Multiple Time Series Analysis:
Syllabus with Extended Information

1 Introductory Remarks

This course is intended to give an introduction to multiple time series analysis with a strong emphasis on vector autoregressive (VAR) processes. We focus on the mechanics of the various procedures and their application. Asymptotic properties of estimators and test statistics will only be mentioned but not derived. We start with introducing some important univariate time series concepts. If time permits, we may also cover factor models and factor-augmented VAR models at the end of the course.

During the course we will discuss a related empirical research paper and a monthly report of the Bundesbank (October 2018), see Section 4. I expect you to read them in advance. Moreover, the lecture will be accompanied by exercise sessions, mostly empirical tutorials. I add some more comments on the software below in Section 5. Moreover, there will be two assignments to be handed in which together count for 25% of the final grade. In addition to the two assignments, there will a written exam that counts for 75% of the final grade.

2 Course Outline

1. Introduction and Overview (**L**: Ch. 1)
2. Univariate time series concepts and models (**E**: Chs. 2, 4; **H**: Ch. 3)
    - Time series concepts: data vs. stochastic process, stationarity, ergodicity/mixing
    - (Stable) AR process
    - Integrated processes and unit root tests
3. Stable vector autoregressive (VAR) Processes (**L**: Sect. 2.1)
    - Model representations
    - Properties
4. Estimation of VAR processes (**L**: Sects. 3.1-3.4)
5. VAR model selection and model diagnostic (**L**: Ch. 4)
    - Information criteria
    - Checking model adequacy (autocorrelation, non-normality, stability)
6. Forecasting (**L**: Sects. 2.2, 3.5)

7. Structural analysis with VAR models (**L**: Sects. 2.3, 3.6-3.7; Appendix D, **KL**: Sects. 12.1-12.5)
    - Granger causality
    - Impulse response analysis
    - Forecast error variance decomposition
8. Structural VAR models **L**: Ch. 9; **KL**: Sect. 4.3)
    - Model representations
    - Identification Schemes
    - Historical decompositions
9. Multivariate Integrated Processes (**L**: Sects. 6.1-6.4, 7.1-7.2 or **KL**: Sects. 3.1-3.2)
    - Cointegration
    - Cointegration-robust inference in VARs of $I(1)$ variables
10. Factor Models and Factor-Augmented VAR Models (**KL**: Sects. 3.1-3.2) or **SW**

3 Literature

The main reference for the course is Lütkepohl (2005), (**L**). However, we proceed partly in a different order then the textbook does. The textbook introduces forecasting and structural analysis tools based on the true VAR model (parameters). Then, it picks them up again after discussing estimation of VARs, i.e., it discusses forecasting, impulse response analysis etc. based on an estimated VAR model. We aggregate this 'two-step' approach into one 'unified' treatment in Parts 6 and 7 of the course after we have discussed estimation, model selection, and diagnostic.

The textbook by Kilian and Lütkpepohl (2018), (**KL**), extensively deals with structural VAR analysis. We partly draw on this textbook as a main reference, e.g., when discussing the bootstrap in Part 7. It may also be your preferred reference for Part 9. It contains concise descriptions of VAR processes and related models and time series tools in Chapters 2 to 4. Indeed, Chapter 2 compactly covers the material of Parts 3 to 6 and partly of Parts 2 and 7. Therefore, it makes a lot of sense to consider Chapter 2 of Kilian and Lütkpepohl (2018) for a first reading. Afterwards you can dive into the relevant parts of Lütkepohl (2005) which is more detailed. I should add that Lütkepohl (2005) is often more detailed than we can be in this course. In terms of content covered we lean somewhat into the direction of Kilian and Lütkpepohl (2018).

Moreover, we use some material from Enders (2004), (**E**), and Hamilton (1994), (**H**), for the univariate part. Chapter 3 of Hamilton (1994) is a very useful reference for time series concepts like stationarity and ergodicity and provides a rather extensive discussion of AR and ARMA processes. This said, both references contain more 'univariate material' than we (can) cover. Topics like model selection and forecasting, e.g., are 'just' introduced in the multivariate VAR context. Hence, you could easily simplify things to univariate AR processes which are one-dimensional VAR processes.

For section 10 on factor models we may either rely on Section 3.1 and 3.2 from Kilian and Lütkpepohl (2018) or on the handbook chapter by Stock and Watson (2016). I will provide you with more information once we see how quickly we proceed with the lecture material.

Due to legal constraints I am not allowed to upload pdf-scans of (substantial parts of) the textbooks. However, all books are available at the University Library. Moreover, Lütkepohl (2005) and Kilian and Lütkpepohl (2018) are even available as an online-resource, i.e., you can download pdfs of the book chapters.

References

Enders, W. (2004), *Applied Econometric Time Series*, 2nd ed., Wiley. (**E**)

Hamilton, J.D. (1994), *Time Series Analysis*, Princeton. (**H**)

Kilian, L. and Lütkepohl, H. (2018), Structural Vector Autoregressive Analysis, Cambridge University Press. (**KL**)

Lütkepohl, H. (2005), *New Introduction to Multiple Time Series Analysis*, Springer, Berlin. (**L**).

Stock, J.H. and Watson, M.W. (2016), *Dynamic Factor Models, Factor-Augmented Vector Autoregressions, and Structural Vector Autoregressions in Macroeconomics*, in J.B. Taylor and H. Uhlig (eds), Handbook of Macroeconomics, Volume 2A, Chapter 8, Elsevier. (**SW**).

4 Paper and Report Discussed in Class

Christiano, L. J., Eichenbaum, M., and Evans, C. (1996), The effects of monetary policy shocks: evidence from the flow of funds, The Review of Economics and Statistics: 78, 16-34.

The macroeconomic impact of uncertainty, Deutsche Bundesbank Monthly Report: October 2018, 49-64.

5 Software

The empirical exercises rely on Matlab code. The empirical problem sets are not about coding but rather about empirical analyses: data work, using appropriate econometric tools and inference procedures, interpretation of results etc.. It would be good if you have some background knowledge in Matlab. Unfortunately, Matlab is no longer used in Advanced Macroeconomics. So, we may switch to R. Then, however, things would not be that smooth since I have to translate the code. Moreover, I am not an expert in R. In either case, we should briefly talk about the software used in the first session.

Mannheim students can obtain a Matlab licence for free. For further information, please check `https://www.uni-mannheim.de/en/it/students/software/#c131177`.