Robustness of Bayesian ordinal response model against outliers via divergence approach

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Abstract

Ordinal response model is a popular and commonly used regression for ordered categorical data in a wide range of fields such as medicine and social sciences. However, it is empirically known that the existence of "outliers", combinations of the ordered categorical response and covariates that are heterogeneous compared to other pairs, makes the inference with the ordinal response model unreliable. In this article, we prove that the posterior distribution in the ordinal response model does not satisfy the posterior robustness with any link functions, i.e., the posterior cannot ignore the influence of large outliers. Furthermore, to achieve robust Bayesian inference in the ordinal response model, this article defines general posteriors in the ordinal response model with two robust divergences (the density-power and γ-divergences) based on the framework of the general posterior inference. We also provide an algorithm for generating posterior samples from the proposed posteriors. The robustness of the proposed methods against outliers is clarified from the posterior robustness and the index of robustness based on the Fisher-Rao metric. Through numerical experiments on artificial data and two real datasets, we show that the proposed methods perform better than the ordinary bayesian methods with and without outliers in the data for various link functions.

Keywords: Density-power divergence; γ-divergence; General bayesian inference; Link function; Ordered category; Robust inference

Mathematics Subject Classification: Primary 62F35; Secondary 62F15

1 Introduction

Ordered categorical data appear frequently in a wide range of fields such as medicine, sociology, psychology, political sciences, economics, marketing, and so on, and studies on their analysis methods have been quite active even today (Franses and Paap, 2001; Rossi and Allenby, 2003; Agresti, 2010; Madahian et al., 2015; Agresti and Kateri, 2017; Satake et al., 2018; Liu and Zhang, 2018; Baetschmann et al., 2020). Ordered categorical data are, for example, the progression of a certain disease expressed as stage 1, 2, 3, or 4, or opinions on a certain policy expressed as opposition, neutrality, or approval. Additionally, when continuous data are summarized into categorical data, such as ages 0-20, 21-40, 41-60, 61-80, and 80 or more, the categorical data are ordered categorical data. For this reason, ordered categorical data are often considered to be discretized values of latent continuous variables. For more details on ordered categorical data, its traditional analysis methods, and related studies, we refer the reader to Agresti (2010), which is a very excellent book.

The ordinal response model has been gaining popularity in regression for the ordered categorical data thanks to its interpretability and flexibility since it was proposed by a pioneering work Walker and Duncan (1967) in this field. The ordinal response model is also being developed as a package in **R** (R Core Team, 2022), one of the most popular programming languages

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Robustness Of Bayesian Analyses

Andrew Gelman,John B. Carlin,Hal S. Stern,David B. Dunson,Aki Vehtari,Donald B. Rubin

Robustness Of Bayesian Analyses:

   Robust Bayesian Analysis David Rios Insua,Fabrizio Ruggeri,2012-12-06 Robust Bayesian analysis aims at overcoming the traditional objection to Bayesian analysis of its dependence on subjective inputs mainly the prior and the loss Its purpose is the determination of the impact of the inputs to a Bayesian analysis the prior the loss and the model on its output when the inputs range in certain classes If the impact is considerable there is sensitivity and we should attempt to further refine the information the incumbent classes available perhaps through additional constraints on and or obtaining additional data if the impact is not important robustness holds and no further analysis and refinement would be required Robust Bayesian analysis has been widely accepted by Bayesian statisticians for a while it was even a main research topic in the field However to a great extent their impact is yet to be seen in applied settings This volume therefore presents an overview of the current state of robust Bayesian methods and their applications and identifies topics of further in terest in the area The papers in the volume are divided into nine parts covering the main aspects of the field The first one provides an overview of Bayesian robustness at a non technical level The paper in Part II con cerns foundational aspects and describes decision theoretical axiomatisa tions leading to the robust Bayesian paradigm motivating reasons for which robust analysis is practically unavoidable within Bayesian analysis   *Bayesian Robustness* James O. Berger,1996   **Robustness of Bayesian analysis** edited by Joseph B. Kadane,   *Robustness of Bayesian Factor Analysis Estimates* Sang Eun Lee,1994   *Robustness of Bayesian Analyses* Joseph B. Kadane,1984   Robustness of Bayesian Analysis Helena Truszczynska,1990   *An Introduction to Bayesian Analysis* Jayanta K. Ghosh,Mohan Delampady,Tapas Samanta,2007-07-03 Though there are many recent additions to graduate level introductory books on Bayesian analysis none has quite our blend of theory methods and ap plications We believe a beginning graduate student taking a Bayesian course or just trying to find out what it means to be a Bayesian ought to have some familiarity with all three aspects More specialization can come later Each of us has taught a course like this at Indian Statistical Institute or Purdue In fact at least partly the book grew out of those courses We would also like to refer to the review Ghosh and Samanta 2002b that first made us think of writing a book The book contains somewhat more material than can be covered in a single semester We have done this intentionally so that an instructor has some choice as to what to cover as well as which of the three aspects to emphasize Such a choice is essential for the instructor The topics include several results or methods that have not appeared in a graduate text before In fact the book can be used also as a second course in Bayesian analysis if the instructor supplies more details Chapter 1 provides a quick review of classical statistical inference Some knowledge of this is assumed when we compare different paradigms Following this an introduction to Bayesian inference is given in Chapter 2 emphasizing the need for the Bayesian approach to statistics

   Bayesian Analysis in Statistics and Econometrics Donald A. Berry,Kathryn M. Chaloner,John K. Geweke,1996 This book is a definitive work that captures the current state of knowledge of Bayesian Analysis in Statistics and Econometrics and

attempts to move it forward It covers such topics as foundations forecasting inferential matters regression computation and applications   **Robust Statistics, Data Analysis, and Computer Intensive Methods** Helmut Rieder,2012-12-06 To celebrate Peter Huber s 60th birthday in 1994 our university had invited for a festive occasion in the afternoon of Thursday June 9 The invitation to honour this outstanding personality was followed by about fifty colleagues and former students from mainly allover the world Others who could not attend sent their congratulations by mail and e mail P Bickel It s hard to imagine that Peter turned 60 After a welcome address by Adalbert Kerber dean the following lectures were delivered Volker Strassen Konstanz Almost Sure Primes and Cryptography an Introduction Frank Hampel Zurich On the Philosophical Foundations of Statistics 1 Andreas Buja Murray Hill Projections and Sections High Dimensional Graphics for Data Analysis The distinguished speakers lauded Peter Huber a hard and fair mathematician a cooperative and stimulating colleague and an inspiring and helpful teacher The Festkolloquium was surrounded with a musical program by the Univer 2 sity s Brass Ensemble The subsequent Workshop Robust Statistics Data Analysis and Computer Intensive Methods in Schloss Thurnau Friday until Sunday June 9 12 was organized about the areas in statistics that Peter Huber himself has markedly shaped In the time since the conference most of the contributions could be edited for this volume a late birthday present that may give a new impetus to further research in these fields   **Decision Theory and Bayesian Analysis** Mr. Rohit Manglik,2024-04-14 EduGorilla Publication is a trusted name in the education sector committed to empowering learners with high quality study materials and resources Specializing in competitive exams and academic support EduGorilla provides comprehensive and well structured content tailored to meet the needs of students across various streams and levels   Bayesian Thinking, Modeling and Computation ,2005-11-29 This volume describes how to develop Bayesian thinking modelling and computation both from philosophical methodological and application point of view It further describes parametric and nonparametric Bayesian methods for modelling and how to use modern computational methods to summarize inferences using simulation The book covers wide range of topics including objective and subjective Bayesian inferences with a variety of applications in modelling categorical survival spatial spatiotemporal Epidemiological software reliability small area and micro array data The book concludes with a chapter on how to teach Bayesian thoughts to nonstatisticians Critical thinking on causal effects Objective Bayesian philosophy Nonparametric Bayesian methodology Simulation based computing techniques Bioinformatics and Biostatistics   **Statistical Decision Theory and Bayesian Analysis** James O. Berger,2013-03-14 In this new edition the author has added substantial material on Bayesian analysis including lengthy new sections on such important topics as empirical and hierarchical Bayes analysis Bayesian calculation Bayesian communication and group decision making With these changes the book can be used as a self contained introduction to Bayesian analysis In addition much of the decision theoretic portion of the text was updated including new sections covering such modern topics as minimax multivariate Stein estimation   **Robustness Analysis in Decision Aiding, Optimization, and Analytics**

Michael Doumpos,Constantin Zopounidis,Evangelos Grigoroudis,2016-07-12 This book provides a broad coverage of the recent advances in robustness analysis in decision aiding optimization and analytics It offers a comprehensive illustration of the challenges that robustness raises in different operations research and management science OR MS contexts and the methodologies proposed from multiple perspectives Aside from covering recent methodological developments this volume also features applications of robust techniques in engineering and management thus illustrating the robustness issues raised in real world problems and their resolution within advances in OR MS methodologies Robustness analysis seeks to address issues by promoting solutions which are acceptable under a wide set of hypotheses assumptions and estimates In OR MS robustness has been mostly viewed in the context of optimization under uncertainty Several scholars however have emphasized the multiple facets of robustness analysis in a broader OR MS perspective that goes beyond the traditional framework seeking to cover the decision support nature of OR MS methodologies as well As new challenges emerge in a big data era where the information volume speed of flow and complexity increase rapidly and analytics play a fundamental role for strategic and operational decision making at a global level robustness issues such as the ones covered in this book become more relevant than ever for providing sound decision support through more powerful analytic tools **Sensitivity Analysis** Andrea Saltelli,K. Chan,E. M. Scott,2000-10-03 Sensitivity analysis is used to ascertain how a given model output depends upon the input parameters This is an important method for checking the quality of a given model as well as a powerful tool for checking the robustness and reliability of its analysis The topic is acknowledged as essential for good modelling practice and is an implicit part of any modelling field Offers an accessible introduction to sensitivity analysis Covers all the latest research Illustrates concepts with numerous examples applications and case studies Includes contributions form the leading researchers active in developing strategies for sensitivity analysis The principles of sensitivity analysis area carefully described and suitable methods for approaching many types of problems are given The book introduces the modeller to the entire causal assessment chain from data to predictions whilst explaining the impact of source uncertainties and framing assumptions A hitch hiker s guide is included to allow the more experienced reader to readily access specific applications Modellers from a wide range of disciplines including biostatistics economics environmental impact assessment chemistry and engineering will benefit greatly form the numerous examples and applications **Bayesian Theory** José M. Bernardo,Adrian F. M. Smith,2009-09-25 This highly acclaimed text now available in paperback provides a thorough account of key concepts and theoretical results with particular emphasis on viewing statistical inference as a special case of decision theory Information theoretic concepts play a central role in the development of the theory which provides in particular a detailed discussion of the problem of specification of so called prior ignorance The work is written from the authors s committed Bayesian perspective but an overview of non Bayesian theories is also provided and each chapter contains a wide ranging critical re examination of controversial issues The level of mathematics

used is such that most material is accessible to readers with knowledge of advanced calculus In particular no knowledge of abstract measure theory is assumed and the emphasis throughout is on statistical concepts rather than rigorous mathematics The book will be an ideal source for all students and researchers in statistics mathematics decision analysis economic and business studies and all branches of science and engineering who wish to further their understanding of Bayesian statistics

Bayesian Data Analysis Andrew Gelman,John B. Carlin,Hal S. Stern,David B. Dunson,Aki Vehtari,Donald B. Rubin,2013-11-27 Winner of the 2016 De Groot Prize from the International Society for Bayesian AnalysisNow in its third edition this classic book is widely considered the leading text on Bayesian methods lauded for its accessible practical approach to analyzing data and solving research problems Bayesian Data Analysis Third Edition continues to take an applied

Bayesian Methods for Data Analysis, Third Edition Bradley P. Carlin,Thomas A. Louis,2008-06-30 Broadening its scope to nonstatisticians Bayesian Methods for Data Analysis Third Edition provides an accessible introduction to the foundations and applications of Bayesian analysis Along with a complete reorganization of the material this edition concentrates more on hierarchical Bayesian modeling as implemented via Markov chain Monte Carlo MCMC methods and related data analytic techniques New to the Third Edition New data examples corresponding R and WinBUGS code and homework problems Explicit descriptions and illustrations of hierarchical modeling now commonplace in Bayesian data analysis A new chapter on Bayesian design that emphasizes Bayesian clinical trials A completely revised and expanded section on ranking and histogram estimation A new case study on infectious disease modeling and the 1918 flu epidemic A solutions manual for qualifying instructors that contains solutions computer code and associated output for every homework problem available both electronically and in print Ideal for Anyone Performing Statistical Analyses Focusing on applications from biostatistics epidemiology and medicine this text builds on the popularity of its predecessors by making it suitable for even more practitioners and students **Bayesian Analysis in Statistics and Econometrics** Prem K. Goel,N. Sreenivas Iyengar,2012-12-06 This volume is based on the invited and the contributed presentations given at the Indo U S Workshop on Bayesian Analysis in Statistics and Econometrics BASE Dec 19 23 1988 held at the Hotel Taj Residency Bangalore India The workshop was jointly sponsored by The Ohio State University The Indian Statistical Institute The Indian Econometrics So ciety U S National Science Foundation and the NSF NBER Seminar on Bayesian Inference in Econometrics Profs Morrie DeGroot Prem Goel and Arnold Zellner were the program organizers Unfortunately Morrie became seriously ill just before the workshop was to start and could not participate in the workshop Almost a year later Morrie passed away after fighting valiantly with the illness Not to find Morrie among ourselves was a shock for most of us He was a continuous source of inspiration and ideas Even while Morrie was fighting for his life we had a lot of discussions about the contents of this volume and the Bangalore Workshop He even talked about organizing a Second Indo U S workshop some time in the near future We are dedicating this volume to the memory of Prof Morris H DeGroot We have taken a conscious decision not to include any

biography of Morrie in this volume An excellent biography of Morrie has appeared in Statistical Science 1991 vol 6 1 14 and we could not have done a better job than that **Bayesian Inference in Wavelet-Based Models** Peter Müller,Brani Vidakovic,2012-12-06 This volume presents an overview of Bayesian methods for inference in the wavelet domain The papers in this volume are divided into six parts The first two papers introduce basic concepts Chapters in Part II explore different approaches to prior modeling using independent priors Papers in the Part III discuss decision theoretic aspects of such prior models In Part IV some aspects of prior modeling using priors that account for dependence are explored Part V considers the use of 2 dimensional wavelet decomposition in spatial modeling Chapters in Part VI discuss the use of empirical Bayes estimation in wavelet based models Part VII concludes the volume with a discussion of case studies using wavelet based Bayesian approaches The cooperation of all contributors in the timely preparation of their manuscripts is greatly recognized We decided early on that it was impor tant to referee and critically evaluate the papers which were submitted for inclusion in this volume For this substantial task we relied on the service of numerous referees to whom we are most indebted We are also grateful to John Kimmel and the Springer Verlag referees for considering our proposal in a very timely manner Our special thanks go to our spouses Gautami and Draga for their support *Frontiers of Statistical Decision Making and Bayesian Analysis* Ming-Hui Chen,Peter Müller,Dongchu Sun,Keying Ye,Dipak K. Dey,2010-07-24 Research in Bayesian analysis and statistical decision theory is rapidly expanding and diversifying making it increasingly more difficult for any single researcher to stay up to date on all current research frontiers This book provides a review of current research challenges and opportunities While the book can not exhaustively cover all current research areas it does include some exemplary discussion of most research frontiers Topics include objective Bayesian inference shrinkage estimation and other decision based estimation model selection and testing nonparametric Bayes the interface of Bayesian and frequentist inference data mining and machine learning methods for categorical and spatio temporal data analysis and posterior simulation methods Several major application areas are covered computer models Bayesian clinical trial design epidemiology phylogenetics bioinformatics climate modeling and applications in political science finance and marketing As a review of current research in Bayesian analysis the book presents a balance between theory and applications The lack of a clear demarcation between theoretical and applied research is a reflection of the highly interdisciplinary and often applied nature of research in Bayesian statistics The book is intended as an update for researchers in Bayesian statistics including non statisticians who make use of Bayesian inference to address substantive research questions in other fields It would also be useful for graduate students and research scholars in statistics or biostatistics who wish to acquaint themselves with current research frontiers

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