Peter Hall: My Mentor, Collaborator and Friend

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Abstract

Peter Hall has left us for about a year. His passing is an irreplaceable loss to our entire statistical community. To me, I lost a long-time mentor, collaborator and friend. In this article, I will share with readers certain episodes in my career during which Peter provided me much precious help, things that I learned from him about research and our research attitude, our research collaborations, and some others. I know that I am only one of many statisticians who ever benefited from Peter's generosity in helping others, especially young researchers. My example could perfectly demonstrate the importance and influence of Peter and his generosity on our growth and career development.

Key Words: Collaboration; Density deconvolution; Fond memories; Image processing; Inverse problems; Jump regression analysis; Photography; Steam trains.

1 Introduction

Professor Peter Hall passed away on January 9, 2016. His passing is a tremendous loss to our statistical community. According to Wikipedia (https://en.wikipedia.org/wiki/Peter_Gavin_Hall), Peter had a total of 606 publications listed in MathSciNet as of January 2016. In the past

about 40 years, Peter made fundamental contributions in a wide range of statistical research areas, especially in bootstrap methods, nonparametric smoothing approaches, measurement error problems, and so forth. Peter possessed many characteristics that made him unique among all of us. Besides his talents and important contributions in statistical research, he was nice to people and always handled things gracefully. This demeanor made him many friends and research collaborators in our community. In MathSciNet, there were 240 distinct people listed as his co-authors as of January 2016, and these people were distributed in many different departments/institutes around the world. One important characteristic of Peter is that he was generous in helping other researchers, especially young researchers. This generosity is seen in the large number of reference letters that he wrote for many of us during different stages of our career. Through research collaborations, formal or informal conversations, and many different kinds of precious and timely help, Peter had a great positive influence on the growth and career development of many statisticians, including myself.

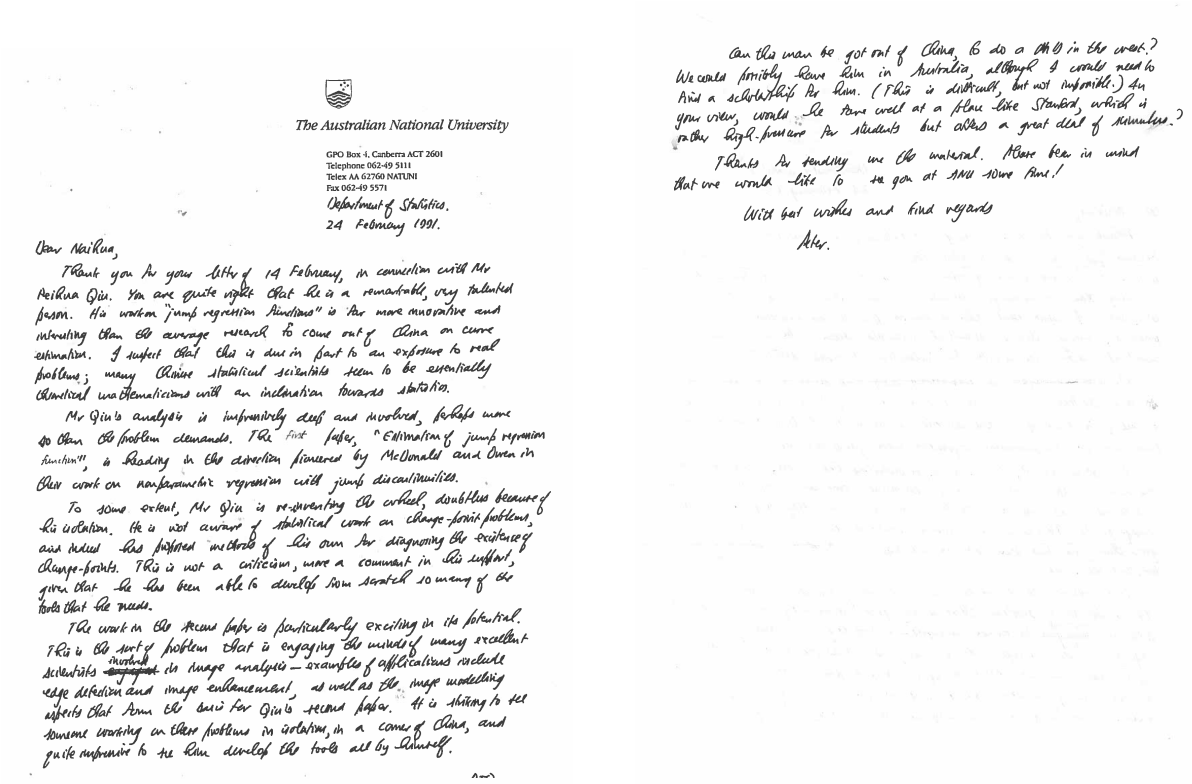
I am one of many people who benefited tremendously from Peter and his generosity in helping others. In this article, I would like to share with readers certain episodes in my career during which Peter provided me much precious help and guidance. I would also share with you certain things that I learned from him about research, and certain aspects of his scientific life that I observed during my visits with him. The remaining part of the article is organized as follows. In Section 2, I will describe my early contacts with Peter and his influence on my research in jump regression analysis and image processing. In Section 3, I will introduce my research collaborations with Peter, and his talent, diligence and efficiency in research. Then, in Section 4, I will share with readers many of my fond memories of Peter,

including some of our intersting conversations during my visits with him.

2 Early Contacts

Back in year 1990, I was an assistant professor in statistics at Fudan University in Shanghai, China. During that year, Professor Naihua Duan from RAND Corporation visited Fudan, and I was a seminar coordinator and responsible for arranging his accommodation during the visit. At that time, China was still quite isolated academically. For instance, we could only have access to old issues (usually 2-3 years old) of a limited number of statistical journals, such as *Annals of Statistics*. Also, printing and copying were expensive and in poor quality. After Naihua knew that I was doing research in jump regression analysis (JRA), namely, regression analysis when the regression function has jumps or other singularities, he thought that the research was interesting and it would be helpful for me to get advice from some related researchers in the West. So, after he went back to USA, he made copies of two research manuscripts of mine and sent them to some researchers working on the related topics. One of these researchers was Professor Peter Hall. On February 24, 1991, Peter wrote a letter to Naihua about my research, and Naihua forwarded Peter's letter to me afterwards. That letter is shown in Figure 1.

In his letter, Peter mentioned that "The work in the second paper is particularly exciting in its potential. This is the sort of problem that is engaging the minds of many excellent scientists involved in image analysis ... It is striking to see someone working on these problems in isolation, in a corner of China, and quite impressive to see him develop the tools all by



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24 February 1991.

Dear Naihua,

Thank you for your letter of 14 February, in connection with Mr Naihua Qiu. You are quite right that he is a remarkable, very talented person. His work on "jump regression functions" is far more innovative and interesting than the average research to come out of China on curve estimation. I suspect that this is due in part to an exposure to real problems; many Chinese statistical scientists seem to be essentially theoretical mathematicians with an inclination towards statistics.

Mr Qiu's analysis is impressively deep and involved, perhaps more so than the problem demands. The first paper, "Estimation of jump regression functions", is leading in the direction pioneered by McDonald and Owen in their work on nonparametric regression with jump discontinuities.

To some extent, Mr Qiu is re-inventing the wheel, doubtless because of his isolation. He is not aware of statistical work on change-point problems, and indeed has proposed methods of his own for diagnosing the existence of change-points. This is not a criticism, more a comment on his support, given that he has been able to develop from scratch so many of the tools that he needs.

The work in the second paper is particularly exciting in its potential. This is the sort of problem that is engaging the minds of many excellent scientists involved in image analysis — examples of applications include edge detection and image enhancement, as well as the image modelling aspects that form the basis for Qiu's second paper. It is thrilling to see someone working on these problems in isolation, in a corner of China, and quite impressive to see him develop the tools all by himself.

Can this man be got out of China, to do a PhD in the west? We could possibly have him in Australia, although I would need to find a scholarship for him. (This is difficult, but not impossible.) In your view, would he have well at a place like Stanford, which is rather high-pressure for students but offers a great deal of stimulation?

Thanks for sending me the material. Hope to see in mind that one would like to have you at ANU some time!

With best wishes and kind regards

Peter.

Figure 1: Peter Hall's letter dated February 24, 1991 about my research on jump regression analysis.

himself." In his letter, he also stated "Can this man be got out of China, to do a PhD in the West? We could possibly have him in Australia, although I would need to find a scholarship for him." At that time, I did not know Peter or his research. So, when there was an opportunity for me to visit the USA in the summer of 1991, I decided to pursue my PhD in the USA. However, Peter's letter gave me a great encouragement in continuing my research in JRA. After I became a graduate student at the University of Georgia (UGA) in early 1992, I started to learn image processing by taking a course in computer vision and graphics from the UGA computer science department and by reading numerous image processing papers in the UGA library. Today, many JRA methodologies have been proposed, and JRA has become a powerful tool for analyzing image data. In the preface of my research

monograph Qiu (2005), I wrote "Encouragement and help from Peter Hall and Steve Marron have had a great impact on my research .... It was Peter who first told me the connection between jump curve/surface estimation and image processing."

3 Research Collaborations

My first research visit to Peter was during May 23 - June 20, 2002 when I took a single-semester leave from the University of Minnesota (UMN). At that time, Peter was at the Australian National University (ANU) at Canberra, and I was an assistant professor at UMN. That was our first meeting in person, although we had several email conversations about research and he helped me at several occasions already before the visit, including a strong reference letter for my tenure and promotion case that was finalized that summer. Before the visit, I prepared several research problems for possible collaborations with him. One problem is described briefly as follows. Around that time, I was working on developing flexible edge detection methods for image analysis using local kernel smoothing. My methods did not require restrictive assumptions on the number and shape of the edge curves (e.g., Qiu 2002). But, the detected edge pixels could not form curves. Instead, they were a set of disconnected points located around the true edge curves. I regarded this as a drawback and was thinking about possible ways to connect the detected edge pixels.

After I settled down at Peter's department during my first day of the visit, we had a meeting and discussed these problems. He told me that he liked the edge detection problem and we could work on the problem together. In the next few days, I tried to come up with

some possible ways to connect the edge pixels detected by an existing edge detector and reported to Peter daily. After several meetings and several rounds of modifications, he was still unsatisfied with my plan. He told me that he had two main concerns: 1) my proposed post-processing edge-linking method seemed inconvenient to use, and 2) it might be hard to formulate it well mathematically. Soon after that conversation, he came to my office with a brilliant idea. That idea was based on edge tracking. Namely, from an initial edge point detected by an existing edge detector, we can track the edge curve step by step with a small step size along the most probable edge direction. At each step, the edge direction can be estimated by a weighted local maximum likelihood estimation approach that was considered in Hall and Rau (2000) and Hall et al. (2001). To handle the complexity of crossing edge curves, he borrowed the concept of a vertex of degree k in graph theory to describe an edge point at which k edge curves join. Then, in the next few days, we worked out the method and the related theory. In that process, Peter took the lead and I gave him feedbacks and suggested some possible improvements. At that time, Professor Christian Rau was pursuing his PhD under Peter's supervision and our research was closely related to Christian's thesis topic. Peter suggested that we could ask Christian to help us with the numerical studies. That work was later published in Hall et al. (2008).

When working with Peter, my first impression of him was that he was very efficient. For the above project, it took us roughly three weeks to determine the research topic, develop the methodology and finish the theoretical justifications. Before I left Australia, we finished the design of the numerical studies. Peter often had several visitors at one time, and needed to work on several different projects simultaneously. He was efficient partly because he knew

so many different things in different areas and disciplines. In the project described above, he connected edge tracking in image processing with graph theory in mathematics and weighted local maximum likelihood estimation in statistics. At one point during my collaborations with him, I doubted whether there was any statistical problem that he knew nothing about. Peter was efficient also because he worked extremely hard. He might be the hardest working researcher I've ever met. He was thinking about things all the time, even during walking. For instance, he told me sometimes that he needed to leave the office for meetings or other commitments. Once he returned, he often stopped by my office to tell me certain new ideas that came to his mind during those short periods of time. At ANU, the regular working hours were between 9am and 5pm during week days. Peter usually arrived to his office before 9am and left the office after 7pm. He usually only spent the morning of a Saturday for shopping and laundry, and spent the remaining part of a weekend in working. After a trip (even an international trip), if it was during working hours, he usually went to his office directly to work until his regular leaving time. Before the visit, it was difficult for me to believe that Peter could publish more than 20 papers a year and that most of these papers were published in top journals. After the visit, I was convinced he could achieve this. I also realized that Peter's greatness was reflected not only in his talent, but also in his passion and extraordinary effort in his research. Peter deserved everything he achieved.

Peter was selected as the Buehler-Martin Lecturer by the School of Statistics at UMN in 2003 and he delivered three lectures on April 29, 30, and May 1 of that year. For the trip, he only spent 4-5 days in Minnesota. After I picked him up from the airport and had a dinner with him that night, he asked me to accompany him to a drug store to buy some pain relief

medicine. He told me that he had a head-ache, probably due to a lack of sleep. After he bought the medicine and I took him to his hotel, he told me he had a research idea while on the airplane and would like to discuss with me the next morning. The next morning, after Peter settled down in our department, we had a meeting immediately. His idea was about the following nonparametric density deconvolution problem:

$$Z = X + \delta, \tag{1}$$

where Z was the observed version of X, δ was the random error, X and δ were independent, and the distribution of δ was assumed known. Our major goal here was to estimate the density of X in a nonparametric context from certain observations of Z. For this problem, there had been several existing methods, including some kernel-based approaches (e.g., Delaigle and Gijbels 2002). Peter believed that he found a simpler and possibly more effective method to solve the problem. His idea was based on the discrete Fourier transformation and the following property of the sine and cosine functions:

$$\begin{aligned} E\{\cos(jZ)\} &= E\{\cos(jX)\}E\{\cos(j\delta)\} - E\{\sin(jX)\}E\{\sin(j\delta)\} \\ E\{\sin(jZ)\} &= E\{\sin(jX)\}E\{\cos(j\delta)\} + E\{\cos(jX)\}E\{\sin(j\delta)\}, \end{aligned} \tag{2}$$

where j was an index in the trigonometric-series expansions, Z was assumed to follow model (1), and "E" denoted the expectation. In (2), $E\{\cos(jZ)\}$ and $E\{\sin(jZ)\}$ could be estimated from the observed data, and $E\{\cos(j\delta)\}$ and $E\{\sin(j\delta)\}$ could be computed from the assumed distribution of δ. So, $E\{\cos(jX)\}$ and $E\{\sin(jX)\}$ could be estimated easily by (2). By the inverse discrete Fourier transformation, the density of X could be estimated afterwards. One major assumption to make this method work was that the support of the

distribution of X was a compact interval, or contained in a compact interval. Peter asked me whether I could think of some real applications in which this assumption was reasonable. I mentioned to him that in certain medical studies we would consider a treatment (e.g., surgery) only when some medical indices were in some specific ranges. In such applications, that assumption might be valid. I also suggested that besides the discrete Fourier transformation, we could consider cosine-series or sine-series expansions which were simpler. The next day, he told me that he found the cosine-series expansion generally had a better theoretical property for estimating a density with a bounded support. So, that expansion was adopted in our method. Because of the close relationship between the density deconvolution problem and the errors-in-variables problem, a similar method was proposed for solving the errors-in-variables problem. Before Peter left Minnesota, the methodology was mostly developed. Remember that during the visit, he needed to give three lectures, chat with my colleagues at UMN, and attend some social activities arranged for him. His efficiency and diligentness were once again well demonstrated. After Peter left Minnesota, he led the effort in developing the theory and I led the effort in completing the numerical studies. The paper was finished in about a month. That work was published in Hall and Qiu (2005). After that paper was finished, Peter told me that he found the method in Hall and Qiu (2005) could be properly modified for solving the Berkson errors-in-variables problem. Professor Aurore Delaigle provided a substantial contribution to that work in both numerical study and theoretical development. That work was later published in Delaigle et al. (2006). Aurore was Peter's major collaborator in the past about 10 years in research areas such as density deconvolution, errors-in-variables problems, functional data analysis, and so forth. See Delaigle (2016) for a more detailed description about their joint research.

In the 2004-2005 academic year, I took a full-year sabbatical leave from UMN. I decided to visit Peter again during that year. After an email conversation with Peter, he asked me to visit him as soon as possible. My visit time was finalized to be between September 1 and November 30, 2004. At that time, my research in image processing was in a transition period. Besides the traditional problems of edge detection and edge-preserving image denoising, I was exploring some other challenging problems. One such problem was image deblurring, which could be described by the following model:

$$Z(x,y) = H\{f\}(x,y) + \varepsilon(x,y), \quad \text{for } (x,y) \in \Omega, \tag{3}$$

where $H\{f\}(x,y) = \int\int_{R^2} h(u,v) f(x-u, y-v)\ dudv$ denoted the convolution between a *point spread function (psf)* h and a true image intensity function f, $\varepsilon(x,y)$ was the pointwise noise, and Ω was the design space of the image. The psf h described how the true image f was spatially degraded (i.e., blurred) in the imaging process. Image deblurring was mainly to estimate $f(x,y)$ from $Z(x,y)$. In the literature, h is often assumed to be known. Otherwise, the image deblurring problem could be "ill-posed" in the sense that there could be multiple sets of h and f that corresponded to the same Z, even when no noise was contained in Z. So, most papers in the literature at that time tried to estimate $f(x,y)$ from $Z(x,y)$ when h was assumed known, using various inverse filtering algorithms. That task alone was challenging because the inverse filtering was often numerically unstable, caused mainly by random noise. Therefore, the major focus of the existing research at that time was on how to overcome the numerical challenge in the inverse filtering. In my opinion, the assumption that h was known might not be realistic for certain applications. For instance, satellite images were often blurred because of wind, atmospheric turbulence, aberrations of the optical system,

relative motion between the camera and the object, and other various reasons. It could be difficult to describe the blurring mechanism in an imaging process by completely specifying the psf h. What I wanted to contribute to the image deblurring problem was to estimate $f(x, y)$ from $Z(x, y)$ without specifying a specific function for h. So, in my list of possible research problems prepared for the visit to Peter, that topic was the focus.

After I arrived at ANU and discussed the image deblurring problem with Peter, he was very interested. I believe his interest was partly because photography used to be his hobby, although he gave up that hobby for a while at the time when I visited him (probably because he wanted to spend more time in his research). Therefore, he understood the concepts of image blur and psf extremely well. One night he came to my office to share with me an article that he downloaded from a web site which said that all pictures were actually blurred to a certain degree. So, we both agreed that the image deblurring problem was important. I told him that although it was difficult to specify the psf h completely in certain applications, it might be possible to estimate it using test images of some known structures (e.g., lines of different widths). He agreed and told me that camera companies usually calibrated the lens of a camera by taking pictures of mesh grids or other structures. Therefore, that idea seemed reasonable to him. We then tried to develop the method based on that idea. In the setup of model (3), f would be the test image whose structure was assumed known, and we wanted to estimate the psf h from the observed image Z. To this end, we proposed an estimator based on the Fourier transformation and a ridge-regulated inverse Fourier transformation. That work was later published in Hall and Qiu (2007a). In a follow-up research, we went back to the original image deblurring problem where the focus was on estimating $f(x, y)$

from $Z(x, y)$. For that purpose, we suggested a two-step procedure. In the first step, the psf h was estimated from an observed test image. Then, in the second step, any observed image $Z(x, y)$ taken by the same camera could be deblurred using the estimated psf obtained in the first step. To make the problem and our solution better described mathematically, the psf h was assumed to follow a parametric function with a parameter θ in that research. When estimating θ, Peter suggested a novel metric for measuring the sharpness of a blurred test image. That work was published in Hall and Qiu (2007b). The method without the parametric assumption on h was published in Qiu (2008). Another follow-up research to make the methods more flexible was published in Qiu and Kang (2015).

To work with Peter, besides his talent, passion and diligentness in research, I observed that he treated all details in a research project carefully. He was careful about all the conditions in a theorem, whether they were necessary, and whether they were already the weakest possible conditions. He was also careful about the wording and the punctuation in a paper to make sure that the related methods, and/or their properties, were accurately described. His attention to details reflected in all revisions of a paper during the paper reviewing process. I personally learned a lot from him about proper ways and attitude in revising a paper. To my surprise, Peter also got many paper rejections, at least with our joint research papers described above. During our private conversations, he would express his disappointment after receiving a paper rejection. In most such cases, he would suggest alternative journals for resubmission. I only had one case when he thought that the reviewers did not understand our proposed method well and that most of their comments did not make sense to him. In this situation, he chose to write back to the editor to further explain our

method and explain why he thought the reviewers misunderstood our method. In revising a paper written jointly with me alone, he usually focused on the theoretical issues and I focused on the numerical issues. He also drafted the authors' response to reviewers, and I provided my feedbacks. His draft response would address all issues raised in the review reports, plus certain issues that had not been noticed by the referees but rather we noticed during the paper revision. What impressed me about his draft response was its tone. It was polite and things were always stated positively. In some occasions, the referees misunderstood certain parts of a paper and made irrelevant comments. In such cases, Peter might say that it was our fault that we did not describe the related parts clearer and they were either modified in the revision or left as is but they actually meant such and such. On one occasion, I asked him why he said it was our fault when the fact was that the related description in the paper was already clear and appropriate. He explained that we should not expect our readers to be as familiar to our research subject as ourselves and it would always be a good idea to polish some statements from readers' perspective. I believe that my own authors' response has a similar tone nowadays.

4 Fond Memories of Peter

Peter had many visitors each year. A major benefit to visiting Peter was that we would have opportunities to meet other visitors and make new friends. Besides the visits mentioned above, my last visit to Peter was during January 20 - March 5, 2012 at the University of Melbourne. That year I took my second full-year sabbatical leave from UMN. During all

these visits, I met many colleagues, including Ray Carroll, Ming-Yen Cheng, Aurore Delaigle, and Alexander Meister. Peter took care of his visitors well. We usually had lunch with Peter and some of his colleagues in his department on a daily basis. During these lunches, topics could range from US presidential elections to unique traditions of a small town on a corner of the world. I learned many things from these lunch conversations. For instance, Alan Welsh once mentioned that most animals we ate were vegetarian. This was in fact true, although I never realized it. For my first visit to Peter, he took care of all accommodations for me. He even arranged Christian Rau to pick me up from the airport, and then brought me some food the next day by himself. During my second visit, I remembered that I mentioned during our casual chat at a lunch that a bicycle I bought several days before was stolen although it was properly locked. Peter apologized for the incidence, although that was not his fault at all, and worried that the incidence might change my impression about ANU and Australia. He explored the possibility of buying another bicycle for me. I thanked him for his concern, and told him that another bicycle was unnecessary. Although many years have passed, those small but warm episodes are still vivid in my mind, and I am sure they will be in my memory for many years to come.

Peter usually took his visitors to a fun place for a half day or so if the timing was good for both himself and his visitors. During my first visit, he took me to a quiet suburb of Canberra and told me that he went there quite often to take pictures when he was younger. That trip was just two of us and we had many interesting conversations. Of course I asked him about the tricks to taking a good picture. He told me his major theory was that we should try to add more dimensions to the scene to be pictured. He explained this theory

using several examples. For instance, when we took a picture of a house, it might be better to include a corner or the roof in the picture, which was three-dimensional, than just to include a flat part of the house, which was two-dimensional. When we took a picture of a tree, if our picture could give viewers an impression that some branches or leaves were moving because of the wind, then such a picture would usually be more impressive than a picture of a tree that was completely still. We also discussed different social systems in the world, the major characteristics of different people and societies, different religions (when we walked around a beautiful church), gun control in different countries, as well as several other topics. To my surprise, Peter knew so many things besides statistics, and I learned a lot from our conversations. During my second visit, Peter and his wife Jeannie took Ray Carroll, Ray's wife, and myself to a local winery in a suburb of Canberra to taste local wines. We also visited stores, including a furniture store, and had a lunch together. That was an enjoyable trip that was full of warm conversations and laughs which is reflected in the picture shown in Figure 2, that was taken by Ray. During my third visit to Peter, he

Figure 2: A picture with Peter Hall during a local trip to a winery located in a suburb of Canberra.

and Aurore organized a trip to take a steam train in a suburb of Melbourne. He told us that he liked to take pictures of trains when he was young, and there were only a small number of steam trains left nowadays in the world.

During my contact with Peter, of course many conversations were related to statistics and our research in statistics. We often talked about certain active research areas, our own opinions about the main reasons why they were active, and the fundamental research problems in these areas. We once discussed English writing of a paper, and exchanged our views on certain writing styles and habits (e.g., cases to use past tense versus present tense). One conversation that left me a quite deep impression was about mistakes that we found in research papers during our paper reviews. He said that we should be more flexible to some of these mistakes as long as they were not critical. He further explained that we all made mistakes in our papers and theoretically every paper had mistakes in it. As long as these mistakes were correctable, we should give authors a chance to correct them, and the editorial recommendations and decisions should not focus too much on these mistakes. Those comments were especially helpful to me as I was named the editor-elect of *Technometrics* during my third visit to Peter in 2012. Around the same time, he was named a co-editor of *Annals of Statistics*. During a lunch of that visit, he initiated a discussion about how to maintain a healthy academic environment. He specifically mentioned that we should avoid using any prior information regarding which research group the authors belonged to when we judged the quality of a paper. Today, my term as the editor of *Technometrics* just ended several days ago, and during my editorship I never forgot his kind advices.

When I went to Peter's office to say goodbye on the last day of my visit in 2012, he said

some warm words that I will never forget. He said, "Peihua, please visit me more often. Do not wait until the next sabbatical. I can always make appropriate arrangements for your next visit. I myself will try to slow down and make less trips." I do not know whether Peter ever had any slowdown times in his life. All I know is that he still tried to work even during his last days in hospital. Peter is a real researcher! In one private conversation with Peter when we visited a local church in a suburb of Canberra, we talked about the possibility of an afterlife. At that time, I told him that I tended to believe there was no afterlife because no scientific evidence was found about its existence, but there could be a possibility since we human beings did not know much about the world beyond our globe. Today, I hope there is an afterlife and Peter is still doing his beloved research.

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