University of St.Gallen

Time Series Econometrics: Course Outline

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1 Course Details

Lecture Time	:	Mondays and Wednesdays, 14:15 – 16:00 (Weeks 1 – 6 of the semester).
Lecture Room	:	01-U121
Course Code	:	8,314,1.00.
Instructor	:	Daniel Buncic Bodanstrasse 6, 3. Floor, Office 28-303 email: daniel.buncic@unisg.ch.
Office Hours	:	Fridays, 10:30-12:00 or by appointment.
Course Website	:	http://www.danielbuncic.com/tse.html.

2 Information about the course

2.1 Course Details

This course is a foundation course in Time Series Econometrics. Time series data are commonly encountered in many empirical finance and macroeconomic settings as well as in a number of other social sciences that use observations recorded over time and also in marketing and sales. Since time series data are different in their nature to cross sectional data studied in standard econometric textbook treatments, it has become a field of study of its own over the last $50 - 60$ or so years.

The objective of this course is to provide students with a solid understanding of some fundamental concepts in time series econometrics and to outline a few common difficulties that arise when dealing with time series data in theory as well as in practice. The course is designed to bring students that have not had much exposure to time series data and/or analysis up to speed and to offer a more detailed treatment to students that already are familiar with time series concepts.

It should be kept in mind though that time series analysis in general is a vast area of study and there are many topics that will not be covered in this course. For example, we will exclusively focus on the time domain and not cover spectral analysis (or frequency domain topics) at all in this course. Also, we will not deal with models for volatility, which is available as a separate course. The focus of the course is on some fundamental time series concepts and will offer a solid first foundation/introduction to time series analysis and the *"algebra"* that is commonly employed when dealing with time series.

The course will be split into approximately two parts. The first part will largely focus on (univariate) ARMA type models and the time series algebra that lies behind it, together with some treatment of unit roots as well as decompositions of times series with unit-roots. Most of the material here will rely upon an algebraic type of treatment. The second part expands the models to a multivariate setting and also looks at multivariate unit-root processes/cointegrated series. In the second part, we will mainly rely on the computer to calculate results as needed. For that reason, it is important (and a requirement) that students familiarise themselves with a computer *"language/environment"* of their liking. I will use Matlab for the empirical illustrations throughout the course.

Topics : The course will cover the following main topics:

1: Overview and background to time series data
- Introduction to time series data
- Review of statistical concepts
- CLTs and LLNs for time series data and conditioning rules
- Stationarity, Ergodicity and mixing conditions

2: ARMA models
- Overview and background
- Working with AR and MA models
- Stationarity and Invertibility
- Estimation and forecasting
- Empirical selection of ARMA models

3: Non-stationarity, Unit roots and decompositions of time series
- Forms of non-stationarity
- Unit-root asymptotics, tests and practical issues when testing for unit-roots
- Beveridge Nelson Decomposition and the Hodrick Prescott filter

4: Vector Autoregressions
- Use of VARs and VAR mechanics
- VARs in Policy Analysis and Causality
- Structural VARs and identification
- VARs with Long-run restrictions

5: Cointegration
- Conceptual overview and intuition
- Testing for Cointegration in the Bivariate case
- VECM representation and system estimation of cointegrating vectors
- Common trends representation, permanent and transitory shocks in systems

2.2 Course literature

The reading material for this course will come from a variety of sources. There are a number of textbooks that are quite good to gain a fundamental understanding and overview of time series econometrics in general. However, as it is always the case, there are some sections that are explained better in one book and other sections that are better explained in another book. Therefore, it is necessary to utilise a variety of different sources as references.

Also, there are a number of different levels of difficulty and detail in the treatment in the different textbooks. For example, for students that need a bit more intuition and that have not had much exposure to time series data and analysis in general, the texts by Enders (2010) [AETS] and Kirchgässner and Wolters (2007) [IMTSA] are excellent references to gain a bit more intuition about what time series analysis is about. Nonetheless, these texts are different in their scope than, for example, the encyclopedic and very detailed treatments of Hamilton (1994) [TSA] and Lütkepohl (2005) [MTSA]. The two types of texts should not be seen as competitors, but rather as complements to one another. Often, the intuition can be build up and reassured by reading the relevant sections in Enders (2010) and Kirchgässner and Wolters (2007), while the exact details necessary for the computational implementation when coding from scratch can be found in Hamilton (1994) and Lütkepohl (2005). The texts by Hamilton (1994) and Lütkepohl (2005) also offer a number of proofs that are too time consuming to go through in the lectures, and which can be called upon as required. The book by Brockwell and Davis (2002) [ITSF] is also useful but will be used less frequently than the other 4 textbooks above. Any other journal articles will be referenced throughout the lecture notes. All the reading material will be available through the University library.

A list of the textbooks that are used in the course is given on the last page under the References heading. The corresponding required readings for each of the Topics that are going to be covered is listed in the last column of the Weekly Lecture Schedule Table. We will try to stick to this list as much as possible, nevertheless, since there are always additions and modifications that come up during the course, the schedule is tentative and therefore subject to change.

2.3 Pre-requisites

The prerequisite for the course is a solid understanding of standard statistics and matrix algebra at the level of the bachelor courses and the introductory mathematics and statistics course at the masters level.

2.4 Computing requirements

Although the course will deal with fundamental time series concepts and derivations, the focus of the course — especially towards the second half of the semester — is on the **computation** of time series models. I thus expect students to be competent enough to work independently with a (high level) matrix computing language such as Matlab, R, GAUSS or any other software program of their choice. I will use Matlab throughout the course. Matlab is probably one of the most widely used, most powerful and intuitive high level matrix programming *"languages"* that is used in finance, economics and also in engineering. Matlab is available in the university's computing labs.

Part of the homework assessment of the course will involve the estimation (ie. computation using Matlab) of a some of the models that will be discussed in the lectures. Students will thus not be able to pass the course without getting their hands sticky on a computer.

For the Matlab computing part, I will call upon the MFE Toolbox of Kevin Sheppard from Oxford University. This is an excellent toolbox which has a lot of functions built in that do not come in standard Matlab distribution (or are improvements on them). There used to be an "old" toolbox which was called UCSD GARCH or something like this. Its main focus was on the estimation of GARCH models and this is a major improvement of it which includes many useful functions. I thus highly recommend it to you, not only for the purpose of this course, but also for your own research later on. A current version of the MFE Toolbox is available for download from Bitbucket at https://bitbucket.org/kevinsheppard/mfe_toolbox.[1] The pdf manual is available from http://www.kevinsheppard.com/images/9/95/MFE_Toolbox_Documentation.pdf.

Another general purpose toolbox that was very popular with Matlab is the LeSage toolbox available from http://www.spatial-econometrics.com/ of James P. LeSage. However, this toolbox is not being updated anymore (although it has great functions). So you may want to check the functions in the LeSage toolbox as well. The link to the documentation is http://www.spatial-econometrics.com/html/mbook.pdf.

There exist a number of tutorials on the web on how to get started with Matlab. I have put up a few documents on my website at http://www.danielbuncic.com/teaching.html. By far the best introduction, at least from my perspective, is again the one by Kevin Sheppard, which is available from http://www.kevinsheppard.com/images/0/04/MATLAB_Notes_2012.pdf.

2.5 Lectures

I will try to keep the lecture environment as informal and *'student'* friendly as possible, so that students feel comfortable enough to ask questions that will help deepen and strengthen their understanding of the material that is being taught.

I expect from Students to carefully read the lecture notes and consult any of the assigned readings outlined in the Weekly Lecture Schedule, as needed, **before** the week's lecture, so that they are prepared when they come to class. Since lecture time is scarce, the focus of the lectures will be on outlining the statistical details necessary to conduct the required econometric analysis and on going through a few selected derivations and exercises as carefully as necessary. Although some intuition about why we are performing a particular transformation or how to think about the results that we obtain will be provided in the lectures, students will get most of the intuition from the lecture notes and the assigned readings.

It should be stressed here that time series econometrics is a large field in econometrics. This means that we will not have time to cover every aspect of time series econometrics and every detail there is to be covered. We will, therefore, have to cover and introduce some concepts and other important results on the fly, that is, along the way, as is needed. It may thus happen that a concept or terminology is used without having previously defined or formerly introduced it, so I expect students to ask — or to work out themselves — what is meant.

Note that there are no official lab (or computing) sessions scheduled for this course. Students

[1] Look on the right where it says download. It is a zip file with many functions, which will need to be unzipped and added to the matlab path.

are, therefore, expected to familiarise themselves independent of class time with the required computing material and use the resources that are provided on the course's website, such as, for example, the introductory material on how to get started with Matlab.

2.6 Notation

Since we will pool information from different textbooks and articles, it is most likely that some differences in notation will arise due to the pooling. I will try to be consistent with the notation (and language) used in the lectures and lecture notes. However, it is inevitable that there will be some inconsistencies that will creep in. I thus ask students to be flexible in the use of the notation. It is much more important to understand a concept and the building blocks behind a result that is derived rather than try to memorise the formulas.

I will try to use the notation that seems most natural in terms of the readings/references and what most authors use in the literature. Overall, I will use γ (Γ) as a scalar covariance (matrix) parameters, and I will follow the standard convention to put hats ($\hat{}$) to denote estimated quantities.

3 Course Assessment

3.1 Formal Requirements

In order to pass this course, you must obtain a total grade of at least 50% (ie, 50 out of 100). The total mark is computed as the sum of two separate assessment items (see table below). There will be a final exam at the end of the course covering all topics and there will be some take-home (homework) exercises which will be a mix of analytical exercises and computer based ones.

3.2 Assessment Details

The assessment components are summarised in the table below.

What	How much	When / Due in
Take-home Exam (Homework)	20%	further details to be announced.
Final Exam	80%	de-central exam, further details to be announced.
Total	100%	

Details of the take-home assignment will be handed out during class time. This will be group work and you will need to form groups of $3-4$ people for this. The final exam will cover **all** the topics of the course. It will be largely structured to assess your technical skills but will also contain questions related to general concepts to test your understanding of the material.

3.3 Comments on course assessment

The format of the assessment items were designed to maximise the students' learning outcomes. There exist many pedagogical studies that show that a continuous stream of learning is much more efficient and beneficial to students than a short intense period of study, since more course material is retained for a longer period of time after the end of the semester. Also, learning material from lecture notes or a book is less likely to get the students understanding of the topics to a level where these can be independently implemented. The assessment is thus split into two parts rather than a single assessment item, so that students are *encouraged* to study for the course on a weekly basis and are *forced* to put the knowledge that they have gained from the readings and the lecture material into practice by coding up independently some of the models that are studied and by discussing any problems that they may encounter with the class. My view is that you will learn much more from replicating a result from scratch than from simply attending lectures and taking exams.

4 Weekly Lecture Schedule

An overview of The lecture schedule for this course is provided in Table 1. Note that there is likely to be some overlap of the different topics that are covered, so the table is best used as a guide and not a definite schedule.

The *'Required Readings'* are the assigned reading requirements for the students to be able to follow the lecture material in a sensible way. The Lecture Notes are written so as to condense and to supplement the information provided in the *'Required Readings'*.

References

[ITSF] Brockwell, Peter J. and Richard A. Davis (2002): *Introduction to Time Series and Forecasting*, *2nd Edition*, Springer.

[AETS] Enders, Walter (2010): *Applied Econometric Time Series*, *3rd Edition*, Wiley.

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

[IMTSA] Kirchgässner, Gebhard and Jürgen Wolters (2007): *Introduction to Modern Time Series Analysis*, Springer Verlag.

[MTSA] Lütkepohl, Helmut (2005): *New introduction to multiple time series analysis*, Springer.

Table 1: Weekly Lecture Schedule

Lecture (Date)	Lecture Topic	Required Readings
1 (22.02.2016)	Overview/background of time series data.	**Topic 1:** Chap. 1 in AETS, IMTSA, ITSF and TSA.
2 (24.02.2016)	Times series concepts, Stationarity, Ergodicity.	
3 (29.02.2016)	Intro. to ARMA models	**Topic 2:** Chap. 2 and 3 in TSA and ITSF, Chap. 1 and 2 in AETS and IMTSA, and Chap. 7 in TSA.
4 (02.03.2016)	Operations and properties of ARMA models	
5 (07.03.2016)	Estimation and forecasting with ARMA models.	
6 (09.03.2016)	Estimation and forecasting continued.	
7 (14.03.2016)	Non-stationary series, unit-root asymptotics, tests and practical issues when testing for unit-roots.	**Topic 3:** Chap. 5 in IMTSA, Chap. 4 in AETS, Chap. 15 and 17 in TSA.
8 (16.03.2016)	Decompositions of time series, Beveridge Nelson Decomposition and the Hodrick Prescott filter.	
9 (21.03.2016)	Introduction to VARs: Mechanics, Estimation and forecasting, Granger Causality.	**Topic 4:** Chap. 3 and 4 in IMTSA, Chap. 5 in AETS, Chap. 11 in TSA, Chap. 4, 5 and 9 in MTSA.
10 (23.03.2016)	VARs in Policy analysis. Structural VARs, identification, estimation and long-run restrictions.	
11 (28.03.2016)	Public Holiday => Introduction to cointegration.	**Topic 5:** Chap. 6 in AETS and IMTSA, Chap. 18 – 20 TSA.
12 (30.03.2016)	Cointegration continued. Testing for cointegration and estimation of VECM models.	

Note that this schedule is tentative and therefore subject to change!