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staff from industry simultaneously provides favourable prerequisites to efficient theoretical and practice-oriented full-time study courses. The agreement concluded between the Minister of Higher Education and the head of the State Central Statistical Office according to which no lecturer or professor in the field of accountancy and statistics will be appointed unless he or she has worked in practice at least for one year after taking his or her degree is a further contribution in this direction.

In addition to the main forms of advanced courses mentioned above, a number of universities and colleges provide special courses and courses dealing with a limited number of specific subjects, e.g. 1 or 2-week summer courses, including those for graduates of different fields and employments.

Another form of advanced courses consists in systematically promoting gifted specialists and key personnel enabling them to take a doctor's degree, viz. the next academic degree of a Dr.sc. The candidates are usually engaged in solving problems of research, which, as a rule, are dealt with at universities at the request of institutions engaged in practical work.

2.7 CONCLUDING REMARKS

The system of education, postgraduate studies and advanced courses in the field of accountancy and statistics is, as in other fields, constantly improved. Special importance is attached to the task of ensuring the necessary orientation towards further development based on the results of the scientific and technological revolution. Considering the experience gained in practice today, its theoretical generalisation as well as the cognitions of the future development of economic and social processes and the corresponding requirements of management and planning, special emphasis has to be placed on attaining the necessary lead for training and further education on the basis of the results achieved by the scientific and technological revolution (particularly computing techniques with all facilities of data transfer). This can only be ensured by a close co-operation of theorists and those working in practice. In this respect, special attention has to be devoted to the formation and steady improvement of a uniform series of textbooks containing supplementary special references. In the GDR scholars from institutions of higher education, experts from research institutions and senior officers from the State Central Statistical Office are actively engaged in this work.

CHAPTER 3

The Training of Statisticians in the United States and Canada

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3.1 BACKGROUND

3.1.1 Demographic and Geographic Information

The United States consists of 50 states of which 48, excluding Alaska and Hawaii, are contiguous. Government is hierarchical beginning with the central Federal Government responsible for international, national and interstate affairs, state governments concerned with state affairs, and county governments involved with county or district governance, followed by local, city or town, governments in the form of councils or commissions.

The population of the United States (1984 estimate) is listed as 235,100,000, with major recent population increases occurring in the southern tier of states. Distances are great in comparison with most countries, examples of road distances being New York City to Los Angeles, 2,790 miles (4,500 kms.), Boston to Seattle, 2,980 miles (4,810 kms.), and Chicago to New Orleans, 920 miles (1,480 kms.). Regional cultural differences exist but are decreasing with modern mobility and communications. Legal systems have variations from state to state and this is true also of state and local taxes. Living costs vary substantially from urban to rural areas and tend to be lowest in the South-east.

The situation in Canada is much like that in the United States and living standards are similar. The population of Canada (1983 estimate) is 24,880,000, with a major portion of the population urban and located within one hundred miles of Canada's southern border. Canada is the second largest country with a land area of 3,849,700 square miles (9,970,600 sq. kms.) and distances are somewhat greater than in the United States.

Canada is divided into 10 provinces and two sparsely settled northern territories. Administratively, with provinces rather than states, the governmental organisation is similar to that of the United States. The provinces have generally larger land areas than those of states, but tend to have similar population sizes. Both English and French are official languages.

3.1.2 Educational Systems

Public education at the primary and secondary levels is free in both the United States and Canada. The general structure of the public education

system is specified by the State or Province, with some general requirements specified by the Federal Government which provides a portion of the funding, particularly for special programs. The school systems are usually operated locally by counties, municipalities or school districts. A portion of the cost is borne by the State while the major source of local funding is derived from property taxes. Attendance is usually compulsory for ages 6 to 16. Some school systems include a public kindergarten and some include a thirteenth grade; all systems include grades 1 to 12. The organisation of school systems vary, examples being (i) elementary school, grades 1–8, high school, grades 9–12; elementary school, grades 1–4, middle school, grades 5–8, high school, grades 9–12; elementary school, grades 1–6, junior high school, grades 7–8; senior high school, grades 9–12.

Private and parochial schools exist and their prevalence varies geographically. In the northeast of the United States and in eastern Canada, some private schools have evolved from the model of the English 'public' schools. In other areas, private schools were founded to provide high quality education and sometimes special religious training. In general, tuition charges are made at private schools.

Graduation from high school is based on the attainment of passing grades in a prescribed number of courses. Some specified courses are required for graduation but considerable flexibility in choice of elective courses is permitted. The senior examinations are usually determined in individual schools, but some systems of state-wide or province-wide examinations exist. Canada tends to have somewhat more structured programs than the United States, but current US concerns for the quality of education, particularly in English, Science and Mathematics, is likely to bring change. College-bound students may need to select certain high-school courses to meet entrance requirements of some colleges and universities. Options exist in some high schools for more practical, 'technical' programs provided for students not intending to proceed to higher education.

The college and university system in the United States and Canada is diverse. The United States has both private and public institutions, the latter consisting of both state and municipal systems. In Canada, some of the colleges and universities are essentially provincial institutions, but are funded through Provincial and Federal grants with less direct public administration than in the United States. In the Province of Quebec, French may be the basic language of instruction. The systems of higher education range from junior or community colleges, usually two-year colleges that also provide community continuing education programs, through four-year colleges to universities offering advanced degree programs in many disciplines. In the United States the basic funding for state universities comes from the State. Federal funding is usually directed towards special programs or development, usually graduate and research programs, and may be open to both public and private institutions. The typical state university will have some 20,000 full-time students, with some considerably larger and some smaller.

The evolution of the university system varied from state to state and province to province. Some of the best universities are private and some are public. The best private universities were usually founded early, were or became well endowed with funds from private sources, and have maintained high admission and scholastic standards. Early in their histories, states established one or more state universities. The Morrill Act (sometimes called the Land Grant College Act) of 1862 provided Federal land grants to the states to establish training in agriculture and mechanics (engineering). This led to the establishment of a second state institution in many states, although some states appended the designated programs to existing universities. Following the Second World War, spurred by the large increase in the student population of the sixties, many additional state universities were founded, so that the number of state institutions now approaches one per million of population.

Admission standards to colleges and universities vary greatly. Admission is based on high-school grades and placement tests, the latter sometimes being state-sponsored college admission tests and sometimes national tests such as the SAT (Scholastic Aptitude Test). Some attention may be given to stated student goals and a desire for well-rounded students. Admission standards are high for the best institutions, both private and public, while some state colleges and universities may be required to accept all high-school graduates from the State, this being particularly true of the two-year junior colleges. Even when a state university has higher admission standards, it may be required to accept transfer students into the junior year who have received the appropriate diploma from the academic program of a junior college in the state. Admission to graduate study in a university is based on the completion of a baccalaureate degree appropriate to the graduate field of study, good grades in such a program, and a specified minimum GRE (Graduate Record Examination) score. (Professional programs such as Law, Business Administration, and Medicine may have special requirements.) Foreign students must meet these requirements with the possible exception of the GRE score and are required to have a student visa or equivalent, financial support, possibly through an award of a fellowship or assistantship, and have an acceptable TOEFL (Test of English as a Foreign Language) score[*]. Graduate admission requirements in Canada are somewhat different. Any student seeking admission to a particular university or college is advised to check with its Admissions Office for specific requirements.

The academic calendar for American colleges and universities is usually based on a Quarter System or a Semester System with various arrangements for a more limited summer program. The traditional academic year has been from late September to early June, divided into three quarters, September–December, January–mid-March, mid-March–June, or two semesters, September–January, February–June. There has been a recent trend to 'early' semester systems, August–December, January–May. In

[*] This test may be scheduled through US embassies or consulates abroad.

Canada, there have been some changes towards the semester calendar after use of full-year and half-year courses in a shorter academic year (September–April). The typical course load for an undergraduate is 15–18 hours, five or six courses, each meeting three hours per week, although five-hour courses exist. For a graduate student, a load of 12 hours is more typical. The bachelor's degree will require approximately 180 Quarter hours (120 Semester hours) of credit including specified general education credits and requisite advanced course credit in a major field of study. The master's degree typically requires 48 Quarter hours (36 Semester hours) of graduate credits, possibly including thesis credit. Doctoral programs must be approved by individual student supervisory committees and meet any special departmental requirements. As a rough guide, in statistics, total graduate credit is likely to approach 135 Quarter hours (90 Semester hours), a third of which would be dissertation research credit. Graduate study in Canada tends to require more independent study with less formal course work. Some courses are offered in sequences and are most conveniently scheduled if entry into academic study is in the Fall.

Tuition and living costs differ by locality and type of institution. Major universities usually have both dormitories and student apartment units; junior colleges and some state and urban universities may cater to commuting students and be less involved with student housing. Tuition costs at private universities are high, $12,000/year not being unusual. At state universities, tuition for residents of the state are more nominal, perhaps as low as $1,200/year, but additional out-of-state tuition charges, that can be substantial, may apply to nonresidents of the state. Living costs, particularly housing, are likely to be highest in large urban universities and lower in smaller college towns. Both public and private colleges and universities may have full or partial tuition scholarships and graduate student fees may be totally or partially waived for students awarded graduate university fellowships or assistantships. Students offered financial assistance should consider both the amount of the award and the tuition and living expenses to be incurred.

Students who have determined their desired area of specialisation should use care in selecting a college or university. The better institutions are likely to have generally good undergraduate programs in traditional areas of specialisation, although they may not be uniformly excellent. While bachelor's degree programs in mathematics may exist almost always, programs in statistics are rarer, less uniform, and may focus on special applied directions. Potential graduate students should compare several major graduate programs in the discipline of interest, note special strengths and weaknesses, and pay particular attention to the quality of the faculty. Various publications exist on college and university programs. At the graduate level, it is suggested that *Peterson's Guides**, with

* Peterson's Guides, Department 3607, P.O. Box 2123, Princeton, N.J. 08540, USA. For statistics and mathematics, consult Peterson's Book 4, *Graduate Programs in the Physical Sciences and Mathematics*. The Guides are revised annually.

information on specific disciplines, be consulted; both American and Canadian graduate programs are included. Examination of annual listings* of US and Canadian colleges and universities offering degree programs in statistics may be helpful. Libraries in association with US and Canadian embassies may provide useful information.

The formal educational systems of the United States and Canada are supplemented in various ways. Evening academic programs are available in population centers to permit part-time students to pursue degree objectives. Colleges and universities, particularly community colleges, and community centers offer programs in both academic subjects and in skills and crafts. On the job training programs in business and industry are common. Short courses, workshops, advanced seminars and symposia are available in many disciplines to assist professionals to gain knowledge of the latest advances and techniques in their fields.

3.2   TRAINING IN STATISTICS

3.2.1   *Overview*

In this article, statistics is used broadly to include both the theoretical and applied aspects of probability and statistics and also stochastic components of various areas of application, examples being operations research, econometrics and epidemiology. Professional status in statistics generally requires completion of a master's or doctoral degree; it is at these levels that most employment opportunities arise. After an overview of statistical training at various levels, subsequent subsections concentrate on graduate training in statistics.

Perhaps both the United States and Canada lag in the introduction of precollege training in statistics. A few high schools offer elective courses in statistics but this is not widespread. Through concern for this situation, the American Statistical Association, in cooperation with the National Council of Teachers of Mathematics, is currently engaged in a teacher training program in statistics with support from the US National Science Foundation. The objective of the program is to improve quantitative literacy and public understanding of statistics. The method adopted is to help teachers incorporate statistical and probabilistic concepts into their mathematics and science curricula. It is hoped that this program will produce students better motivated to the study of mathematics and science and more likely to consider future study of statistics.

At the college level, the role of statistics in many disciplines is recognised through degree requirements for study of statistics, usually for a year of study of statistical methods. The result is often a proliferation of elementary applied courses offered in various schools (faculties) and departments. It seems to be a characteristic of the discipline that users of

* US and Canadian Schools Offering Degrees in Statistics, pp. 52–64, *Amstat News*, No. 129, November 1986.

statistics in other fields wish to teach the subject to their own students, perhaps because of concern for the marginal quantitative abilities of some of their students. The situation is much the same at the graduate level and very similar requirements exist. In graduate study in some disciplines, statistics may be a substantial component and extend to a minor in statistics.

Programs for undergraduate majors in statistics exist but are not universal. Some are offered by departments of statistics, although some such departments concentrate only on graduate programs. Smaller colleges and universities offer mathematical sciences degrees with statistics among the options for concentration. Departments and programs in statistics exist in colleges of business or management and in colleges of education. The strong bachelor's degree program in statistics, giving good preparation for graduate study in the discipline, necessarily becomes a 'double major' with the essential parts of a mathematics major included. Some degree programs concentrate on applications, usually in business or education; these programs provide inadequate preparation for graduate study in statistics but may be good preparation for graduate study in some other disciplines or lead to reasonable employment opportunities in directed areas. Reference is made again to the cited listing of US and Canadian colleges and universities offering degree programs in statistics. A count shows some 190 schools in the United States and 22 in Canada offering degrees in statistics, a ratio roughly comparable to that of population sizes. Some schools list degree programs in several divisions of the institution. Information is given also on the numbers of degrees at the several levels awarded in the 1985–86 academic year.

Further examination of the list of schools granting degrees in statistics shows that graduate degree programs exist in colleges of arts and sciences, business, education and engineering and in schools of public health, medicine and management. Degree programs in arts and sciences are generally more theoretical and more directly related to statistics as a discipline. Programs in schools of public health and medicine will be oriented towards biostatistics or biometry with associated training in epidemiology. Programs in schools of business and management emphasize business and economic statistics, perhaps with training in applied operations research and programming. Programs in colleges of education have components of psychometrics and educational testing and in colleges of engineering direction is towards industrial engineering, quality control, and research in production and development. In general, graduate programs in the United States and Canada include more formal courses than is usually the case in Western Europe.

Information on numbers of graduate degrees awarded gives some insight into the vigor of the various graduate degree programs. A second annual listing* gives titles of doctoral dissertations, providing some insight into research emphases at the various institutions. A rough count

* *Doctorates in Statistics, 1983–1985*, the *Institute of Mathematical Statistics Bulletin 14*, 192–202, 1985.

shows 126 doctorates awarded in statistics and 33 in biostatistics in the United States and 8 in Canada for 1983–84, a likely undercount with some degrees not reported. In addition, many of the major departments have brochures with extensive information on programs, areas of specialisation, faculty and graduates.

3.2.2 *Prior Training and Graduate Admission*

Requirements noted above apply to graduate admission to programs in statistics. Requests for information on a specific graduate program may be sent to the graduate school or the department itself, with requests to the department being more likely to elicit more detailed information. A graduate admission application, transcripts of prior academic study, and letters of recommendation must typically be submitted to the graduate school or graduate admissions office of the university. Fellowship/assistantship applications may be submitted either through the graduate school or directly to the department of statistics or biostatistics, depending on school policy. The teaching assistantship with a one-third or half-time work commitment is the most typical form of graduate student support and is most likely to involve assistance to a faculty member on grading or student help sessions for an elementary statistics class.

The typical prospective graduate student in statistics is likely to have majored in mathematics as an undergraduate but there is considerable diversity in backgrounds. Students from biology, economics, engineering, the physical sciences and, indeed, other areas enter graduate programs in statistics or biostatistics, sometimes on condition that deficiencies in mathematics be corrected. Recipients of graduate degrees in statistics with training in an area of application are particularly desired in employment areas in industry, business and government associated with the area of application. Graduates with strong prior training in mathematics seem most likely to concentrate on theoretical statistics with the goal of academic employment.

General basic entering qualifications for beginning graduate study in statistics are a one-year course in advanced calculus, a good course in linear algebra or matrix algebra, an introduction to statistical methods or statistical theory and probability, and some facility in computer programming. The better prepared student is likely to have completed a basic course sequence in the theory of statistics, a course in probability, and an introduction to design of experiments, together with additional training in mathematics, perhaps real analysis or numerical analysis. A substantial number of students of statistics enter doctoral programs as transfer students after completion of a master's program either in the US or Canada or abroad. The numbers of students from abroad are increasing with the majority from India and the Orient. Transfer students with prior graduate training in statistics develop doctoral programs of study to meet departmental requirements and approvals.

3.2.3   *The Statistics Masters Degree*

Three types of masters level programs have evolved in statistics in the United States and Canada. The first is the traditional program with a substantial thesis and an emphasis on the theory of statistics and probability. The second is a non-thesis degree similar to the first, but with additional advanced course work, perhaps 12 Quarter hours (9 Semester hours), replacing the thesis. The motivation for the second type of degree is that it provides more breadth of training and permits the student to proceed more rapidly into a doctoral program. The third type of degree is in applied statistics, usually without a thesis requirement, but sometimes requiring a written paper on an applied statistics project. The applied masters degree is usually regarded as a terminal or professional degree. The student acquires more knowledge of statistical methodology, useful in employment in business, government or industry, but less training in theory. The additional methodology may be specially oriented when the program is in a special school or college – education, business, public health or engineering. All three types of masters programs may exist in a major department of statistics or only one or two of them will be offered in smaller programs. Master of Science is the typical degree designation, but variations exist. The Diploma in Statistics is not used as in Western Europe.

The extent of the study required for a masters degree has been indicated above in terms of credit hours. The two theoretical masters degrees will typically include course sequences in probability, statistical inference, statistical methods and measure-theoretic real variables, along with courses on linear models and design of experiments. The work in mathematics may be supplemented in various ways, possibly by courses on numerical analysis, functional analysis, group theory or computer science. The work in statistics will be augmented by courses on stochastic processes, multivariate analysis, nonparametric statistics, or sequential analysis. The applied masters program will usually require an introduction to probability, and course sequences in the theory of statistics and in statistical methods. Various additional courses in statistical methodology will be included, examples being applied courses in regression, multivariate analysis, design of experiments, time series, nonparametric statistics and data analysis. Courses in computer science and numerical analysis may be included. Many masters programs require final comprehensive examinations, written or oral or both.

3.2.4   *The Statistics Doctoral Degree*

The choice of a doctoral program in statistics is important, particularly for students preparing for academic appointments. The best departments of statistics get good students and have excellent records in the placement of their doctoral graduates. Other programs, oriented towards particular areas of application, provide good entry to positions in government, business, industry and education.

Doctoral programs of study will vary considerably because they should provide the flexibility needed for research in various areas of specialisation. It is recognised however that a central core of courses in advanced statistical inference and advanced measure-theoretic probability is necessary. The student should receive training through advanced courses and special seminars to the frontiers of research in at least one area of specialisation in which dissertation research will be undertaken, but there should be also sufficient breadth in the program of study for the student to be knowledgeable in several other areas. A doctoral dissertation is uniformly required and its preparation constitutes a major part of doctoral training. While each student has a doctoral supervisory committee headed by his/her major professor, the dissertation research is usually conducted primarily under the supervision of the major professor alone. One standard for the quality of a dissertation is that it should yield at least one substantial research paper publishable in a major journal. Some doctoral programs still require demonstration of a reading knowledge of one or two relevant foreign languages, usually French, German or Russian, while other programs may substitute research skills such as computing.

Entry into a doctoral program in statistics usually follows completion of one or two years of course work similar to that of a masters degree, although the masters degree itself may not be a requirement. Some programs have a doctoral qualifying examination, possibly taken concurrently with the masters comprehensive examination, to demonstrate ability for doctoral study. Doctoral programs usually have a doctoral preliminary or comprehensive examination that has both oral and written parts for admission to degree candidacy. The final examination is an oral one in presentation and defense of the doctoral dissertation. Time to completion of the doctorate varies considerably, usually from four to six years of intensive graduate study. The preliminary examination is usually taken after most advanced course work has been completed. Some programs require that doctoral candidates receive some experience in supervised teaching and/or consulting.

3.2.5   *Statistical Consulting*

In many areas of employment, the professional statistician participates in research investigations as a statistical consultant. In colleges and universities, statistics faculties recognise a responsibility to provide statistical assistance to faculty and graduate students on research in areas of application of statistics, and may have effort assigned to such activities. Some universities have statistical laboratories or consulting centers established to provide such services. The statistical consulting center not only provides a needed university service but serves as an important training facility to a department of statistics. It provides the means for graduate students to gain some consulting experience under supervision, to improve ability to interact with other scientists, and to gain experience in the use of statistical methodology. Problems coming to a consulting center may also motivate research in statistics. It is becoming common for both masters and doctoral students to be required to gain consulting experience and this can be most beneficial in preparation for employment.

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3.3 PROFESSIONAL STATISTICAL ACTIVITIES

All professional statisticians need the means to maintain currentness in the profession, whether engaged in applications or research. Statisticians in the United States and Canada are fortunate in the number of society meetings, conferences, symposia, workshops and short courses available to them. Such activities exist in both countries and attract participants from both countries. Rather than attempt to list all such activities, the reader is referred to *International Statistical Information*, the *Biometric Bulletin*, the *Institute of Mathematical Statistics Bulletin*, *Amstat News*, and the *Statistical Society of Canada Newsletter*, the news publications of the International Statistical Institute, the Biometric Society, the Institute of Mathematical Statistics, the American Statistical Association, and the Statistical Society of Canada respectively; each of these publications regularly or periodically provides a calendar of forthcoming meetings on statistics. In addition, universities with programs in statistics hold regular statistics seminars, usually weekly. Community needs of business, industry and education are served by the 74 local or regional chapters of the American Statistical Association which usually have monthly meetings.

A second means of keeping up to date with the profession is through membership in statistical societies and their publications. Additional publications or periodicals in statistics are sponsored by commercial publishers. The Biometric Society's Eastern and Western North American Regions, the Statistical Society of Canada, the Institute of Mathematical Statistics, and the American Statistical Association hold regular annual and regional meetings, often jointly and sometimes separately. Their publications, apart from newsletters, are listed briefly as follows: The Biometric Society – *Biometrics*, The Statistical Society of Canada – *The Canadian Journal of Statistics*, The Institute of Mathematical Statistics – *The Annals of Statistics*, *The Annals of Probability* and *Statistical Science* (new in 1986), The American Statistical Association – *Journal of the American Statistical Association*, *Technometrics* (jointly with the American Society for Quality control), *Current Index to Statistics* (jointly with the Institute of Mathematical Statistics), *The American Statistician*, *The Journal of Educational Statistics* (jointly with the American Educational Research Association), the *Journal of Business and Economic Statistics*, along with *Proceedings* of a number of its sections. Through an agreement with the American Mathematical Society, *Current Index to Statistics* is now electronically searchable as a subfile of the MathSci database; all information in CIS since 1975 may now be so located. Membership directories are available through all of the major statistical societies with heavily overlapping memberships. The American Statistical Association has the most varied activities and the broadest membership base, a membership approaching 15,000. In recent years, it has carried out an expanding program of continuing education in statistics.

CHAPTER 4

The Training of Statisticians in Australia

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4.1 BACKGROUND

The Australian Commonwealth consist of six States, the Australian Capital Territory (which includes the national capital) and the Northern Territory. In order of population size, these are New South Wales (5 million), Victoria, Queensland, South Australia, Western Australia, Tasmania, the Australian Capital Territory, and the Northern Territory, with a total population of rather more than 16 million. English is the universal language.

Each has its own Department of Education, set up under State legislation, which controls the State (Public) schools which are attended by a little less than 80% of the school population. Most of the remainder are at Roman Catholic schools with a smaller number at private schools generally affiliated with religious bodies. Education is compulsory from ages 6 to 16 (Years 1 to 10), with a steadily increasing proportion staying on to Year 12. Course specification for primary education (Years 1 to 6) is more or less directly controlled by Education Departments, while Statutory Authorities (which issue Certificates at the successful completion of Years 10 and 12) prescribe acceptable courses of study and conduct public examinations at the secondary level. A Higher School Certificate (Year 12) is the normal requirement for entry to a tertiary institution, but there are also selective entrance requirements applied by individual institutions.

At post-Secondary level, there are nineteen universities (all funded by the Commonwealth, although, with the exception of the Australian National University, set up under State legislation), some seventy Colleges (or Institutes) of Advanced Education (Commonwealth and State funded), and State Departments of Technical and Further Education (Commonwealth and State funded) which administer Technical Colleges.

4.2 STATISTICAL EDUCATION IN SCHOOLS

The subject which includes most statistics instruction in schools is mathematics, although there is incidental work in some other subjects, e.g. geography, economics and science. The mathematics component typically includes data collection (especially directed to the stability of long run proportions), an introduction to probability (usually based on set algebra), calculations with data, and an introduction to inference