STATISTICA, anno LXX, n. 4, 2010

CHARACTERISTICS OF THE MOST RECENT DEVELOPMENTS IN STATISTICAL METHODOLOGY[1]

Corrado Gini (1950)

Over the last fifty years, statistics has seen an impressive development that has spread to all its scientific manifestations, as well as to administrative ones. While in the past statistics was confined to social sciences and some topics of anthropometry and physics, it has now reached all scientific fields. The contrast between statistical and natural laws has disappeared: all the laws of physics are nowadays considered to be statistical laws. It may be said that the concept of the world has become a statistical concept.

However, developments which are too fast are dangerous: growth crisis will occur. Is statistics perhaps affected by a crisis of this kind? Many believe so; even some of the most famous statisticians are pessimistic with regard to the possibility of overcoming the crisis and think that the deterioration of statistics will take place. I am not one of the pessimists, but I believe that one must strongly counteract dangers which are already quite obvious. The crisis derives from the use of mathematics, which I do not judge to be excessive, but irresponsible. Does one need to be reminded that mathematics is a powerful tool for research? But it is and will always remain a tool. Tools should not become aims for the sciences to which they are applied. This is true and accepted by all sciences. Why is this danger particularly serious for statistics? For two reasons, the first is because statisticians usually do not have a mathematical background. This may appear to be a paradox, but it is not so. And it is because of the lack of a mathematical background that most statisticians are dazzled when they face some formulae and believe that they are stepping up the scientific ladder when using them, even without understanding them.

The second reason concerns, in particular, the applications of statistics to social sciences, which still represent the major part of statistical research and almost represent the total part entrusted in public organizations. In the field of social sciences it is often very difficult to verify theoretical conclusions, and the checking of the conclusions, to which one arrives by mathematical procedures, is not al-

[1] Long abstract of the *Opening lesson of the course of Statistics, given on the 4th of December 1950 at University of Instanbul, published in its original French version "Caractères des plus récents développements de la méthodologie statistique" in "Statistica", XI, I, 1951.*

ways possible, and the practical advantage obtained is shown to be practically uncertain.

Statistics must be treated "with mathematics", not "like mathematics". Here is the rule summing up the viewpoint of statisticians who have contributed most to the progress of our discipline. There certainly are many areas to which mathematics has brought essential developments and other areas for which there would not have been any further progress without it. This does not mean that the use of mathematics is indiscriminately advisable for every problem, or that it must be used without limits, precautions or control.

The most famous statisticians of the old generation, who have most contributed to the introduction of wisely chosen mathematical methods into statistics are nowadays negatively impressed by the amount and quality of mathematics, almost blindly used by a large number of young statisticians.

This is partially the result of the war; hence one may hope that one day it will disappear.

War brings an *esprit de suite*, an unconditional conformity, a lack of criticism creating a mental attitude that is difficult to abandon, even in activities, such as scientific ones, where independent thinking and critical spirit are the essential conditions for real progress.

On the other hand it is natural, however unpleasant from many points of view, that, after a war, nations ending up with a halo and the advantage of victory takes the lead even in areas such as scientific ones, where prestige should be independent of political factors. However, these nations may also nurse the illusion that their superiority is not limited to just the military aspect, and wish to supply others with the results that they believe they have achieved. That is why, nowadays, we see groups of young people crossing the Atlantic, going to learn statistical techniques in America, techniques that, in the majority of cases, are nothing but applications, which are not always shrewd, of European discoveries. They are taught by professors who, sometimes, did not meet with much of luck in European universities, but who have had the opportunity of finding refuge in America at a suitable time and the possibility to employ to advantage that which was then, as regards statistical methods, an uncultivated ground; and this must be said in their favor.

Among all people, Americans, mostly descending from the European working classes, are perhaps the ones most motivated by a desire for action and which is mostly lacking in critical spirit. Hence, it comes as no surprise that in the sciences Americans have turned, with more impulse than reflection, to using mathematical procedures introduced into statistics by the European schools.

In practice, what are the rules to be deduced from what has been said? The first is that statistical methods should never be proposed without supplying their applications. Statistical methods do not have an intrinsic value, they are exclusively valid for the benefits one may draw from them. Such benefits depend on the nature and importance of the areas to which the methods apply, on the approximation allowed by the available data and sufficient for the problems to be solved and, last but not least, on time and work required for their use. It should

not be allowed to propose methods while leaving to others the problem of their applications, as if the inventor of a dangerous device did not take on himself the responsibility of testing it and left to others the risk of breaking their necks. Karl Pearson, who more than anybody else has perhaps contributed to the spread of mathematical methods in statistics, never accepted, as I was told by Major Greenwood, one of his most famous students, an article for Biometrika, unless it was complete with applications showing results. I have adopted the same principle for Metron, the international statistical journal I edit. Karl Pearson is dead, so is Major Greenwood. Biometrika continues to be published under the supervision of Pearson junior with the help of a group of capable statisticians, but the rule laid down by Karl Pearson is not observed anymore and the published articles are often mathematical works of dubious statistical value. Luckily, I am still alive and, as long as I live, Metron will not abandon its wise tradition.

Another practical rule to be laid down is that, results being equal, the simplest methods must be preferred. Any mathematical artifice must be avoided; on one hand, a restriction, of the group of statisticians who are able to adopt the methodology and, on the other hand, even for them, applications and also verifications often become more difficult. Mathematical artifice also involves another drawback: it causes the importance of the problem to be solved, to depend on the difficulty of the solution, thus at times causing, for trifling problems, loss of time and work that could be used much more efficiently.

Another aspect must be taken into consideration: mathematics is a deductive discipline, statistics is an inductive discipline. The difference is fundamental. For the mathematician the relevance of the result is independent of the initial hypotheses and, given that these are clearly formulated, the procedure is blameless. On the contrary, for the statistician, the value of the conclusions is dependent on the truth of the assumed hypotheses. Those who apply mathematical methods to statistics should never forget that these applications are not allowed, except to the extent to which hypotheses implicit in the methods are valid.

The considerations outlined above hold not only for scientific studies, but for practical jobs in statistical offices as well, where the essential jobs required by the administration run the risk of being neglected in favor of less consistent studies, but to which mathematical fashion has attributed a halo of superiority. It is quite some time since representative investigations, based on random and non probabilistic samples, have been set up and carried out when it was not possible to analyze the phenomena in the totality of cases. The credit goes to Kiaer, director of the Norway statistical department, for having proposed, at the beginning of this century, this method that Jensen, director of the Danish statistical department, Bowley and I myself with Galvani studied long ago from a theoretical and practical viewpoint. However, it always meant replacing a complete study with an incomplete one and I took care to point out the dangers to which one is exposed if a study, which is representative of a phenomenon regarding some characteristics, is extended to other characteristics as well.

Today we forget this wise advice and, seduced by the fascination of methodological problems, we take into consideration and support the indiscriminate use

of samples. This causes enormous expense for the study of new methods, with the aim of making doubtful savings and without considering that in public management accurate and complete data are required as far as it is possible, whenever the data must supply the basis for the application of laws.

Resorting to survey sampling instead of census, is a matter of convenience and this does not meet with objections from a theoretical viewpoint when the population constants are approximately known, while the passage from the constants observed in the sample to those, of which nothing is known, related to the population from which that sample has been drawn, may represent an operation which cannot be justified from a theoretical viewpoint.

But for the official statistic surveys, it is true that, our observations usually concern only a portion of the cases in which the phenomenon occurs, hence, consequently, it would be advisable to assess the uncertainty by which the observed values reflect population values. However, this cannot happen without the formulation of hypotheses and it is at any rate impossible in the majority of cases to measure to what extent they depart from truth and how much we depart from it. This has been indisputably demonstrated theoretically and proved by astonishing examples. To continue to calculate the significance tests and confidence intervals without a preliminary study, by refusing to make up one's mind regarding the truth of such hypothesis and without even acknowledging that the calculation is based on hypotheses, is a procedure that nothing can justify. For quite a long time it has been accepted that mathematics may only elaborate information which has already been acquired and not add new knowledge. The gap between the knowledge of population values and that of sample values is so wide that no mathematical elaboration can fill it and it may only be overcome, thanks to hypotheses.

The use of mathematics in statistics is useful within the limits in which it is appropriate, without having to surpass these limits with daring applications. We shall certainly try to avoid this in the course of our lectures and we will warn our students to beware of it. Now we wish to state that statistics is open ground for everybody: there certainly are peaks which may only be reached with the help of mathematics and we will show which specialized tools are to be used for such a goal. There are, however, ample spaces that can be usefully exploited by instrumentation available to all educated people and this instrumentation must, first of all, be made available to statisticians for regular application.

The characteristics of the latest developments in statistical methodology, which I have just criticized, fortunately are not the only ones to be mentioned. There is a basic result, which cannot but bring satisfaction statistics has become in it an organic discipline in the last few years. The first steps in methodological statistics were made by borrowing procedures from everywhere: the means from Pythagoreans, the curve of accidental errors and interpolation from the physicists, some theorems from probability calculus, the correlation coefficient from astronomers, the graphical representations from geometers.

The first statistical treatises were a mosaic of more or less heterogeneous contributions. Actual progress was achieved when statisticians started to consider the

methodological problems they had to face in their studies, as problems proper to statistics, which had to be solved by methods invented for that purpose, or, at least, suitably adapted to the considered topics.

One may well say that now all the aspects related to statistical phenomena have been considered and that, for each of them, the appropriate methods of elaboration have been proposed: intensity, intensity ratios, variability and relations between distributions, concentration, transvariation, association and concordance, synthetic indices and analyses by procedures of representation and interpolation, elimination or, at least, evaluation of the accidental factors and decomposition of the systematic factors, discovery and specification of causes, formulation of laws an their application, are the titles of chapters which by now form an organic, that is, autonomous and complete, handling of the subject. Obviously, some chapters are more developed than others. The English School has above all contributed to enrich some chapters, the Italian School to fill the system gaps by taking into consideration new aspects and introducing new chapters.

In almost all of the chapters the final refinements of the methods required the contribution of mathematics, either elementary or advanced; but the fundamental problems of the statistical method have been and always remain logical problems. It is the fundamental duty of a course on statistics to emphasize the basis and the importance of statistical procedures from a logical viewpoint. Without this knowledge, the use of statistical instruments may become extremely dangerous. Should one confess that some danger cannot be avoided? It is the danger arising, not from the method used, but from the nature itself of the phenomena studied.

The collective phenomena considered by statisticians are particularly complex. They are called "collective" because they only occur in a collection, that is, in a more or less large number of observations. They occur in a more or less large number of observations because they depend on numerous factors which cannot be split. When one wishes to specify the influence of some amongst these, one realizes that almost always it is practically impossible to take into consideration all of them and isolate only those one would like. One must choose among these and for such choice set rules cannot be given. This is why in statistics intuition is still playing, and will always play, a fundamental role. In effect, statistics is not just a science, it is also an art. One cannot learn it in books alone; an apprenticeship phase, under the guidance of a teacher, is necessary.

In many countries Schools and Faculties of Statistics have already been established. The first Faculty was the one started in Rome, of which I was the promoter in 1936, and before this, since 1927, there had been a School of Statistics that I also had the honor to found. After the war, Italy's example was followed by the United States, at the University of North Carolina, by France, Russia, Bulgaria and Argentina.

My personal experience suggested this idea to me. When I joined the University of Bologna, almost fifty years ago, statistics was only taught in the Faculty of Law, along with economics and politics and finance. By choosing sex from a statistical viewpoint as the subject of my thesis, I quickly realized the importance of courses on anthropology and biology and afterwards of the courses on mathe-

matics; but, I witnessed the difficulties met by students who had to follow courses in other faculties, necessary to become a complete statistician.

More than ever, this necessity is felt today, due to the importance that statistics has acquired in the biological sciences and physics. Not only students, but professors as well, benefit from these faculties, because the progress of statistical methods takes place sometimes in one scientific area and sometimes in another, depending on the different requirements of the themes under consideration. It has already occurred that the same method has been developed within different sciences following different directions and the best profit could only be obtained when all the results had been assembled. This is the case of the method of the direct standardization that was elaborated in demography and of the price indexes, elaborated in economics.

These syntheses naturally occur in the Faculties of Statistics, which, consequently, are not only necessary for the formation of young well rounded statisticians, but are also very useful for the formation of well rounded professors of statistics. [...]

CORRADO GINI

The recent Reform of Italian University System makes provision for the closure of Faculties including those of Statistics. In the following, Editors produce a:

Comment by the last Dean of the Faculty of Statistics of Bologna University.

…BACK TO THE FUTURE

Angela Montanari

Every now and then, papers appear in statistics journals where well known researchers wonder about the meaning of statistics and its role in modern society (see, for instance, Birnbaum 1971, Cox 1990, Gnanedesikan 1990, Rubin 1993, Breiman 2001, Lindsay et al. 2004, Brown and Kass, 2009, Hand 2009, Xiao-Li Meng 2009).

This is not surprising and many reasons can be envisaged for it.

Statistics is an evolving discipline. Due to its essential connection with the analysis of reality it is strongly solicited by the appearance of new kind of data, which urge it to develop instruments and methods capable of drawing as much information as possible from them.

Furthermore, the enormous amounts of data being collected and the more and more widespread use of quantitative information in science, technology, business

and government increases the need of statistical professional expertises. This in turn requires to render statistics more appealing to new generations and makes academics wonder about the best ways of teaching statistics.

What, on the contrary, I find really surprising, is that, after about 60 years, Gini's ideas appear in the recent debate (mostly involving overseas statisticians) not only almost unchanged, but even described and fostered as new points of view.

First of all "*the use of mathematics*".

In their comment on the paper by Brown and Kass (2009), Madigan and Gelman (2009) state that "*the characterization of statistics as a branch of mathematics underlies many of the problems*" statistical training is facing and they go on saying that "(seeing statistics as a branch of mathematics) *makes no more sense than considering chemical engineering as a branch of mathematics. Both are highly quantitative subjects, and both use mathematics extensively. But in statistics, a purely mathematical agenda is often at the fore front*".

From this, the truth of Gini's assertion that "*statistical methods do not have an intrinsic value, (but) are exclusively valid for the benefits one can draw form them*" naturally stems. And it is echoed by Meng's one that "*students (should) learn statistics as a way of scientific thinking for whatever they do, not a collection of tools that they may or may not need some days*".

Indeed the stress on the importance of helping students develop statistical reasoning, rather than emphasizing mastery of techniques, informs most of the above mentioned papers. "*It is the fundamental duty of a course on statistics to emphasize the basis and the importance of statistical procedures from a logical viewpoint*" Gini says, and this has long become the core of many statistics courses in Italian Universities. I perfectly remember Italo Scardovi's Inference lessons during which he led us understand that statistics is first of all a *modus intelligendi*, from which its role of *modus operandi* derives.

The mastery of statistical thinking thus becomes a key for the successful analysis of real phenomena, whose knowledge must be part of the study programme too. Flexible cross-disciplinarity is seen in the modern debate as the key-word of successful study programmes: "*We need a switch turned on, a value established, for impelling statisticians to be challenged intellectually and through a desidere to contribute to solving major problems in other fields*" (Gnanedesikan, 1990); "*Skilled statistical thinking cannot derive from experience in just one area*" Madigan and Gelman (2009).

Gini had already understood all of that when he founded the first Faculty of statistics in Rome in 1936. Since then, Italian faculties of statistics have promoted statistical reasoning, also by providing an interdisciplinary and up to date approach to the analysis of real life phenomena.

Now, new university regulations may lead to the disappearance of the Italian Faculties of statistics and to the constitution of monodisciplinary departments with a potential cross-cultural loss for students and professors. The organization models that our overseas colleagues have experimented in the past and now deplore will inform our departments. Our present organization and cultural approach might become their future one.

What about us? A foreign colleague once told me "*you shouldn't copy, you should simply jump*"…but where? maybe we should jump on the spot and carefully reconsider Gini's intuitions.

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