Ph.D. in ECONOMICS – Universities of Milan and Pavia

Time Series Econometrics
Academic year 2025-26 – Second Term

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Course description:

In this module, we will discuss the foundations of time series: linear models for univariate time series, unit roots, and extensions for vector-valued time series.

Learning objectives

A great variety of physical and economic data are in the form of time series. Typical objectives include:

- Identify the effect of past shocks on the current state of the world: were the shocks transitory or permanent? How much of a past shock is still relevant today?
- Forecasting future values

For multivariate time series, we are also interested in

- Modelling the dynamic interaction between different series.

Much empirical literature in macroeconomics uses time series. By the end of the module you should have a working knowledge to understand the techniques used in this literature

Learning Outcomes

By the end of the module you will be able to:

Understand the difference between a time series and an independent random sample.
Apply non-parametric and parametric techniques to model time series.
Choose and estimate parametric models for time series.
Compute the impulse response function.
Forecast future values.
Practical competence with Matlab is part of the learning outcomes. By the end of the module, students should be able to use basic functions in Matlab and build small programs, and to run an articulated, independent analysis.

Course prerequisites: Econometrics

Course organization: 20 hours of lectures

Course Assessment:

There is a final compulsory exam.
The exam will be composed of TWO parts.

- There will be TWO practical mini-projects, to be completed by the date of the exam (details about these projects will be given during the lectures).

- There will be an oral conversation, discussing the projects but also covering other topics covered in the module.

Syllabus

The syllabus is subject to time constraints, so not all topics may be touched upon. A tentative syllabus is as follows.
Appropriate references to the relevant item(s) in the reading list are given during each lecture.
Please be aware that the time devoted to each topic and the list of subjects may change according to the requirements of the course. Please notice that there is no coincidence between the points of this plan and the lectures; some topics may take more than one session and vice versa.
Whilst lecture notes are enough, the book by Hamilton (see below for a reference) is mainly followed, and referred to as H; the book by Brockwell and Davis (BD) is also a possible reference.

Introduction

Moments (H, Appendix A.5 and Chapter 3);

Lag & Difference operators (H, Chapter 2);
Stationarity (definition) (H, Chapter 3);
Wold decomposition (H, Chapter 4);
Mixing / weak dependence (definition) (H Chapter 3; W. Chapter 3)
Bernoulli shifts (definition) (please consult the lecture notes);
Autocovariance (definition) (H Chapter 3).

Linear processes

Beveridge Nelson Decomposition (PS)
Non-parametric and parametric estimation of the long run variance. (DM)
Forecasting and Impulse Response for Stationary processes
Impulse Response Function (H Chapter 1 and 11);
Partial autocorrelation (definition) (H, Chapter 4);
Forecasting and linear projection (H, Chapter 4).

Foundations of inference in ARMA models

Estimation from the correlogram (BD Chapter 5)
Exact Maximum Likelihood estimation (H, Chapter 5)
Conditional Maximum Likelihood estimation (H, Chapter 5)
Optimisation of the (Pseudo) Maximum Likelihood
Order selection

Vector Autoregressions

Vector White Noise, Vector ARMA, (H, Chapter 10)
Inference for VARs, (H, Chapter 11)
Granger- causality, (H, Chapter 11)
Impulse Response Function, (H, Chapter 11)
Structuralised IRF, (H, Chapter 11)
Forecast error variance decomposition (H, Chapter 11)

Unit roots

Brownian motion (H, Chapter 17)
Functional central limit theorem and applications (H, Chapter 17)
The Dickey Fuller test: various cases
Choice of the unit root test (H, Chapter 17)

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Augmented Dickey Fuller test for a unit root when the disturbances have a stationary AR(p) structure (H,
Chapter 17; BD, Chapter 6)
Choice of the order p in the ADF test (H, Chapter 17)
Phillips-Perron tests for a unit root in a generic I(1) process (H, Chapter 17)

Spurious regression and cointegration

Unit root VARs (H, Chapter 18)
Spurious regression for I(1) processes (H, Chapter 18)
Cointegration for I(1) processes (H, Chapter 19)
Testing for cointegration with the ADF test (H, Chapter 19)
The Vector Error Correction Model (H, Chapter 19)
Maximum likelihood inference in the Vector Error Correction Model

References

The main reference textbook for the course is:

Time Series Analysis, by J. D. Hamilton, 1994, Princeton University Press. Other main references may be mentioned as the course progresses.

Other references

Brockwell, P.J; and R.A. Davis, 2002. Introduction to time series and forecasting. New York: Springer
White, H., 2000, Asymptotic Theory for Econometricians, Revised Edition, New York: Academic Press.

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