

ECONOMETRICS III 2021 (TIME SERIES)

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Objective: The main goal of the course is to make the student familiar with and able to implement univariate and multivariate time series models by using both frequentist and Bayesian approaches. All classroom examples and implementations as well as projects will be carried out by the open-source statistical software R.

Course description: PART I: Basic univariate time series models: AR, MA and ARMA models; Unit-root non-stationarity and long-memory processes; Seasonal models. PART II: Bayesian ingredients (prior, likelihood, posterior, predictive, Bayes factor and posterior model probability); Monte Carlo (MC) methods (MC integration, sampling importance resampling (SIR)) and Markov chain Monte Carlo (MCMC) methods (Gibbs sampler and Metropolis-Hastings (MH) algorithms). PART III: More univariate time series: ARCH/GARCH models; EGARCH, GARCH-M, TGARCH; Bayesian GARCH; Bayesian inference in the local level model; Dynamic models; Stochastic volatility models. We will use MCMC as well as sequential Monte Carlo (SMC) schemes to perform batch and online posterior inference. PART IV: Multivariate time series models: Vector autoregressive (VAR) models; Large Bayesian VAR (BVAR) models, factor augmented VAR (FAVAR) models, time-varying parameter BVAR (TVP-BVAR) models, Bayesian FAVAR (BFAVAR) models; Factor models and time-varying covariance models.

Bibliography

Gamerman and Lopes (2006) MCMC: Stochastic Simulation for Bayesian Inference, 2nd Edition. Chapman & Hall/CRC.

Tsay (2010) Analysis of Financial Time Series, Third Edition. Wiley-Interscience, Probability and Statistics.

Tsay (2014) Multivariate Time Series Analysis with R and Financial Applications. Wiley.

Shumway and Stoffer (2011) Time Series Analysis and Its Applications with R Examples, Third Edition. Springer.

Take-home midterm exam: 9am of Tuesday, February 23th to 12pm of Thursday, February 25th. (data)

Homework assignments

1. HW1: Problems 1,2,3,8,19,20 and 21, chapter 1 of Shumway and Stoffer's book (4th edition) - [HW1 by Alexandre](#) + [HW1 by Livia](#) + [HW1 by Victoria](#)
2. HW2: Problem 2.15 (page 107) of Tsay (2010). However, download the up-to-date quarterly gross domestic implicit price deflator time series from the [Federal Reserve Bank of St Louis](#). Fit the ARIMA models with data up to the 4th quarter of 2018 and use 2019.I to 2020.III (7 quarters) for forecasting comparisons - [HW2 by Thaline](#)
3. [HW3](#)
4. HW4: Fit Gaussian and Student's t GARCH(1,1) to [Vale S.A. \(VALE\)](#) using the R packages `garchFit`, `bayesGARCH` and `RSTAN` that I have provided when we studied Petrobras (PBR). Feel free to add other (non-Bayesian) GARCH-type fits based on the ARCH-glossary that we have discussed in class.
5. HW5: Collect meaningful time-series (suggestion: Apple & SP500 for US market or Vale & Ibovespa for the Brazilian market). Use the time series in a simple CAP-M model which allows for time-varying slope. Repeat it by allowing ONLY time-varying slope. Then, allow both time-varying intercept and slope. Compare the three models to the benchmark OLS fit. You can use whatever Bayesian R package (such as `bsts`) that produces posterior summaries of the latent variables (intercepts and slopes) as well as static parameters. Comment your findings. There are lots of papers out there, and I recommend a 16-year old one here: [Jostova and Philipov \(2005\) Bayesian analysis of stochastic betas, Journal of Financial and Quantitative Analysis, 747-778.](#)

Paper presentations

- Graziadei, Lopes and Marques (2020) [Bayesian generalizations of the integer-valued autoregressive model, Journal of Applied Statistics.](#)
- Silva, Lopes and Migon (2006) [The extended generalized inverse Gaussian distribution for log-linear and stochastic volatility models, Brazilian Journal of Probability and Statistics, 67-91.](#)
- Carvalho and Lopes (2006) [Simulation-based sequential analysis of Markov switching stochastic volatility models, Computational Statistics and Data Analysis, 51 \(9\), 4526-4542.](#)
- Warty, Lopes and Polson (2018) [Sequential Bayesian learning for stochastic volatility with variance-gamma jumps in returns, Applied Stochastic Models in Business and Industry, 2018, 34, 460-483.](#)
- Prado and Lopes (2013) [Sequential parameter learning and filtering in structured autoregressive state-space models, Statistics and Computing, 23 \(1\), 43-57.](#)
- Primiceri (2005) [Time Varying Structural Vector Autoregressions and Monetary Policy, The Review of Economic Studies, Vol. 72, No. 3, 821-852.](#)
- Carriero, Todd and Massimiliano (2019) [Large Bayesian vector autoregressions with stochastic volatility and non-conjugate priors, Journal of Econometrics, 212\(1\), 137-154.](#)
- Shirota, Omori, Piao and Lopes (2017) [Cholesky realized stochastic volatility model, Econometrics and Statistics, 2017, 3, 34-59.](#)
- Kastner, Fruehwirth-Schnatter and Lopes (2017) [Efficient Bayesian inference for multivariate factor SV models, Journal of Computational and Graphical Statistics, 26, 905-917.](#)
- Kastner and Huber (2020) [Sparse Bayesian vector auto-regressions in huge dimensions, Journal of Forecasting, 30\(7\), 1142-1165.](#)
- Lopes, McCulloch and Tsay (2020) [Parsimony inducing priors for large scale state-space models, Journal of Econometrics \(Revised & Resubmitted\).](#)
- Levy and Lopes (2021) [Dynamic ordering learning in multivariate forecasting.](#)

Examples developed in class

1. Brief introduction to time series in R
2. AR(1), random walk and AR(p) models
3. ARMA & ARIMA models
4. ARFIMA models
5. Bayesian AR(1)
6. Bayesian AR(1) with Normal and t priors
7. Bayesian AR(2) with Normal and t priors
8. Bayesian AR(2) with Normal and t models
9. Bayesian nonlinear regression – SIR and RW-MH
10. Bayesian AR(p) – conjugate analysis vs Gibbs sampler
11. Comparing MCMC strategies – Gibbs, MH, block/single
12. Nonlinear regression – comparing SIR and Gibbs+RWMH
13. Bimodal posterior: comparing random-walk MH and independent MH + R code
14. Linear Gaussian regression with Normal-Half-Cauchy prior – MCMC with Gibbs and RWMH steps + R code
15. Petrobras (PBR): ARCH(1,1) + GARCH(1,1)
16. Petrobras (PBR): garchFit – bayesGARCH – rstan (stan file)
17. Modeling S&P 500 realized volatility & log returns (stan code + graphs + data)
18. Modeling COVID-19 death: an exercise in state-space modeling
19. Hamilton's (2017) paper "Why you should never use the HP filter"
20. SV-AR(1) for PBR: MCMC, SMC/particle filter and sequential MCMC (data)
21. Univariate stochastic volatility, factor analysis, & factor stochastic volatility
22. Bayesian time-varying covariance: DCC and FSV models (R code)

TEACHING MATERIAL

PART I: Basic univariate time series

1. Autoregressive (AR) models and moving average (MA) models (HTML output)
2. Unit-root nonstationarity and long-memory processes (HTML output)
3. Seasonal models
 - SARIMA in R – Brazilian industrial production
 - R code for airline data – ARIMA(0,1,1)(0,1,1)[12] (R markdown html output)

PART II: Basic Bayes

1. Bayesian ingredients
2. Monte Carlo (MC) methods
3. Markov chain Monte Carlo (MCMC) methods
4. Using stan/rstan for approximate Bayesian inference via Hamiltonian MC (HMC) methods
5. MC and MCMC: Key References

PART III: Garch-type, dynamic linear and stochastic volatility models – MCMC and SMC

1. ARCH/GARCH-type models
 - Glossary of ARCH models
 - EGARCH, GARCH-M, TGARCH
 - Bayesian GARCH
2. Dynamic linear models (DLMs)
 - GARCH(1,1) versus stochastic volatility AR(1): motivating dynamic modeling (R code)
 - Local level model: $O(n^2)$ updates versus $O(n)$ updates (the FFBS) (R code)
 - Normal dynamic linear regression: Kalman, FFBS/MCMC and sequential MCMC (Rcode)
 - Normal dynamic linear regression: block sampling (FFBS) vs component-wise sampling (Rcode)
 - Toy DLM + Another toy DLM + AR1 + noise DLM
3. Nonlinear dynamic model – MCMC sampling individual states conditional on all other states
4. Sequential Monte Carlo – pure filter
 - Bootstrap filter (BF)
 - BF and sequential importance sampling (SIS)
 - BF, auxiliary particle filter (APF), optimal particle filter (OPF)
5. Sequential Monte Carlo – parameter learning
 - SMC with parameter learning
6. Stochastic volatility models
 - MCMC for the SV-AR(1) model
 - BF for the SV-AR(1) model
7. Using R packages "stochvol" & "rstan" for SV with Gaussian or Student's t errors

PART IV: Multivariate time series

1. Vector autoregressive models
 - o R code for VAR, Chapter 2 of Tsay MTS book + packages
2. Large BVAR, FAVAR, TVP-BVAR & BFAVAR
 - o Koop and Korobilis (2009) Bayesian MTS Methods for Empirical Macroeconomics.
3. Factor models (Standard factor analysis, Spatial dynamic factors, Factor stochastic volatility)
4. Time-varying covariance models
 - o Efficient Bayesian inference for multivariate FSV models (Kastner, Fruewirth-Schnatter & Lopes)
 - o Factor stochastic volatility with time varying loadings and Markov switching regimes (Lopes & Carvalho)
 - o Cholesky realized SV models (Shirota, Omori, Lopes & Piao)
 - o Bayesian inference for stochastic volatility modeling (Lopes & Polson)
 - o A Review of Stochastic Volatility: univariate and multivariate models (Platanioti, McCoy & Stephens)

Additional reading material on Bayesian time series

1. Bayesian Statistics (a very brief introduction) (Ken Rice, April, 2014)
2. Lopes and Salazar (2006) Bayesian model uncertainty in smooth transition autoregressions, *Journal of Time Series Analysis*, 27, 99-117.
3. Huerta and Lopes (2000) Bayesian forecasting and inference in latent structure for the Brazilian industrial production index, *Brazilian Review of Econometrics*, 20, 1-26.
4. Kleibergen and Hoek (2000) Bayesian Analysis of ARMA Models. Tinbergen Institute Discussion Paper.
5. Marriott, Ravishanker, Gelfand and Pai (1995) Bayesian Analysis of ARMA Processes: Complete Sampling Based Inference under Exact Likelihoods. *Bayesian Statistics and Econometrics: Essays in honor of Arnold Zellner*. Berry, Chaloner and Geweke, eds., John Wiley & sons, 241-254.

R stuff

Radford Neal's 13 lectures about R

McLeod, Yu and Mahdi's (2012) Time Series Analysis with R

MATERIAL FROM PREVIOUS YEARS (2018-2020)

Homework assignments and take-home exams

- Take-home midterm exams: 2020 + 2019
- Midterm exam 2017: solution
- 2020: HW1 + HW2 + HW3 (R code) + HW4 (R code)
- 2019: HW1: Simple MA model + Exercises 1.1 to 1.5 and 2.1 to 2.4 of Tsay (2010) - HW2 (dataset) - HW3: Problems 2.4, 2.5 and 2.6 of Tsay (2014).
- 2018: HW2: Exercises 3.1 and 3.2 of Hamilton (1994) and 2.7, 2.8 and 2.9 of Tsay (2010) - HW3
- 2017: HW1 (Solution to 2b and 2c + Additional MC exercise + Solution to 2d) - HW2 (dataset)

Paper presentations

- Del Negro and Schorfheide (2004) Priors from General Equilibrium Models for VARs. *IER*, 45, 643-673.
- Banbura, Giannone and Reichlin (2010) Large BVARs, *JAE*, 25(1), 71-92.
- Koop and Korobilis (2013) Large TVP VARs. *JoE*, 177, 185-198.
- Giannone, Lenza, Primiceri (2015) Prior selection for VARs. *The RES*, 97, 436-451.
- Carriero, Clark, Marcellino (2015) BVARs: Specification choices and forecast accuracy. *JAE*, 30, 46-73.
- Chan and Eisenstat (2018) Bayesian model comparison for TVP VARs with SV. *JAE*, 33, 509-532.
- Carriero, Clark and Marcellino (2019) Large BVARs with SV and flexible priors. *JoE*, 212, 137-154.
- Kastner and Huber (2020) Sparse BVARs in huge dimensions, *JoF*, 30(7), 1142-1165.
- Korobilis and Pettenuzzo (2020) Adaptive hierarchical priors for HD-VARs. *JoE*, 212(1), 241-271.
- Koop, Korobilis and Pettenuzzo (2019) Bayesian Compressed VARs. *JoE*, 210, 135-154.

Examples developed in class

- 2020: ACF of white noise and random walk processes
- 2020: AR(3) simulation exercise (R markdown code)
- 2020: AR(1) models: predictive analysis (R markdown code)
- 2020: AR(3) models: Gibbs sampler (html) (R markdown code)
- 2020: Our first Metropolis-Hastings algorithm
- 2020: Bayesian regression with the normal-gamma prior

- 2019: ACF of white noise and random walk processes
- 2019: AR(3) simulation exercise (R markdown code)
- 2019: Gaussian and non-Gaussian GARCH models + Rmarkdown + Petrobras data
- 2019: Our first state-space model: AR(1) plus noise model
- 2019: Linear regression with AR(1) errors (graphs)
- 2019: AR(1) plus noise model: FFBS
- 2019: AR(1) plus noise model: block-move vs single-move
- 2019: My first particle filter
- 2019: SV-AR(1): MCMC & SMC + (R code)
- 2019: SV & FSV + (R code) + (dados)
- 2019: DCC-GARCH & FSV + (R code)

- 2018: [ACF of white noise and random walk processes](#)
- 2018: [AR\(3\) simulation exercise\(R markdown code\)](#)
- 2018: [Sampling distribution of the Dickey-Fuller ratio](#)
- 2018: [SARIMA for unemployment rate in Sao Paulo \(R code\)](#)
- 2018: [Sequential Bayesian learning](#)
- 2018: [Monte Carlo integration/simulation](#)
- 2018: [Gaussian AR\(2\) model with conditionally conjugate priors: Gibbs Sampler](#)
- 2018: [Bayesian linear regression](#)
- 2018: [Binomial model and mixture of betas prior: comparing SIR and Metropolis-Hastings schemes](#)
- 2018: [Bayesian CAPM](#)
- 2018: [Gaussian and non-Gaussian GARCH models + Rmarkdown + Petrobras](#)
- 2018: [Modeling time-varying variances via stochastic volatility \(SV\) models](#)
- 2018: [Hidden Markov model: forward filtering, backward sampling \(Rmd code\)](#)
- 2018: [VAR homework](#)

- 2017: [R code for the AR\(2\) example worked in class](#)
- 2017: [R for Shumway and Stoffer's chapter 1](#)
- 2017: [More R code for the AR\(1\) and AR\(2\) processes \(Slides\)](#)
- 2017: [R markdown script \(run via Rstudio\) \(PDF output or HTML output\)](#)
- 2017: [Monte Carlo exercise: studying the sampling behavior of the t test under unit root](#)
- 2017: [Bayesian inference for the Gaussian AR\(2\) model \(R code\)](#)
- 2017: [Computing pi via rejection sampling: our first MC sampling scheme](#)
- 2017: [MC integration for a simple normal-normal example](#)
- 2017: [Gibbs sampler for AR\(1\) model with a changing point \(changing in the intercept\)](#)
- 2017: [Brazilian monthly production of cement \(January 2002 to February 2017\)](#)
- 2017: [AR\(1\) plus noise + Figure 1 + Figure 2.](#)
- 2017: [AR\(1\) plus noise – Kalman filter and smoother + Figures.](#)
- 2017: [AR\(1\) plus noise – Bayesian inference via MCMC/FFBS + Figures.](#)
- 2017: [AR\(1\) plus noise – Modeling Alcoa realized volatilities via 1st order DLM + Data.](#)
- 2017: [AR\(1\) plus noise – Comparing block move \(FFBS\) with single move MCMC schemes](#)
- 2017: [Linear regression with Markov switching intercept – R code + Figures](#)