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Bayesian Dynamic Modelling for Multivariate Time Series Analysis

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This short-course covers principles and methodology of Bayesian dynamic modelling, with a main focus on methodology for multivariate time series analysis and forecasting. Following introductory conceptual and perspective development in univariate settings, the course works through a series of contexts of multivariate dynamic modelling for multiple time series. 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 course includes recent modelling and methodological developments in multivariate time series and forecasting, and contacts current research frontiers.

Course Material & Website:

- The 2010 text by Raquel Prado & Mike West, Time Series: Modeling, Computation, and Inference, Chapman Hall/CRC Press Taylor & Francis Group, provides basic statistical and modelling background as well as contact with some core areas of Bayesian multivariate dynamic modelling. 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 **(to be provided)** at the direct link
  publisher web page to be provided

- In addition to this information document and the book, the course web page
  course web page to be provided here
  provides supporting reading material in terms of key papers linked to core material, as well as course slides and software.

Aims: Course participants will gain

- 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;
- exposure to central developments in multivariate methodology, connecting to recent and current research frontiers concerned with scale-up of both methodology and ideas for addressing increasing large dynamic systems and data sets; this includes exposure to recent and current research topics and aspects of dynamic sparsity modelling in time series and forecasting, in particular.

Coverage & Schedule

Topics listed below are annotated by sections of Prado & West (P&W) with– importantly– much reliance on additional key readings in the research literatures 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. Major attention will be given to more recent multivariate dynamic modelling and time series topics interfacing with current research frontiers and economic and financial applications, represented by linked research papers.

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

Slides:

A superset of Course Slides (to be linked later ....) is in sequence with the topics on the schedule below. Some of these slides relate to core material in the P&W text book, while some go beyond to more recent/frontier topics, to aid students in connecting with allied and more advanced topics.

Topics:

1. Brief Overview of Bayesian Dynamic Modelling and Forecasting — P&W 4.1-3, 4.5, 5.1-2

2. Multivariate Time Series: Common Components, Multivariate Volatility & Time-Varying Vector AR and Related Models — P&W 10.2, 10.3, 10.4.1–10.4.8; P&W 8.1.1, 9.1

3. Dynamic Latent Factor Models — P&W 8.1.2, 10.4.9
   - Omar Aguilar & MW *Journal of Business and Economic Statistics* 338-357, 2000, Bayesian dynamic factor models and portfolio allocation
   - Sailor Zhou, Jouchi Nakajima & MW *International Journal of Forecasting*, 30:963-980, 2014 Bayesian forecasting and portfolio decisions using dynamic dependent sparse factor models

4. Dynamic Graphical Models (I) — P&W 10.5
   - Carlos Carvalho & MW, *Bayesian Analysis* 2:69-98, 2007, Dynamic matrix-variate graphical models

5. Dynamic Graphical Models (II): Dynamic Dependence Networks
   - Zoey Zhao, Amy Xie & MW, *Applied Stochastic Models in Business and Industry* 32:311-339, 2016, Dynamic dependence networks: Financial time series forecasting and portfolio decisions (with discussion) of increasing interest in macroeconomics, finance and related areas.

6. Simultaneous Dynamic Graphical Models, at research frontiers in terms of scale-up and flexible modelling of univariate time series coupled with increasingly large multivariate volatility matrices–
   - Lutz Gruber & MW *Bayesian Analysis*, 11:125-149, 2016, GPU-accelerated Bayesian learning in simultaneous graphical dynamic linear models

7. Dynamic sparsity via latent thresholding– in economic and financial forecasting and decisions,
   - Lutz Jouchi Nakajima & MW *Journal of Business and Economic Statistics*, 31:151-164, 2013, Bayesian analysis of latent threshold dynamic models
   - Sailor Zhou, Jouchi Nakajima & MW *International Journal of Forecasting*, 30:963-980, 2014 Bayesian forecasting and portfolio decisions using dynamic dependent sparse factor models

Background, Preparation & Code:

- The course 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.

- Most importantly, the course will have time for only brief review of core foundations of Bayesian dynamic modelling and forecasting in *univariate time series*, so participants should become familiar with this as much as possible prior the course. The core material is covered in Prado & West Sections P&W 4.1-3, 4.5, 5.1-2.

  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, and multi- and matrix-variate distribution theory, P&W 10.6.

- Instructor code in **Matlab** will be used for course examples, and is available to participants. Working familiarity in Matlab will be needed in advance of the course 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 course will be able to spend time after/between course meetings to run examples, explore variants, new data sets, etc.

Other Comments & Connections:

- MCMC & SMC: Some topics rely on simulation methods for posterior and predictive computations. We will use direct simulation routinely throughout this course, 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 course topics and papers, but detailed development is beyond the scope of this particular course.

- More Background and Some 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).

  The web page here also has several other videos of more recent presentations by Mike West on several of the core course topics on multivariate dynamic modelling and time series analysis/forecasting. Students might benefit from selectively viewing some of these videos both in advance and during the short course.

- More Software: The Matlab code available in the course 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 this course does 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.