Bayesian Time Series Modelling, Forecasting & Decisions

Bocconi University, Milan

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These lectures cover principles and methodology of Bayesian dynamic modelling in multivariate time series. Several key model developments and examples involve analysis, inference and forecasting in financial and econometric contexts, including Bayesian decision analysis overlaying modelling and computational methodology. Several examples are drawn from these areas, while others exemplify use of this range of models in other fields. The lectures includes recent modelling and methodological developments in multivariate time series and forecasting, and contacts current research frontiers.

Lecture Material & Website:
- Much of the lecture material is linked to the 2010 text by Raquel Prado & Mike West, Time Series: Modeling, Computation, and Inference, Chapman Hall/CRC Press Taylor & Francis Group. Reviewing at least introductory material in the book in advance is highly recommended. The publisher has provided a 20% discount for purchase: if interested, use the promotion code XXXX not yet at the direct link https://www.crcpress.com/9781420093360
- In addition to this information document and the book, the lecture web page https://stat.duke.edu/~mw/Bocconi2015lectures provides supporting reading material in terms of key papers linked to core material, as well as lecture slides and software.

Aims: The lectures will aim to give attendees
- exposure to the basic ideas and approaches of Bayesian model-based time series analysis using key classes of dynamic models;
- exposure to the integration of Bayesian forecasting with decision analysis in financial applications;
- an appreciation of the roles of analytic and simulation-based Bayesian computation in fitting and using multivariate time series models;
- awareness of texts, papers and software that will enable follow-on explorations and analysis;
- appreciation of some of the breadth of application Bayesian dynamic modelling;
- exposure to recent and current research topics, especially focused on scale-up of models and methods to higher-dimensional series, and dynamic sparsity modelling in time series and forecasting.
Coverage & Schedule

Topics listed below are annotated by sections of Prado & West (P&W); students should review in advance. Additional key reading is represented by linked published papers in several sections; students should download and review papers in advance. Examples and data throughout are drawn from econometric forecasting, financial portfolio decisions, and other areas.

While the overall coverage is defined here, the lectures will partly respond to student interests as it evolves. Some material may be skipped or supplemented depending on interests and feedback.

Slides:

This superset of Lecture Slides is in sequence with the topics on the schedule below. Some of these slides represent core background material also detailed in the P&W textbook.

Topics/Schedule:

1. Multivariate Time Series and Multivariate Volatility  
P&W 10.2, 10.3, 10.4.1–10.4.8
P&W 8.1.1, 9.1, 10.2
3. Dynamic Latent Factor Models  
P&W 8.1.2, 10.4.9
     Bayesian dynamic factor models and portfolio allocation
4. Dynamic Graphical Models  
P&W 10.5
   - Carlos Carvalho & MW, Bayesian Analysis 2:69-98, 2007  
     Dynamic matrix-variate graphical models
5. Dynamic Dependence Network Models  
     Dynamic dependence networks: Financial time series forecasting & portfolio decisions
6. Dynamic Simultaneous Graphical Models  
   - Lutz Gruber & MW, Bayesian Analysis 2015 (March, advance online publication)  
     GPU-accelerated Bayesian learning in simultaneous graphical dynamic linear models
7. Dynamic Sparsity: Latent Threshold Models  
     Bayesian analysis of latent threshold dynamic models
     Bayesian forecasting and portfolio decisions using dynamic dependent sparse factor models
**Background, Preparation & Code:**

- The lecture material will be accessible to advanced students with strong statistical modelling backgrounds and prior exposure to Bayesian analysis and aspects of time series. Working facility in multivariate distribution theory and statistical inference are prerequisites; prior exposure to some areas of time series analysis will be useful.

- All participants will benefit from reviewing background material on Bayesian analysis and time series, as laid out in introductory and appendix material in the Prado & West text. Key background includes
  - Bayesian analysis review, P&W 1.5
  - Multi- and matrix-variate distribution theory, P&W 10.6

- Instructor code in Matlab will be used for examples, and is available to participants. Working familiarity in Matlab will be needed in advance of the lectures to get the most out of the examples, and the code provides multiple examples— and supporting utilities— for customization to a range of problems. Participants with Matlab up-and-running on laptops during the lectures will be able to spend time after/between lecture meetings to run examples, explore variants, new data sets, etc.

**Other Comments & Connections:**

- **MCMC & SMC:** Much applied Bayesian statistics in all fields, including time series, relies on simulation methods for posterior and predictive computations. We will use direct simulation routinely throughout, but the emphasis is on modelling concepts and we will not extensively discuss more advanced computational methods. Markov chain Monte Carlo (MCMC, P&W 1.5.5, 4.5) and Sequential Monte Carlo (SMC P&W 6.2) will be mentioned in context, as they play key roles as computational methods in some of the lecture topics and papers, but detailed development is beyond the scope of these particular lectures.

- **Relaxation:** Participants may be interested in a gentle video on Bayesian dynamic modelling, Mike's ISBA Lecture on Bayesian Foundations from 2012. This is a tutorial/overview presentation that contacts key foundational concepts and models (among other things).

- **More Software:** The Matlab code available in the lectures is working code of the instructor on core models. Some participants may be interested in additional software for time series and other topics, linked at the instructor's software webpage.

- **Gary Koop** and Dimitris Korobilis have substantial Matlab code for some key models, as well as an extensive relevant publication base. See a wide range of papers, books and software links at Gary Koop's personal website. While these lectures do not use this material, the reading there on Bayesian econometrics, time-varying vector autoregressive models, and Bayesian dynamic factor models is all relevant (and excellent). Then, more recent material and extensive software can be found at Dimitris Korobilis' website, along with other links of relevance.

- **R Software:** Some participants may be interested in R code.
  - Some software for (univariate) dynamic linear models, and including a range of examples with analytic, MCMC- & SMC-based analyses, is available as part of the R package and Springer text Dynamic Linear Models with R by Giovanni Petris, Sonia Petrone & Patrizia Campagnoli.
Mike West holds a Duke University distinguished chair as the Arts & Sciences Professor of Statistics & Decision Sciences in the Department of Statistical Science, where he led the development of statistics from 1990-2002. A past president of the International Society for Bayesian Analysis (ISBA), Mike has served the international statistics profession broadly. This includes founding roles for ISBA and the Bayesian section of the American Statistical Association, among other areas of professional society development. He was a member of establishment committees and founding boards of the National Institute of Statistical Sciences and the Statistical & Applied Mathematical Sciences Institute in the USA, and has served on advisory boards of other national research institutes in the EU and Asia.

Mike’s expertise spans a wide range of areas in Bayesian statistical modelling and computation, focusing on methodology and applications of complex stochastic modelling in high-dimensional problems. His current research emphasizes large-scale computation, multivariate time series and dynamic modelling, sparsity modelling in statistics, foundations of scientific inference and decision analysis, and emulation of computer models with efficient/effective statistical approaches, among other topics. Current areas of emphasis in applications include financial time series and decision analysis with increasingly complex, structured models, macro-econometrics and societally relevant big & fast data issues in global financial systems, monitoring and fast data analysis in dynamic networks, and Big Data IT/e-commerce. among others.

Since his PhD in 1982, Mike has published around 180 papers in core statistics and interdisciplinary applications in business, econometrics and finance, signal processing, climatology, public health, genomics, immunology, neurophysiology, systems biology and other areas. He is co-author of three books on Bayesian time series analysis and dynamic modelling, several edited volumes, and multiple software packages. He has been a statistical consultant for multiple companies, banks, government agencies and academic centers in UK and USA. In the business world beyond consulting, Mike co-founded the biotechnology company Expression-analysis (EA Inc.), now a wholly-owned subsidiary of Quintiles, has been advisor or board member of several financial investment firms including BEAM Multi-Strategy Master Fund, Ltd., and is a current member of the board of directors of the IT energy solutions company Panton Inc.

Mike has received a number of awards for research and professional service, including the international Mitchell Prize for research in applied Bayesian statistics (in 1994, 1997 and again in 2012), outstanding statistical application paper award of the American Statistical Association (in 1997), the Zellner Medal of the International Society for Bayesian Analysis (in 2014), professional society service awards, and multiple distinguished speaking awards.

Mike teaches broadly in Bayesian statistics, in academia and through short-courses. His professional “kicks” come from a variety of sources, but teaching and working with smart, young, emerging statisticians from all over the world is what he prizes most. In addition to working with and advising many undergraduates and Master’s students, Mike has advised nearly 60 PhD students and postdoctoral associates, most of whom are now in academic, industrial or governmental positions involving advanced statistical research.