UNIFYING GRADUATE STATISTICS: A BIG UMBRELLA FOR A SMALL COUNTRY

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Slovenia, as a small country, has limited human resources. Eight years ago statisticians active in the Statistical Society of Slovenia established the country's first university graduate program on statistics. It included biostatistics, mathematical statistics, official statistics and social statistics modules. The program was quite successful and became extremely important for statistical education and research in Slovenia. Recently, all university programs had to be reformed according to the Bologna principles. In renewing the doctoral statistical program, we added three new modules: economic and business statistics, psychological statistics and technical statistics. The interest expressed by other departments and faculties for inclusion in this doctoral program of statistics emphasizes both the original need for such a graduate program of statistics and its success.

INTRODUCTION

In the past decades, statistics as an independent scientific discipline has made enormous contributions to science and society. It has become a tool applicable in such diverse fields as agriculture, biology, business and economics, education, engineering, law, medicine, the military, public administration, social sciences, etc. The quality of its use, however, varies considerably due to different levels of users' statistical literacy, which, on average, is rather low. Lack of adequate education is doubtless one of the reasons for such a state of affairs.

Given the presence of graduate and undergraduate courses in statistics at universities, it is very important to educate appropriately teachers of statistics at universities. Courses are often taught at a department of statistics that includes mathematical statistics and different applied statistics. At some universities, mathematical statistics is taught in a mathematics department while in other universities it is in one or several other departments. As a result, there is no unique and widely accepted way of organizing statistical education at the university level.

Slovenia, as a small country, has limited human resources and for a long time did not have university level statistical education programs. Eight years ago statisticians active in the Statistical Society of Slovenia established the country's first university graduate program on statistics. It included biostatistics, mathematical statistics, official statistics and social statistics modules. The program was organized and carried out by lecturers from the Biotechnical Faculty, the Faculty of Economics, the Faculty of Mathematics and Physics, the Faculty of Medicine and the Faculty of Social Sciences. It was quite successful and became extremely important for statistical education and research in Slovenia. Recently, all university programs had to be reformed according to the Bologna principles. In renewing the doctoral statistical program, we added three new modules: economic and business statistics, psychological statistics and technical statistics. Beside the five Faculties also the Faculty of Arts and the Faculty of Electrical Engineering expressed the interest to be included into the program.

The structure and the organization of Slovenian graduate program of statistics are presented together with remaining problems and suggested ways for improvements.

ESTABLISHING THE FIRST EDUCATION PROGRAM OF STATISTICS IN SLOVENIA

While courses on statistics are in almost all undergraduate and graduate education programs at the University of Ljubljana, no education program at any university level in the past offered students a well-rounded education in statistics. At that time, only one lecturer of statistics graduated in statistics abroad. All others graduated in information sciences or other scientific fields. Therefore, in 1995 lecturers of statistics from several faculties at the University of Ljubljana took the initiative to organize a first graduate program on statistics in Slovenia for a new generation of university scholars teaching statistics so that they would have a better statistical education than us. The Statistical Society of Slovenia served as a platform for numerous discussions on possible solutions. A number of eminent foreign experts helped us in the process by sharing their points of

view and experiences (e.g., Prof. Tamas Rudas, University of Budapest, Prof. Michael Schemper, University of Vienna, Prof. Jacques Hagenaars, University of Tilburg, Prof. Bojan Basrak, University of Zagreb, Prof. Pietro Millossovich, University of Trieste). All discussions showed that an independent interdisciplinary graduate education program in statistics would be of interest to graduates from a number of faculties. However, it was not easy to organize this program; it took as seven years to have it accredited.

The main goals of the graduate program in statistics were the following (see STATISTICS–University Graduate Study Programme, 2003):

- To deepen and broaden basic knowledge of statistical theory (probability and statistics, multivariate methods and statistical modeling).
- To deepen and broaden knowledge of statistics representing foundations of empirical research in individual scientific fields.
- To deepen and broaden statistical knowledge specifically required by individual students (e.g. qualitative methodology, cause-and-effect models).
- To further develop statistical knowledge related to individual scientific disciplines regularly using the statistical tools (e.g., specific knowledge of biomedicine, specific knowledge of business sciences and economics, or specific knowledge of social sciences).

In larger countries, specialized graduate education programs in statistics tend to be organized by numerous different faculties at the same university (e.g., a graduate study program in biostatistics offered at the biotechnical faculty). However, as Slovenia is a small country with limited human resources it was decided at the University of Ljubljana that a single interdisciplinary graduate education program in statistics would be appropriate to provide opportunities for lecturers of statistics employed by different faculties at the University of Ljubljana to join forces and thus contribute their share to the integration processes at the university level.

The interdisciplinary University Graduate Study Program in Statistics, which began in 2002/03, was organized and carried out by lecturers from the Biotechnical Faculty, Faculty of Economics, Faculty of Mathematics and Physics, Faculty of Medicine and Faculty of Social Sciences. Visiting professors participating in the program came from other faculties at the University of Ljubljana and from established foreign institutions.

The organization and implementation of the interdisciplinary University Graduate Study Program in Statistics was coordinated by the Program Council, where each of the participating institutions had one representative. Additional council members were the module coordinators. Both representatives of participating institutions and module coordinators were appointed by the senates of participating institutions. The Program Council was chaired by a president, elected from the members of the Program Council for a period of four years. The seat of the Program Council was at the University of Ljubljana.

The master's degree program took two years (four semesters) and required 120 credits. The doctoral degree program took four years and required 240 credits. Organized pedagogic processes in form of lectures and seminars took place for the master degree level. The remaining two years were spent on students' individual research projects using statistical knowledge.

International exchanges took place according to international contracts and agreements of cooperation and mutual acknowledgement of grades between the University of Ljubljana and institutions in other countries. The graduate program in statistics was directly linked to undergraduate and graduate programs at the Biotechnical Faculty, Faculty of Economics, Faculty of Mathematics and Physics, Faculty of Medicine, and Faculty of Social Sciences. Additional links were with the programs at other faculties within the University of Ljubljana (e.g., Faculty of Computer and Information Science, Faculty of Arts).

The entire program was evaluated according to the European Credit Transfer System (ECTS), thus allowing students and lecturers to participate in international exchange schemes in countries where ECTS or some other comparable system is implemented.

During the first year of study, three core courses and a seminar took place (an equivalent of 42 ECTS). The *core courses and the seminar* were: Probability and statistics, Information technology in data analysis, Multivariate analysis, and a Seminar on official statistics. As the

students enrolled into the program had very different backgrounds, we decided to organize the Seminar in mathematics for those having a weaker mathematical background. Later, we noticed that the students coming from the Faculty of Mathematics and Physics had no experience with data analysis. For these students, we organized also an introductory course of statistical data analysis.

In the second year of study, students chose among four modules: Biostatistics, Mathematical Statistics, Official Statistics and Statistics for Social Science. Each module consisted of two core and two elective courses, together amounting to 48 credit points. The modules follow.

Module 1: Biostatistics (Carried out by the Biotechnical Faculty and Faculty of Medicine)
In the framework of this module students learned about theoretical foundations of the most frequently applied modern statistical methods in medicine and biology. Core module courses were: Statistics in medicine and Design and analysis of experiments.

Module 2: Statistics for Social Sciences (Carried out by the Faculty of Social Sciences)
This module focused on topics from methodology and statistics specific for the field of social sciences. Conducting surveys is the most frequently used mode of data collection here and students familiarized themselves with the potential errors and ways to avoid or minimize them. Given the properties of the measurement scale of most variables in social sciences (nominal and ordinal), students learned about details of categorical data analysis. Core module courses were thus: Survey errors and Categorical data analysis.

Module 3: Mathematical Statistics (Carried out by the Faculty of Mathematics and Physics)
Both development and application of new statistical methodology demand familiarity with mathematical foundations of statistics. The module "Mathematical Statistics" is intended for students with adequate background in mathematics. (In practical terms, this means having a bachelor degree in technical or natural sciences, with courses in mathematics stretching over at least four semesters.) The two core module courses were: Mathematical statistics and Stochastic processes and time series. The first course focused on mathematical foundations of statistical concepts. The second dealt with time series data and stochastic models applicable in their analysis.

Module 4: Official Statistics (Carried out by the Faculty of Economics)
Official statistics provide data on current state of affairs and development trends in economic, demographic and social phenomena, as well as in the fields of environment and natural resources. It thus offers a vital platform for decision-making at all government levels, in public and private sector of the economy, and for international integration In the framework of the obligatory seminar in Official Statistics, students familiarized themselves with contents and general institutional, legal as well as organizational issues of official statistics. The module "Official Statistics" built on the knowledge obtained in the seminar by focusing on an in-depth study of theoretical and conceptual foundations for measurement of economic and other social phenomena constituting the field of official statistics. The two core module courses were: Index numbers and National accounting.

Each student was free to choose two *elective courses*:

- from the following list of elective courses: Longitudinal research, Econometrics, Statistical methods in ecology, Demographic statistics, analysis, and models, Network analysis, Data mining and knowledge discovery, Industrial statistics, Financial mathematics,
- from the list of core courses offered in other than the student's selected program module,
- from the list of courses taught in the framework of any graduate study program at the University of Ljubljana,
- from the list of courses offered at the Essex and Michigan Summer Schools in Social Science Data Analysis and Collection, or
- from the list of courses taught at eminent graduate study programs abroad.

The choice of elective courses (together they need to amount to 24 credit points) had to be approved by the Program Council.

For the module "Mathematical Statistics" students had to choose an elective course Financial Mathematics and one of the graduate courses offered at the Faculty of Mathematics and Physics, Department of Mathematics. The list of courses included: Computational mathematics I and II, Selected topics from discrete mathematics I and II, Functional analysis I and II, Selected topics in complex analysis I and II, General topology I and II, Selected topics in algebra I and II.

Registration of topics, the nomination of an academic supervisor, as well as the nomination of an expert committee for evaluation of a master or doctoral thesis and a graduation committee, were all done in the domain of the senate at participating institutions responsible for a given study module. When enrolling in the module "Biostatistics", students needed to choose between the Biotechnical Faculty and Faculty of Medicine as the assigned responsible participating institution. The Senate of the University of Ljubljana had to consent to the topic of all doctoral theses and the proposed academic supervisor(s).

In order to be awarded the Master's degree, students were requested to collect at least 120 credit points with fulfilled requirements in all selected courses and the positively evaluated Master's thesis. Students of the module "Mathematical Statistics" were required to take an additional Master's exam after submitting their Master's thesis prior to its oral defense.

After fulfilling all study obligations, a diploma jointly signed by the Rector of the University of Ljubljana and the dean of the responsible participating institution was awarded to the candidate by the University of Ljubljana. Master's degree diplomas were handed out by the dean of the responsible participating institution. Doctoral degree diplomas were handed out by the Rector of the University of Ljubljana. Graduates of the University Graduate Master's Study Program in Statistics were awarded the title "Master of Science". Graduates of the University Graduate Doctoral Study Program in Statistics received the title "Doctor of Science".

The first graduate education program in statistics was quite successful. The first four doctoral degree diplomas were awarded and the program became extremely important for statistical education and research in Slovenia.

DOCTORAL PROGRAM IN STATISTICS ACCORDING TO BOLOGNA SCHEME

The strategic goal of European Union for the first decade of the 21st Century was 'to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion' (European Commission, 2000). The European Commission (2003) stated that universities play a vital role in the 'Europe of knowledge'. To achieve this, the Bologna process was promoted with the goals of modernizing higher education for the better employability of graduates, diversifying study programs, promoting mobility of students, and internationalizing academic programs.

As the other universities in Europe did, the University of Ljubljana reformed all levels of the education programs according to the Bologna scheme. Consistent with this direction, we had to transform also our graduate program in statistics. On the basis of good experience in the past seven years, and of the noticeable advantages of the interdisciplinary approach, the Interdisciplinary Doctoral Program in Statistics is also organized at the university (and not at the faculty) level. Also, in the reformed doctoral program in statistics, the main goal is to further educate experts who have some fundamental knowledge in statistical theory, some experience in the field of statistics or some general statistical knowledge, specific to an individual scientific discipline. The goal is that the doctoral graduates will be qualified for creative and independent research work and for solving statistical problems for future employers. They will be capable linking together the existing methods, develop new methods with a critical approach and using clearly defined criteria based on statistical theory. They will be able to critically assess research results and capable of transferring new knowledge into practice. Due to distinct international orientation of the program, they will acquire the ability to communicate in an international scientific environment.

The duration of the Interdisciplinary Doctoral Program in Statistics is three years (180 ECTS credits), and according to the Bologna educational scheme, this represents the third cycle of education. The program consists of organized classes (60 credits) and individual research work for the doctoral thesis (120 credits).

The doctoral program results in the degree of Doctor of Science and consists of seven modules (three of them are new modules): Biostatistics, Statistics for Social Sciences,

Mathematical Statistics, Economics and Business Statistics, Official Statistics, Psychological Statistics, and Technical Statistics. The program is organized by the University of Ljubljana through its seven faculties (two of them are added according to the previous graduate program): Biotechnical Faculty, Faculty of Arts, Faculty of Economics, Faculty of Electrical Engineering, Faculty of Mathematics and Physics, Faculty of Medicine, and Faculty of Social Sciences.

Also the Interdisciplinary Doctoral Program in Statistics is both horizontally and vertically linked to other study programs at the University of Ljubljana. International exchanges take place on the basis of international contracts and bilateral agreements. International exchanges are also possible through collaboration in mobility programs for students and professors. The program is also open to foreign students.

Each student must complete three *obligatory core courses*. Modern Statistical Approach is obligatory for all students. The aim of the course is to provide an overview of some of the most contemporary topics of statistics, from which the students can choose their doctoral thesis topics. The lectures are given by local and foreign experts in each selected topic. The course also includes consulting for users of statistical methods. Mathematical Statistics is obligatory for mathematical module students, and Methodology of Statistical Research is obligatory for all other students. Students have another obligatory course from the selected module.

The candidates are free to choose between 23 *elective courses* worth 5 ECTS (Categorical data analysis, Customer data analysis, Data mining, Data mining and knowledge discovery, Demography, analysis and models, Design and analysis of experiments, Econometric analysis of panel data, Environmental statistics, Internet mediated research, Linear algebra for multivariate methods, Modern psychometric test theory, Multivariate analysis, Network analysis, Network analysis in business and economics, Reliability and life testing, Research challenges of national accounts, Statistical background of bioinformatics, Statistical computing, Statistical quality control, Stochastic processes, Survey methodology, Theory of index numbers, Times series, Econometrics). They are allowed to select 10 ECTS from elective courses from other doctoral programs at the University of Ljubljana and comparable programs of foreign universities. The selected courses must be approved by the supervisor and the module coordinator. Elective credits can be selected also from the university pool of the generic skills courses, listed at the web site of the University of Ljubljana.

The module in Mathematical Statistics has some special requirements for choosing the elective courses and some special ones for this module (Financial mathematics, Numerical methods in financing and economics, Mathematical methods in risk theory, Selected chapters from financial mathematics, Bayesian methods in Statistics, Mathematical methods in econometrics, Accidental processes).

In the first year, doctoral candidates, within the framework of two obligatory courses (Modern Statistical Approach and Mathematical Statistics/Methodology of Statistical Research) and three elective courses, obtain fundamental theoretical knowledge and expertise of scientific work. In the second year the students must complete the module's obligatory course and the doctoral thesis has to be presented at the end of the third semester. The focus of the third year is research work, preparation and defence of the doctoral thesis.

The program runs the first time this year. The initial experiences show that the first generation of the reformed doctoral program in statistics is very heterogeneous; there are mathematicians, social scientists, biologists, economists, computer scientists, etc. They have very different mathematical and statistical knowledge. Also, in this program, we have to organize in the first semester of the program seminars on mathematics and basic statistics. The students also need to learn the program R as early as possible.

CONCLUSION

Slovenia, being a small country with limited human capital, has to find its own ways to organize education programs of specific scientific fields as statistics. Fifteen years ago, when we began to prepare the graduate program in statistics we searched for appropriate ones at other universities abroad. We had problems finding good examples of such an interdisciplinary statistical program. We had to consider our specifics and lecturers available at University of Ljubljana. As we have quite good relationships with the statisticians around Slovenia (among other things we

organize annual meetings of Young Statisticians of Austria, Croatia, Hungary, Italy, and Slovenia; this year it will be the fifteenth meeting) we were able also with their help to organize a successful graduate program of statistics. As we do not have a separate organizational unit (e.g., department) of statistics at the University of Ljubljana, we use the graduate program of statistics as a meeting point of lecturers of statistics at the University of Ljubljana. This enables us to cooperate in many other activities.

The first graduate program on statistics included Master's and doctoral level of the study. We were able to organize only the doctoral program in statistics reformed according to the Bologna principles. We still work on the master's program on statistics. Unfortunately, the mathematical statistics module will be organized separately at the Faculty of Mathematics and Physics. The mathematical statistics module had always some special requirements in our statistical programs. This is the main reason for organizing Mathematical Statistics separately from the other modules. The other modules will be included in the Master's Program of Applied Statistics. We plan that this program will obtain the accreditation by the end of 2010, which will enable us to start with the Master's program in the year 2011.

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