Andrew Harvey, Emeritus Professor of Econometrics in the Faculty of Economics and Politics, Cambridge University, Visiting Scholar at Ca' Foscari University

Dario Palumbo, Researcher at the Department of Economics, Ca' Foscari University

Advances in Non-Linear Time Series Modelling

Reading Seminars

May 6, 13, 20, 2025 - 10:00-12:00, Meeting room 7

1st Session – Linear and Non-Linear Structural Time Series (Prof. Andrew Harvey)

In this session we will cover the basics of univariate linear and non-linear structural time series. The linear, and linearised, state space representation and the Kalman Filter. A revision of GARCH and EGARCH models as well as an introduction to score-driven models

Tentative Reading List

Creal, D., S. J. Koopman, and A. Lucas (2013). Generalized autoregressive score models with applications. *Journal of Applied Econometrics* 28, 777‐795.

Harvey, A.C. (1993) *Time Series Models*. 2nd Edition, The MIT Press. Ch. 4, 5 and 8

Harvey A. C. (1990). *Forecasting, Structural Time Series Models and the Kalman Filter*. Cambridge University Press; 1990. Ch.3

Harvey, A. C. (2013). *Dynamic models for volatility and heavy tails: with applications to financial and economic time series*. Econometric Society monograph. Ch. 1,2 and 3

Harvey, A (2022) Score-driven time series models. *Annual Review of Statistics and Its Application,* 9, 321-42. doi: 10.1146/annurev-statistics-040120-021023

R. S. Tsay (2005), *Analysis of Financial Time Series*, 2nd Edition, John Wiley & Sons, New York. Ch. 3

2nd Session – Score-Driven Models for Volatility and Time Varying Tails (Dario Palumbo)

In this session we will be focussing on score driven models for modelling time varying volatility in non-linear heavy-tailed time series and their ability to capture properties of financial data. In the lecture we will cover the beta-t-EGARCH model for time varying volatility, also in the presence of time varying location. We will introduce the location/scale GB2 score-driven model for modelling realized volatility of financial assets and their distribution. At last, we will present a score-driven approach for the modelling of time-varying tails and the occurrence of extreme events. In doing so we will compare the performance of score-driven filters in handling heavy-tailed time series and empirically compare their performance against classical methods for the modelling of volatility and extreme events.

Essential Reading List

Harvey, A. C. (2013). *Dynamic models for volatility and heavy tails: with applications to financial and economic time series*. Econometric Society monograph. Ch. 3-5.

Creal, D., Koopman, S.J. and Lucas, A. (2013), Generalised Autoregressive Score Models with Applications. *Journal of Applied Econometrics*., vol. 28, pg. 777-795.

Harvey, A. C. and A. Luati (2014). Filtering with Heavy Tails. *Journal of the American Statistical Association*, vol. 109, no. 507, pg. 1112–22

Harvey, A. C. and D. Palumbo (2023). Score-driven models for realized volatility. *Journal of Econometrics* 237, vol. 2 (Part B), 105448.

Lucas A. and X. Zhang (2016) Score-driven exponentially weighted moving averages and Value-at-Risk forecasting, *International Journal of Forecasting*, vol. 32, no. 2, pp. 293-302.

Palumbo, D. (2021). Testing and Modelling Time Series with Time Varying Tails. *Cambridge Working Paper Series*. https://doi.org/10.17863/CAM.65414

Extended Reading List

Harvey, A., and Lange, R.-J. (2017) Volatility Modelling with a Generalized *t* Distribution. *Journal of Time Series Analysis*, vol. 38, pg. 175–190.

Corsi, F. (2009). A simple approximate long-memory model of realized volatility. *Journal of Financial Econometrics*, vol. 7, pg. 174‑196.

Follow-up Reading List

Blasques, F., Gorgi, P., Koopman, S. J. and Wintenberger, O. (2018): Feasible invertibility conditions and maximum likelihood estimation for observation-driven models, *Electronic Journal of Statistics*, vol. 12, pg. 1019-1052.

Blasques, F., van Brummelen, J., Koopman, S. J. and Lucas, A. (2022): Maximum Likelihood Estimation for Score-Driven Models, *Journal of Econometrics*, vol. 227, n. 2, pg. 325-346.

Opschoor, A., Janus, P., Lucas, A., & Van Dijk, D. (2017). New HEAVY Models for Fat-Tailed Realized Covariances and Returns. *Journal of Business & Economic Statistics*, vol. 36, n. 4, pg. 643–657.

3rd Session - Multivariate Score-Driven Models and the Modelling of the Term Structure of Interest Rates (Dario Palumbo)

This session explores multivariate score-driven models for heavy-tailed multivariate time series. We will introduce the general framework of multivariate score-driven models, emphasizing their ability to capture time-varying volatilities, correlations, and dynamic dependencies across multiple financial variables. The discussion will highlight the advantages of score-driven filters in high-dimensional settings and their relationship with classical multivariate GARCH and dynamic conditional correlation (DCC) models. A key focus will be on the application of score-driven methods to interest rate modelling, particularly in forecasting the term structure of government bond yields. We will examine a score-driven filter for extracting and modelling the term structure of interest rates directly from bond prices. This will include a score-driven extension of term structure factor models, such as the dynamic Nelson-Siegel approach and its variants. Empirical applications will illustrate how these models enhance the characterization of risk dynamics, capturing shifts in macro-financial conditions, time-varying volatility, and the effects of the zero lower bound with greater accuracy.

Essential Reading List

Harvey, A. C. (2013). *Dynamic models for volatility and heavy tails: with applications to financial and economic time series*. Econometric Society monograph. Ch. 7

Creal, D., S. J. Koopman, and A. Lucas (2011). A dynamic multivariate heavy-tailed model for time-varying volatilities and correlations. *Journal of Business & Economic Statistics*. Vol. 29, n. 4, pg. 552-563.

Lucas, A., B. Schwaab and X. Zhang (2014) Conditional Euro Area Sovereign Default Risk. *Journal of Business & Economic Statistics*, Vol. 32, No. 2 (April 2014), pp. 271-284

Diebold, F. X. and C. Li (2006). Forecasting the term structure of government bond yields. *Journal of Econometrics*, vol. 130, n. 2, pg. 337-364.

Koopman, S., A. Lucas, and M. Zamojski (2017). Dynamic term structure models with score-driven time-varying parameters: estimation and forecasting. *NBP working paper 258*.

Extended Reading List

Bollerslev, T. (1990). Modelling the Coherence in Short-Run Nominal Exchange Rates: A Multivariate Generalized Arch Model. *The Review of Economics and Statistics*, vol. 72, n. 3, pg. 498-505.

Engle, R. (2002) Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models *Journal of Business & Economic Statistics*, vol. 20, n. 3, pg. 339-350

Bauwens, L., S. Laurent, and J.V.K. Rombouts, 2006), Multivariate GARCH models: a survey. *Journal of Applied Econometrics*, vol. 21, pg. 79-109.

Diebold, F. X. and G. D. Rudebusch (2013). *Yield curve modeling and forecasting: The dynamic nelson-siegel approach*. Princeton University Press.

D'Innocenzo, E., A. Luati, and M. Mazzocchi (2023). A robust score-driven filter for multivariate time series. *Econometric Reviews*, vol. 42, n. 5, pg. 441-470.

Gasperoni, F., A. Luati, L. Paci, and E. D'Innocenzo(2021). Score-Driven Modeling of Spatio-Temporal Data. *Journal of the American Statistical Association*, vo. 118, n. 542, pg. 1066–1077.

Follow-up Reading List

Krippner, L. (2015). *Zero lower bound term structure modeling: A practitioner's guide*.

Monfort, A. and F. Pegoraro, (2007) *Switching VARMA Term Structure Models,* Journal of Financial Econometrics, vol. 5, n. 1, pg. 105–153.

Monfort, A., F. Pegoraro, J. P. Renne, G. Roussellet, (2017) Staying at zero with affine processes: An application to term structure modelling, *Journal of Econometrics*, vol. 201, n. 2, pg. 348-366.