

Survey Methodology

My chancy life as a Statistician

by J.N.K. Rao

Release date: May 7, 2019



Statistics
Canada

Statistique
Canada

Canada

How to obtain more information

For information about this product or the wide range of services and data available from Statistics Canada, visit our website, www.statcan.gc.ca.

You can also contact us by

Email at STATCAN.infostats-infostats.STATCAN@canada.ca

Telephone, from Monday to Friday, 8:30 a.m. to 4:30 p.m., at the following numbers:

- | | |
|---|----------------|
| • Statistical Information Service | 1-800-263-1136 |
| • National telecommunications device for the hearing impaired | 1-800-363-7629 |
| • Fax line | 1-514-283-9350 |

Depository Services Program

- | | |
|------------------|----------------|
| • Inquiries line | 1-800-635-7943 |
| • Fax line | 1-800-565-7757 |

Standards of service to the public

Statistics Canada is committed to serving its clients in a prompt, reliable and courteous manner. To this end, Statistics Canada has developed standards of service that its employees observe. To obtain a copy of these service standards, please contact Statistics Canada toll-free at 1-800-263-1136. The service standards are also published on www.statcan.gc.ca under "Contact us" > "[Standards of service to the public](#)."

Note of appreciation

Canada owes the success of its statistical system to a long-standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued co-operation and goodwill.

Published by authority of the Minister responsible for Statistics Canada

© Her Majesty the Queen in Right of Canada as represented by the Minister of Industry, 2019

All rights reserved. Use of this publication is governed by the Statistics Canada [Open Licence Agreement](#).

An HTML version is also available.

Cette publication est aussi disponible en français.

My chancy life as a Statistician

J.N.K. Rao¹

Abstract

In this short article, I will attempt to provide some highlights of my chancy life as a Statistician in chronological order spanning over sixty years, 1954 to present.

Key Words: Bootstrap; Empirical likelihood; Linear mixed models; Small area estimation; Unequal probability sampling.

1 Introduction

Professor Changbao Wu, Guest Editor for this joint special issue between *ISR* and *Survey Methodology*, invited me to write an article tracing my chancy life as a statistician over the past 60 years. The joint special issue consists of papers based on plenary talks presented at a conference held in Kunming, China, May 24-27, 2017. This conference was sponsored by the Research Institute of Big Data, Yunnan University, and the organizing committee was chaired by Professor Jiahua Chen. I wish to first thank Professor Chen for organizing this conference “Contemporary Theory and Practice of Survey Sampling”, celebrating my 80th birthday. I also wish to thank Professor Ray Chambers, Guest co-editor of *ISR* and Wesley Yung, Editor of *Survey Methodology*, for proposing this joint special issue, and to all the speakers for their excellent presentations. In this short article, I will attempt to provide some highlights of my chancy life as a Statistician in chronological order covering the period 1954-1958 in India, 1959-68 in USA with a one year break in 1963 in India, 1968-69 again in India and finally in Canada since 1969.

2 Early life in India

In 1954 I obtained a B.A. degree in Mathematics with specialization in Astronomy. I studied at a local college in my hometown Eluru, affiliated to Andhra University in India. Soon after writing my final exams, I was wondering what to do next and went to see my favorite algebra teacher, C.D. Murthy, for advice. He told me that I should study Statistics. I knew nothing about Statistics at that time but my mind was made up and I applied to some universities, including Bombay University, for admission. Only a few universities in India offered Statistics those days, only seven years after India achieved independence from Britain. But I was refused admission despite my first class in B.A. because my grades were not high enough. Only one student from Andhra University was admitted to Bombay University in 1954 for the Master degree in Statistics and his overall grade in his B. Sc. was 495 out of 500!

I was very frustrated and was wondering what to do next. My uncle, who studied in Bombay, advised me to go to Bombay and join the M.A. degree program in Pure and Applied Mathematics and try my luck afterwards. I was able to get admission and started my studies in Bombay three weeks later. But my mind

1. J.N.K. Rao, School of Mathematics and Statistics, Carleton University, Ottawa, Ontario, K1S 5B6, Canada. E-mail: jr Rao@math.carleton.ca.

was set on Statistics and I did not enjoy the program I enrolled in except for the one course in Statistics I was allowed to take from the Statistics Department. Every week I used to see the Head of the Statistics Department, Professor M.C. Chakrabarti, to express my keen interest in pursuing a degree in Statistics. A month or so passed by and one fine morning, when I was at the Department to attend my statistics class, Professor Chakrabarti asked me if I would like to join his Department because one of the students left the program to study engineering in England. He also warned me that it would be extremely difficult for me to secure even a second class because I had no background in statistics and would be joining almost two months late. I took the chance and joined the program knowing that next year my chances will be slim again. First year was daunting and I managed to scrape through the first year unofficial examinations securing 23rd rank out of 24! I studied very hard next year and my enthusiasm for Statistics helped me a lot in my efforts. To my great surprise, I secured a First Class in the Final Examinations in 1956. (Only four students out of 24 secured first class that year if I remember correctly and that was a record compared to previous years!). I had great teachers including Chakrabarti and Anant Kshirasagar. I learnt a lot from them even though some of the stuff was boring (like working out the recurrence relations for the moments from Kendall's book!). Chakrabarti taught sampling theory and I got attracted to it. Also, it was fortunate for me that three classic books in survey sampling by Cochran, Sukhatme and Hansen, Hurwitz and Madow appeared around 1954. I might add that India produced some great statisticians by that time, including C.R. Rao, R.C. Bose, P.C. Mahalanobis and P.V. Sukhatme. Indian statisticians owe much to Mahalanobis for his vision and pioneering contributions in promoting Statistics in India and putting India on the world map.

After finishing my M.A. degree, I wanted to take a job so that I could support my family (my father died when I was only six), but my mother insisted that I should pursue a Ph.D. degree. Chakrabarti offered me a Government of India Senior Research Scholarship to work with him on the construction of experimental designs but I was not strong in that subject and also had no interest. I applied to the Indian Statistical Institute for a research scholarship without success but I was admitted to the second year of a three- year Diploma course. I joined that program but most of the stuff was a repeat of what I learnt in my M.A. program. At that time Dr. K.R. Nair, well-known for his work on the construction of experimental designs, was looking for a research scholar to work with him at the Forest Research Institute in Dehra Dun, India. I joined him in October 1956 as a research scholar. Seeing my interest in survey sampling, he encouraged me to work on problems related to forest surveys. He also felt that I should go abroad to do my Ph.D. I managed to publish few papers on sampling related to forest surveys. At that time Professor H.O. Hartley was doing great work at Iowa State University (ISU) on survey sampling. Nair studied with Hartley in London, so he advised me to apply to ISU to work with Hartley. Again I was not admitted right away but a chance vacancy occurred and I ended up in Ames, Iowa around the middle of the fall quarter of 1958.

3 Life in USA: 1958-68

Undoubtedly, ISU was among the best (if not the best) applied statistics departments at that time. (I believe it still is.) I even had the chance to take the last course on statistical methods with George Snedecor

before he retired. He was the founder of the Statistics Department at ISU and his close association with R.A. Fisher led to the well-known Snedecor's F and also Fisher going to ISU as a visiting professor. It was most rewarding to learn from great statisticians like Hartley and Kempthorne at ISU and also from others who visited ISU regularly. Professor Hartley was my mentor and Ph.D. supervisor and I learnt from him that the development of statistical theory should be motivated by practical applications. I took economics as a minor in my Ph.D. program and I was fortunate to work with Gerhard Tintner who was a pioneer in Econometrics and one of the inventors of the Variate Difference Method for finding the order of difference that makes a time series stationary. I even wrote two papers and a small monograph with him on this topic. For several years I tried to keep up with the developments in Econometrics.

I stayed at ISU for 5 years, three years as a student and two years as Assistant Professor, before returning to India in 1963 for family reasons. This period was most exciting and professionally rewarding. At that time unequal probability sampling without replacement was a "hot" topic and people were looking for practical procedures. Hartley and I published a paper on this topic in the *Annals of Statistics* (1962) developing an asymptotic theory for randomized probability proportional to size (PPS) systematic sampling (Hartley and Rao, 1962). After finishing my Ph.D. in 1961, I published a paper with Hartley and W.G. Cochran, in the *Journal of the Royal Statistical Society, Series B*, 1962, on a very simple procedure of unequal probability sampling without replacement that has many desirable properties (Rao, Hartley and Cochran, 1962). This method is now known as the RHC method and many papers on this method have appeared since then. Both the PPS systematic sampling method and the RHC method have been used in the Canadian Labour Force Survey for the past 25 years or so. Professor Arijit Chaudhuri of the Indian Statistical Institute has used the RHC method extensively for large-scale sample surveys in India. I also wrote a paper in the *Journal of the American Statistical Association* on composite estimation for repeated surveys with my Canadian friend, Jack Graham, who was also a student at ISU at that time (Rao and Graham, 1964). Jack became my colleague after I joined Carleton University in Ottawa in 1973. More recently, I got back to composite estimation in the context of the Canadian Labour Force Survey and developed a new method in association with Wayne Fuller and Avi Singh, that is currently being used in Canada (Fuller and Rao, 2001 and Singh, Kennedy and Wu, 2001). I shared an office with Wayne Fuller at ISU and he has been a close friend for the past 55 years.

I worked as a sample survey expert at the National Council of Applied Economic Research in New Delhi for one year after I returned to India. During my stay there I was involved in the development of the design and analysis of an All India Consumer Expenditure Survey. But I was very frustrated because there were no facilities there for research. I returned to United States in August 1964 and worked for one year in Dallas in a research group headed by D.B. Owen before joining Hartley at Texas A&M University. (Hartley moved to Texas A&M in 1963 to create an Institute of Statistics there.) My stay at Texas A&M was also most rewarding and professionally exciting. I worked closely with Hartley and also supervised Ph.D. students. I was promoted to Full Professor rank in 1967 and things were going great. My son, Sunil, was born in April 1967 and we were well settled. But I had to return to India in June 1968 due to unexpected family problems.

I took leave from Texas A&M and joined the Indian Statistical Institute (ISI) in Calcutta as Visiting Professor. (I might mention here that my son Sunil is currently Director of Biostatistics Division and Interim Chair of the Department of Public Health Sciences at the University of Miami. He was elected ASA Fellow in 2011 and we two belong to the very small group of father-son ASA Fellows!)

I would like to briefly mention four significant contributions I made during my stay at Texas A&M. In my *Biometrika* 1967 paper with Hartley, we gave a matrix formulation of general ANOVA mixed models that was instrumental to the derivation of maximum likelihood (ML) estimators of both fixed effects and variance components (Hartley and Rao, 1967). We also developed an EM algorithm in this paper but did not pursue it further due to computational limitations at that time. (EM algorithm became popular after the appearance of Dempster, Laird and Rubin (1977)). Patterson and Thompson (1971) modified our ML method and developed restricted maximum likelihood (REML) estimation. Many extensions and refinements have been made over the past 40 years, and several software packages implemented those methods. An excellent review paper by Harville (1977) contributed to the extensive use of those methods. I also worked with Hartley on variance estimation when only one unit is sampled from each stratum (Hartley, Rao and Kiefer, 1969). In this case, standard design-based methods are not applicable and it is necessary to resort to models. We used a linear regression model with unequal error variances and expressed the variance of the stratified mean as a linear combination of the error variances. We then developed a new method of estimating the error variances that in turn led to a new variance estimator for the stratified mean. We submitted this paper for publication in 1968 before I left for India. I gave a seminar talk at ISI on this work. After my talk, Professor C.R. Rao felt that he could establish some optimality properties for our method. This led to C.R. Rao's well-known MINQUE method (Rao, 1970), and Professor Rao notes "The motivation for writing this article is a recent contribution by Hartley, Rao and Kiefer (1969) who obtained unbiased estimator when all the variances are unequal ..." (page 161).

In the 1960's, V.P. Godambe was giving talks at various professional meetings on his important contributions to survey sampling inference; in particular, on the non-existence of a best estimator in a general class of linear unbiased estimator of a total and on the flat likelihood caused by the label property of a finite population. Those negative results are indeed fundamental, but Hartley and I felt that some of the alternative criteria proposed for the choice of an estimator, such as admissibility and hyper-admissibility for any sampling design, are unsatisfactory. In our *Biometrika* 1968 paper we suggested that some aspects of the sample data, depending on the situation at hand, need to be ignored to arrive at an informative likelihood (Hartley and Rao, 1968). We proposed such a non-parametric likelihood that is now called Empirical Likelihood (Owen, 1988). We also showed how to incorporate known population totals of auxiliary variables, and showed that the empirical likelihood (EL) estimator of a total is close to a regression estimator. I gave several lectures on the foundations of inference in survey sampling at ISI and Professor C.R. Rao wrote a nice article afterwards (Rao, 1970) that seems to agree with our approach: "In situations like the one we are considering where the full likelihood does not satisfy our purpose, we may have to depend on a statistic which for every observed value supplies information (however poor it may be) on

parameters of interest.” Our *Biometrika* 1968 paper also contained a short section on Bayesian inference for the mean obtained by combining our likelihood with a diffuse conjugate prior. Ericson (1969) combined Godambe’s flat likelihood with an informative prior to produce informative posterior inferences on the mean. Our results are algebraically identical to Ericson’s, but fundamentally different in the sense that our inferences depend on the probability distribution induced by the survey design, unlike Ericson’s results.

While I was working on my Ph.D. thesis at ISI, I analyzed some farm survey data where the farms were selected with probabilities proportional to farm sizes. I found that some variables of interest, in particular poultry size, was unrelated to farm size and that the use of the widely used Horvitz-Thompson (HT) unbiased estimator in such cases would lead to very large variances. I therefore proposed an alternative estimator that ignores the survey weights but uses the population structure (Rao, 1966). I provided both theoretical and empirical justifications for preferring such an estimator. My result essentially casts doubt on the usefulness of criteria that advocate the HT estimator for ANY design and ANY characteristic. Later, D. Basu used an amusing circus elephant example to demonstrate that the HT estimator leads to absurd results if the sizes are unrelated to the values of interest (Basu, 1971).

4 Life in Canada: 1959-2000

I found that the Canadian universities suited my family circumstances in India at that time and decided to migrate to Canada in 1969 directly from Calcutta. Hartley was very unhappy with my decision, but we continued our collaboration for several years. I worked four years at the University of Manitoba before joining Carleton University, Ottawa in 1969. I have also worked at Statistics Canada for the past 40 years or so as a consultant, and this practical exposure was extremely useful in my later research work. I have collaborated with many statisticians over the past 25 years, thanks to my Canadian NSERC research grant that encourages collaborative work. I supervised many outstanding Ph.D. students in Canada. My first Ph.D. student in Canada, David Bellhouse (co-supervised with Jim Kalbfleish at the University of Waterloo), wrote his thesis on optimal estimation in finite population sampling. He had a distinguished career at the University of Western Ontario and retired recently. Bellhouse is also a leading expert in the history of Statistics. Dan Krewski was my first Ph.D. student at Carleton University. He developed asymptotic theory for stratified multistage sampling designs (Krewski and Rao, 1981) which provided theoretical justification for replication methods, such as the jackknife and balanced repeated replication, widely used for the analysis of complex survey data (see Shao and Tu, 1995, Chapter 6). Krewski is currently a distinguished professor of biostatistics and population health at the University of Ottawa and he is a leading authority on risk assessment. Both Bellhouse and Krewski are ASA Fellows. Several of my Masters and Ph.D. students established successful careers at Statistics Canada and elsewhere.

In 1977, I was looking for a suitable place to spend my sabbatical leave. By chance, I bumped into Fred Smith of the University of Southampton at a survey sampling conference held at the University of North Carolina. He mentioned that he has applied for a research project on the analysis of complex survey data

and if successful I could spend my sabbatical leave at his university working on the project. His research project was approved and I joined the project team (Fred Smith, Tim Holt, Gad Nathan and Alastair Scott) in April 1978 for 4 months. I also had a chance to interact with Graham Kalton who was also at the University of Southampton. I might mention that Smith, Holt and Kalton developed a strong program in survey sampling research at the University of Southampton. In later years, Chris Skinner, Ray Chambers and Danny Pfeffermann contributed greatly and made it into a leading center for survey research.

During my sabbatical leave, Alastair Scott and I worked on methods for the analysis of categorical survey data and published several papers subsequently. In Rao and Scott (1981, 1984), we developed simple corrections to standard chi-squared tests for testing independence in a two-way table of weighted counts that account for the survey design features. It was nice to see the 1981 paper with Scott included among the 19 landmark papers in survey sampling published over the period 1930-90. Scott visited me regularly for several years to continue our work on analysis of survey data and other topics until his health did not permit him to travel alone. He was suffering from brain cancer but hoped to attend the China conference in May 2017. I was deeply saddened by the news of his death on the first day of the conference. I would like to dedicate this joint special issue of *ISR* and *Survey Methodology* to the memory of my dear friend and collaborator, Alastair Scott.

I collaborated with several excellent researchers after my return from sabbatical leave. Jeff Wu and I developed valid bootstrap variance estimators for stratified multistage sampling and other designs (Rao and Wu, 1988) and we introduced the concept of bootstrap weights (Rao, Wu and Yue, 1992). Currently, bootstrap weights are used at Statistics Canada for variance estimation in several large-scale surveys. Other major collaborations include the following: (1) multiple frame surveys with Chris Skinner, Sharon Lohr and Changbao Wu, (2) empirical likelihood intervals for survey data with Changbao Wu, Jiahua Chen, Yves Berger and M. Salehi, (3) analysis of survey data with Alastair Scott, Chris Skinner, Roland Thomas, Mike Hidioglou, Wesley Yung and Jun Shao, (4) imputation for missing data with Jun Shao, Randy Sitter, Jae Kim, Qihua Wang, Jiahua Chen and Y.S. Qin. Randy Sitter and Jun Shao were my colleagues during the period 1990-95, and our statistics group was rated among the top 15 in the world for research productivity. Other collaborators include Arun Nigam, Jurgen Kleffe, K. Vijayan, Avi Singh, Gordon Brackstone, Poduri Rao and P.A.V.B. Swamy.

Around 1985, I got interested in small area estimation after organizing an international symposium on small area statistics in 1985 jointly with Statistics Canada. Invited papers presented at the symposium are published in a Wiley book (Platek, Rao, Särndal and Singh, 1987). Demand for reliable small area statistics has steadily grown in the past 25 years which in turn led to many theoretical and practical contributions. I supervised several Ph.D. students on this topic, including N.G.N. Prasad, Diane Stukel, Ming Yu and Yong You. Prasad developed accurate mean squared error estimators of model-based small area estimators (Prasad and Rao, 1990) and this work is widely cited. Yong You received the Pierre Robillard award of the Statistical Society of Canada for the best Ph.D. thesis in the year he graduated.

5 Post retirement: 2000-present

I took early retirement in 2000, two years before the mandatory 65, but I have not really slowed down since my retirement 17 years ago. I almost died in 2002 of cardiac arrest without any prior symptoms, but by chance it happened in the hospital and I was saved. I was able to complete my Wiley book on small area estimation (Rao, 2003) and I am happy to see that it is well received and highly cited. I had excellent collaborators in small area estimation (SAE), including Isabel Molina, Malay Ghosh, Partha Lahiri, Gauri Datta, Jiming Jiang, Bal Nandram, Kalyan Das, Sharon Lohr, Domingo Morales, Leyla Mohadjer, Hussain Chowdhry and Tatsuya Kubokawa. By chance, I met Isabel Molina at the ISI meetings in Lisbon and she invited me to Madrid to give a workshop. This led to close collaboration on SAE with her and our paper on empirical Bayes (EB) estimation of complex small area parameters, such as poverty indicators, received the best paper award in 2010 from the Canadian Journal of Statistics (Molina and Rao, 2010). Measurement of poverty indicators for small areas received considerable attention after the World Bank promoted a method based on simulated censuses. In the 2010 paper we showed that the EB method can be considerably more efficient. I also collaborated with Molina on the second edition of my Wiley book (Rao and Molina, 2015). I was very fortunate to have two excellent students, M. Torabi and M. Diallo, working on SAE after my retirement. I also supervised another excellent student, David Haziza, on missing data and imputation. All three are “rising stars” and Haziza is also an ASA Fellow and received the prestigious Gertrude Cox Award for 2018.

I am happy that several of my collaborators participated in the China Conference as plenary speakers and contributed to this joint special issue of *ISR* and *Survey Methodology*. My thanks are due to them as well as to other speakers who have contributed to the joint special issue.

All in all, my chancy life as a Statistician has been very rewarding and satisfying. It was a great pleasure to work with many excellent researchers and graduate students. I owe it to my algebra teacher C. D. Murthy, to Professor M.C. Chakrabarti, to my mentor Professor H.O. Hartley, to my mother and to my wife for whatever success I have achieved in my chancy life as a Statistician over the past 60 years.

Acknowledgements

An earlier version of this paper appeared soon after my retirement in a 2004 newsletter of the International Indian Statistical Association (IISA). I thank the IISA Executive for giving permission to update the paper for publication in the joint special issues of *ISR* and *Survey Methodology*.

References

Basu, D. (1971). An essay on the logical foundations of survey sampling, part I. In *Foundations of Statistical Inference*, (Eds. V.P. Godambe and D.A. Sprott), Toronto: Holt, Rinehart and Winston, 203-243.

- Dempster, A.P., Laird, N.M. and Rubin, D.B. (1977). Maximum likelihood from incomplete data via the EM algorithm (with discussion). *Journal of the Royal Statistical Society, Series B*, 39, 1-38.
- Ericson, W.A. (1969). Subjective Bayesian models in sampling finite populations. *Journal of the Royal Statistical Society, Series B*, 31, 195-224.
- Fuller, W.A., and Rao, J.N.K. (2001). A regression composite estimator with application to the Canadian Labour Force Survey. *Survey Methodology*, 27, 1, 45-51. Paper available at <https://www150.statcan.gc.ca/n1/en/pub/12-001-x/2001001/article/5853-eng.pdf>.
- Hartley, H.O., and Rao, J.N.K. (1962). Sampling with unequal probabilities and without replacement. *Annals of Mathematical Statistics*, 33, 350-374.
- Hartley, H.O., and Rao, J.N.K. (1967). Maximum likelihood estimation for the mixed analysis of variance model. *Biometrika*, 54, 93-108.
- Hartley, H.O., and Rao, J.N.K. (1968). A new estimation theory of sample surveys. *Biometrika*, 55, 547-557.
- Hartley, H.O., Rao, J.N.K. and Kiefer, G. (1969). Variance estimation with one unit per stratum. *Journal of the American Statistical Association*, 64, 841-851.
- Harville, D.A. (1977). Maximum likelihood approaches to variance component estimation and to related problems. *Journal of the American Statistical Association*, 72, 322-340.
- Krewski, D., and Rao, J.N.K. (1981). Inference from stratified samples: properties of linearization, jackknife and balanced repeated replication. *Annals of Statistics*, 9, 1010-1019.
- Molina, I., and Rao, J.N.K. (2010). Small area estimation of poverty indicators. *The Canadian Journal of Statistics*, 38, 369-385.
- Owen, D. (1988). Empirical likelihood ratio confidence intervals for a single functional. *Biometrika*, 75, 237-249.
- Patterson, H.D., and Thompson, R. (1971). Recovery of inter-block information when block sizes are unequal. *Biometrika*, 58, 545-554.
- Platek, R., Rao, J.N.K., Särndal, C.-E. and Singh, M.P. (Eds.). (1987). *Small Area Statistics*, New York: John Wiley & Sons, Inc.
- Prasad, N.G.N., and Rao, J.N.K. (1990). The estimation of the mean squared error of small area estimator. *Journal of the American Statistical Association*, 85, 163-171.
- Rao, C.R. (1970). Estimation of heteroscedastic variances in linear models. *Journal of the American Statistical Association*, 65, 161-172.
- Rao, C.R. (1971). Some aspects of statistical inference in problems of sampling from finite populations. In *Foundations of Statistical Inference*, (Eds., V.P. Godambe and D.A. Sprott), Toronto: Wiley, 177-202.
- Rao, J.N.K. (1966). Alternative estimators in PPS sampling for multiple characteristics. *Sankhyā, Series A*, 28, 47-60.

- Rao, J.N.K. (2003). *Small Area Estimation*. New York: John Wiley & Sons, Inc.
- Rao, J.N.K., and Graham, J.E. (1964). Rotation designs for sampling on repeated occasions. *Journal of the American Statistical Association*, 59, 492-509.
- Rao, J.N.K., and Molina, I. (2015). *Small Area Estimation, Second Edition*. Hoboken, New Jersey: Wiley.
- Rao, J.N.K., and Scott, A.J. (1981). The analysis of categorical data from complex sample surveys: Chi-squared tests for goodness of fit and independence in two-way tables. *Journal of the American Statistical Association*, 76, 221-230.
- Rao, J.N.K., and Scott, A.J. (1984). On chi-squared tests for multiway contingency tables with cell proportions estimated from survey data. *Annals of Statistics*, 15, 385-397.
- Rao, J.N.K., and Wu, C.F.J. (1988). Resampling inference with complex survey data. *Journal of the American Statistical Association*, 83, 231-241.
- Rao, J.N.K., Hartley, H.O. and Cochran, W.G. (1962). On a simple procedure of unequal probability sampling without replacement. *Journal of the Royal Statistical Society, Series B*, 24, 482-491.
- Rao, J.N.K., Wu, C.F.J. and Yue, K. (1992). Some recent work on resampling methods for complex surveys. *Survey Methodology*, 18, 2, 209-217. Paper available at <https://www150.statcan.gc.ca/n1/en/pub/12-001-x/1992002/article/14486-eng.pdf>.
- Shao, J., and Tu, D. (1995). *The Jackknife and Bootstrap*. New York: Springer-Verlag.
- Singh, A.C., Kennedy, B. and Wu, S. (2001). Regression composite estimation for the Canadian Labour Force Survey with a rotating panel design. *Survey Methodology*, 27, 1, 33-44. Paper available at <https://www150.statcan.gc.ca/n1/en/pub/12-001-x/2001001/article/5852-eng.pdf>.