THE ANNALS of STATISTICS

An Official Journal of the Institute of Mathematical Statistics

Articles

Slicing regression: A link-free regression method NAIHUA DUAN AND KER-CHAU LI Rank regression methods for left-truncated and right-censored data	505
Tze Leung Lai and Zhiliang Ying	531
Asymptotics of maximum likelihood estimators for the Curie-Weiss model Francis Comets and Basilis Gidas	557
Minimum Hellinger distance estimation of parameter in the random censorship model	579
censorship model	
WING HUNG WONG AND THOMAS A. SEVERINI Geometrizing rates of convergence, II	603 633
Geometrizing rates of convergence, IIIDavid L. Donoho and Richard C. Liu	
Rates of convergence for the estimates of the optimal transformations of variables	702
Estimating a smooth monotone regression function	724 741
Bahadur representation	760
Bootstrap simultaneous error bars for nonparametric regression W. Härdle and J. S. Marron	778
Large sample theory of estimation in biased sampling regression models. I Peter J. Bickel and J. Ritov	797
A comparison of a spline estimate to its equivalent kernel estimate K. Messer	817
Fully coherent inference	830
order restrictions with applications to balanced multivariate variance	
components models James A. Calvin and Richard L. Dykstra Statistical inference for uniform stochastic ordering in several populations	850
RICHARD DYKSTRA, SUBHASH KOCHAR AND TIM ROBERTSON	870
Anomalies of the likelihood ratio test for testing restricted hypotheses J. A. Menéndez and B. Salvador	889
Testing for spherical symmetry of a multivariate distribution LUDWIG BARINGHAUS	899
Sensitive and sturdy p-values	918
QIQING YU AND Mo-suk Chow	935
Shrinkage domination in a multivariate common mean problem Edward I. George Asymptotic theory of sequential estimation: Differential geometrical approach	952
ICHI OKAMOTO, SHUN-ICHI AMARI AND KEI TAKEUCHI Asymptotically optimal hypothesis testing with memory constraints	961
J. A. Bucklew and P. E. Ney The power and optimal kernel of the Bickel-Rosenblatt test for goodness of fit	982
B. K. Ghosh and Wei-Min Huang	999
B. K. Ghosh and Wei-Min Huang Block designs and electrical networks	1010
or optimal moments	1028
WILLEM ALBERS	1042
Empirical likelihood is Bartlett-correctable Thomas DiCiccio, Peter Hall and Joseph Romano	1053
Bahadur representations for uniform resampling and importance resampling.	
with applications to asymptotic relative efficiency Peter Hall The diffuse Kalman filter Piet de Jong	1062 1073
Short Communications	
Prediction in the worst case	1084
Some poset statistics	1091
Bootstrapping unstable first-order autoregressive processes I. V. Basawa, A. K. Mallik, W. P. McCormick, J. H. Reeves and R. L. Taylor	1098
Note on the tail behavior of general weighted empirical processes Martien C. A. van Zuijlen	
A note on Blackwell and Hodges (1957) and Diaconis and Graham (1981)	
Michael Proschan	1106

Vol. 19, No. 2—June 1991

INSTITUTE OF MATHEMATICAL STATISTICS

(Organized September 12, 1935)

The purpose of the Institute is to foster the development and dissemination of the theory and applications of statistics and probability.

OFFICERS AND EDITORS

President: David O. Siegmund, Department of Statistics, Sequoia Hall, Stanford University, Stanford, California 94305

President-Elect: Willem R. van Zwet, Department of Mathematics, University of Leiden, P.O. Box 9512, 2300 RA Leiden, The Netherlands

Past President: Shanti S. Gupta, Department of Statistics, Purdue University, West Lafayette,

Indiana 47907

Diane M. Lambert, AT&T Bell Laboratories, 600 Mountain Avenue, Room **Executive Secretary:** 2C-256, Murray Hill, New Jersey 07974

Treasurer: Jessica Utts, Division of Statistics, University of California, Davis. Please send correspondence to: IMS Business Office, 3401 Investment Boulevard #7, Hayward, California 94545

Program Secretary: Robert E. Kass, Department of Statistics, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213

Editor, The Annals of Statistics: Arthur Cohen, Department of Statistics, Busch Campus, Rutgers University, New Brunswick, New Jersey 08903

Editor, The Annals of Probability: Burgess Davis, Departments of Mathematics and Statistics, Purdue University, West Lafayette, Indiana 47907

Editor, The Annals of Applied Probability: J. Michael Steele, Department of Statistics, University of

Pennsylvania, Philadelphia, Pennsylvania 19104-6302

Executive Editor, Statistical Science: Carl N. Morris, Department of Statistics, Science Center, Harvard University, One Oxford Street, Cambridge, Massachusetts 02138

Editor, The IMS Bulletin: George P. H. Styan, Department of Mathematics and Statistics, Burnside Hall, McGill University, 805 Sherbrooke Street West, Montreal PQ, Canada H3A 2K6

Editor, The IMS Lecture Notes—Monograph Series: Robert J. Serfling, Department of Mathematical Sciences, Johns Hopkins University, Baltimore, Maryland 21218

Managing Editor: Roger L. Berger, Department of Statistics, Box 8203, North Carolina State University, Baleigh North Carolina 27695

University, Raleigh, North Carolina 27695

Managing Editor: Robert Smythe, Department of Statistics, George Washington University, 2201 G Street N.W., Washington, D.C. 20052

Journals. The scientific journals of the Institute are The Annals of Statistics, The Annals of Probability, The Annals of Applied Probability and Statistical Science. The news organ of the Institute is The Institute of Mathematical Statistics Bulletin.

Individual and Organizational Memberships. All individual members receive The IMS Bulletin for basic membership dues of \$40. Each regular member must elect to receive at least one scientific por pasic memoersing dues of \$40. Each regular member must elect to receive at least one scientific journal for an additional amount, as follows: Statistical Science (\$10), The Annals of Statistics or The Annals of Probability (\$20), The Annals of Statistics and The Annals of Probability (\$30), or The Annals of Applied Probability (\$10). Of the total dues paid, \$24 is allocated to The IMS Bulletin and the remaining amount is allocated equally among the scientific journal(s) received. Reduced membership dues are available to full-time students, permanent residents of countries designated by the IMS Council and retired members. Patiend members may pleat to receive the Bulletin and for the IMS Council. and retired members. Retired members may elect to receive the Bulletin only for \$16. Organizational memberships are available to nonprofit organizations at \$350 per year and to for-profit organizations at \$650 per year. Organizational memberships include two multiple-readership copies of all IMS journals in addition to other benefits specified for each category (details available from the IMS Business Office).

Individual and General Subscriptions. Subscriptions are available on a calendar-year basis. Individual subscriptions are for the personal use of the subscriber and must be in the name of, paid directly by, and mailed to an individual. Individual subscriptions for 1991 are available to The Annals of Statistics and The Annals of Probability (\$90), The Annals of Statistics or The Annals of Probability (\$60), Statistical Science (\$50), The Annals of Applied Probability (\$50), and The IMS Bulletin (\$30). General subscriptions are for libraries, institutions and any multiple-readership use. General subscriptions for 1991 are available to The Annals of Statistics (\$110), The Annals of Probability and The Annals of Applied Probability (\$150), Statistical Science (\$60), The Annals of Applied Probability only (\$60), and The IMS Bulletin (\$40). Multiple-item subscriptions are discounted by 10% for two items and 15% for three or more items. Air mail rates for delivery outside of North America are \$65 per title.

Permissions policy. Authorization to photocopy items for internal or personal use, or the internal or personal use of specific clients, is granted by the Institute of Mathematical Statistics, provided that the base fee of \$5.00 per copy, plus \$.00 per page is paid directly to the Copyright Clearance Center, 27 Congress Street, Salem, Massachusetts 01970. For those organizations that have been granted a photocopy license by CCC, a separate system of payment has been arranged. The fee code for users of the Transactional Reporting Service is: 0091-1798/91 \$5.00 + .00.

Correspondence. Mail to IMS should be sent to the IMS Business Office (membership, subscriptions, claims, copyright permissions, advertising, back issues), the Editor of the appropriate journal (submissions, editorial content) or the Production Editor, Patrick Kelly, Department of Statistics, University of Pennsylvania, Philadelphia, Pennsylvania 19104-6302.

The Annals of Statistics (ISSN 0090-5364), Volume 19, Number 2, June, 1991. Published quarterly by the Institute of Mathematical Statistics, 3401 Investment Boulevard #7, Hayward, California 94545. Second-class postage paid at Hayward, California and at additional mailing offices. POSTMASTER: Send address changes to The Annals of Statistics, Institute of Mathematical Statistics, 3401 Investment Boulevard #7, Hayward, California 94545.

EDITORIAL STAFF

Editor Arthur Cohen

ASSOCIATE EDITORS

James O. Berger Robert H. Berk Peter J. Bickel Lawrence D. Brown Andreas Buja Ching-Shui Cheng Linda J. Davis Morris L. Eaton David F. Findley Richard D. Gill FRIEDRICH GÖTZE
PETER HALL
LAIN M. JOHNSTONE
ESTATE V. KHMALADZE
HANS R. KÜNSCH
STEVEN LALLEY
KER-CHAU LI
BRUCE G. LINDSAY
WEI-YIN LOH
J. S. MARRON

IAN W. MCKEAGUE ROBB J. MUIRHEAD DAVID RUPPERT MARK SCHERVISH DAVID W. SCOTT DAVID O. SIEGMUND TERRY SPEED CHING-ZONG WEI MICHAEL WOODROOFE JAMES V. ZIDEK

EDITORIAL ASSISTANT APRIL ALLRIDGE

Managing Editor Roger L. Berger

PRODUCTION EDITOR PATRICK KELLY

EDITORIAL ASSISTANT ANN P. ROUSE

PAST EDITORS THE ANNALS OF MATHEMATICAL STATISTICS

H. C. Carver, 1930–1938 S. S. Wilks, 1938–1949 T. W. Anderson, 1950–1952 E. L. Lehmann, 1953–1955 T. E. Harris, 1955–1958

The Annals of Statistics Ingram Olkin, 1972–1973 I. R. Savage, 1974–1976 RUPERT G. MILLER, JR., 1977–1979 DAVID V. HINKLEY, 1980–1982 MICHAEL D. PERLMAN, 1983–1985 WILLEM R. VAN ZWET, 1986–1988 WILLIAM KRUSKAL, 1958–1961 J. L. HODGES, JR., 1961–1964 D. L. BURKHOLDER, 1964–1967 Z. W. BIRNBAUM, 1967–1970 INGRAM OLKIN, 1970–1972

The Annals of Probability Ronald Pyke, 1972–1975 Patrick Billingsley, 1976–1978 R. M. Dudley, 1979–1981 Harry Kesten, 1982–1984 Thomas M. Liggett, 1985–1987 Peter Ney, 1988–1990

EDITORIAL POLICY

The main purpose of *The Annals of Statistics*, *The Annals of Probability* and *The Annals of Applied Probability* is to publish significant contributions to the theory of statistics and probability and their applications. The emphasis is on importance and interest; formal novelty and mathematical correctness alone are not sufficient for publication. Especially appropriate are authoritative expository papers and surveys of areas in vigorous development. Because statistics is an evolving discipline, the Editors of *The Annals of Statistics* take a broad view of its domain and welcome papers in interface areas. Contributors to *The Annals of Statistics* should review the editorial in the January 1980 issue. All papers are refereed.

ADDITIONAL GUIDELINES FOR PREPARING PAPERS FOR THE ANNALS OF STATISTICS

- 1. The introduction and/or abstract should contain a statement pertaining to the statistical importance of the paper. Sometimes this is clear when reference is made to previous work. Statistical importance, not mathematical complexity for its own sake, is the prime criterion for publication.
- 2. The introduction should be thorough and contain clear yet nontechnical descriptions of the important results. Furthermore, the introduction should give a clear indication of where in the paper the main results and conclusions are to be found.
- 3. In papers where the formulation is general and mathematically abstract, when appropriate, the author should provide a short development of a special case, an example, or an illustration of the results. If possible, the special case or example should be in the introduction or shortly thereafter.
- 4. The manuscript should be proofread thoroughly before being submitted. Manuscripts with many typographical errors will cause unnecessary delays and may require resubmission.

IMS CORPORATE MEMBERS

THE AEROSPACE CORPORATION

Los Angeles, California

AT & T BELL LABORATORIES Murray Hill, New Jersey

BELL COMMUNICATIONS RESEARCH

Morristown, New Jersey

GENERAL MOTORS CORPORATION

Research Laboratories

Warren, Michigan

INTERNATIONAL BUSINESS MACHINES CORP.

Thomas J. Watson Research Center

Yorktown Heights, New York

Springer-Verlag New York Incorporated

New York, New York

IMS INSTITUTIONAL MEMBERS

ACADEMIA SINICA Inst of Statistical Science

Taipei, Taiwan

AMERICAN UNIVERSITY

Dept of Mathematics and Statistics

Washington, DC

ARIZONA STATE UNIVERSITY Committee on Statistics Dept of Mathematics and Decision and Information Systems

Tempe, Arizona

AUSTRALIAN NATIONAL UNIVERSITY

Canberra, ACT, Australia

BOWLING GREEN STATE UNIVERSITY Dept of Mathematics and Statistics

Bowling Green, Ohio

CALIFORNIA STATE UNIVERSITY

AT FULLERTON Dept of Mathematics Fullerton, California

CASE WESTERN RESERVE UNIVERSITY Dept of Mathematics and Statistics

Cleveland, Ohio

CENTRE INTERNATIONAL DE RECONTRE MATH Marseille, France

CORNELL UNIVERSITY Dept of Mathematics Ithaca, New York

DALHOUSIE UNIVERSITY Killam Memorial Library Halifax, Nova Scotia, Canada

FLORIDA STATE UNIVERSITY

Dept of Statistics Tallahassee, Florida

GEORGE WASHINGTON UNIVERSITY

Dept of Statistics Washington, DC

HARVARD UNIVERSITY Dept of Biostatistics Boston, Massachusetts

HARVARD UNIVERSITY Dept of Statistics

Cambridge, Massachusetts

Indiana University Dept of Mathematics Bloomington, Indiana

Instituto Mexicano DEL PETROLEO Mexico, DF, Mexico

IOWA STATE UNIVERSITY Dept of Stat and Statistical Lab

Ames, Iowa

JOHNS HOPKINS UNIVERSITY

Depts of Biostatistics

and Mathematical Sciences

Baltimore, Maryland

Kansas State University

Dept of Statistics Manhattan, Kansas

MARA INSTITUTE OF TECHNOLOGY

Selangor, Malaysia

Massachusetts Institute of Technology

Dept of Mathematics Cambridge, Massachusetts

MIAMI UNIVERSITY LIBRARY

Oxford, Ohio

MICHIGAN STATE UNIVERSITY Dept of Statistics and Probability

East Lansing, Michigan

NATIONAL SECURITY AGENCY Fort George G. Meade, Maryland

New Mexico State University Dept of Mathematical Sciences Las Cruces, New Mexico

NORTH CAROLINA STATE UNIVERSITY

Dept of Statistics

Raleigh, North Carolina

NORTH DAKOTA STATE UNIVERSITY LIBRARY

Fargo, North Dakota

NORTHERN ILLINOIS UNIVERSITY Dept of Mathematical Sciences

DeKalb, Illinois

OHIO STATE UNIVERSITY

Dept of Statistics Columbus, Ohio

OREGON STATE UNIVERSITY

Dept of Statistics Corvallis, Oregon

PENNSYLVANIA STATE UNIVERSITY

Dept of Statistics

University Park, Pennsylvania

PRINCETON UNIVERSITY LIBRARY

Princeton, New Jersey

PURDUE UNIVERSITY LIBRARY West Lafayette, Indiana

QUEEN'S UNIVERSITY

Dept of Mathematics and Statistics

Kingston, Ontario, Canada

RICE UNIVERSITY LIBRARY

Houston, Texas

THE ROCKEFELLER UNIVERSITY LIBRARY

New York, New York

SIMON FRASER UNIVERSITY Dept of Mathematics and Statistics Burnaby, British Columbia, Canada

SOUTHERN ILLINOIS UNIVERSITY Dept of Mathematics and Statistics Edwardsville, Illinois

SOUTHERN METHODIST UNIVERSITY Dept of Statistics

Dept of Statistics Dallas, Texas

STANFORD UNIVERSITY Dept of Statistics Stanford, California

SYRACUSE UNIVERSITY Bird Library Syracuse, New York

TEMPLE UNIVERSITY Dept of Mathematics Philadelphia, Pennsylvania

TEXAS TECH UNIVERSITY Dept of Mathematics Lubbock, Texas

University of Alberta Dept of Statistics

and Applied Probability Edmonton, Alberta, Canada

UNIVERSITY OF ARIZONA Dept of Mathematics Tucson, Arizona

UNIVERSITY OF BRITISH COLUMBIA Dept of Statistics Vancouver, British Columbia, Canada

UNIVERSITY OF CALGARY Dept of Mathematics and Statistics Calgary, Alberta, Canada

UNIVERSITY OF CALIFORNIA Dept of Statistics Berkeley, California

University of California Div of Statistics Davis, California

University of Connecticut Dept of Statistics

Storrs, Connecticut
UNIVERSITY OF FLORIDA
Dept of Statistics

Gainesville, Florida

University of Georgia Dept of Statistics Athens, Georgia

University of Illinois Dept of Statistics Champaign, Illinois

UNIVERSITY OF ILLINOIS AT CHICAGO Dept of Math, Stat, and Comp Sci Chicago, Illinois

University of Iowa

Dept of Statistics and Acturial Sci Iowa City, Iowa

University of Maryland

Dept of Mathematics College Park, Maryland

UNIVERSITY OF MASSACHUSETTS Dept of Mathematics and Statistics Amherst, Massachusetts UNIVERSITY OF MICHIGAN Dept of Statistics Ann Arbor, Michigan

University of Minnesota School of Statistics Minneapolis, Minnesota

University of Montreal Dept of Mathematics Montreal, Quebec, Canada

UNIVERSITY OF NEBRASKA Dept of Mathematics and Statistics Lincoln, Nebraska

University of New Brunswick Library Fredericton, New Brunswick, Canada

UNIVERSITY OF NEW MEXICO Dept of Mathematics and Statistics Albuquerque, New Mexico

University of North Carolina

Dept of Statistics

Chapel Hill, North Carolina

University of Oregon Dept of Mathematics Eugene, Oregon

UNIVERSITY OF OTTAWA Dept of Mathematics Ottawa, Ontario, Canada

University of Pennsylvania Dept of Statistics Philadelphia, Pennsylvania

University of South Carolina

Dept of Statistics

Columbia, South Carolina

University of Stockholm Inst of Actuarial Math and Math Stat

Stockholm, Sweden

University of Texas at Austin Dept of Mathematics

Austin, Texas

UNIVERSITY OF TEXAS AT SAN ANTONIO Div of Math, Comp Sci, and Systems Design San Antonio, Texas

UNIVERSITY OF VICTORIA Dept of Mathematics

Victoria, British Columbia, Canada

UNIVERSITY OF VIRGINIA Dept of Mathematics Charlottesville, Virginia

University of Washington Dept of Statistics

Seattle, Washington

UNIVERSITY OF WATERLOO Dept of Statistics and Actuarial Sci Waterloo, Ontario, Canada

VIRGINIA COMMONWEALTH UNIVERSITY Dept of Mathematical Sciences

Richmond, Virginia

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Dept of Statistics Blacksburg, Virginia

WAYNE STATE UNIVERSITY Dept of Mathematics Detroit, Michigan

YORK UNIVERSITY Dept of Mathematics Downsview, Ontario, Canada

THE ANNALS OF STATISTICS

INSTRUCTIONS FOR AUTHORS

Submission of Papers. Papers to be submitted for publication should be sent to the Editor of *The Annals of Statistics*. (For current address, see the latest issue of the *Annals*.) Four copies should be submitted on paper that will take ink corrections. The manuscript will *not* normally be returned to the author; when expressly requested by the author, one copy of the manuscript will be returned. All manuscripts should be accompanied by a cover letter.

Preparation of Manuscripts. Manuscripts should be typewritten, entirely double-spaced, including references, with wide margins at sides, top and bottom. All copies must be completely legible. When technical reports are submitted, all extraneous sheets and covers must be removed. Typists should check an issue of the Annals for style.

Submission of Reference Papers. Four copies of unpublished or not easily available papers cited in the manuscript should be submitted with the manuscript.

Title. The title should be descriptive and as concise as is feasible, i.e., it should indicate the topic of the paper as clearly as possible, but every word in it should be pertinent.

Abbreviated Title. An abbreviated title to be used as a running head is also required. This should normally not exceed 35 characters. For example, an article with the title "The Curvature of a Statistical Model, with Applications to Large-Sample Likelihood Methods," could have the running head, "Curvature of Statistical Model" or possibly "Asymptotics of Likelihood Methods," depending on the emphasis to be conveyed.

Affiliation. Indicate your present institutional affiliation as you would like it to appear.

Summary. Each manuscript is required to contain a summary, clearly separated from the rest of the paper, which will be printed immediately after the title. Its main purpose is to inform the reader quickly of the nature and results of the paper; it may also be used as an aid in retrieving information. The length of a summary will clearly depend on the length and difficulty of the paper, but in general it should not exceed 150 words. Formulas should be used as sparingly as possible within the summary. The summary should rot make reference to results or formulas in the body of the paper—it should be self-contained.

Footnotes. Footnotes should not be used, except as described under Title Page Footnotes below. Such information should be included within the text.

Title Page Footnotes. Included as a footnote on page 1 should be the headings:

American Mathematical Society 1980 subject classifications. Primary—; secondary—.
Key words and phrases.

The classification numbers representing the primary and secondary subjects of the article may be found with instructions for its use in the *Mathematical Reviews Annual Subject Index*-1980. The key words and phrases should describe the subject matter of the article; generally they should be taken from the body of the paper.

Acknowledgment of support. Grants and contracts should also be included in this footnote.

Identification of Symbols. Manuscripts for publication should be clearly prepared to insure that all symbols are properly identified. Distinguish between "oh" and "zero"; "ell" and "one"; "epsilon" and "element of"; "summation" and "capital sigma," etc. Indicate also when special type is required (Greek, German, script, boldface, etc.); unless indicated otherwise, formula letters will be set in italics. Acronyms should be introduced sparingly. Any handwritten symbols should be clearly identified.

Figures and Tables. Figures, charts, and diagrams should be prepared in a form suitable for photographic reproduction and should be professionally drawn twice the size they are to be printed. (These need not be submitted until the paper has been accepted for publication.) The printer does not improve upon the quality of the figures submitted. Tables should be typed on separate pages with accompanying footnotes immediately below the table.

Formulas. Fractions in the text are preferably written with the solidus or negative exponent; thus,

$$(a+b)/(c+d)$$
 is preferred to $\frac{a+b}{c+d}$, and $(2\pi)^{-1}$

or
$$1/(2\pi)$$
 to $\frac{1}{2\pi}.$ Also, $a^{b(c)}$ and $a_{b(c)}$ are preferred

to a^{b_c} and a_{b_c} , respectively. Complicated exponentials should be represented with the symbol exp. A fractional exponent is preferable to a radical sign.

References. References should be typed double-spaced and should follow the style:

Kiefer, J. C. (1976). Admissibility of conditional confidence procedures. *Ann. Statist.* 4 836–865.

In textual material, the format "... Keifer (1976)..." should be used. Multiple references can be distinguished as "... Kiefer (1976a)...". Abbreviations for journals should be taken from a current index issue of *Mathematical Reviews*.

Addresses. The permanent address of each author should be typed following the references.

Galley Proofs. The author will ordinarily receive galley proofs. Corrected galley proofs should be sent to AOS Redactory, Science Typographers, Inc., 15 Industrial Boulevard, Medford, NY 11763.

Correspondence. All correspondence with the Editor must refer to the manuscript number of the paper. This number will be on the card sent to the author acknowledging receipt of the article.