

# Course Book

## Econometrics III

B.Sc. Econometrics and Operations Research, year 3

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## 1 Course goals

The first part of the course will give you a thorough introduction to the theory and practice of multiple time series analysis, including vector autoregressive and vector error correction models. We will start out by reviewing some concepts from univariate time series analysis. In the second (much shorter) part of the course, you will learn about panel data analysis, including fixed effects and random effects estimation of panel models.

## 2 Classes and materials

### Recorded online lectures

All lectures are delivered in video clips that you can watch online in your own time. Therefore, **the lecture times provided on rooster.vu.nl are irrelevant!** The videos are uploaded every Monday. In total, we will have 6 weeks of lectures, which is the standard SBE teaching period (not 7 weeks).

**Note:** You are strongly encouraged to watch the lecture videos every week, starting in week 1. Knowledge of the lecture materials will be highly beneficial in the live tutorial sessions on Fridays.

### Live online tutorials

The tutorials take place every Friday in two groups at the times provided on rooster.vu.nl. They are Zoom sessions that will not be recorded. The tutorials will be devoted to solving exercises and answering your questions.

### Course materials

Besides weekly sets of lecture slides, there are two types of problem sets with exercises: theoretical and practical. The theoretical exercises can be found in the "Book of Exercises". The practical exercises are provided in 3 problem sets that you are expected to solve mostly in self-study. The practical exercises involve using the software **R** (see section 6 below).

### Homework

Every week, you will be asked to prepare some problems (from the Book of Exercises and the practical problem sets) as homework. It is highly recommended to form study groups and discuss the homework questions amongst each other every week. You may also use the "Discussions" section on the Canvas course page.

## 3 Assignments

There will be **two** assignments. The deadline for handing them in will be communicated via the course page on Canvas. Handing in the assignments is **compulsory**. The results counts for 15% of the final grade each, i.e. the assignments count for 30% in total. There will be no resits for the assignment. In case you already took this course last year, you can keep the assignment grades you obtained then. The assignments will consist of empirical questions that have to be solved using **R** or, alternatively, Matlab, Python, or Ox. You may **not** use Stata or Eviews. The assignments are graded together with the exam. A solution to the assignment questions is sketched in the exercise sessions on Fridays. The assignments should be solved in **groups of four**.

## 4 Textbooks

### Lütkepohl

The main reference for this course.

- Helmut Lütkepohl: [https://www.diw.de/sixcms/detail.php?id=diw\\_01.c.390894.en](https://www.diw.de/sixcms/detail.php?id=diw_01.c.390894.en)

This book is the standard graduate level textbook in multiple time series analysis (well, what's graduate elsewhere is undergrad in our Bachelor ☺). The notation used in the slides is the same as in this book, but the ordering and logic of the slides sometimes deviates from the chapter ordering. The book can be useful if you need to look up something, if you miss a lecture and, generally, to read along. It also has a nice appendix on matrix algebra. Of course, it covers much more than we discuss in this course.

Helmut Lütkepohl (2006): *New Introduction to Multiple Time Series Analysis*. Springer.

### Abadir and Magnus

- Karim Abadir: <https://www.imperial.ac.uk/people/k.m.abadir>
- Jan Magnus: <http://www.janmagnus.nl>

This book is structured as a collection of exercises on all aspects of matrix algebra. Every chapter has an introduction, before the material is presented in step-by-step exercises with solutions. It covers (almost) everything an econometrician needs in terms of matrix algebra. It's available as e-book in the VU library, so I uploaded it on Canvas. The book is a great resource to look up specific concepts – no need to read entire chapters unless it's indicated in class.

Abadir, K.M. and J.R. Magnus (2005): *Matrix Algebra*. Cambridge.

### More literature

- This book is not directly used in this course, but it is the standard textbook in time series analysis and also contains several chapters on multiple time series models:

Hamilton, James D. (1994): *Time Series Analysis*. Princeton University Press.

- For the part on panel data models, we will use the notation from the book of Baltagi (2013). Since we only really cover two chapters, it is not necessary to get it unless you are interested in going further with panel data. In this case the book of Wooldridge (2010) may also be of interest.

Baltagi, Badi H. (2013) *Econometric Analysis of Panel Data*. Wiley.

Wooldridge, Jeffrey M. (2010) *Econometric Analysis of Cross Section and Panel Data*. The MIT Press.

## 5 Content outline

The contents covered in each week will be (approximately) the following:

**Week 1** Introduction to multiple time series analysis, VAR(1) models

- Review of univariate time series analysis: Stability, stationarity, lag operator, autoregressive processes (slides, lecture notes)

- Review of least squares, generalized least squares, and maximum likelihood estimation of the linear regression model in matrix notation (slides, lecture notes)
- Stable VAR(1) processes: construction, moving average representation, moments (Lütkepohl, Ch. 2.1)

#### **Week 2** VAR( $p$ ) models and estimation

- Stable VAR( $p$ ) processes: moments, moving average representation (Lütkepohl, Ch. 2.1)
- Multivariate least squares estimation of VAR( $p$ ) models, including asymptotics (Lütkepohl, Ch. 3.1–3.2)
- Maximum likelihood estimation of VAR( $p$ ) models (Lütkepohl, Ch. 3.4)

#### **Week 3** VAR models: Structural analysis, forecasting, model selection

- Concept of Granger causality, testing for Granger causality (Lütkepohl, Ch. 2.3.1, 3.6)
- Impulse response analysis (Lütkepohl, Ch. 2.3.2, 3.7)
- Forecasting VAR processes (Lütkepohl, Ch. 2.2)
- VAR order selection using tests and information criteria (Lütkepohl, Ch. 4.1.–4.3)

#### **Week 4** Vector error correction models, part 1

- Review of univariate time series analysis: random walks (slides and lecture notes)
- Cointegration and error correction models (Lütkepohl, Ch. 6.3)
- Cointegration in  $K$ -dimensional VAR( $p$ ) processes (Lütkepohl, Ch. 6.3)

#### **Week 5** Vector error correction models, part 2

- Preliminaries: Projections and Frisch-Waugh Theorem
- Least squares and maximum likelihood estimation of VECMs, not including asymptotics (Lütkepohl, Ch. 7.2.3)
- Specification of VECMs (Lütkepohl, Ch. 8.1, 8.2)

#### **Week 6** Panel data models

- One-way error component model: Introduction and notations (Baltagi Ch. 2.1)
- Fixed effects estimation (Baltagi Ch. 2.2)
- Random effects estimation (Baltagi Ch. 2.3)
- Specification testing (Baltagi Ch. 4)

## **6 Software: R**

In the tutorials, we will use the software **R** to illustrate materials, analyze data sets, and solve exercises. **R** is a common tool among data experts at major universities. It is open source and can be installed in any environment on any machine and used with no licensing or agreements needed. **R** code is easily borrowed from and shared with others. The software is under active development, improving constantly, and supported by both professional and academic developers.

**Note:** **R** and the user interface RStudio are installed on the computers in the library and the computer rooms. However, you are encouraged to get your own version and bring your laptop to the first tutorial. That way, you already have everything ready to continue your econometric work wherever you like.

- Download R: <https://www.r-project.org/>
- Download RStudio: <https://www.rstudio.com/products/rstudio/>

## **7 Exam**

There will be an online multiple choice exam that covers the materials we discuss in the lectures and in the tutorials. More information will be provided in due time.