967, 4.2% of all college freshmen planned to major in mathematics or statistics; this steadily eroded to 0.6% in 1987 (see Figure 1). In this survey of freshmen's college major and career plans, mathematician is not listed as a job title, but statistician is and for the last ten years 0.1% of freshmen have stated such a career plan (Cooperative Institutional Research Program 1987).

Undergraduate enrollment in collegiate

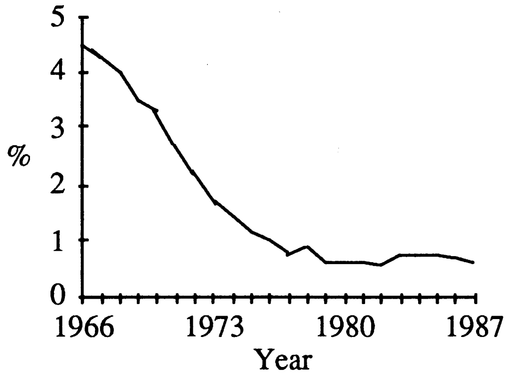

Fig. 1. Entering College Freshmen Expecting to Major in Statistics
Source: Cooperative Institution Research Program (1987).

mathematics courses has soared since 1965, but the largest increases have been in remedial and pre-calculus courses again reflecting lack of preparation of many entering students. Enrollment in statistics courses, which accounts for about 10% of all mathematical science departments enrollment, differs from mathematics enrollment in that there has been increased enrollment at both elementary and advanced levels. While enrollment in advanced mathematics courses has not increased during the period 1965 to 1985, advanced statistics enrollment has doubled from 32,000 to 64,000 (see Table 3), demonstrating the applicability of statistics.

Increased quantification of society including the business community, increased use of computers, and more interest and integration of statistics in the business curriculum have been cited as likely reasons for the increased enrollment in undergraduate statistics courses (Conference Board of the Mathematical Sciences 1987). Data are not readily available on undergraduate enrollment in statistics courses taught in departments other than mathematical sciences, but it is likely significant since many majors (most social and life sciences – psychology,

Table 3. Total Undergraduate Enrollments in Mathematical Sciences Departments (in thousands)

	1965[A]	1970	1975	1980	1985
Remedial	198	292	487	683	733
Pre-Calculus[B]	661	862	1,007	1,118	1,042
Calculus	361	483	526	681	740
Advanced	133	162	106	91	138
Total	1,353	1,799	2,126	2,573	2,653

Undergraduate Enrollments in Statistics (in thousands)

	1960	1965	1970	1975	1980	1985
Elementary	4	11	57	99	104	144
Advanced	16	32	35	42	43	64
Total	20	43	92	141	147	208

[A]1966 data used for two-year colleges, since 1965 data are not available.
[B]Includes other, computer and data processing, and statistics at two-year colleges.
Source: Conference Board of the Mathematical Sciences (1987, pp. 18, 31, and 120).

economics, biology, sociology, etc.) include a statistics requirement.

The nature of elementary courses in mathematics and statistics differs in that elementary statistics courses are not usually taught in high school and so do not generally duplicate high school course work as elementary mathematics courses often do. Low cost computing makes it possible to teach statistics with a greater emphasis on data manipulation and many statisticians advocate teaching such data-driven introductory courses, but as the following survey summary from liberal arts schools indicates that is not always the case. "The extent to which data are currently being excluded from introductory statistics education is not clear. A conservative estimate is obtained from the use of computer software in introductory statistics courses since the latter is a necessary although not sufficient condition for teaching a data-driven course. In our survey 67 of the 80 responding mathematics departments offer an introductory statistics course. Of these, 30% (20) use no computer software in the course" (Moore and Roberts 1989, p. 81).

Not all college students enroll in mathematics courses. According to a National Longitudinal Study of 1972 high school graduates being conducted by the Department of Education, two out of five students who enrolled in college took no mathematics courses at all, but of those who earned degrees only one out of five took no mathematics (Adelman 1988). In the early eighties, an average college graduate took 8.4 semester hours of college mathematics which translates to between 2 and 3 courses. The number of semester hours for various non-mathematics majors ranged from a low of 2 hours (less than one course) for fine arts and English majors to a high of 21 hours (6–7 courses) for computer science majors.

Low interest among entering college freshmen in a mathematics major and low enrollment in advanced courses would forecast fewer bachelor's degrees in mathematics. This indeed has been the case – degree production in 1986 (16,000) was

Table 4. Bachelor's Degrees Awarded in Mathematical Sciences

	Total	Men	Women	Percent Women
1950	6,382	4,942	1,440	23
1952	4,696	3,374	1,322	28
1954	4,078	2,717	1,361	33
1956	4,646	3,128	1,518	33
1958	6,905	4,943	1,962	28
1960	11,399	8,293	3,106	27
1962	14,570	10,331	4,239	29
1964	18,624	12,656	5,968	32
1966	19,977	13,326	6,651	33
1968	23,513	14,782	8,731	37
1970	27,442	17,177	10,265	37
1972	23,713	14,454	9,259	39
1974	21,635	12,791	8,844	41
1976	15,984	9,475	6,509	41
1978	12,569	7,398	5,171	41
1980	11,378	6,562	4,816	42
1982	11,599	6,593	5,006	43
1984	13,211	7,366	5,845	44
1986	16,306	8,725	7,581	46

Source: National Center for Education Statistics (1988).

about half of what it was during the peak production period of 1970 (27,000). Less than 1,000 of these 16,000 mathematics degrees awarded are statistics degrees, but this may be misleading, since at the undergraduate level mathematics is a "catch-all" discipline. Longitudinal data on the number of statistics bachelor's degrees awarded is not readily available, but according to the 1985 survey by the Conference Board of the Mathematical Sciences (CBMS), the number of degrees awarded in statistics was 570 in 1975 and 816 (278 of which were joint majors) in 1985 (Conference Board of the Mathematical Sciences 1987). Those planning graduate studies in statistics usually major in mathematics as undergraduates, and the number of bachelor's degrees awarded in mathematics is given in Table 4. The trend in the number of bachelor's degrees awarded has turned around since the early eighties when it was at a low of 11,000; this turn around appears to be because of students' deciding to major in mathematics while in college.

Women are receiving a larger share of the bachelor's degrees awarded in mathematics. Their share has steadily climbed from about one-third in the mid-1960s to almost one-half (46%) in 1986, accounting for almost 7,600 of the 16,000 bachelor's degrees. This near parity of representation at the baccalaureate level has not translated to graduate enrollment or graduate degrees. Women are persisting in the "mathematical pipeline" through college, but are not enrolling in graduate mathematical sciences programs or pursuing graduate degrees at the same rate as their male counterparts. While attrition of women appears to be occurring after the bachelor's degree, for non-Asian minorities it is much earlier.

Non-Asian minorities are under-represented among mathematics degree holders as they are among most science and engineering fields. Blacks and Hispanics are less likely to complete high school and those who do are less likely to enroll in college. In 1986 one-third of all high school graduates enrolled in college; the rate for whites was 35% compared to 29% for blacks and Hispanics. Because of this, whites are disproportionately represented in total enrollment at colleges and universities. However, considering these other factors blacks and Hispanics still receive a smaller share of mathematical sciences degrees than they do of other degrees. Attrition of non-Asian minorities appears to be occurring both prior to and during the college years, and the under-representation becomes more extreme at the graduate and professional levels. Retaining and recruiting future mathematicians and statisticians to meet increasing demands must include members of all groups including those currently under-represented.

According to information gathered by the American Statistical Association (ASA), of the 69 departments offering baccalaureate degrees in statistics, 42 are in statistics departments and 27 are in mathematical sciences departments. Another 42 departments offer bachelor's degrees with an emphasis in statistics.

5. Graduate Programs

At the graduate level the distinction between mathematics and statistics programs becomes clearer, but there is still a tendency to combine data under the heading of mathematical sciences when counting and classifying majors. The separation is made only with respect to the actual number of degrees awarded and primarily those at the doctorate level. Graduate statistics programs are distributed across many departments and schools and are duplicated with a different emphasis. This is illustrated by data from the ASA survey (American Statistical Association 1987), which reports that there are 217 master's programs at 172 institutions and 164 doctoral programs at 122 institutions with either a degree in statistics or a degree in another discipline with an emphasis in statistics. Growth occured during the fifties and sixties in the number of separate statistics departments, as is shown by Moore and Olkin (1984) where they report that the number of doctoral statistics departments rose from 8 in 1950 to 40 in 1980. The ASA data show that in 1987 there were 56 statistics departments offering doctorates. Further examination of the ASA data reveal that only 13 mathematics or mathematical sciences departments offer Ph.D. degrees in statistics and, with few exceptions, they are not considered to have strong mathematics programs. On the other hand statistics is still well grounded in mathematics programs in that 34 departments offer mathematics doctorates with an emphasis in statistics. Table 5 shows the diversity of degree programs in statistics.

A profile of the graduate students in the mathematical sciences will provide a picture that is consistent with that of statistics. This assumption is supported by the finding that the ethnic and gender characteristics of mathematics and statistics degree recipients are similar. Data from the National Science Foundation (NSF) show that of the approximately 18,000 graduate students in the mathematical sciences graduate departments, over 40% are non-U.S. citizens, with the level reaching 50% at the top graduate institutions. Among the U.S. students, women (30%), blacks (4.1%) and Hispanics (2.8%) are under-represented, again more so at the doctoral level. The percentage of women enrolled in doctoral granting institutions has increased from 21% in 1975 to 27% in 1986, however the percentage for

Table 5. Degree Programs in Mathematics and Statistics

	Masters	Doctoral
Math or Math Science Departments (87 Departments) offering		
Degree in statistics	41	13
Degree in math with an emphasis in statistics	44	34
Statistics Departments (65 Departments) offering		
Degree in statistics	64	56
Other Departments offering		
Degree in statistics	44	38
Degree with an emphasis in statistics	21	21

Source: American Statistical Association (1987).

blacks and Hispanics has remained constant (National Science Foundation 1988a).

Institutional support is the primary source of aid for graduate students in the mathematical sciences. In 1986, 70% was in the form of teaching assistantships or institutional fellowships, with 17% from self-support and only 8% from federal sources. The type of support in the mathematical sciences is weighted towards teaching assistantships with 59% in this form, much higher than in any other area of science or engineering, where the next highest level is about 40% in the physical sciences (National Science Foundation 1988d). This picture of heavy institutional support is similar for statistics. However, teaching assistants (TAs) are more likely to support the teaching of a course, as opposed to doing the actual instruction. In statistics departments about one-quarter of the TAs teach their own classes, where as in mathematics the fraction is nearer to one-half (Conference Board of the Mathematical Sciences 1987).

The 1985 CBMS survey asked responding mathematical sciences departments to rate the lack of quality and the lack of quantity of graduate students as problems in their programs. More than half of the responding departments in both mathematics and statistics rated the lack of quality and quantity as a major problem (Conference Board of the Mathematical Sciences 1987).

The number of master's degrees in the mathematical sciences has varied dramatically over the past 40 years when they increased from about 1,000 in 1950 to peak in 1970 at 5,600 and then declined until 1980 when a slight upward trend brought the level to 3,200 degrees in 1986, about that of the mid-sixties. On the other hand, the picture in statistics does not show these sharp variations. Data for master's degrees in statistics are available from the Department of Education and show a constant

Table 6. Number of Doctorate Degrees Awarded in Mathematical Sciences and Statistics, 1976 to 1988

	1976	1978	1980	1982	1984	1986	1988
Total, Mathematical Sciences	1,003	838	744	720	698	730	749
Mathematical Statistics*	123	135	121	140	162	115	130
Mathematical Statistics as Percent of Total	12	16	16	19	23	16	17

*AMS counts for Probability have been subtracted from NRC counts for combined sub-field of Probability and Mathematical Statistics.
Source: American Mathematical Society (1976–1989) and National Research Council (1989b).

annual production of about 475 degrees during the eighties. This is about 15% of the total degrees in the mathematical sciences in 1986, and 18% in 1981 when the total number of degrees was close to 2,560 (National Center for Education Statistics 1988).

The only information available on graduate enrollment in statistics is from the annual American Mathematical Society (AMS) survey. This data obtained from departments and programs of statistics, biostatistics or biometrics with doctoral programs show a small increase of 2 or 3% in total enrollment each year from the early 1980s. However, over the last three years of information, 1985-87, there has been a noticeable increase in the number of first year graduate students of about 15%.

The sex and racial composition of students receiving master's degrees in statistics has not been separated from that of the other areas in the mathematical sciences. However, for U.S. citizens in the mathematical sciences, white males receive about 55% of the master's degrees, while 32% and 13% are given to white females and minorities, respectively, and in general about three-quarters of the total degrees are earned by U.S. citizens.

Again the production of doctorates in statistics resembles that of the master's degree with a steady increase from about 60 degrees in the early sixties to 160 in the late seventies and somewhat constant levels through the eighties. This is based on data from the NRC which combine mathematical statistics and probability. If the number of doctorates is adjusted by subtracting from the NRC data the number in probability from the AMS survey, the numbers are again somewhat constant through the late seventies and into the eighties at about 140, but show a decline in recent years to around 110. This pattern is different from the one for the mathematical sciences as a whole in which there was an increase from about 200 in 1950 to a high of 1,000 in the early seventies, followed by a decline until the early eighties when the production became constant at about 700 (see Table 6).

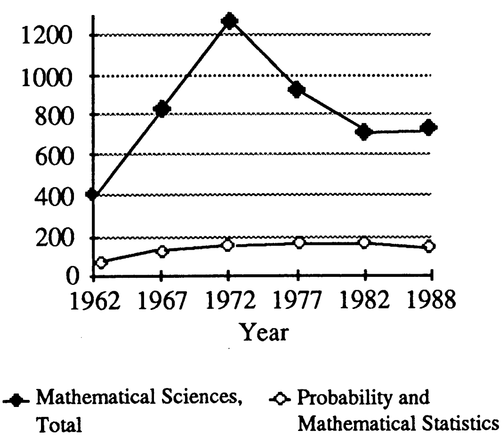

Fig. 2. Number of Doctorates Awarded in Mathematical Sciences
Source: National Research Council (1989b).

Table 7. Number of Doctorate Degrees Awarded in Broadly-Interpreted Statistics Fields, 1962 to 1988

	1962	1967	1972	1977	1982	1987	1988
Total	110	210	324	294	299	263	284
Probability and Mathematical Statistics	66	123	151	159	165	143	152
Biometrics and Biostatistics	10	26	30	52	59	37	47
Psychometrics	19	15	25	19	8	9	11
Econometrics	15	30	33	29	24	25	27
Social Sciences Statistics	0	16	85	35	43	49	47

Source: National Research Council (1989b).

The production of doctorates in statistics follows the pattern for research doctorates in general awarded at U.S. universities, where the number increased in the sixties to a high of 34,000 in 1973 and was followed by a modest decline to a stable level of about 31,000. The phenomenon of a sharp rise and equally sharp fall in the mathematical sciences as opposed to the more steady growth in statistics may be due to the reaction to Sputnik and the perceived need for people in the basic sciences and not a real need to supply the work force. Figure 2 shows trends in degree production over the past 26 years; more detailed information for the last decade is given in Table 6.

The broadly-interpreted statistical fields that include the social and life sciences show a steady increase in doctorate degrees during the sixties, and since then the rate of degree production has been stable at about 300 per year with mathematical statistics and probability degrees accounting for about half of these degrees (see Table 7). The inclusion of other programs into the broadly-interpreted mathematical sciences, such as operations research, computer sciences, and mathematics education, shows that the level of doctorate production has been constant at 1,400 for the last decade, with declines in mathematics and education, stability in statistics and operations research, and growth in computer science (see Table 8).

When viewed as sub-fields of the mathematical sciences, the trends in degree production in mathematics and statistics have been very different – the number in mathematics has dropped drastically, while statistics has been stable (See Table 6). With a broader view of both statistics and the mathematical sciences, degree production has been fairly constant. This is yet another example of the similar but different trends in mathematics and statistics.

In mathematics and statistics, the ethnic distribution among U.S. citizen and perma-

Table 8. Number of Doctorate Degrees Awarded in Broadly-Interpreted Mathematical Sciences, 1976 to 1988

	1976	1978	1980	1982	1984	1986	1988
Total	1,411	1,290	1,258	1,246	1,331	1,499	1,638
Mathematics	696	605	569	533	496	574	578
Computing	267	252	293	303	364	486	623
Statistics	234	249	218	266	284	238	257
Operations Research	118	127	104	94	123	129	123
Mathematics Education	96	57	74	50	64	72	55

Source: American Mathematical Society (1976–1989) and National Research Council (1989b).

Table 9. Racial or Ethnic Composition of Mathematical Doctorate Degree Recipients, 1975 to 1986

	White	Black	Hispanic	Asian	Indian	Total
Mathematical Sciences, Total	6,061	97	100	481	11	6,750
Probability and Math Statistics	1,139	20	20	144	3	1,359
Percent Distribution						
Mathematical Sciences, Total	89.8	1.4	1.4	7.1	0.2	100
Probability and Math Statistics	85.9	1.5	1.5	10.9	0.2	100

Note: Includes U.S. citizens and permanent residents only, and of these only those whose race or ethnicity is known.
Source: National Science Foundation (1988b).

nent resident doctorates exhibits similar characteristics. Blacks and Hispanics are significantly under-represented among doctorate recipients in statistics (see Table 9). The number of non-citizens with temporary visa status has grown with mathematics to about 40%, and this poses a concern for the future supply of domestic statisticians.

6. Mathematicians and Statisticians in the Workplace

Little information is available from standard U.S. labor market sources about where persons with mathematics or statistics degrees work or what they do. During the past forty years approximately 600,000 persons have been awarded baccalaureate degrees in mathematics or statistics, 100,000 have received master's degrees and 25,000 doctorates. However, estimates of the current work force in the mathematical sciences range between 100,000 and 150,000, about one-fourth of what is expected (National Research Council 1990). Three possible reasons for this are: mathematician has not been generally regarded as a professional title and statistician has only recently obtained professional recognition, and this is compounded by the fact that workers with the title of statistician may hold degrees in mathematics or statistics; persons with degrees in mathematics work under various job titles, such as statistician, computer specialist, engineer, analyst, and actuary; and many secondary school teachers are not classified as mathematical scientists.

Although general labor market data are limited, what are available indicate some trends. The number of identified mathematical scientists in the workplace has increased dramatically in recent years and they depend more heavily on academic employment than any other group in science and engineering. There continues to be a shortage of secondary school mathematics teachers. Women, blacks, and Hispanics are under-represented throughout the work force.

An NSF survey (National Science Foundation 1987) of bachelor's and master's degree recipients shows that about half of all graduates at both degree levels work in business and industry and about one-quarter of bachelor's holders and one-third of master's holders teach. Of new doctorates, three out of four plan academic work, according to an NRC survey (National Research Council 1989b). These employment patterns for mathematical scientists and all scientists are summarized in Table 10.

Disaggregated data for mathematics and statistics for the total work force are given earlier (see Table 1) and show a 290% increase in employment for statisticians,

Table 10. Type of Employer of Mathematical Scientists by Degree Level, 1986, in percent

	Bachelor's	Master's	Doctorates	All Math Scientists	All Scientists
Educational Institutions	26	37	73	51	29
Business and Industry	55	48	20	34	48
Government and Other	20	15	8	15	24

SOURCES: National Science Foundation (1987) and National Research Council (1989b).

from 5,200 in 1976 to 20,300 in 1986. The increase for all of science and engineering over this ten-year period was about 100%. More detail on the nature of employment is available for doctoral mathematicians and statisticians from the NSF. Here the growth in research and administration type employment for mathematicians provides the significant increases, while for statisticians growth has been across all employment types (see Table 11).

It is interesting to note that the almost constant rate of doctorate production in mathematical statistics, only about 850 U.S. citizens received degrees over the past ten years, if the actual number is adjusted for the current rate of 40% foreign degrees. Assuming a 30-year career span, this rate of doctorate production will only be sufficient to replace the current work force. The situation in mathematics is even more of a concern since the percentage of doctorates awarded to foreign students is closer to 45%, and the adjusted total production for the past five years, since mathematics degrees have stabilized, is about 2,000, or 12,000 over a 30-year period, and therefore less than the current work force.

The college and university mathematical sciences faculty number is approximately 50,000, including 8,000 graduate assistants and 15,000 part-time members. Of the

Table 11. Primary Work Activities of Doctoral Mathematical Scientists

	1975	1981	1985	% dist 1985
Mathematicians				
Research/development	2,300	2,700	3,200	24
Mgt./administration	1,000	1,200	1,500	11
Teaching	8,100	8,300	8,200	61
Consulting	100	200	200	1
Other	0	100	300	2
Total	11,500	12,500	13,400	100
Statisticians				
Research/development	400	600	800	30
Mgt./administration	200	200	200	7
Teaching	1,000	1,300	1,300	48
Consulting	100	300	200	7
Other	0	100	200	7
Total	1,700	2,500	2,700	100

Source: National Science Foundation (1988a).

Table 12. Numbers of Faculty Members at Universities for Selected Years

	1970	1975	1980	1985
Mathematics				
Full-time	6,235	5,405	5,605	5,333
Part-time	615	699	1,038	1,044
Statistics				
Full-time	700	732	610	662
Part-time	93	68	132	103

Source: Consolidated from CBMS survey information, Conference Board of the Mathematical Sciences (1987).

doctorate holding full-time faculty in four-year colleges and universities, about 13,200 teach in the area of mathematics and 1,500 in statistics. The size of the research faculty in the mathematical sciences is estimated at 10,000 with 9,000 of these in educational institutions and have research as their primary or secondary activity. Table 12 shows that there has been a decline of full-time faculty and a sharp increase of part-time faculty at the university level for both mathematics and statistics.

According to the CBMS survey the representation of women on statistics faculties is about 10% as compared to 15% on mathematics faculties and the ethnic dis-

Table 13. Mathematical Sciences Faculty Salaries at Doctorate Granting Institutions in 1985 Constant Dollars

	1970	1975	1980	1985
Group I *				
Asst. Prof.	29,400	25,600	25,900	27,700
Assoc. Prof.	36,800	33,200	32,800	34,700
Full Prof.	57,000	52,300	49,500	48,800
Group II *				
Asst. Prof.	30,900	27,100	25,400	27,200
Assoc. Prof.	38,300	33,600	32,100	33,200
Full Prof.	54,700	48,400	44,200	44,400
Group III *				
Asst. Prof.	30,900	26,600	24,500	26,600
Assoc. Prof.	38,500	33,400	31,400	31,900
Full Prof.	51,500	44,000	41,900	42,400
Group IV (Statistics) *				
Asst. Prof.	30,400	27,000	26,400	28,700
Assoc. Prof.	36,800	35,100	34,700	34,600
Full Prof.	49,400	50,700	48,100	50,000

* AMS classifies the doctorate-granting mathematical sciences institutions by their ranking in the 1982 assessment; Group I consists of the 39 top-ranked programs, Group II the next 43, and Group III the remaining 73 programs. Group IV consists of 69 departments (or programs) of statistics, biostatistics, or biometrics that offer doctoral degrees.

Source: American Mathematical Society (1976–1989).

tribution for mathematical sciences in general is 7% Asian, 3.5% black, and 3.4% Hispanic. The only notable difference for statistics departments is that 22% are Asian.

Generally, wages increase as the demand for workers increases and as the supply decreases. Not so in the college and university mathematics faculties where there has been a constant decline in salaries when measured in real dollars, and the situation in statistics is almost as negative. But statisticians' salaries have not fallen off as dramatically as mathematicians' have, and full professors in group IV institutions were the highest paid in 1985 according to an AMS survey (American Mathematical Society 1976–1989) (see Table 13).

With respect to teaching duties there has been a trend toward lighter loads for statistics faculties in recent years. Findings from the 1985 CBMS survey show that in 1980 about 50% of the faculty taught six hours or less, as compared to 75% of the faculty with the same teaching load in 1985. Teaching loads for mathematics faculties at universities have remained about constant from 1980 to 1985 with 75% of the faculty teaching eight hours or less. The inconsistency between decreased teaching loads for statistics faculties and increased enrollment in statistics courses could be partially explained by data from the same CBMS survey which showed that the number of teaching assistants in statistics has increased over this five-year period and their duties have shifted from tutoring and grading to teaching their own classes or conducting recitation and query sections.

7. Conclusions

The health of the mathematical sciences appears strong when viewed from the standpoint of research activity and scholarly production, but its resources and capacity to advance the profession may be in danger. Statistics has not suffered from the extreme highs and lows of mathematics, but the slowed growth of the last two decades is not a good indicator of future vitality.

Mathematics and statistics, as with all science and engineering disciplines, will be drawing from the same pool of students. Based on current trends, the fastest growing segments of this pool are not likely to pursue mathematically related careers. Given the current pre-college mathematics preparation and career plans of students, a real question arises about who will be the mathematicians and statisticians of the future.

The universality and utility of statistics and mathematics are demonstrated by substantial increases in college courses enrollment; the increases in statistics enrollment have been significant at both the elementary and advanced levels. However, since faculty size has not increased with course enrollment, there is a concern that teaching duties could overburden faculties and lead to a migration of senior faculty to business and industry. It appears that university administrations may be trying to offset any movement of statisticians by reducing their teaching loads and by paying more competitive salaries.

The under-representation of women is problematic in both mathematics and statistics. At the bachelor's and master's level in the mathematics sciences, women receive 46% and 32% of the degrees, respectively. At the doctoral level, only about 18% of the degrees in each of mathematics and statistics are awarded to women. Finally, the nation's faculties are composed of 10% and 15% women, respectively, in statistics and mathematics. Increases in degree production in general, and an adequate flow of professionals into the workplace cannot occur until women are more fully represented.

Statistics and mathematics exhibit some of the same characteristics when it comes to sex and racial composition, appeal as a profession, and the need for good pre-college preparation. They also both grew in the sixties with respect to the number of degrees awarded and the size of college and university faculties. However, growth in statistics was more controlled and degree production did not decline sharply in the seventies as it did in mathematics. New departments of statistics were formed and new employment opportunities became available in business and industry.

It appears that statistics is moving out from the shadow of mathematics, and now is beginning to stand as a separate discipline. This belief comes from the increased visibility of the degree programs and employment opportunities in the statistical sciences. However, until more detailed information, disaggregated from mathematics, is available, the extent of this separation will not be clear.

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