Application of Sampling Variance Smoothing Methods for Small Area Proportion Estimation

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Sampling variance smoothing is an important topic in small area estimation. In this article, we propose sampling variance smoothing methods for small area proportion estimation. In particular, we consider the generalized variance function and design effect methods for sampling variance smoothing. We evaluate and compare the smoothed sampling variances and small area estimates based on the smoothed variance estimates through analysis of survey data from Statistics Canada. The results from real data analysis and simulation study indicate that the proposed sampling variance smoothing methods perform very well for small area estimation.

Key words: Coefficient of variation; design effect; generalized variance function; log-linear model; relative error.

1. Introduction

Small area estimation has become very popular and important in both public and private agencies due to the growing demand for reliable small domain estimates. Small area estimation is based on models that borrow strength across areas and combine different sources of information in order to obtain reliable estimates. In this article, we focus on area level models that are based on direct survey estimates aggregated from the unit level data and area level auxiliary variables. Various area level models have been proposed in the literature to improve the precision of the direct survey estimates: a good summary of these methods is discussed in Rao and Molina (2015). The Fay-Herriot model (Fay and Herriot 1979) is a basic area level model that is widely used in practice. The Fay-Herriot model has two components, namely, a sampling model for the direct survey estimates and a linking model for the small area parameters of interest. The sampling model assumes that there exists a direct survey estimator y_i, which is usually design unbiased, for the small area parameter θ_i such that

$$y_i = \theta_i + e_i, \quad i = 1, ..., m, \quad (1)$$

where e_i is the sampling error associated with the direct estimator y_i and m is the number of small areas. It is customary in practice to assume that the e_i's are independently distributed normal random variables with mean $E(e_i) = 0$ and sampling variance $Var(e_i) = \sigma_i^2$. The linking model assumes that the small area parameter of interest θ_i is related to area level auxiliary variables $\boldsymbol{x}_i = (x_{i1}, ..., x_{ip})'$ through a linear regression model

$$\theta_i = \boldsymbol{x}_i' \boldsymbol{\delta} + v_i, \quad i = 1, ..., m, \quad (2)$$

Small Area Estimation In Survey Sampling

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Small Area Estimation in Survey Sampling Parimal Mukhopadhyay,1998 This book gives a systematic exposition of the problems and procedures in producing statistics for small areas districts subdivisions municipal areas batches of industrial products which have been lying scattered over different journals over the last three decades The motivations of the different procedures have been explained the promising results have been emphasized and the new research areas are indicated The manner of exposition has been tried to be made lucid The book will generate further interest in the area and would be helpful to the researchers and the survey statisticians working in this field   Small Area Estimation J. N. K. Rao,Isabel Molina,2015-08-24 Praise for the First Edition This pioneering work in which Rao provides a comprehensive and up to date treatment of small area estimation will become a classic I believe that it has the potential to turn small area estimation into a larger area of importance to both researchers and practitioners Journal of the American Statistical Association Written by two experts in the field Small Area Estimation Second Edition provides a comprehensive and up to date account of the methods and theory of small area estimation SAE particularly indirect estimation based on explicit small area linking models The model based approach to small area estimation offers several advantages including increased precision the derivation of optimal estimates and associated measures of variability under an assumed model and the validation of models from the sample data Emphasizing real data throughout the Second Edition maintains a self contained account of crucial theoretical and methodological developments in the field of SAE The new edition provides extensive accounts of new and updated research which often involves complex theory to handle model misspecifications and other complexities Including information on survey design issues and traditional methods employing indirect estimates based on implicit linking models Small Area Estimation Second Edition also features Additional sections describing the use of R code data sets for readers to use when replicating applications Numerous examples of SAE applications throughout each chapter including recent applications in U S Federal programs New topical coverage on extended design issues synthetic estimation further refinements and solutions to the Fay Herriot area level model basic unit level models and spatial and time series models A discussion of the advantages and limitations of various SAE methods for model selection from data as well as comparisons of estimates derived from models to reliable values obtained from external sources such as previous census or administrative data Small Area Estimation Second Edition is an excellent reference for practicing statisticians and survey methodologists as well as practitioners interested in learning SAE methods The Second Edition is also an ideal textbook for graduate level courses in SAE and reliable small area statistics   *Small Area Estimation* J. N. K. Rao,2005-02-25 An accessible introduction to indirect estimation methods both traditional and model based Readers will also find the latest methods for measuring the variability of the estimates as well as the techniques for model validation Uses a basic area level linear model to illustrate the methods Presents the various extensions including binary response data through generalized linear models and time series

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    <u>Missing Data and Small-Area Estimation</u> Nicholas T. Longford,2005-08-05 This book evolved from lectures courses and workshops on missing data and small area estimation that I presented during my tenure as the rst C pion Fellow 2000 2002 For the Fellowship I proposed these two topics as areas in which the academic statistics could contribute to the development of government statistics in exchange for access to the operational details and background that would inform the direction and sharpen the focus of a demic research After a few years of involvement I have come to realise that the separation of academic and industrial statistics is not well suited to either party and their integration is the key to progress in both branches Most of the work on this monograph was done while I was a visiting l turer at Massey University Palmerston North New Zealand The hospitality and stimulating academic environment of their Institute of Information S ence and Technology is gratefully acknowledged I could not name all those who commented on my lecture notes and on the presentations themselves apart from them I want to thank the organisers and silent attendees of all the events and with a modicum of reluctance the grey gures who kept inquiring whether I was any nearer the completion of whatever stage I had been foolish enough to attach a date   **Small area estimation in forest inventories: New needs, methods, and tools** Barry Wilson,John Coulston,Steve Prisley,Philip Radtke,2023-04-17   <u>A Course on Small Area Estimation and Mixed Models</u> Domingo Morales,María Dolores Esteban,Agustín Pérez,Tomáš Hobza,2021-03-12 This advanced textbook explores small area estimation techniques covers the underlying mathematical and statistical theory and offers hands on support with their implementation It presents the theory in a rigorous way and compares and contrasts various statistical methodologies helping readers understand how to develop new methodologies for small area estimation It also includes numerous sample applications of small area estimation techniques The underlying R code is provided in the text and applied to four datasets that mimic data from labor markets and living conditions surveys where the socioeconomic indicators include the small area estimation of total unemployment unemployment rates average annual household incomes and poverty indicators Given its scope the book will be useful for master and PhD students and for official and other applied statisticians   **Handbook of Statistics_29B: Sample Surveys: Inference and Analysis** ,2000   <u>Topics in Survey Sampling</u> Parimal Mukhopadhyay,2012-12-06 The aim of this book is to make a comprehensive review on some of the research topics in the area of survey sampling which has not been covered in any book yet The proposed book aims at making a comprehensive review of applications of Bayes procedures Empirical Bayes procedures and their ramifications like linear Bayes estimation restricted Bayes least square prediction constrained Bayes estimation Bayesian robustness in making inference from a finite population sampling Parimal Mukhopadhyay is Professor at the Indian Statistical Institute ISI Calcutta He received his Ph D degree in Statistics from the University of Calcutta in 1977 He also served as a faculty member in the University of Ife

Nigeria Moi University Kenya University of South Pacific Fiji Islands and held visiting positions at University of Montreal University of Windsor Stockholm University University of Western Australia etc He has to his credit more than fifty research papers in Survey Sampling some co authored three text books on Statistics and three research monographs in Survey Sampling He is a member of the Institute of Mathematical Statistics and an elected member of the International Statistical Institute **Sample Surveys: Inference and Analysis** ,2009-09-02 Handbook of Statistics_29B contains the most comprehensive account of sample surveys theory and practice to date It is a second volume on sample surveys with the goal of updating and extending the sampling volume published as volume 6 of the Handbook of Statistics in 1988 The present handbook is divided into two volumes 29A and 29B with a total of 41 chapters covering current developments in almost every aspect of sample surveys with references to important contributions and available software It can serve as a self contained guide to researchers and practitioners with appropriate balance between theory and real life applications Each of the two volumes is divided into three parts with each part preceded by an introduction summarizing the main developments in the areas covered in that part Volume 1 deals with methods of sample selection and data processing with the later including editing and imputation handling of outliers and measurement errors and methods of disclosure control The volume contains also a large variety of applications in specialized areas such as household and business surveys marketing research opinion polls and censuses Volume 2 is concerned with inference distinguishing between design based and model based methods and focusing on specific problems such as small area estimation analysis of longitudinal data categorical data analysis and inference on distribution functions The volume contains also chapters dealing with case control studies asymptotic properties of estimators and decision theoretic aspects Comprehensive account of recent developments in sample survey theory and practice Covers a wide variety of diverse applications Comprehensive bibliography Model Assisted Survey Sampling Carl-Erik Särndal,Bengt Swensson,Jan Wretman,2003-10-31 Now available in paperback this book provides a comprehensive account of survey sampling theory and methodology suitable for students and researchers across a variety of disciplines It shows how statistical modeling is a vital component of the sampling process and in the choice of estimation technique The first textbook that systematically extends traditional sampling theory with the aid of a modern model assisted outlook Covers classical topics as well as areas where significant new developments have taken place *THEORY AND METHODS OF SURVEY SAMPLING* PARIMAL MUKHOPADHYAY,2008-12-19 This is a comprehensive exposition of survey sampling useful both to the students of statistics for the course on sample survey and to the survey statisticians and practitioners involved in consultancy services marketing opinion polls and so on The text offers updated review of difficult classical techniques of survey sampling besides covering prediction theoretic approach of survey sampling and nonsampling errors NEW TO THIS EDITION Two new chapters Nonparametric Methods of Variance Estimation Chapter 19 and Analysis of Complex Surveys Chapter 20 have been added These would greatly benefit the readers KEY FEATURES Covers concepts of unequal probability

sampling Provides problems of making inference from finite population using tools of classical inference Describes nonsampling errors including Randomised Response Techniques Gives over 70 worked out examples and more than 120 problems and solutions Supplies live data from India and Sweden in examples and exercises What the Reviewer says This is a very comprehensive modern text on survey sampling with a strong slant towards theoretical results The book is an excellent reference book and would be a good graduate level sampling text for a course with an emphasis on sampling theory JESSE C ARNOLD Virginia Polytechnic Institute and State University **Survey Sampling Theory and Applications** Raghunath Arnab,2017-03-08 Survey Sampling Theory and Applications offers a comprehensive overview of survey sampling including the basics of sampling theory and practice as well as research based topics and examples of emerging trends The text is useful for basic and advanced survey sampling courses Many other books available for graduate students do not contain material on recent developments in the area of survey sampling The book covers a wide spectrum of topics on the subject including repetitive sampling over two occasions with varying probabilities ranked set sampling Fays method for balanced repeated replications mirror match bootstrap and controlled sampling procedures Many topics discussed here are not available in other text books In each section theories are illustrated with numerical examples At the end of each chapter theoretical as well as numerical exercises are given which can help graduate students Covers a wide spectrum of topics on survey sampling and statistics Serves as an ideal text for graduate students and researchers in survey sampling theory and applications Contains material on recent developments in survey sampling not covered in other books Illustrates theories using numerical examples and exercises **Advanced Sampling Theory With Applications** Sarjinder Singh,2003 A comprehensive expose of basic and advanced sampling techniques along with their applications in the diverse fields of science and technology **Advanced Sampling Theory with Applications** S. Singh,2013-01-07 This book is a multi purpose document It can be used as a text by teachers as a reference manual by researchers and as a practical guide by statisticians It covers 1165 references from different research journals through almost 1900 citations across 1194 pages a large number of complete proofs of theorems important results such as corollaries and 324 unsolved exercises from several research papers It includes 159 solved data based real life numerical examples in disciplines such as Agriculture Demography Social Science Applied Economics Engineering Medicine and Survey Sampling These solved examples are very useful for an understanding of the applications of advanced sampling theory in our daily life and in diverse fields of science An additional 173 unsolved practical problems are given at the end of the chapters University and college professors may find these useful when assigning exercises to students Each exercise gives exposure to several complete research papers for researchers students *Sampling Spatial Units for Agricultural Surveys* Roberto Benedetti,Federica Piersimoni,Paolo Postiglione,2015-03-20 The research and its outcomes presented here focus on spatial sampling of agricultural resources The authors introduce sampling designs and methods for producing accurate estimates of crop production for harvests across

different regions and countries With the help of real and simulated examples performed with the open source software R readers will learn about the different phases of spatial data collection The agricultural data analyzed in this book help policymakers and market stakeholders to monitor the production of agricultural goods and its effects on environment and food safety **Handbook of Spatial Epidemiology** Andrew B. Lawson,Sudipto Banerjee,Robert P. Haining,Maria Dolores Ugarte,2016-04-06 Handbook of Spatial Epidemiology explains how to model epidemiological problems and improve inference about disease etiology from a geographical perspective Top epidemiologists geographers and statisticians share interdisciplinary viewpoints on analyzing spatial data and space time variations in disease incidences These analyses can provide imp Practical Methods for Design and Analysis of Complex Surveys Risto Lehtonen,Erkki Pahkinen,2004-03-05 Large surveys are becoming increasingly available for public use and researchers are often faced with the need to analyse complex survey data to address key scientific issues For proper analysis it is also important to be aware of the different aspects of the design of complex surveys Practical Methods for Design and Analysis of Complex Surveys features intermediate and advanced statistical techniques for use in designing and analysing complex surveys This extensively updated edition features much new material and detailed practical exercises with links to a Web site helping instructors and enabling use for distance learning Provides a comprehensive introduction to sampling and estimation in descriptive surveys including design effect statistic and use of auxiliary data Includes detailed coverage of complex survey analysis including design based ANOVA and logistic regression with GEE estimation Contains much new material including handling of non sampling errors and model assisted estimation for domains Features detailed real li fe case studies such as multilevel modeling in a multinational educational survey Supported by a Web site containing software codes real data sets computerized exercises with solutions and online training materials Practical Methods for Design and Analysis of Complex Surveys provides a useful practical resource for researchers and practitioners working in the planning implementation or analysis of complex surveys and opinion polls including business educational health social and socio economic surveys and official statistics In addition the book is well suited for use on intermediate and advanced courses in survey sampling *An Introduction to Model-Based Survey Sampling with Applications* Ray L. Chambers,Robert Clark,2012-01-12 This text brings together important ideas on the model based approach to sample survey which has been developed over the last twenty years Suitable for graduate students and professional statisticians it moves from basic ideas fundamental to sampling to more rigorous mathematical modelling and data analysis and includes exercises and solutions *Applied Survey Data Analysis* Brady T. West,Steve G. Heeringa,Patricia A. Berglund,2025-04-15 Highly recommended by the Journal of Official Statistics The American Statistician and other top statistical journals Applied Survey Data Analysis Third Edition provides an up to date overview of state of the art approaches to the analysis of complex sample survey data Building on the wealth of material on practical approaches to descriptive analysis and regression modeling from the first and second editions this third edition

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