

THE ANNALS of STATISTICS

AN OFFICIAL JOURNAL OF
THE INSTITUTE OF MATHEMATICAL STATISTICS

Memorial Article

William Gemmell Cochran 1909-1980 G. S. WATSON 1

Special Invited Paper

A review of selected topics in multivariate probability inequalities MORRIS L. EATON 11

Articles

- Asymptotic lognormality of P -values DIANE LAMBERT AND W. J. HALL 44
- Natural exponential families with quadratic variance functions CARL N. MORRIS 65
- Selecting a minimax estimator of a multivariate normal mean JAMES O. BERGER 81
- Simultaneous estimation of several Poisson parameters under k -normalized squared error loss KAM-WAH TSUI AND S. JAMES PRESS 93
- Piecewise exponential models for survival data with covariates MICHAEL FRIEDMAN 101
- Diagnostic tests for multiple time series models D. S. POSKITT AND A. R. TREMAYNE 114
- The evaluation of certain quadratic forms occurring in autoregressive model fitting R. J. BHANSALI 121
- A central limit theorem for stationary processes and the parameter estimation of linear processes YUZO HOSOYA AND MASANOBU TANIGUCHI 132
- Least squares estimates in stochastic regression models with applications to identification and control of dynamic systems TZE LEUNG LAI AND CHING ZONG WEI 154
- Sequential estimation through estimating equations in the nuisance parameter case PEDRO E. FERREIRA 167
- Contamination distributions MICHAEL GOLDSTEIN 174
- De Finetti's theorem for symmetric location families DAVID FREEDMAN AND PERSI DIACONIS 184
- Confidence intervals for the coverage of low coverage samples WARREN W. ESTY 190
- Nonparametric interval and point prediction using data trimmed by a Grubbs-type outlier rule RONALD W. BUTLER 197
- Qualitative robustness of rank tests HELMUT RIEDER 205
- Estimated sampling distributions: the bootstrap and competitors RUDOLF BERAN 212
- Binary experiments, minimax tests and 2-alternating capacities TADEUSZ BEDNARSKI 226
- On the limiting distribution of and critical values for the multivariate Cramér-Von Mises statistic DEREK S. COTTERILL AND MIKLÓS CSÖRGO 233
- Admissibility in linear estimation LYNN ROY LAMOTTE 245
- Maximum likelihood and least squares estimation in linear and affine functional models C. VILLEGAS 256
- Combining independent noncentral Chi squared or F tests JOHN I. MARDEN 266
- Monotone regression estimates for grouped observations F. T. WRIGHT 278
- Asymptotic distributions of slope-of-greatest-convex-minorant estimators SUE LEURGANS 287

Short Communications

- An inequality comparing sums and maxima with application to Behrens-Fisher type problem SIDDHARTHA R. DALAL AND PETER FORTINI 297
- Bounds on mixtures of distributions arising in order restricted inference TIM ROBERTSON AND F. T. WRIGHT 302
- Invariance principles for recursive residuals PRANAB KUMAR SEN 307
- Covariance stabilizing transformations and a conjecture of Holland C. C. SONG 313
- The consistency of nonlinear regression minimizing the L_1 -norm WALTER OBERHOFER 316

Notes and Corrections

- Correction to "Uniform asymptotic normality of the maximum likelihood estimator" T. J. SWEETING 320
- Correction to "Properties of Student's t and of the Behrens-Fisher solution to the two means problem" G. K. ROBINSON 321
- Correction to "Simultaneous confidence bounds" CHARLES H. ALEXANDER 321

Vol. 10, No. 1—March 1982

THE INSTITUTE OF MATHEMATICAL STATISTICS

(Organized September 12, 1935)

The purpose of the Institute of Mathematical Statistics is to encourage the development, dissemination, and application of mathematical statistics.

OFFICERS

President:

Mark Kac, Rockefeller University, New York, New York 10021

President-Elect:

Patrick Billingsley, Department of Statistics, University of Chicago, Chicago, Illinois 60637

Past President:

Peter Bickel, Department of Statistics, University of California, Berkeley, California 94720

Executive Secretary:

Kjell Doksum, Department of Statistics, University of California, Berkeley, California 94720

Treasurer:

Heebok Park, Department of Statistics, California State University, Hayward, California 94542
IMS Business Office, 3401 Investment Blvd., Suite 6, Hayward, California 94545

Program Secretary:

Richard Johnson, Department of Statistics, University of Wisconsin, 1210 West Dayton St., Madison, Wisconsin 53706

Editor: *Annals of Statistics*

David V. Hinkley, Department of Applied Statistics, University of Minnesota, St. Paul Campus, St. Paul, Minnesota 55108

Editor: *Annals of Probability*

Richard M. Dudley, Department of Mathematics Room 2-245, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

Managing Editor:

Jagdish S. Rustagi, Department of Statistics, The Ohio State University, Columbus, Ohio 43210

Membership. Membership dues including a subscription to one *Annals* and *The Institute of Mathematical Statistics Bulletin* are \$37.00 per year for all members. Special rates of \$17.00 per year are available to students. The dues are approximately twenty five percent higher for members who wish both *Annals* as well as the *Bulletin*. Inquiries regarding membership in the Institute should be sent to the Treasurer at the Business Office.

Subscription Rates. Current volumes (four issues per calendar year) of the *Annals of Probability* are \$48.00. Single issues are \$13.00 each. Current volumes (four issues per calendar year) of the *Annals of Statistics* are \$55.00. Single issues are \$15.00 each. Members of the Institute of Mathematical Statistics pay different rates (see above). Back numbers of both *Annals* and the *Annals of Mathematical Statistics* (Volume 1 through 43) may be purchased from the Treasurer.

The Annals of Statistics. Volume 10, Number 1, March 1982. Published in March, June, September, and December by The Institute of Mathematical Statistics, IMS Business Office, 3401 Investment Blvd., Suite 6, Hayward, California 94545.

Mail to the *Annals of Statistics* should be addressed to either the Editor, Managing Editor or the Treasurer, as described above. It should not be addressed to Waverly Press.

PRINTED AT THE
WAVERLY PRESS, INC., BALTIMORE, MARYLAND 21202 U.S.A.

Second-class postage paid at Hayward, California and at additional mailing offices

Copyright © 1982 by the Institute of Mathematical Statistics

NOTICE

Beginning with the calendar year 1982, the two journals of The Institute of Mathematical Statistics will be printed quarterly. The total numbers of pages per volume will be approximately the same as before. Months of publication for 1982 are as follows.

Annals of Statistics: March, June, September and December

Annals of Probability: February, May, August and November

EDITORIAL STAFF

EDITOR

DAVID V. HINKLEY

ASSOCIATE EDITORS

RUDOLPH J. BERAN
JAMES O. BERGER
DONALD A. BERRY
A. PHILIP DAWID
MORRIS L. EATON

JOHN D. KALBFLEISCH
BARRY H. MARGOLIN
CARL N. MORRIS
DONALD A. PIERCE
JOHN RICE

BRIAN D. RIPLEY
DAVID O. SIEGMUND
WILLIAM E. STRAWDERMAN
WILLIAM D. SUDDERTH
CHIEN-FU WU

EDITORIAL ASSISTANT
DAVID LARAWAY

MANAGING EDITOR
JAGDISH S. RUSTAGI

EDITORIAL ASSISTANTS

DOROTHY GARVIN TONJES

LINDALEE W. BROWNSTEIN

PAST EDITORS

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

WILLIAM KRUSKAL, 1958-1961
J. L. HODGES, JR., 1961-1964
D. L. BURKHOLDER, 1964-1967
Z. W. BIRNBAUM, 1967-1970
INGRAM OLKIN, 1970-1972

ANNALS OF STATISTICS

INGRAM OLKIN, 1972-1973
I. R. SAVAGE, 1974-1976
RUPERT G. MILLER, JR., 1977-1979

ANNALS OF PROBABILITY

RONALD PYKE, 1972-1975
PATRICK BILLINGSLEY, 1976-1978
R. M. DUDLEY, 1979-1981

EDITORIAL POLICY

The main purpose of the *Annals of Statistics* and the *Annals of Probability* is to publish contributions to the theory of statistics and probability and to their applications. The emphasis is on importance and interest, not formal novelty and correctness. Especially appropriate are authoritative expository papers and surveys of areas in vigorous development. All papers are refereed.

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*.) The original (or xerox copy) should be submitted with three additional copies 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.

Preparation of Manuscripts. Manuscripts should be typewritten, entirely double-spaced, including references, with wide margins at sides, top and bottom. Dittoed or mimeographed papers are acceptable only if completely legible; xerox copies are preferable. When technical reports are submitted, all extraneous sheets and covers should be removed.

Submission of Reference Papers. Copies (preferably two) of unpublished or not easily available papers cited in the manuscript should be submitted with the manuscript.

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

Summary. Each manuscript is required to contain a summary, which will be printed immediately after the title, clearly separated from the rest of the paper. 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. It should be typed on a separate page, under the heading "Summary," followed by the title of the paper. Formulas should be used as sparingly as possible. The summary should not make reference to results or formulas in the body of the paper—it should be self-contained.

Footnotes. Footnotes should be reduced to a minimum and, where possible, should be replaced by remarks in the text or in the references; formulas in footnotes should be avoided. Footnotes in the text should be identified by superscript numbers and typed together, double-spaced, on a separate page.

Key Words. Included as the first footnote on page 1 should be the headings:

American Mathematical Society 1970 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, as an Appendix to *Mathematical Reviews* Index to Volume 39, June 1970. (See also, *The Notices of the American Mathematical Society*, June 1970, *Bulletin of the Institute of Mathematical Statistics*, September 1974; or a current index issue of *Mathematical Reviews*.) The key words and phrases should describe the subject matter of the article; generally they should be taken from the body of the paper.

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"; "kappa" and "kay," etc. Indicate also when special type is required (Greek, German, script, bold-face, etc.); other letters will be set in italics. Acronyms should be introduced sparingly.

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.) 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:

Wilks, S.S. (1938). The large-sample distribution of the likelihood ratio for testing composite hypotheses. *Ann. Statist.* 1 60–62.

In textual material, the format "... Wilks (1938) ..." should be used. Multiple references can be distinguished as "... Wilks (1938a) ..." Abbreviations for journals should be taken from a current index issue of *Mathematical Reviews*.

Proofs. Author will ordinarily receive galley proofs. Corrected galley proofs should be sent to the Managing Editor of the *Annals of Statistics*. (For current address, see the latest issue of the *Annals*.)

IMS INSTITUTIONAL MEMBERS

- AEROSPACE CORPORATION**
El Segundo, California
- ARIZONA STATE UNIVERSITY**
Tempe, Arizona
- BELL TELEPHONE LABORATORIES, TECHNICAL LIBRARY**
Murray Hill, N.J.
- BOWLING GREEN STATE UNIVERSITY, DEPT. OF MATHEMATICS**
Bowling Green, Ohio
- CALIFORNIA STATE UNIVERSITY, FULLERTON, DEPARTMENT OF MATHEMATICS**
Fullerton, California
- CALIFORNIA STATE UNIVERSITY, HAYWARD, DEPARTMENT OF STATISTICS**
Hayward, California
- CASE WESTERN RESERVE UNIVERSITY, DEPARTMENT OF MATHEMATICS**
Cleveland, Ohio
- CORNELL UNIVERSITY, DEPARTMENT OF MATHEMATICS**
Ithaca, New York
- FLORIDA STATE UNIVERSITY, DEPARTMENT OF STATISTICS**
Tallahassee, Florida
- GENERAL MOTORS CORPORATION, RESEARCH LABORATORIES**
Warren, Michigan
- GEORGE WASHINGTON UNIVERSITY, DEPARTMENT OF STATISTICS**
Washington, D.C.
- INDIANA UNIVERSITY, MATHEMATICS DEPT.**
Bloomington, Indiana
- INTERNATIONAL BUSINESS MACHINES CORPORATION**
Armonk, New York
- IOWA STATE UNIVERSITY, STATISTICAL LABORATORY**
Ames, Iowa
- JOHNS HOPKINS UNIVERSITY, DEPARTMENT OF BIostatISTICS, DEPARTMENT OF MATHEMATICAL SCIENCES**
Baltimore, Maryland
- KANSAS STATE UNIVERSITY, STATISTICS DEPARTMENT**
Manhattan, Kansas
- MARQUETTE UNIVERSITY, MATHEMATICS AND STATISTICS DEPARTMENT**
Milwaukee, Wisconsin
- MASSACHUSETTS INSTITUTE OF TECHNOLOGY MATHEMATICS DEPARTMENT**
Cambridge, Massachusetts
- MIAMI UNIVERSITY, DEPARTMENT OF MATHEMATICS**
Oxford, Ohio
- MICHIGAN STATE UNIVERSITY, DEPARTMENT OF STATISTICS AND PROBABILITY**
East Lansing, Michigan
- NATIONAL SECURITY AGENCY**
Fort George G. Meade, Maryland
- NEW MEXICO STATE UNIVERSITY, DEPARTMENT OF MATHEMATICAL SCIENCES**
Las Cruces, New Mexico
- NORTHERN ILLINOIS UNIVERSITY, DEPARTMENT OF MATHEMATICAL SCIENCES**
De Kalb, Illinois
- NORTHWESTERN UNIVERSITY, DEPARTMENT OF MATHEMATICS**
Evanston, Illinois
- OHIO STATE UNIVERSITY, DEPARTMENT OF STATISTICS**
Columbus, Ohio
- OREGON STATE UNIVERSITY, DEPARTMENT OF STATISTICS**
Corvallis, Oregon
- PENNSYLVANIA STATE UNIVERSITY, DEPARTMENT OF STATISTICS**
University Park, Pennsylvania
- PRINCETON UNIVERSITY, DEPARTMENT OF STATISTICS**
Princeton, New Jersey
- PURDUE UNIVERSITY LIBRARIES**
Lafayette, Indiana
- QUEEN'S UNIVERSITY, DEPT. OF MATHEMATICS AND STATISTICS**
Kingston, Ontario, Canada
- RICE UNIVERSITY, DEPARTMENT OF MATHEMATICAL SCIENCES**
Houston, Texas
- THE ROCKEFELLER UNIVERSITY**
New York, New York
- SANDIA CORPORATION, SANDIA BASE**
Albuquerque, New Mexico
- SIMON FRASER UNIVERSITY, MATHEMATICS DEPARTMENT**
Burnaby, Canada
- SOUTHERN ILLINOIS UNIVERSITY, MATHEMATICAL STUDIES**
Edwardsville, Illinois
- SOUTHERN METHODIST UNIVERSITY, DEPARTMENT OF STATISTICS**
Dallas, Texas
- STANFORD UNIVERSITY, GIRSHICK MEMORIAL LIBRARY**
Stanford, California
- STATE UNIVERSITY OF NEW YORK, BUFFALO, DEPARTMENT OF STATISTICS**
Amherst, New York
- TEMPLE UNIVERSITY, MATHEMATICS DEPARTMENT**
Philadelphia, Pa
- TEXAS TECH UNIVERSITY, DEPARTMENT OF MATHEMATICS**
Lubbock, Texas 79409

- THE TOBACCO INSTITUTE**
Washington, D.C.
- UNION OIL COMPANY OF CALIFORNIA, UNION RESEARCH CENTER**
Brea, California
- UNIVERSITY OF ALBERTA, DEPARTMENT OF MATHEMATICS**
Edmonton, Alberta, Canada
- UNIVERSITY OF ARIZONA, DEPARTMENT OF MATHEMATICS AND COMMITTEE ON STATISTICS**
Tucson, Arizona
- UNIVERSITY OF BRITISH COLUMBIA, DEPARTMENT OF MATHEMATICS**
Vancouver, B.C., Canada
- UNIVERSITY OF CALGARY, MATHEMATICS DEPARTMENT**
Calgary 44, Alberta, Canada
- UNIVERSITY OF CALIFORNIA, BERKELEY, STATISTICAL LABORATORY**
Berkeley, California
- UNIVERSITY OF CALIFORNIA, DAVIS, DIVISION OF STATISTICS**
Davis, California
- UNIVERSITY OF CINCINNATI, DEPARTMENT OF MATHEMATICAL SCIENCES**
Cincinnati, Ohio
- UNIVERSITY OF GUELPH, MATHEMATICS AND STATISTICS DEPARTMENT**
Guelph, Ontario, Canada
- UNIVERSITY OF ILLINOIS AT CHICAGO CIRCLE, DEPARTMENT OF MATHEMATICS**
Chicago, Illinois
- UNIVERSITY OF ILLINOIS, MATHEMATICS DEPT.**
Urbana, Illinois
- UNIVERSITY OF IOWA, DIVISION OF MATHEMATICAL SCIENCES**
Iowa City, Iowa
- UNIVERSITY OF MANITOBA, DEPARTMENT OF STATISTICS**
Winnipeg, Manitoba, Canada
- UNIVERSITY OF MARYLAND, DEPARTMENT OF MATHEMATICS**
College Park, Maryland
- UNIVERSITY OF MICHIGAN, DEPARTMENT OF STATISTICS**
Ann Arbor, Michigan
- UNIVERSITY OF MINNESOTA, SCHOOL OF STATISTICS**
Minneapolis, Minnesota
- UNIVERSITY OF MISSOURI, DEPARTMENT OF STATISTICS**
Columbia, Missouri
- UNIVERSITY OF MISSOURI AT ROLLA, DEPARTMENT OF MATHEMATICS**
Rolla, Missouri
- UNIVERSITY OF MONTREAL, DEPARTMENT OF MATHEMATICS**
Montreal, Quebec, Canada
- UNIVERSITY OF NEBRASKA, MATHEMATICS AND STATISTICS DEPARTMENT**
Lincoln, Nebraska
- UNIVERSITY OF NEW MEXICO, DEPARTMENT OF MATHEMATICS AND STATISTICS**
Albuquerque, New Mexico
- UNIVERSITY OF NORTH CAROLINA, DEPARTMENT OF STATISTICS**
Chapel Hill, North Carolina
- UNIVERSITY OF OREGON, MATHEMATICS DEPARTMENT**
Eugene, Oregon
- UNIVERSITY OF OTTAWA, DEPARTMENT OF MATHEMATICS**
Ottawa, Ontario, Canada
- UNIVERSITY OF SOUTH CAROLINA, DEPARTMENT OF MATHEMATICS AND COMPUTER SCIENCE**
Columbia, South Carolina
- UNIVERSITY OF TEXAS, DEPARTMENT OF MATHEMATICS**
Austin, Texas
- UNIVERSITY OF TEXAS, MATHEMATICS DEPT.**
San Antonio, Texas
- UNIVERSITY OF VICTORIA, DEPT. OF MATHEMATICS**
Victoria, British Columbia, Canada
- UNIVERSITY OF VIRGINIA, DEPT. OF MATHEMATICS**
Charlottesville, Virginia
- UNIVERSITY OF WASHINGTON, DEPARTMENT OF MATHEMATICS**
Seattle, Washington
- UNIVERSITY OF WATERLOO, STATISTICS DEPARTMENT**
Waterloo, Ont., Canada
- UNIVERSITY OF WISCONSIN, MADISON, DEPARTMENT OF STATISTICS**
Madison, Wisconsin
- UNIVERSITY OF WISCONSIN, MILWAUKEE, DEPARTMENT OF MATHEMATICS**
Milwaukee, Wisconsin
- VIRGINIA COMMONWEALTH UNIVERSITY, DEPARTMENT OF MATHEMATICAL SCIENCES**
Richmond, Virginia
- WAYNE STATE UNIVERSITY, DEPARTMENT OF MATHEMATICS**
Detroit, Michigan
- WESTINGHOUSE ELECTRIC CORPORATION, RESEARCH LABORATORIES**
Pittsburgh, Pennsylvania