

# THE ANNALS of STATISTICS

ISSN (0090-5364)

AN OFFICIAL JOURNAL OF THE  
INSTITUTE OF MATHEMATICAL STATISTICS

## Special Invited Paper

Prediction and design . . . . . DONALD YLVIASAKER 1

## Articles

The trimmed mean in the linear model . . . . .	A. H. WELSH	20
Discussion . . . . .	P. J. DE JONGH AND T. DE WET	36
Discussion . . . . .	ROGER KOENKER	39
Rejoinder . . . . .	A. H. WELSH	44
Asymptotic distributions of prediction errors and related tests of fit for nonstationary processes . . . . .	I. V. BASAWA	46 <sup>o</sup>
A sieve estimator for the mean of a Gaussian process . . . . .	JAY H. BEDER	59
Regression models for nonstationary categorical time series: Asymptotic estimation theory . . . . .	HEINZ KAUFMANN	79
Robust spectral regression . . . . .	ALEXANDER M. SAMAROV	99
On adaptive estimation in stationary ARMA processes . . . . .	JENS-PETER KREISS	112
Limiting behavior of functionals of higher-order sample cumulant spectra DANIEL MACRAE KEENAN		134
A comparison of cross-validation techniques in density estimation . . . . .	J. S. MARRON	152
On the amount of noise inherent in bandwidth selection for a kernel density estimator . . . . .	PETER HALL AND J. S. MARRON	163
Variable bandwidth kernel estimators of regression curves HANS-GEORG MÜLLER AND ULRICH STADTMÜLLER		182
$k$ -statistics and dispersion effects in regression PETER McCULLAGH AND DARYL PREGIBON		202
The limiting distribution of least squares in an errors-in-variables regression model . . . . .	LEON JAY GLEESER, RAYMOND J. CARROLL AND PAUL P. GALLO	220
A distribution-free $M$ -estimator of multivariate scatter . . . . .	DAVID E. TYLER	234
Admissibility as a touchstone . . . . .	AVI MANDELBAUM AND L. A. SHEPP	252
Using the stepwise Bayes technique to choose between experiments REDA MAZLOUM AND GLEN MEEDEN		269
Asymptotic expansions in Anscombe's theorem for repeated significance tests and estimation after sequential testing . . . . .	HAJIME TAKAHASHI	278
Sample size savings for curtailed one-sample nonparametric tests for location shift . . . . .	NIRA HERRMANN AND TED H. SZATROWSKI	296
Standardized log-likelihood ratio statistics for mixtures of discrete and continuous observations . . . . .	J. L. JENSEN	314
An extension of partial likelihood methods for proportional hazard models to general transformation models . . . . .	KJELL A. DOKSUM	325
Confidence regions in curved exponential families: Application to matched case-control and survival studies with general relative risk function . . . . .	SURESH H. MOOLGAVKAR AND DAVID J. VENZON	346
A large sample study of the Bayesian bootstrap . . . . .	ALBERT Y. LO	360
A comparison of classes of single replicate factorial designs . . . . .	D. T. VOSS AND A. M. DEAN	376
On simple adjustments to chi-square tests with sample survey data J. N. K. RAO AND A. J. SCOTT		385
On the effect of substituting parameter estimators in limiting $\chi^2$ $U$ and $V$ statistics . . . . .	TERTIUS DE WET AND RONALD H. RANGLES	398

## Short Communications

The asymptotic equivalence of some modified Shapiro-Wilk statistics— complete and censored sample cases . . . . .	STEVE VERRILL AND RICHARD A. JOHNSON	413
On testing whether new is better than used using randomly censored data YOSHIKI KUMAZAWA		420

*continues on back cover*

Vol. 15, No. 1—March 1987



# 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 AND EDITORS

### President:

Ronald Pyke, Department of Mathematics GN-50, University of Washington, Seattle, Washington 98195

### President-Elect:

Bradley Efron, Department of Statistics, Sequoia Hall, Stanford University, Stanford, California 94305

### Past President:

Paul Meier, Department of Statistics, University of Chicago, 5734 University Avenue, Chicago, Illinois 60637

### Executive Secretary:

Francisco J. Samaniego, Division of Statistics, 469 Kerr Hall, University of California, Davis, California 95616

### Treasurer:

Nicholas P. Jewell, Group in Biostatistics, University of California, Berkeley. *Please send correspondence to:* IMS Business Office, 3401 Investment Boulevard #7, Hayward, California 94545

### Program Secretary:

Lynne Billard, Department of Statistics, University of Georgia, Athens, Georgia 30602

### Editor: *The Annals of Statistics*

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

### Editor: *The Annals of Probability*

Thomas M. Liggett, Department of Mathematics, University of California, Los Angeles, California 90024

### Executive Editor: *Statistical Science*

Morris H. DeGroot, Department of Statistics, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213

### 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*

Shanti S. Gupta, Department of Statistics, Purdue University, West Lafayette, Indiana 47907

### Managing Editor:

Paul Shaman, Department of Statistics, University of Pennsylvania, Philadelphia, Pennsylvania 19104

---

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

**Individual, Institutional, and Corporate Memberships.** All *individual members* receive *Statistical Science* and *The IMS Bulletin* for a basic annual dues rate of \$30. Individual members may elect to receive one *Annals* for an additional \$10 or both *Annals* for an additional \$20. Dues allocations to each journal are set by Council resolution. Of the total dues paid, \$8 is allocated to *The IMS Bulletin* and the remaining amount is allocated equally among the scientific journals received. Memberships are available at a reduced rate (40% of regular rates) for full-time students, permanent residents of developing countries, and retired members. Retired members may also elect to receive the *Bulletin* only for \$10. *Institutional memberships* are available to nonprofit organizations at \$230 per year and *corporate memberships* are available to other organizations at \$500 per year. Institutional and corporate 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. For 1987, all subscriptions to one or both *Annals* automatically include one subscription to *Statistical Science*. *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 1987 are available to both *Annals* and *Statistical Science* (\$79), one *Annals* and *Statistical Science* (\$52), *Statistical Science* only (\$25), and *The IMS Bulletin* (\$15). *General subscriptions* are for libraries, institutions, and any multiple-readership use. General subscriptions for 1987 are available to both *Annals* and *Statistical Science* (\$160), one *Annals* and *Statistical Science* (\$85), *Statistical Science* only (\$40), and *The IMS Bulletin* (\$20). Air mail rates for overseas delivery of general subscriptions are \$40 per title.

**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 Managing Editor (production).

*The Annals of Statistics* (ISSN 0090-5364), Volume 15, Number 1, March 1987. Published in March, June, September, and December 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

WILLEM R. VAN ZWET

ASSOCIATE EDITORS

JAMES O. BERGER  
PETER J. BICKEL  
LAWRENCE D. BROWN  
RAYMOND J. CARROLL  
CHING-SHUI CHENG  
DENNIS D. COX  
SÁNDOR CSÖRGŐ  
MORRIS L. EATON

DAVID F. FINDLEY  
RICHARD D. GILL  
FRIEDRICH GÖTZE  
PETER HALL  
R. Z. HASMINSKII  
IAIN JOHNSTONE  
NIELS KEIDING  
STEFFEN L. LAURITZEN  
BRUCE G. LINDSAY

ROBB J. MUIRHEAD  
RICHARD A. OLSHEN  
DAVID POLLARD  
DAVID O. SIEGMUND  
A. F. M. SMITH  
TERRY SPEED  
JON A. WELLNER  
MICHAEL WOODROOFE

EDITORIAL ASSISTANT

LUCIE W. VAN ZWET

---

MANAGING EDITOR

PAUL SHAMAN

EDITORIAL ASSISTANT

TAMMY MORROW

---

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

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 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

THE ANNALS OF PROBABILITY

RONALD PYKE, 1972–1975  
PATRICK BILLINGSLEY, 1976–1978  
R. M. DUDLEY, 1979–1981  
HARRY KESTEN, 1982–1984

---

## EDITORIAL POLICY

The main purpose of *The Annals of Statistics* and *The Annals of 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.

---

## NOTICE

Manuscripts submitted for *The Annals of Statistics* should be sent to the Editor at the following address:

Willem R. van Zwet  
Department of Mathematics  
University of Leiden  
P. O. Box 9512  
2300 RA Leiden  
The Netherlands

## 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

UNION OIL COMPANY OF CALIFORNIA  
Brea, California

## IMS INSTITUTIONAL MEMBERS

ACADEMIA SINICA  
Inst of Statistics  
Taipei, Taiwan

ARIZONA STATE UNIVERSITY  
Dept of Mathematics  
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  
Depts of Math and Management Science  
Fullerton, California

CASE WESTERN RESERVE UNIVERSITY  
Dept of Mathematics and Statistics  
Cleveland, Ohio

CENTERS FOR DISEASE CONTROL  
Atlanta, Georgia

CENTRE INTERNATIONAL DE  
RECONTRE MATH  
Marseille, France

CORNELL UNIVERSITY  
Dept of Mathematics  
Ithaca, New York

FLORIDA STATE UNIVERSITY  
Dept of Statistics  
Tallahassee, Florida

GEORGE WASHINGTON UNIVERSITY  
Dept of Statistics  
Washington, DC

HARVARD UNIVERSITY  
Dept of Statistics  
Cambridge, Massachusetts

INDIANA UNIVERSITY  
Dept of Mathematics  
Bloomington, Indiana

IOWA STATE UNIVERSITY  
Dept of Stat and Statistical Lab  
Ames, Iowa

JOHNS HOPKINS UNIVERSITY  
Dept of Biostatistics  
Baltimore, Maryland

KANSAS STATE UNIVERSITY  
Dept of Statistics  
Manhattan, Kansas

MARA INSTITUTE OF TECHNOLOGY  
Selangor, West Malaysia

MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
Dept of Mathematics  
Cambridge, Massachusetts

MIAMI UNIVERSITY  
Dept of Mathematics and Statistics  
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

NORTHERN ILLINOIS UNIVERSITY  
Dept of Mathematical Sciences  
DeKalb, Illinois

NORTHWESTERN UNIVERSITY  
Dept of Mathematics  
Evanston, 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  
Dept of Mathematical Sciences  
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 Math, Stat, and Comp Sci  
Edwardsville, Illinois

**SOUTHERN METHODIST UNIVERSITY**  
Dept of Statistics  
Dallas, Texas

**STANFORD UNIVERSITY**  
Dept of Statistics  
Stanford, California

**TEMPLE UNIVERSITY**  
Dept of Mathematics  
Philadelphia, Pennsylvania

**TEXAS TECH UNIVERSITY**  
Dept of Mathematics  
Lubbock, Texas

**UNIVERSITY OF ARIZONA**  
Dept of Mathematics  
Tucson, Arizona

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

**UNIVERSITY OF CALGARY**  
Division of Statistics  
Calgary, Alberta, Canada

**UNIVERSITY OF CALIFORNIA**  
Dept of Statistics  
Berkeley, California

**UNIVERSITY OF CALIFORNIA**  
Division of Statistics  
Davis, California

**UNIVERSITY OF FLORIDA**  
Dept of Statistics  
Gainesville, Florida

**UNIVERSITY OF GEORGIA**  
Dept of Statistics  
Athens, Georgia

**UNIVERSITY OF ILLINOIS**  
Dept of Statistics  
Urbana, Illinois

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

**UNIVERSITY OF IOWA**  
Dept of Statistics and Actuarial Sci  
Iowa City, Iowa

**UNIVERSITY OF MANITOBA**  
Dept of Statistics  
Winnipeg, Manitoba, Canada

**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 MISSOURI AT COLUMBIA**  
Dept of Statistics  
Columbia, Missouri

**UNIVERSITY OF MONTREAL**  
Dept of Mathematics  
Montreal, Quebec, Canada

**UNIVERSITY OF NEBRASKA**  
Dept of Mathematics and Statistics  
Lincoln, Nebraska

**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 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**  
Depts of Statistics and Mathematics  
Seattle, Washington

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

**UNIVERSITY OF WISCONSIN AT MILWAUKEE**  
Dept of Mathematical Sciences  
Milwaukee, Wisconsin

**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 not 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.