# Forecasting


## Bruce E. Hansen

### University of Wisconsin


The three-day course will cover modern forecasting tools and methods. Some of the material will be based on the *Handbook of Economic Forecasting* (2006), edited by Elliott, Granger and Timmerman. Other material will be based on research by the instructor.

The course will cover forecasting theory, methods, and applications. The primary emphasis will be on forecasting methods, with forecasting theory presented as an aid to understanding the methods. All methods will be carefully illustrated in full detail by applications to U.S. macro aggregates: quarterly GDP and monthly unemployment rates.

**Day 1: Foundations**

- One-step-ahead point forecasting using linear models
- One-step-ahead point forecasting using non-linear models
- One-step-ahead interval forecasting
- One-step-ahead density forecasting
- Multi-step-ahead point forecasting using iterated one-step forecasts
- Multi-step-ahead point forecasting using direct multi-step forecasts
- Multi-step-ahead interval and density forecasts

**Day 2: Forecasting with Breaks**

- Types of Breaks
    - Breaks in the Mean
    - Breaks in the Variance
    - Breaks in covariances
    - One-time breaks
    - Multiple breaks
    - Smooth structural change
- Detection of Breaks
    - Testing for a break
    - Testing for multiple breaks
- Estimating Breaks
    - Least-Squares estimation
    - GMM estimation
    - Confidence intervals for breaks
    - Estimating multiple breaks
- Forecasts after breaks
- Estimation and forecasting with smooth structural change

**Day 3: Forecast Selection and Combination**

- Selection methods
    - AIC
    - BIC
    - Predictive Least Squares
    - Leave-h-out cross validation
- Combination methods
    - Bates-Granger weights
    - Granger-Ramanathan weights
    - Bayesian model averaging
    - AIC weights
    - Forecast model averaging
    - Leave-h-out cross validation
- Theory of forecast combination
    - Mean-square forecast error
    - Information criterion as estimates of MSFE
- Forecast combination for multi-step forecasts
- Forecast combination for forecast intervals and densities

# BRUCE E. HANSEN
## Trygve Haavelmo Professor of Economics


| | | |
|---|---|---|
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| Telephone: | (608) 263-3880 | |
| Email: | behansen@wisc.edu | |
| url: | www.ssc.wisc.edu/~bhansen | |
| Born: | April 18, 1962 | |
| Personal: | U.S. citizen, married, two children | |


### Education

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|---|---|
| 1984 | A.B. (Economics/Philosophy) Occidental College, Summa Cum Laude |
| 1986 | M.A. (Economics) Yale University |
| 1989 | Ph.D. (Economics) Yale University |

### Academic Positions

| | |
|---|---|
| 1989-1992 | Assistant Professor, Department of Economics, University of Rochester |
| 1992-1994 | Associate Professor, Department of Economics, University of Rochester |
| 1994-1995 | Associate Professor, Department of Economics, Boston College |
| 1995-1998 | Professor, Department of Economics, Boston College |
| 1998-2008 | Professor, Department of Economics, University of Wisconsin |
| 2008- | Trygve Haavelmo Professor of Economics, University of Wisconsin |

### Grants

| | |
|---|---|
| 1991-1992 | National Science Foundation Grant SES-9022176 |
| 1992-1993 | National Science Foundation Grant SES-9120576 |
| 1994-1996 | Alfred P. Sloan Foundation Research Fellowship |
| 1994-1997 | National Science Foundation Grant SBR-9412339 |
| 1998-2001 | National Science Foundation Grant SBR-9807111 |
| 2003-2006 | National Science Foundation Grant SBR-0241152 |
| 2006-2009 | National Science Foundation Grant SES-0550908 |
| 2010-2013 | National Science Foundation Grant SES-0961258 |
| 2013-2016 | National Science Foundation Grant SES-1258858 |

### Editorial & Professional Positions

| | | |
|---|---|---|
| 1995-2008 | Co-Editor | *Econometric Theory* |
| 1996-2008 | Associate Editor | *Econometrica* |
| 1992-1995 | Associate Editor | *Econometric Theory* |
| 2011- | Board of Directors | National Bureau of Economic Research |

### Honors and Awards

Fellow, Econometric Society, 2000
Fellow, Journal of Econometrics, 2000
Kellett Mid-Career Award, University of Wisconsin, 2005
WARF Professorship, University of Wisconsin, 2008
Leon Epstein Faculty Fellow Award, University of Wisconsin, 2010-2011

**Refereed Publications**

[1] "Estimation and inference in models of cointegration: A simulation study," with P.C.B. Phillips, ***Advances in Econometrics*** (1990), 8, 225-248.

[2] "Statistical inference in instrumental variables regression with I(1) processes," with P.C.B. Phillips, ***Review of Economic Studies*** (1990), 57, 99-125.

[3] "Strong laws for dependent heterogeneous processes," ***Econometric Theory*** (1991), 7, 213-221, and "Erratum" (1992), 8, 421-422.

[4] "GARCH(1,1) processes are near-epoch dependent," ***Economic Letters*** (1991), 36, 181-186.

[5] "Efficient estimation and testing of cointegrating vectors in the presence of deterministic trends," ***Journal of Econometrics*** (1992), 53, 87-121.

[6] "Testing for parameter instability in linear models," ***Journal of Policy Modeling*** (1992), 14, 517-533.

[7] "Heteroskedastic cointegration," ***Journal of Econometrics*** (1992), 54, 139-158.

[8] "Tests for parameter instability in regressions with I(1) processes," ***Journal of Business and Economic Statistics*** (1992), 10, 321-335. Reprinted in Twentieth Anniversary Commemorative Issue of ***Journal of Business and Economic Statistics*** (2002), 20, 45-59.

[9] "Convergence to stochastic integrals for dependent heterogeneous processes," ***Econometric Theory*** (1992), 8, 489-500.

[10] "The likelihood ratio test under non-standard conditions: Testing the Markov switching model of GNP," ***Journal of Applied Econometrics*** (1992), 7, S61-S82. Also in ***Nonlinear Dynamics, Chaos and Econometrics***, ed. M.H. Pesaran and S.M. Potter (1993), John Wiley & Sons. Also "Erratum", ***Journal of Applied Econometrics***, (1996), 11, 195-198.

[11] "Consistent covariance matrix estimation for dependent heterogeneous processes," ***Econometrica*** (1992), 60, 967-972.

[12] "Asymptotic theory for the GARCH(1,1) quasi-maximum likelihood estimator," with Sang-Won Lee, ***Econometric Theory*** (1994), 10, 29-52.

[13] "Autoregressive conditional density estimation," ***International Economic Review*** (1994), 35, 705-730.

[14] "Are seasonal patterns constant over time? A test for seasonal stability," with Fabio Canova, ***Journal of Business and Economic Statistics*** (1995), 13, 237-252.

[15] "Rethinking the univariate approach to unit root tests: How to use covariates to increase power," ***Econometric Theory*** (1995), 11, 1148-1171.

[16] "Regression with non-stationary volatility," ***Econometrica*** (1995), 63, 1113-1132.

[17] “Residual-based tests for cointegration in models with regime shifts,” with Allan Gregory, ***Journal of Econometrics*** (1996), 70, 99-126.

[18] “Stochastic equicontinuity for unbounded dependent heterogeneous arrays,” ***Econometric Theory*** (1996), 12, 347-359.

[19] “Tests for cointegration in models with regime and trend shifts,” with Allan Gregory, ***Oxford Bulletin of Economics and Statistics***, (1996), 58, 555-560.

[20] “Inference when a nuisance parameter is not identified under the null hypothesis,” ***Econometrica*** (1996), 64, 413-430.

[21] “Review article. Methodology: Alchemy or Science?” ***The Economic Journal***, (1996), 106, 1398-1413.

[22] “Approximate asymptotic p-values for structural change tests,” ***Journal of Business and Economic Statistics*** (1997), 15, 60-67.

[23] “On the issue of functional form choice in hedonic price functions: Further evidence,” with John Halstead and Rachel Bouvier, ***Environmental Management*** (1997), 21, 759-765.

[24] “Inference in TAR models,” ***Studies in Nonlinear Dynamics and Econometrics***, (1997), 2.

[25] “Testing for linearity,” ***Journal of Economic Surveys*** (1999), 13, 551-576.

[26] “Threshold effects in non-dynamic panels: Estimation, testing, and inference,” ***Journal of Econometrics*** (1999), 93, 345-368.

[27] “The grid bootstrap and the autoregressive model,” ***Review of Economics and Statistics*** (1999), 81, 594-607.

[28] “Sample splitting and threshold estimation” ***Econometrica*** (2000), 68, 575-603.

[29] “Testing for structural change in conditional models,” ***Journal of Econometrics*** (2000), 97, 93-115.

[30] “Threshold autoregression with a unit root,” with Mehmet Caner, ***Econometrica*** (2001), 69, 1555-1596.

[31] “The new econometrics of structural change: dating changes in U.S. Labor Productivity, ***Journal of Economic Perspectives***, (2001), 15, 117-128.

[32] “Testing for two-regime threshold cointegration in vector error-correction models,” with Byeongseon Seo, ***Journal of Econometrics*** (2002), 110, 294-318.

[33] “Generalized Method of Moments and Macroeconomics,” with Kenneth West, ***Journal of Business and Economic Statistics*** (2002), 20, 460-469.

[34] “On the Reliability of Recounts from Undervotes: Evidence from the 2000 Presidential Election,” ***Journal of the American Statistical Association*** (2003), 98, 292-298.

[35] “How responsive are private transfers to income? Evidence from a laissez-faire economy,” with Donald Cox and Emmanuel Jimenez, ***Journal of Public Economics*** (2004), 88, 2193-2219.

[36] “Instrumental variable estimation of a threshold model,” with Mehmet Caner. ***Econometric Theory***, (2004), 20, 813-843.

[37] “Challenges for Econometric Model Selection,” ***Econometric Theory***, (2005), 21, 60-68.

[38] “Exact Mean Integrated Squared Error of Higher-Order Kernel Estimators,” ***Econometric Theory***, (2005), 21, 1031-1057.

[39] “Interval Forecasts and Parameter Uncertainty,” ***Journal of Econometrics*** (2006), 135, 377-398.

[40] “Least Squares Model Averaging,” ***Econometrica***, (2007), 75, 1175-1189.

[41] “Uniform Convergence Rates for Kernel Estimation with Dependent Data,” ***Econometric Theory***, (2008), 24, 726-748.

[42] “Least Squares Forecast Averaging,” ***Journal of Econometrics***, (2008), 146, 342-350.

[43] “Averaging Estimators for Regressions with a Possible Structural Break,” ***Econometric Theory***, (2009), 35, 1498-1514.

[44] “Averaging Estimators for Autoregressions with a Near Unit Root,” ***Journal of Econometrics***, (2010), 158, 152-155.

[45] “Threshold autoregression in economics,” ***Statistics and Its Interface***, (2011), 4, 123-127.

[46] “Jackknife model averaging,” with Jeffrey Racine, ***Journal of Econometrics***, (2012), 167, 38-46.

[47] “The Integrated Mean Squared Error of Series Regression and a Rosenthal Hilbert-Space Inequality,” ***Econometric Theory***, forthcoming.

## Textbook

***Econometrics***
Graduate Textbook (draft)
http://www.ssc.wisc.edu/~bhansen/econometrics/

## Edited Volume

***Econometric Theory and Practice: Frontiers of Analysis and Applied Research***, edited by Dean Corbae, Steven N. Durlauf and Bruce E. Hansen. (2006) Cambridge University Press.

## Papers in Edited Volumes

[1]"Edgeworth expansions for the Wald and GMM statistics for nonlinear restrictions," (2006) ***Econometric Theory and Practice: Frontiers of Analysis and Applied Research***, edited by Dean Corbae, Steven N. Durlauf and Bruce E. Hansen. Cambridge University Press.

[2] "Nonparametric Sieve Regression: Least Squares, Averaging Least Squares, and Cross-Validation (2012) ***Handbook of Applied Nonparametric and Semiparametric Econometrics and Statistics***, edited by Aman Ullah, Jeffrey Racine and Liangjun Su, Oxford University Press, forthcoming

## Reviews and Comments

[1] "Discussion of 'Data Mining Reconsidered' by Kevin Hoover and Stephen Perez," ***Econometrics Journal*** (1999), 2, 192-201.

[2] "Book Review: *Handbook of Econometrics*, Volume 4," with Joel Horowitz, ***Econometric Theory*** (1997), 13, 119-132.

[3] "Book Review: *Time Series Analysis* by James D. Hamilton," ***Econometric Theory*** (1995), 11, 625-631.

[4] Comment on "Testing for common features" by R. Engle and S. Kozicki, ***Journal of Business and Economic Statistics*** (1993), p. 385-386.

[5] Comment on "Further evidence on business cycle duration dependence" by F.X. Diebold, G.D. Rudebusch and D.E. Sichel, ***Business Cycles, Indicators, and Forecasting***, ed. J.H. Stock and M.W. Watson (1993), p. 280-284.

[6] Comment on "Feature Matching in Time Series Modeling" by Yingcun Xia and Howell Tong, ***Statistical Science,*** (2011), 26, 47-48.

## Special Courses

December 1996

Workshop of the Netherlands Network of Economics, Maastricht, Netherlands
"The Econometrics of Structural Change"
5-day course for graduate students

June 2004

Centro Interuniversitario di Econometria (CIDE) Summer School, Bertinoro, Italy
"Structural Change and Threshold Models"
5-day course for graduate students

August 2010

International Monetary Fund
"Forecast Combination"
1-day course for IMF Staff

November 2010

UC Riverside
Distinguished visitor

September 2011

Boston University
Distinguished visitor
5-day course for graduate students

October 2011

International Monetary Fund
"Forecasting"
3-day course for IMF Staff

July 2012

Advanced Summer School in Economics and Econometrics, University of Crete
"Time Series and Forecasting"
5-day course for graduate students

## Conference Presentations

| | |
|---|---|
| 1987 | Econometric Society Summer Meetings |
| 1990 | ENSAE Conference on ARCH Models (Paris) |
| | World Congress of the Econometric society, Barcelona |
| | Canadian Econometric Study Group |
| | Econometric Society Winter Meetings |
| 1991 | Conference on Nonlinear Dynamics and Econometrics, UCLA |
| | NBER conference on "Business cycles, leading indicators and forecasting" |
| | Econometric Society Summer Meetings |
| 1992 | Econometric Society Winter Meetings |
| | Yale Conference on Bayes Methods and Unit Roots |
| | Yale Conference on Empirical processes and dependent random variables |
| | Recent Developments in the Econometrics of Structural Change (University of Montreal) |
| 1993 | Econometric Society Winter Meetings |
| | Yale/NSF Conference on Multiple Trending Time Series |
| | $EC^2$ Conference (Oxford University) |
| 1994 | Econometric Society Winter Meetings |
| 1996 | Econometric Society Winter Meetings |
| | Society for Nonlinear Dynamics and Econometrics |
| | NBER Summer Institute – Forecasting Workshop |
| | Canadian Econometric Study Group |
| | Bergamo Conference on Applied Economics |
| | NBER/NSF Time Series Conference (Rotterdam) |
| 1997 | Econometric Society Winter Meetings |
| 1998 | Econometric Society Winter Meeting |
| | NBER Summer Institute – Forecasting Workshop |
| | Mid-West Econometrics Group |
| 1999 | Econometric Society Winter Meeting |
| | Econometric Society Summer Meeting |
| | Econometric Society Latin American Meeting |
| | Cowles Econometrics Conference |
| 2000 | Econometric Society Winter Meeting |
| | Cardiff conference on long memory and nonlinear time series |
| | ESRC Econometric Study Group Conference, Bristol |
| | World Congress of the Econometric society, Seattle |
| 2001 | Joint Statistical Meetings |
| | Econometric Society European Meeting |
| | Exchange Rate conference (UW Madison) |
| 2003 | Econometric Society Winter Meeting |
| | North Triangle Econometrics Conference (keynote speaker) |
| 2004 | Econometric Society Winter Meeting |
| | Retirement Conference for Clive Granger (UCSD) |
| | Texas Camp Econometrics (keynote speaker) |
| | Joint Statistical Meetings |
| 2005 | Canadian Econometrics Study Group (keynote speaker) |
| 2006 | Econometrics in Rio (keynote speaker) |
| | Midwest Econometrics Group (keynote speaker) |
| | New York Area Econometrics conference |

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|---|---|
| 2007 | 20 Years of Cointegration, Tinbergen Institute (keynote speaker) |
| | NBER-NSF Time Series Conference |
| | Conference in Honor of Paul Newbold, University of Nottingham (keynote speaker) |
| | $EC^2$: Recent Advances in Econometric Time Series (Faro, Portugal) (keynote speaker) |
| 2008 | London Time Series Workshop (keynote speaker) |
| | Dutch Econometrics Study Group (keynote speaker) |
| | UK Econometrics Study Group (keynote speaker) |
| 2009 | CIREQ Time Series Conference (Montreal) |
| 2010 | World Congress of the Econometric society, Shanghai |
| | Midwest Econometrics Group |
| | CIREQ Time Series Conference (Montreal) |
| 2011 | Yale Economics Alumni Conference |
| | Econometric Society Summer Meeting |
| | Econometric Society Australasian Meeting (keynote speaker) |
| | Joint Statistical Meetings |
| | Info Metrics Workshop on Shrinkage at American University |
| 2012 | CIREQ conference on High Dimensional Problems in Econometrics |
| | Vienna conference on statistical inference in complex/high-dimensional problems |
| 2013 | CIREQ conference on Time Series and Financial Econometrics (Montreal) |
| | International Conference on Econometrics, Operations Research, and Statistics (Sarajevo) (keynote speaker) |
| | Workshop on "Model Selection, Nonparametrics, and Dependence" (Rennes, France) |

## Seminar Presentations

| | |
|---|---|
| 1989 | Queen's University |
| | University of Rochester |
| 1990 | Indiana University |
| | UCLA |
| | Yale University |
| 1991 | University of Pennsylvania |
| | Northwestern University |
| | Oxford University |
| | University of Alberta |
| | University of Saskatchewan |
| | University of Wisconsin – Madison |
| | University of Iowa |
| | UCLA |
| | MIT |
| 1992 | UCSD |
| | John Hopkins University |
| | University of Michigan |
| | McGill University |
| | University of Montreal |

Queen's University
Princeton University
University of Illinois
Northwestern University
Cornell University
1993 Washington University, Finance Department
Columbia University
Syracuse University
University of Texas – Austin
Rice University
Erasmus University
1994 UCLA
USC
UC Irvine
Cal Tech
Penn State University
Ohio State University
Boston College
Board of Governors, Federal Reserve System
Harvard University
1995 Yale University
Texas A&M University
Southern Methodist University
1996 Cornell University
Brown University
SUNY Albany
University of New Hampshire
University of Rochester
University of Michigan
Michigan State University
Tilburg University
1997 University of Maryland
M.I.T.
Northwestern University
University of Chicago
New York Federal Reserve Bank
University of Guelph
Princeton University
University of Wisconsin, Madison
University of Pennsylvania
University of Michigan
1998 Duke University
Harvard University
New York University
University of Kansas
St. Louis Federal Reserve Board
University of Southern California/UCLA
University of Illinois, Urbana-Champagne
University of Iowa

| | |
|---|---|
| 1999 | Board of Governors (Visiting Scholar, Two presentations) |
| | Northern Illinois State University |
| | Northwestern University |
| | Iowa State University |
| | UW Chaos and Complexity Seminar |
| 2000 | University of Virginia |
| | University of Montreal |
| 2001 | University of Pittsburgh |
| 2004 | Southern Methodist University |
| | Princeton University |
| | University of Chicago GSB |
| | Ohio State University |
| | University of Rochester |
| | UC Riverside |
| | UCSD |
| | Stanford |
| | UCLA |
| 2005 | Harvard University |
| 2006 | Duke University |
| | McMaster University |
| | Texas A&M University |
| | New York University |
| 2007 | University of Pittsburgh |
| | Columbia University |
| 2008 | University of British Columbia |
| | Queen's University |
| | University of Montreal |
| | Indiana University |
| | Yale University |
| | Michigan State University |
| 2009 | NYU Stern School, Statistics Department |
| | University of Southern California |
| | Carnegie Mellon University, Statistics Department |
| | Brown University |
| | Purdue University |
| | Northwestern University |
| 2010 | UC Riverside |
| | UW Madison, Statistics Department |
| 2011 | ITAM (Mexico) |
| | University of Pennsylvania |
| | Boston University |
| | Penn State University |
| | Queen's University |
| | University of Michigan |
| 2012 | UW Milwaukee |
| | Rice University |
| | MIT/Harvard |
| 2013 | University of Chicago Booth School of Business |