FINANCIAL ECONOMETRICS

Module 3, 2023-2024

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Course information

Course Website: https://my.nes.ru/

Class Time: Fridays, 10:15-11:45 and 11:50-13:20

Room Number: 403

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Instructor's Office Hours: TBA; tentatively on Fridays 15:30-16:30

Course description

This module aims to provide students with advanced methods of statistical inference, econometrics and time series analysis, including those for Big Data. It will cover classical and modern statistical and econometric models and methods used to analyse data in Finance, Economics, Risk Management and Computer Science. The module will further discuss applications of the methods in the analysis of important research problems and key variables in the above fields using real-world datasets and their implementation in *Python*, *R* and other packages. The treatment of the module topics will involve many examples and applications of statistical and econometric approaches and models.

Among other topics, the module will focus on time series models for key financial and economic variables and indicators, their properties, estimation, and empirical applications. The module will discuss the main statistical regularities common for many variables and databases in Finance, Economics, Computer Science and other fields, including dependence, volatility clustering, heterogeneity, heavy-tailedness, effects of structural breaks, crises and their propagation, and modern methods for modelling and analysis of these properties and phenomena.

The treatment of the material and empirical examples in the module will be based on applications of statistical and computer software environments such as *Python*, *R,* and other packages, e.g., *STATA* and *Matlab* will also be discussed.

The emphasis of the module will be on empirical applications for datasets, time series and models in Finance, Economics, Risk Management and Computer Science, and mathematics of the statistical methods covered will be introduced only as needed and will not be a central focus.

Course prerequisites

- Students are assumed to have completed introductory courses in statistics, probability, calculus, matrix algebra and have taken the Econometrics-1 course.

  An excellent review of probability and statistics that should suffice for the course is provided in Chs. 2 and 3 of SW (2020) (see also HAGS, 2021, for the treatment and illustrations of the concepts and topics therein using *R*).

Grading policy

- There will be 2 problem sets and a take home assignment each of which involves empirical analysis. These will be counted for 20% of the final grade. The empirical exercises may be completed using any software such as STATA, *R* or Python (using the latter two is recommended). Please append your computer codes to the problem sets.

- Further, there will be a take home assignment that will focus on different topics and methods covered in the course and their empirical applications. This will be counted for 80% of the final grade. Like problem sets, the empirical questions in the assignment may be completed using any software such as STATA, *R* or Python (using the latter two is recommended). Please append your computer codes to the problem sets.

Recommendations for students on how to succeed in the course (optional but encouraged)

- Participation and discussion in the course is important. Showing up is the key to success in this course.
- Please let the lecturer know at any time during class if you have any questions or we need to discuss any topics or concepts in further detail.
- Review lecture materials before classes.
- Reading the suggested readings is recommended (not necessarily in detail) and will give you a deeper understanding of the material.

Module Aims & Objectives

This module aims to provide students with advanced methods of statistical inference, econometrics and time series analysis, including those for Big Data, and discuss their implementation in *Python*, *R* and other packages. Applications to modelling, the analysis and forecasting key variables and indicators in Finance, Economics, Computer Science and related fields, including asset prices, financial returns, foreign exchange rates, returns on technological innovations and cryptocurrency prices and returns, will be covered.

The tentative topics are listed below (some of the topics will be covered if time allows):

1. Introduction and overview. Stylized facts and key statistical properties of important variables and indicators in Finance, Economics, Computer Science and related fields, e.g., asset prices, financial returns, foreign exchange rates, cryptocurrency prices and returns, and returns on technological innovations.

a) Absence of linear correlations;

b) Crises, structural breaks, large dowfalls and fluctuations and heavy tails;

c) Volatility clustering;

d) Financial contagion.

2. Time series models of the mean, stationary and nonstationary time series and their empirical applications.

a) Introduction to time series data and serial correlation; stationarity and nonstationarity; autoregressions; autoregressive distributed lag (ADL) models; lag length selection methods;

b) Nonstationary time series models I: Deterministic and stochastic trends, random walk and unit root processes;

c) Long memory processes;

d) Nonstationary time series models II: Structural breaks;

e) Co-integration.

3. Time series models of the variance, their properties and applications in Finance, Economics and related fields.

a) Generalized auto-regressive conditional heteroskedasticity (GARCH) models and their properties, including generation of stylized facts of financial markets, e.g., absence of linear autocorrelations; volatility clustering and nonlinear dependence; large downfalls and large fluctuations, and heavy-tailedness.

b) Applications: Asset prices, financial returns, foreign exchange rates, cryptocurrency prices and returns, and returns on technological innovations.

4. Heavy-tailed distributions and their applications in Finance, Economics, Computer Science and related areas, including modelling large downfalls and fluctuations and the effects of crises.

a) Stylized facts of financial and economic markets. Crises, structural breaks, large downfalls and large fluctuations in asset prices, financial returns, foreign exchange rates, cryptocurrency prices and returns, and returns on technological innovations.

b) Heavy-tailed distributions and their applications in Finance, Economics, Computer Science and related fields;

c) Inference on the degree of heavy-tailedness and probabilities of large downfalls and fluctuations in financial and economic markets and key variables in Finance, Economics, Computer Science and related fields: Hill's and log-log rank-size regression approaches.

5. Modelling and inference on financial contagion and propagation of crises and other structural shocks in financial and economic markets.

a) Copula dependence models for cross-sectional and time series data;

b) Inference on copula dependence structures;

c) Applications in modelling and inference on financial contagion and propagation of crises and other structural shocks.

6. Prediction and forecasting with many regressors and Big Data. Applications of machine learning methods in Economics, Finance and related fields.

a) Prediction and forecasting with many regressors and the analysis of Big Data. Introduction to machine learning methods;

b) Forecasting with many predictors in time series data and the analysis of big time series;

c) Applications in Economics, Finance and related fields.

READING LIST

Module readings	Core: ● Lecture Notes
	Supplementary: Very useful textbooks with an excellent treatment of the material and many empirical examples are Wooldridge (W, 2020) and Stock and Watson (SW, 2020). ● Wooldrige, J. M. (W, 2020) *Introductory Econometrics*: *A Modern Approach.* 7th edition (or other editions). CENGAGE. Boston, MA. ISBN: 978-1-337-55886-0.

The 5th edition of the textbook is available at https://economics.ut.ac.ir/documents/3030266/14100645/Jeffrey_M._Wooldridge_Introductory_Econometrics_A_Modern_Approach__2012.pdf

The book's companion website at

https://www.cengage.com/cgi-wadsworth/course_products_wp.pl?fid=M20b&product_isbn_issn=9781337558860 provides student resources for W (2020), including data sets and solutions for odd-numbered exercises in the book.

The following are empirical companions to W (2020) that build on the textbook and demonstrates how to replicate the empirical applications and examples discussed therein using *Python* and *R*.

- Heiss, F. and Brunner, D. (HD, 2020). *Using Python for Introductory Econometrics.* 1st edition. CreateSpace Independent Publishing Platform. Available at http://www.upfie.net/
- Heiss, F. (H, 2016). *Using R for Introductory Econometrics*. CreateSpace Independent Publishing Platform. Available at http://www.urfie.net

Stock and Watson' (2020) excellent textbook is

- Stock, James H. and Watson, M. W. (SW, 2020) *Introduction to Econometrics*. Fourth edition, Global edition. Harlow, England : Pearson Education Limited. ISBN: 9781292264455.

The 3rd edition of the textbook is available at https://www.ssc.wisc.edu/~mchinn/stock-watson-econometrics-3e-lowres.pdf

The following websites provide student resources for SW (2019), the data and other materials (like the data for empirical exercises, the answers to odd-numbered exercises in the book, etc.): https://www.princeton.edu/~mwatson/Stock-Watson_4E/Stock-Watson-Resources-4e.html

The following is an empirical companion to Stock and Watson (2020) that blends *R* programming with the context of the book:

- Hanck, Christoph, Arnold, M., Gerber, A. and Schmelzer, M. (HAGS, 2021) *Introduction to Econometrics in R*. Available at https://www.econometrics-with-r.org/

The following books provide an advanced treatment of different topics covered and related to those in the course.

- Campbell, John Y., Lo, A. W. and MacKinlay, A. C. (CLM, 1997) *The Econometrics of Financial Markets*. Princeton University Press. ISBN: 0691043019.
- Tsay, R. S. (Tsay, 2013). *An Introduction to Analysis of Financial Data with R.* Wiley.
- Tsay, R. S. (2010). *Analysis of Financial Time Series*. *Wiley.*
- Tsay, R. S. (2013). *Multivariate Time Series Analysis With R and Financial Applications*. Wiley.
- McNeil, Alexander J., Frey, R. and Embrechts, P. (MFE, 2015) *Quantitative Risk Management*: *Concepts, Techniques, and Tools*. Revised Edition. Princeton University Press. ISBN: 9780691166278.
- Ibragimov, M., Ibragimov, R., & Walden, J. (IIW, 2015) *Heavy-Tailed Distributions and Robustness in Economics and Finance*. Springer. ISBN: 9783319168760.
- Embrechts, Paul, Klüppelberg, C. and Mikosch, T. (EKM, 1997) *Modelling Extremal Events for Insurance and Finance*. Springer. ISBN: 3540609318.
- Christoffersen, Peter F. (Christoffersen, 2011) *Elements of Financial Risk Management.* 2nd ed.. Elsevier Science. ISBN: 9780080922430.
- Ibragimov, R. and Prokhorov, A. (IP, 2017). Heavy Tails and Copulas: Topics In Dependence Modelling In Economics And Finance. World Scientific.
- Hamilton, James D. (1997) *Time series analysis*. Princeton University Press. ISBN: 0691042896.
- Maddala, G. S. (c2009.) *Introduction to econometrics* / [electronic resource] G.S. Maddala, Kajal Lahiri.. pp.1 electronic resource (634 p.). 4th ed.. Wiley. ISBN: 9781119958994.
- Johnston, Jack (2007) *Econometric methods*. 4th. McGraw Hill. ISBN: 9780071259644.
- Wooldrigde, J. M. (2010). *Econometric Analysis of Cross Section and Panel Data*. Second Edition, MIT Press.
- Hansen, B. (2019). *Econometrics*. https://www.ssc.wisc.edu/~bhansen/econometrics/

	Hansen (2019) provides more advanced treatment of statistical inference and econometrics, with many empirical examples of the analysis of economic and financial data in *R*. • Casella, G. and Berger, R. L. (2002). *Statistical Inference.* 2nd ed. Duxbury. An advanced treatment of statistical theory. • James, G., et al. (2013) *An Introduction to Statistical Learning with Application in R*. Springer. Available at https://link.springer.com/book/10.1007/978-1-4614-7138-7 James *et al.* (2013) is a very useful reference for regression models from machine learning perspective and other topics in machine learning. • Hastie, T., Tibshirani, R. and Friedman, J. (2009). *The Elements of Statistical Learning: Data Mining, Inference and Prediction*. 2nd ed. Available at https://hastie.su.domains/ElemStatLearn/ An advanced treatment of machine learning and related topics. On the course website we will also post suggested readings that will illustrate the concepts and methods covered; reading the material is recommended (not necessarily in detail) and will provide a deeper understanding of the material. Computer-projected overhead lecture slides will be available on the course website the day before the class.

TOPICS COVERED AND TENTATIVE SCHEDULE

1. Introduction and overview. Stylized facts and key statistical properties of financial markets a) Absence of linear correlations b) Crises, large fluctuations and heavy tails c) Volatility clustering d) Financial contagion	Core: • Lecture Notes Supplementary: • W, HD and H – Ch. 1 and the overview in Chs. 10, 11 & 12; SW & HAGS - Chs. 1-3, and the overview in Ch. 15; Tsay - Ch. 1; CLM - Chs. 1-2; • Cont (2001) and other supplementary readings at the course website • IIW (Stylized facts and key statistical properties of financial and economic markets, and their importance for financial, economic models and econometric inference)

2. Time series models of the mean, stationary and nonstationary time series and their financial applications a) Introduction to time series data and serial correlation; stationarity and nonstationarity; autoregressions; autoregressive distributed lag (ADL) models; lag length selection methods b) Robust inference methods for time series: Heteroskedasticity and autocorrelation consistent (HAC) inference and other heteroskedasticity and autocorrelation robust (HAR) methods	Core: • Lecture Notes Supplementary: • W, HD and H - Chs. 10-11; SW, Chs. 15-16 (e.g., Sections 15.1-15.6; 16.1-16.8) & HAGS - Chs. 14-15 (Sections 14.1-14.6; 15.1-15.6); Tsay, Chs. 2-3 (e.g., Sections 2.1-2.6; Sections 3.1-3.3); Christoffersen, Ch. 3; CLM – Chs., 1-2 (Stationary time series, inference on them and the use in forecasting) • W, HD and H – Ch. 12 (including Section 12.2 in W for HAC inference); SW, Section 16.4 & HAGS, Section 15.4 (HAC inference) • IIW, Section 3.3 (*t*-statistic approaches to heteroskedasticity and autocorrelation robust – HAR - inference) • Supplementary readings at the course website
3. Time series models of the mean, stationary and nonstationary time series and their financial applications – Ctd. b) Nonstationary time series models I: Deterministic and stochastic trends, random walk and unit root processes	Core: • Lecture Notes Supplementary: • W, HD and H - Chs. 10-11 and Sections 18.1-18.3 (including Section 11.3 and 18.2 in W for tests for unit roots); SW Section 15.7 & HAGS – Section 14.7; Tsay, Chs. 2-3 (e.g., Sections 2.7, 3.2); CLM – Ch. 2 (e.g., Sections 2.1-2.4) (Deterministic and stochastic trends, and tests for unit roots) • Supplementary readings at the course website
4. Time series models of the mean, stationary and nonstationary time series and their financial applications – Ctd. b) Nonstationary time series models I: Deterministic and stochastic trends, random walk and unit root processes -ctd. c) Co-integration	Core: • Lecture Notes Supplementary: • W, HD and H – Chs. 10-11 and Sections 18.1-18.3; SW Chs. 15-16 (e.g., Sections 15.1-15.6; 16.1-16.8) & HAGS - Chs. 14-15 (Sections 14.1-14.6; 15.1-15.6); Tsay, Chs. 2-3 (e.g., Sections 2.1-2.6; Sections 3.1-3.3); CLM – Chs., 1-2 (Deterministic and stochastic trends, and tests for unit roots) • W, HD and H –Sections 18.4; SW, Section 17.4 & HAGS, Section 16.3 (Cointegration) • Supplementary readings at the course website
5. Time series models of the mean, stationary and nonstationary time series and their financial applications – Ctd. d) Long memory processes e) Nonstationary time series models II: Structural breaks	Core: • Lecture Notes Supplementary: • CLM, Section 2.6, Tsay, Sections 2.11 and 4.14 (Long memory models and their empirical applications) • W, HD and H – Section 13.1a; SW, Section 15.8 & HAGS, Section 14.8 (Structural breaks, tests and inference on them: the case of known and unknown break date) • Supplementary readings at the course website

6. Time series models of the variance a) Generalized auto-regressive conditional heteroskedasticity (GARCH) models and their properties, b) Applications: Asset prices, financial returns and foreign exchange rates	Core: • Lecture Notes Supplementary: • SW Section 17.5 & HAGS, Section 16.4; Tsay, Chs. 4 and 5; Christoffersen, Ch. 4 and others; CLM – Section 12.2 (GARCH processes and their empirical applications) • Supplementary readings at the course website
7. Heavy-tailed distributions and their financial and economic applications, including crises modelling a) Stylized facts of financial markets, crises, large downfalls and large fluctuations b) Heavy-tailed distributions and their applications in finance and economics c) Inference on the degree of heavy-tailedness and probabilities of large downfalls and fluctuations in financial and economic markets: Hill's and log-log rank-size regression approaches	Core: • Lecture Notes Supplementary: • MFE; IIW; EKM; Christoffersen, Ch. 6; Tsay, Section 7.6 and 7.7 (Heavy-tailed distributions, inference on the degree of heavy-tailedness, and empirical applications: Crises modelling)
8. Modelling and inference on financial contagion and propagation of crises and other structural shocks in financial and and economic markets a) Copula dependence models for cross-sectional and time series data b) Inference on copula dependence structures c) Applications in modelling and inference on financial contagion and propagation of crises and other structural shocks	Core: • Lecture Notes Supplementary: • MFE, Christoffersen, Ch. 9, IP • Ibragimov (2010, Copula Estimation) and other references in supplementary readings on the course website (Copula models and inference; empirical applications: modelling financial contagion and propagation of crises in financial and economic markets)
9. Prediction and forecasting with many regressors and Big Data. Applications of machine learning methods in Economics, Finance and related fields. a) Prediction and forecasting with many regressors and the analysis of Big Data. Introduction to machine learning methods; b) Forecasting with many predictors in time series data and the analysis of big time series; c) Applications in Economics, Finance and related fields.	Core: • Lecture Notes Supplementary: • SW Chs. 14 and Section 17.6; JWHT (Prediction and forecasting with many predictors and Big Data; intro to machine learning methods)

Description of course methodology

A typical lecture will provide a theoretical part on course material as well as discuss how the econometric methodology discussed can be applied for practical cases.

Sample tasks for course evaluation

Time-Varying Volatility in Phillips Curve (Motivated by research of R. F. Engle and C. W. J. Granger, Economics Nobel Prize - 2013)

You have collected quarterly Canadian data on the unemployment and the inflation rate from 1962 to 1999. You want to estimate the ADL(3,1) formulation of the Phillips curve using a GARCH(1,1) specification for errors u_t . The results are as follows:

$$\widehat{\Delta Inf C_t} = \underset{(0.48)}{1.17} - \underset{(0.08)}{0.56}\,\Delta InfC_{t-1} - \underset{(0.10)}{0.47}\,\Delta InfC_{t-2} - \underset{(0.09)}{0.31}\,\Delta InfC_{t-3} - \underset{(0.06)}{0.13}\,UnempC_{t-1} + u_t \quad (4)$$

where the errors u_t follow a GARCH(1, 1) process $u_t = \sigma_t \varepsilon_t$ with i.i.d. standard normal innovations $\varepsilon_t \sim N(0,1)$ and the volatility dynamics estimated as

$$\sigma_t^2 = \underset{(0.40)}{0.86} + \underset{(0.11)}{0.27}\,u_{t-1}^2 + \underset{(0.15)}{0.53}\,\sigma_{t-1}^2 .$$

(a) Test the two coefficients at u_{t-1}^2 and σ_{t-1}^2 in the GARCH volatility dynamics model individually for statistical significance.

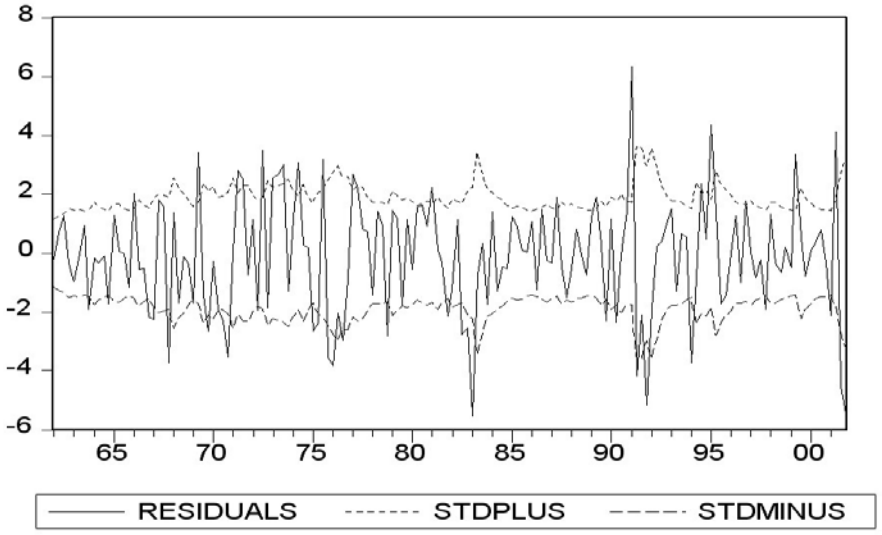
(b) Estimating the same equation by OLS results in

$$\widehat{\Delta Inf C_t} = \underset{(0.54)}{1.19} - \underset{(0.10)}{0.51}\,\Delta InfC_{t-1} - \underset{(0.11)}{0.47}\,\Delta InfC_{t-2} - \underset{(0.08)}{0.28}\,\Delta InfC_{t-3} - \underset{(0.07)}{0.16}\,UnempC_{t-1}$$

Briefly compare the estimates with those in Eq. (4) with GARCH(1, 1) errors. Which of the two methods do you prefer? Explain your answer.

(c) Given your results from the test in (a), what can you say about the variance of the error terms in the Phillips Curve for Canada?

(d) The following figure plots the residuals along with bands of plus or minus one predicted standard deviation (that is, $\pm\widehat{\sigma_t}$) based on the GARCH(1,1) model.



Describe what you see.

Course materials

Core: Lecture Notes

Suggested: The above recommended references and readings posted on the course website.

Academic integrity policy

Cheating, plagiarism, and any other violations of academic ethics at NES are not tolerated.