Mathematical Conversations

Jianqing FAN: Methodology and Insight in Statistics, Financial Crisis, High Dimensional Challenges >>>

Jianqing FAN

Interview of Jianqing Fan by Y.K. Leong

Jianqing Fan is world-renowned for significant contributions to theory and methods in statistics and for developing understanding and insight into statistical methods used in diverse disciplines ranging from financial econometrics to computational biology. He is the co-author of two highly regarded and influential books *Local Polynomial Modelling and its Applications* (with Irene Gijbels, 1996) and *Nonlinear Time Series: Nonparametric and Parametric Methods* (with Qiwei Yao, 2003). He is the author or co-author of more than 150 research papers. His research interests range from the foundational aspects of statistical theory and methods to practical statistical methodology used in other areas such as financial econometrics, risk management, computational biology, biostatistics, high-dimensional statistical learning, data-analytic modeling, longitudinal and functional data analysis, nonlinear time series and wavelet analysis.

Fan obtained his B.S. from Fudan University (Shanghai) and M.S. from Academia Sinica (Beijing) before going to University of California at Berkeley for his doctorate. Upon graduation, he joined the University of North Carolina at Chapel Hill in 1989 and was on its faculty until 2003. During this period, he was also appointed a professor at the Chinese University of Hong Kong (CUHK) (1996–97), University of California at Los Angeles (1997–2000) and Professor of Statistics and Department Chairman at CUHK (2000–2003). In 2003, he joined the Department of Operations Research and Financial Engineering at Princeton University, where he is currently the Frederick L. Moore '18 Professor of Finance and Professor of Statistics. He also holds joint appointments at Princeton's Department of Economics,

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Multiscale Modeling, Simulation, Analysis and Applications (1 November 2011 – 20 January 2012)

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Bendheim Center for Finance and the Program in Applied and Computational Mathematics.

He has received the following prestigious awards: the COPSS (Committee of Presidents of Statistical Societies) Presidents' Award in 2000, given annually to an outstanding statistician under the age of 40, the Humboldt Research Award for lifetime achievement in 2006 and the Morningside Gold Medal of Applied Mathematics in 2007, honoring triennially an outstanding applied mathematician of Chinese descent. He was a Guggenheim Fellow in 2009, and elected to the fellowships of the American Association for Advancement of Science, Institute of Mathematical Statistics and American Statistical Association. He has been invited to give lectures at professional conferences and workshops throughout the world and was an invited speaker at the International Congress of Mathematicians in 2006. He has contributed much to the international statistics and finance communities through various leadership roles. He has served on the editorial boards of various journals, notably co-editors of the *Annals of Statistics* and *Probability Theory and Related Fields*. He is currently the co-editor of *Econometrical Journal*, published by Royal Economics Society and an associate editor of the *Journal of American Statistical Association*, *Econometrica*, *Journal of Financial Econometrics*, among others. Fan was President of the Institute of Mathematical Statistics (IMS (US)) in 2008 and President of the International Chinese Statistical Association in 2009.

Fan has close professional and personal ties with probabilists, statisticians and econometricians in National University of Singapore (NUS). During his presidency of IMS (US), the 7th World Congress in Probability and Statistics was held in NUS in July 2008. Sponsored by the Bernoulli Society and the Institute of Mathematical Statistics, it was jointly organized by NUS's Department of Statistics and Probability (DSAP), Department of Mathematics and Institute for Mathematical Sciences (IMS). He was back in 2010 to give invited lectures at DSAP and the Risk Management Institute. His links with NUS are further strengthened by his recent appointment to the Scientific Advisory Board of IMS. On behalf of *Imprints*, Y.K. Leong took the opportunity to interview him on 9 July 2008. The following is an edited and enhanced version of the interview in which he traced the path he took from Fudan University in the early 1980s to Berkeley, North Carolina, Hong Kong and finally Princeton. The interview reveals a passionate and total commitment to the pursuit of statistical methodology and of fundamental understanding of statistics beyond its applications. We also get a glimpse of the financial circumstances that led to the Global Financial Crisis that erupted in 2008.

Imprints: Was your interest in statistics formed during your university education in China?

Jianqing Fan: I was one of the first generations after the Cultural Revolution to be admitted to universities. I was admitted into Fudan University at age 15. At that time the best students majored in math, physics and so on. I got into mathematics and personally I was too young to know what it was for. I was not very interested in the mathematics that I was taught because I could not see the light of its applications (my hindsight then, of course). Therefore I skipped most of the classes and only studied for exams during the last two weeks. I was prepared to work after my graduation. One day, after coming back from school after Chinese New Year, my friend told me that there is a trend in continuing to graduate study. He told me that only the very best students could go to graduate study. I decided to take the entrance exams and gave it a try. I wasn't prepared at all, so I chose the probability and statistics major at the Institute of Applied Mathematics, Academia Sinica, as the courses to be tested such as analytic mathematics, probability, linear algebra did not require much preparation. In other words, I chose to major in statistics mainly because of inadequate time to prepare for the exams. Another important reason for me to study statistics is that I always like those research with high social impact. As a personal choice, statistics also gave me a better chance of knowing the sciences and humanities, in addition to mathematics.

I: Who was your supervisor?

F: My supervisor for Master's thesis was Professor Fang Kaitai at the Institute of Applied Mathematics. At that time not many people could supervise Master's students. Professor Fang had just returned from Stanford and had been on leave at Stanford and other parts of the US for two years. He took all four students of my year who majored in probability and statistics. He is a great statistician. Everybody was starting to do research — that was in 1983.

I: Was there anybody at Fudan who influenced you?

F: At that time, there were a couple of very successful probabilists and statisticians at Fudan. One of them was Li Xianping who taught us an undergraduate course on introduction to statistics. Statistics is a hard subject and I

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cannot recall how much I learned there. I don't know when and how I get to master fundamental ideas and reasoning of statistics. I still think that it is a very difficult subject to learn at the beginning — there are so many concepts and ideas. I then continued onto the study of probability and stochastic processes. I got more and more interested in random phenomena and their applications.

I: Why did you go to the University of California at Berkeley for your PhD?

F: I wrote about 10 papers when I was a Master's student. I felt that I had run out of ideas of carrying myself to a high level of research. I was eager to go abroad to learn more about other areas of statistics and to know where I would be placed at an international stage. We were one of the first generations to go abroad and the choice for us at that time was very limited. We had to search together in the major public libraries far away from us to learn about the Ph.D. programs. I saw that Berkeley was ranked top in all sciences and engineering. I thought that was what I liked to learn. That was how I chose to go to Berkeley.

I: Did you apply for any scholarship?

F: I did apply for a scholarship. Actually, I was extremely lucky to get both Regent Fellowship and a University Fellowship. In addition, I was offered the usual TA[Teaching Assistant] and RA[Research Assistant]-ship, and additional summer supports. Berkeley is a public university and doesn't have many fellowships. The offer was not only highly prestigious but also very generous.

I: Who was your supervisor?

F: Actually I had two supervisors. I originally approached Lucien Le Cam, who was one of the greatest statisticians and was extremely kind to me. He told me that he was too old for me and suggested my working with David Donoho, who was very young and full of ideas (according to Le Cam), getting a PhD four years ago. David advised me to also work with more mature people like Peter Bickel who knew practically everything and who was at my age today at that time. Peter was happy to be my supervisor too. So one part of my thesis was with David Donoho and the other part with Peter Bickel.

I: You were still on the faculty of University of North Carolina when you took up a professorship at the Chinese University of Hong Kong. Did you then contemplate continuing your scientific career in China?

F: The short answer is yes. The University of North Carolina has always been very kind to me. I started as an assistant professor and went all the way to full professor. During my fourteen-year tenure there, I took one-year sabbatical leave at MSRI at Berkeley (1991–92), one-and-a-half-year leave at Chinese University of Hong Kong (1995–97), and two-year leave at UCLA (1998–2000), and over three-year leave at Chinese University of Hong Kong again (2000–2003). The last two positions were tenured full professorships. At the time that I took a position at the Chinese University of Hong Kong, the initial arrangement was for me to chair the department for a year. At the same time, I was supposed to establish the risk management science program in the Department of Statistics that I got involved with during my visit in 95-97. There was virtually no curriculum on risk management back then, but students were already admitted. Upon my arrival, the university hired another person to help launch risk management and my pressure was substantially released. At the beginning, I thought I wouldn't stay that long but I started to like Hong Kong. I still like Hong Kong, as it has a culture where I fit the best. I intended to stay for good and create a stronger link with China. But then something changed in 2002 when I got a phone call from Princeton University (where it had no statistics department and I did not know anybody) asked me if I had any interest in helping them on financial statistics or financial econometrics. I said, "Well, it is always worth a try." Eager to get a job there for the profession, I gave a talk on risk management. I think I gave the worst talk, but I still got the job.

I: Was it the Department of Mathematics?

F: No, it's the Department of Operations Research and Financial Engineering. There is a center for finance (Bendheim Center for Finance) but the center cannot hire people, just like the Institute [for Mathematical Sciences] here cannot hire people directly. My new appointment is in Operations Research and Financial Engineering but I need to teach for the Bendheim Center for Finance where I have an office. I am also an associated faculty member at the Department of Economics. It was a joint appointment among these three departments. Now I have four — including the Program of Applied and Computational Mathematics too. Our department consulted other departments on the suitability of my hiring. I was seriously interviewed by Ben Bernanke [then Economics Department chair],

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who promised me the possibility of an affiliated faculty in Economics Department (he delivered his promise). We are currently establishing bioengineering and I'm quietly involved too. All these examples show how useful mathematical sciences can be to other scientific disciplines.

I: Princeton University still has no statistics department?

F: It still has no statistics department. After my arrival, we hired three additional statisticians, placed in different departments, one of them in our department.

I: Is there any special reason why Princeton has no statistics department?

F: We used to have some of the best statisticians in the world such as John Tukey, Jeffery Watson, Samuel S. Wilks and many others, and we had one of the finest statistics departments in the world. But for whatever reason, it was closed 20 years before my arrival. That was around my graduate days in China.

I: As I understand it, longitudinal data analysis refers to the same single object of study — a sort of single variable analysis. Is there such a thing as longitudinal data analysis for two specific objects under study, or even for a given number of specific objects?

F: Longitudinal study is one area of my research but not my main focus. Longitudinal studies arise in many areas of sciences and humanities like in the biomedical sciences where we want to monitor every six months, let's say, cardiovascular diseases, along with its associated risk factors such as blood pressure, height, weight and so on. In this case, we have many measurements over time and would like to investigate which are the risk factors and understand the extent to which their associations with the risks under study and how such associations evolve over time. This kind of study occurs in many other areas. For example, under the name of panel data in econometrics, you have two or more time series based on, let's say GDP, housing pricing indices, or other macroeconomic variables such as interest rates or labor supply or unemployment rates. Certainly people follow this kind of data and try to understand whether the macroeconomic variables lead the business cycle or the business cycle leads these macroeconomics variables: Does unemployment lower housing prices or decreasing prices induce higher unemployment rates? There is a lot of study on multivariate time series. The main differences between biomedical studies and econometric studies are on the problems under concern, but the statistical methodology is similar.

I: Has longitudinal data analysis been applied to the pattern analysis of past earthquakes in a specific region?

F: These kinds of seismological data have been collected and studied, but personally I have not studied them. But my former professor, David Brillinger, has spent many years of his life studying these kinds of problems. Very unfortunately, just like financial markets, earthquakes are very difficult to predict, but there are certainly some aspects that can be predicted with confidence.

I: From the statistical and econometric viewpoint, what do you make of the current global economic or financial crisis?

F: Many people have tried to answer this question and I'm pretty sure that different people have different versions. The financial system is highly complex. The current crisis stems from the subprime crisis and the subprime crisis stems from what is called the mortgage backed securities, which was one of the most creative financial products in recent years. It enables people to buy affordable houses. So, I think that it's a good product. Like any products, they can be properly used or abused. Finance deregulation and government push for more ownership of houses contributed to the expeditious lending to subprime owners. But, you need to calculate the values at the risks involved in order to get reasonable risk compensations. I think the subprime crisis is probably due to the miscalculation of the risks involved. In other words, one has to price correctly to get risks properly compensated, know how to hedge against the risks involved, and understand black swans. The deregulations of the financial products contribute to the greed of corporate America. Risks are always rewarded in good environments. Corporate executives are under peer pressures, too. When their peers take more risks and get better returns, they have to be more aggressive too, like investing more aggressively and indiscriminately in CDOs. I think this is related to corporate culture and corporate compensation schemes. The handsome returns of CDOs make mortgage lending much easier, which in turn fueled housing prices to the point that they are seriously inflated. Then, the housing bubble burst, starting from subprime crisis, pulling down CDO prices, dragging financial markets, resulting in less consumer spending, yielding higher unemployment rates, causing credit crisis and then financial crisis, further depressing the

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housing prices, CDO prices, and so on, spiraling down on the asset prices, finance and economics. I am not sure that we have agreed on the actual cause of the current financial crisis and understood fully the causes. History has always repeated itself.

I: What are CDOs?

F: CDO stands for collateral debt obligation. It's basically the insurance of a basket of bonds or mortgage-backed securities, whose risks are further sliced into many tranches. The riskiest one is the equity tranche, which insures the top 3 percent of failures, the second tranche is to insure the failures between 3–7 percent failures and so on. It's a kind of derivatives based on the mortgage-backed securities. When the market is booming, no one thinks that the chance of getting default of 10 percent or more is likely so that the senior tranches get AAA rating, collecting very little premium. Last year, there were 30 trillions in the mortgage-backed securities market. That's a lot of money. Many financial institutions took a lot of positions in CDOs. The famous examples include Bear Stearns, Lehmann Brothers and AIG. Lending more money than what qualified to get is the primary source of troubles.

I: It's surprising nobody foresaw all these.

F: Many people in academia saw some aspects of these, understood the limitations of mathematical models, and inadequacy of data to statistically, reliably calibrate these probabilistic models. However, they are not in the decision circle, but on advisory roles. When those products made money and everybody made money on these products, few decision makers would like to take academic advice seriously.

I: You were rated as one of the 10 most cited mathematical scientists during the period 1991–2001. What is your most cited piece of research work?

F: This is due to my work on local polynomial models, which are a special method in a broad area called semiparametric and nonparametric statistics, but we should not take these rankings seriously. My work stimulated a lot of subsequent papers and revised the area. It now becomes clear how to do nonparametric estimation and inference using local modeling principles. You have probably noticed that I'm one of the mathematical scientists that always made it to the top 10 rank ever since the existence of such a ranking. That is due to many other contributions. I'm one of the earlier persons to lay down some foundations on high-dimensional statistical inference and on nonparametric inferences such as the generalized maximum likelihood ratio tests. I also worked intensively on the varying-coefficient models from different scientific disciplines. I like working on problems with wide applicable principles rather than some very specific problems. The collection of my work enabled me to be rated as one of the 10 most highly cited mathematical scientists. Having said that, I should say again that I am not one of the believers of this kind of numerical measures because intellectual value cannot be measured by one number, just like you cannot judge a person's health by weight alone. You need other measures as well as experts' judgments. Intellectual values are highly complex. Lately, the International Mathematical Union, International Council for Industrial and Applied Mathematics, and Institute for Mathematical Statistics (of which I am the President) have endorsed a Citations Statistics report on the problems of citation statistics as a measure of research impact. Personally, there are three reasons why I am highly cited. One is that I generally like to work in different areas, secondly I like to work on the problems that has broad implications rather than just solve problems that can easily be solved by others, and thirdly, I believe that mathematical sciences are application-driven theory and methods and thus would like to work on the mathematical problems having high social impact.

I: You must have got the insight to choose the right kind of problems.

F: It's the intellectual curiosity to see where the problem leads to and what kind of implications it has in other scientific disciplines.

I: Statisticians seem to have the advantage of their work being more widely used by others, in contrast to pure mathematicians.

F: I don't quite think the citations by nonmathematical sciences were actually counted on the ranking of the 10 most cited mathematical scientists. Actually, citations vary with subjects and are not directly comparable. I think the real advantage of statisticians is probably that there are more people working on the field than algebra or number theory, say. That's my broad hunch. The others relate to the tradition. There are some culture differences. For example, pure mathematics papers tend to have few references,

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whereas other fields such as biology or medicine have far more references in their publications.

I: I notice that statisticians like to collaborate. Pure mathematics papers often have only one or two authors.

F: That is true. Different people have different expertise and collaborations combine the expertise. Statistics is an application driven theory and methods. It needs to know the disciplinary sciences, to develop methods and models that are suitable for disciplinary sciences, to actually compute and interpret the results, and to develop theory to understand the methods in use. Therefore, it requires more team work, like engineering and sciences. An analogy would be if you open a small restaurant you can run it by myself, whereas if you open a department store it's a different kind of business and involves many people and more specialized collaborators.

I: Among the Presidents' Award (COPSS) recipients from 1981 to 2005, six of them were Chinese scholars. Do you think that culturally, and perhaps genetically, the Chinese are attracted to statistics by the applied nature of the subject?

F: This is a very good question and an important factor is that there is a very large proportion of Chinese in statistics nowadays than many other fields. First of all, I disagree that there are any genetic differences between the Chinese and other races. I think cultural differences probably play a more central role. Let me talk about culture. Chinese tend to have a conservative type of culture that prevents us from being extreme. This dates back to Confucius' time or even earlier. We like to be more in the middle, but I wouldn't call it "mediocracy". Being a statistician, you can prepare yourself easily for mathematical research or its applications to the society. Maybe another thing is that Chinese culture tends to evaluate success not in terms of purely academic achievements but in terms of how successful you are in the job. Statistics is easier to get a job in and more flexible to move into other professions. That plays a role. You would understand that the Chinese come from a country that is poor in 80's and 90's, and getting a good job after graduation is understandably one of the important objectives of education. Because of that, a lot of Chinese, very talented ones, majored in statistics and applied sciences. Right after the Cultural Revolution, a lot of the most talented students majored in mathematics and physics. Some were fond of theoretical work, and some were interested in using mathematical power to solve societal problems. They continued onto America and studied statistics. Certainly there are large clusters of very good students going to other countries and other disciplines. So you have a first big wave of students. As years go by, the so-called feedback effect kicks in. Where there is success, more and more talented people go into it. Chinese statisticians are very successful in their profession. If you look at the graduate departments in the United States, you'll see that a large number of graduate students in statistics are from China. As a result, it doesn't surprise me that the Chinese get more and more [awards]. They are attracted to applied math because they like to use mathematics to understand the world they live in. If one does not like or cannot succeed in academia, being in statistics, one can work in industry or other fields of academia and succeed there. So, statistics is a very attractive major to many people of Chinese descent. The broader Chinese culture clearly played a role here.

I: Did the Cultural Revolution affect your studies?

F: It did affect me one way or another. I was not taught very much during the period and did not learn much like history and literature. During my time at the university, there was virtually no general education on sciences, arts and humanities. We had to go to the library and learned a bit ourselves, and we did not know how much we learned without exams.

I: Are there any central problems in theoretical or applied statistics today? Have any important theoretical problems arisen from work on concrete problems?

F: One of the hottest areas nowadays is high-dimensional data analysis. The 21st century has seen an explosion in data collection from the biological, health and earth sciences to business, finance, economics, and so on. Because of the high dimensionality, it challenges statistics from many angles in computation and methodology. How to process data with such high dimension? Traditional statistical theory cannot capture the phenomenon such as noise accumulation and spurious correlation because it assumes dimensionality is low. Now you have more dimensions than the sample size. The theory is not fully understood and there are a lot of new phenomena that need to be discovered because of the high dimensionality. At one point, I was not that interested and thought they were not so exciting. But now it is a really exciting moment for statisticians because the massive and high dimensional data stimulated a lot of new theoretical problems and statistical methods.

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I: Is it just a computational problem using computers?

F: Not entirely. Statisticians differ from bioinformaticians and financial researchers. In addition to developing methods to solve the disciplinary problems, they also provide theory to understand the methodology in use from statistical prospects. This actually pushes all theory, applications, computation, and methodology further. We are not really a service department to the sciences. We are actually an independent intellectual discipline. In addition to providing methodology, we also furnish a lot of fundamental understanding and insight into it, thanks to mathematical power. A lot of insights in the high dimensional problem are actually very beautiful, just like pure mathematics problems. I'm very fortunate to work at the frontiers of research in massive and high dimensional data sets.

I: Do you have to create new mathematics to deal with it?

F: Yes, we do have to create new mathematics. Because of these new areas of applications, new areas of understanding, you have to build new stochastic tools for unveiling the seemingly random phenomena. Even the traditional tools of computational mathematics popular at one time in the sixties and seventies played a part, because the high dimensionality forges the intersections among mathematics, probability, statistics, optimization and computer science. A lot of new tools had to be made and phenomena need to be discovered.

I: Is stochastic analysis used in high dimensional data?

F: Stochastic analysis is intensively used in large random matrices, describing how they and their eigenvalues behave. It is very useful for high-dimensional statistical analysis such as understanding spurious correlations and properties of large matrices. It is more frequently used in finance to understand the behavior and dynamics of stocks, and other financial assets, pricing financial derivatives, and hedging of financial risks.

I: What advice would you give to graduate students who wish to pursue a research career in statistics?

F: It's a difficult question. I'm myself a director of graduate studies. First of all, you have to understand what statistics is. Statistics is an intellectual discipline that deals with stochastic phenomena of data. It speaks multiple languages from the computational and theoretical aspect to interdisciplinary work. That means a graduate student has to be strong in one of these areas: mathematics, health sciences, biological sciences and others. Statistics as a discipline has the advantage that it is easy to find a job because one can work directly on disciplinary problems. The job opportunities and prospects are very good. As the core of quantitative science, as you collect more and more data, you try to quantify and understand them more fully. Its interdisciplinary nature along with an information and technology age make the future of statistics brighter than ever. A lot of mathematical scientists are needed to meet the challenges from this information and technology age. We face a lot of pressure from computer science and other areas. Just like in any frontiers of science, they compete with each other. When people want to study statistics they

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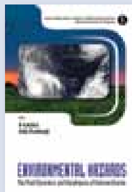

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Edition: Sep 2011, 280 pages
ISBN: 978-981-4360-89-0
981-4360-89-9

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need to recognize that statistics is a discipline that speaks multiple languages. It is actually a fun thing.

I: Is it also very demanding?

F: No, not really. Mathematics is into depth, but statistics is into breadth and depth. But you also need to be as deep as a mathematician even if mathematics is used only as a tool.

I: You still have to prove theorems, right?

F: Actually, I still have to do the hard stuff. It is part of the fun. It's just that the discipline has a different thinking. In statistics, you want to create a theory that actually works and helps create understanding and insight into statistical methods and problems, rather than purely mathematical considerations.

I: How do you judge whether a student is suitable to pursue further research in statistics?

F: I think first of all one should like the mathematical sciences and needs to have a broad appreciation of intellectual values and be adapted to work on a number of problems, not necessarily at the same time. For example, today I may be working on genomics, tomorrow I may be working on finance. Everybody is doing that, albeit not such a big change, as statistics always evolves with the need of the society. So you should have more appreciation of what mathematical scientists can offer to other fields. Really it's like working in somebody's front yard or backyard. Statistics is a very interesting discipline to be in.

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Printer: World Scientific Publishing Pte Ltd

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