Economics 676: Macroeconometrics

Lecture: Monday/Wednesday 10:00AM-11:30AM in Lorch 173
Office hours: Monday 7:00PM
First Day of Class: Wednesday, January 7.
Last Day of Class: Monday, April 20.
Email: lkilian@umich.edu

Requirements:
The course covers topics in time series analysis with an emphasis on applications in macroeconomics. The aim of the course is to equip students with a working knowledge of important econometric techniques used in monetary economics, financial economics, international economics, and econometric theory. Substantial emphasis will be placed on the development of programming skills in MATLAB (a matrix algebra program).

Students taking 676 are required to have completed the first-year Ph.D. sequence in econometrics (Economics 671/672). Ph.D. students taking international finance or advanced macroeconomics are strongly advised to take Economics 676 concurrently. The course is not open to Master students.

Grading:
Course grades for Economics 676 will be based on a course paper (40%) and regular homework assignments (60%). This may not sound like much, but this course is quite work-intensive and will involve long hours in the computer lab. If you do not have the time to give this course your full attention, you may want to take the course at some other time. The investment will be worth it once you embark on your thesis.

The problem sets typically consist of programming exercises in the matrix algebra software MATLAB. They may be prepared in groups of up to three students, but must be written up and handed in individually. Everyone is responsible for writing their own code. Please indicate the other group members, as applicable, and include all of the code along with your interpretation of the results. Electronic submissions are not acceptable. The problem sets are due in class (or under my door by the end of class) on the due date. There will be no extensions.

All problem sets for this course must be coded in MATLAB. There are no exceptions. One of the aims of this course is to make you proficient in MATLAB programming, so you can tackle new challenges on your own, when you start writing your thesis. MATLAB is used extensively among practitioners and among researchers and is indispensable for your career whether you plan to go to Wall Street, the Federal Reserve Board or a research university. It might not be the only software you will have to master, but it will be the most useful and versatile software. MATLAB is available on UNIX and on the PCs in the department’s econometrics lab. In addition, the university provides virtual access to MATLAB.
The term project involves identifying an econometric technique for time series that has not been covered in class. You are supposed to write MATLAB code implementing this technique. The code should be well documented and accompanied by a readme.txt file, by a description of how this technique works and what each file accomplishes. Most papers will focus on an empirical application to actual data. The empirical application may replicate some findings in the literature, but it has to be of substantive interest. The empirical analysis should be concisely written and clearly spell out the question of interest and the findings. You may also substitute a methodological question for the empirical application. All topics are subject to my approval.

The course paper should not normally exceed 15-20 pages in length and is due at the end of the course without fail. Electronic submissions are not acceptable. The format of the papers should adhere to the standards required for submission to a journal. Papers that do not meet these standards will not be accepted. Please consult my homepage for examples of acceptable formats. A short, but polished paper is vastly preferred to a longer, but shoddy one. Papers must not be co-authored. The paper is due on April 24 at noon. Please drop them off at my office. There will be no extensions of this deadline. Electronic submissions are not acceptable.

Readings:

There will be a coursepack for this course (available for purchase at Dollar Bill and online at ctools). You are expected to bring the coursepack to class. The coursepack will form the backbone of this course. In addition, there are selective readings from journal articles on each topic and there are two required textbooks:


Both books are worthwhile having on your shelf, whether you are interested in finance, macroeconomics, international finance or econometrics. Hamilton (1994) is best thought of as a reference book. It is somewhat dated, but still the only graduate-level textbook that covers all aspects of time series econometrics. Lütkepohl’s book is a substantially revised version of his earlier book *Introduction to Multiple Time Series Analysis*. Rather than cover a wide range of time series methods, it focuses on multivariate time series models only. This includes the vector autoregressive framework which has become the workhorse model of applied time series analysis. For the purpose of this course, either version of this book will do. Lütkepohl’s book is especially useful for this course in that it is very explicit, which facilitates the programming of econometric procedures in a matrix algebra software such as MATLAB. Lütkepohl’s book is also available online through mirlyn. You should nevertheless buy the book in my view. It is a worthwhile investment.

Another good resource is the Handbook of Econometrics, the Handbook of Statistics and the Handbook of Economic Forecasting. The selective list below contains additional textbooks and monographs that you may find useful:
General Books on Macroeconometrics:

Spectral Analysis:

Nonlinear Models:

Unit Roots and Cointegration:

Forecasting:

Applications:

Historical Perspective:
Econometrics Background:


# Table of Contents

## Part 1: Preliminaries

1. Introduction to MATLAB ................................................................. 3  
   1.1. MATLAB as a language .............................................................. 3  
   1.2. Basics ...................................................................................... 3  
   1.3. Script Files and Function Files ................................................. 4  
   1.4. File Management Inside MATLAB ........................................... 5  
   1.5. Variables .................................................................................. 5  
   1.6. Loading and Saving Data .......................................................... 7  
   1.7. Mathematical Operators .......................................................... 8  
   1.8. Pausing and Terminating Programs .......................................... 10  
   1.9. Using Logical Statements and Writing Loops ............................. 10  
   1.10. Random Number Generators and Distributions ....................... 12  
   1.11. Some Useful Functions for Generating Descriptive Statistics .... 13  
   1.12. The Basics of Plotting Data in MATLAB ............................... 14  
   1.13. Data Sources for Economic Time Series ................................. 16  
   1.14. Check Your Data ..................................................................... 18  
   1.15. Simple Data Transformations ................................................. 18  
   1.16. MATLAB Exercises .............................................................. 19  
      1.16.1. Random Draws ................................................................. 20  
      1.16.2. Estimating Distributions of Sample Statistics .................... 21  
      1.16.3. Numerical ML Estimation .................................................. 24

## Part 2: Univariate Time Series Models

2. Basic Concepts in Time Series Analysis ........................................... 28  
   2.1. The Origins of Time Series Econometrics in Business Cycle Theory 29  
      2.1.1. Periodic Cycles? ................................................................. 29  
      2.1.2. Irregular Cycles ................................................................. 30  
   2.2. Stochastic Processes ............................................................... 32  
      2.2.1. Stationarity ....................................................................... 33  
      2.2.2. Ergodicity ........................................................................ 33  
   2.3. White Noise ............................................................................ 34  
   2.4. The Wold Representation Theorem .......................................... 34  
3. Approximating the Wold Representation ........................................ 35  
   3.1. MA(q) Models ........................................................................ 36  
   3.2. AR(p) Models ......................................................................... 37  
   3.3. Impulse Response Functions ................................................... 43  
   3.4. ARMA(p,q) Models ............................................................... 44  
4. Data Transformations ..................................................................... 47  
   4.1. Time-Varying Variances .......................................................... 48  
   4.2. Time-Varying Means .............................................................. 48  
      4.2.1. Deterministic Detrending ................................................... 48  
      4.2.2. Log-Differencing ............................................................... 50  
      4.2.3. The Hodrick-Prescott (HP) Filter ....................................... 53  
      4.2.4. Other Forms of Detrending ............................................... 54  
   4.3. Seasonality ............................................................................. 54  
      4.3.1. Seasonal Dummies .............................................................. 54  
      4.3.2. Seasonal Differencing ....................................................... 55  
      4.3.3. Other Forms of Seasonal Adjustment ............................... 55
12.2. General to Specific: Tests for Parsimony .............................................. 112
12.3. Information Criteria ................................................................. 113
  12.3.1. The Population PMSE of the VAR(p) Model ............................. 113
  12.3.2. The Forecast Prediction Error (FPE) Criterion ....................... 115
  12.3.3. The Akaike Information Criterion (AIC) .............................. 117
  12.3.4. The Relationship between the FPE and AIC ......................... 117
  12.3.5. Conditions for Consistent Lag Order Selection ..................... 118
    Hannan-Quinn Criterion (HQC) ................................................ 119
    Schwarz Information Criterion (SIC) ....................................... 120
  12.3.6. Small-Sample Results ...................................................... 120
  12.3.7. Pitfalls in Programming Information Criteria ....................... 120
  12.3.8. How Important is the Consistency of the Lag Order? ............... 121
  12.3.9. Beyond the Consistency of the Lag Order ............................ 122
  12.3.10. Other Approaches to Lag Order Selection ........................... 122
  12.3.11. Further Caveats ........................................................... 123
  13.2. Granger Causality, Predeterminedness, and Exogeneity ..................... 126
    13.2.1. Basic Concepts ......................................................... 126
    13.2.2. (Granger) Causality in Stock Markets ............................. 128
    13.2.3. Exogeneity Testing: The Case of Oil Prices ...................... 130
  13.3. Responses to Unanticipated Changes in Money Growth .................... 132
    13.3.1. The Narrative Approach to Monetary Policy ........................ 132
    13.3.2. News Shocks ............................................................. 133
    13.3.3. VAR Shocks ............................................................. 134
  13.4. Structural VAR Examples ..................................................... 137
  13.5. VAR Impulse Responses ....................................................... 140
  13.6. VAR Forecast Error Variance Decompositions ............................. 143
  13.7. VAR Historical Decompositions ............................................. 145
  13.8. The Relationship between Structural VAR Models, Dynamic Simultaneous
        Equation Models, and DSGE Models ....................................... 147
    13.8.1. The Legacy of Large-Scale Dynamic Simultaneous Equation Models ... 147
    13.8.2. The Relationship between VAR Models and Traditional Dynamic SEMs. 147
    13.8.3. The Relationship between VAR Models and DSGE Models .......... 148
      Basics ............................................................................ 148
      The Role of Data Transformations ....................................... 150
      Why Not Use VARMA Models? .............................................. 150
      Autoregressive Sieve Approximations of VAR(∞) Processes .......... 150
  13.8.4. Summary Comparisons of Alternative Structural Models ............. 152
  13.8.5. Combining Dynamic SEMs and VAR Models ............................. 152
  13.8.6. Combining DSGE and VAR Models ....................................... 153
  13.8.7. Policy Analysis ............................................................ 155

Part 4: Other Forecasting Methods
14. Forecasting a Scalar Time Series ................................................. 157
  14.1. The Bias-Variance Trade-Off ................................................ 158
  14.2. The Role of Trends ............................................................. 159
  14.3. The Role of Forecast Uncertainty .......................................... 159
  14.4. Forecasting Model Selection ................................................ 160
    14.4.1. Recursive Pseudo Forecasts ....................................... 161
    14.4.2. Rolling Pseudo Forecasts ........................................... 162
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tests Based on Covariates</td>
<td>224</td>
</tr>
<tr>
<td>Tests of the I(0) Null Hypothesis</td>
<td>225</td>
</tr>
<tr>
<td>25.2.7. Summary of the Literature on Unit Root Tests</td>
<td>226</td>
</tr>
<tr>
<td>Testing Economic Theories</td>
<td>226</td>
</tr>
<tr>
<td>Data Description</td>
<td>228</td>
</tr>
<tr>
<td>Forecasting</td>
<td>228</td>
</tr>
<tr>
<td>Pre-Tests for 2nd Stage Inference</td>
<td>228</td>
</tr>
<tr>
<td>26. Robust Inference in the Presence of Possible Autoregressive Unit Roots</td>
<td>229</td>
</tr>
<tr>
<td>26.1. Asymptotic Approximations and Near Unit Roots</td>
<td>229</td>
</tr>
<tr>
<td>26.2. Confidence Intervals in the Presence of Possible Unit Roots</td>
<td>231</td>
</tr>
<tr>
<td>26.3. Other Approaches</td>
<td>232</td>
</tr>
<tr>
<td>26.4. ARFIMA Models</td>
<td>233</td>
</tr>
<tr>
<td>27. The Quantitative Importance of Unit Roots</td>
<td>235</td>
</tr>
<tr>
<td>27.1. The Beveridge-Nelson Decomposition</td>
<td>236</td>
</tr>
<tr>
<td>27.2. The Variance Ratio</td>
<td>238</td>
</tr>
<tr>
<td>27.3. Other Measures of Persistence</td>
<td>239</td>
</tr>
<tr>
<td>27.3.1. Long-Run Impulse Responses</td>
<td>239</td>
</tr>
<tr>
<td>27.3.2. Sum of AR Coefficients</td>
<td>241</td>
</tr>
<tr>
<td>27.3.3. Half-Life</td>
<td>241</td>
</tr>
<tr>
<td>28. Unit Root Regressions</td>
<td>242</td>
</tr>
<tr>
<td>28.1. Regressions of I(1) Variables on Deterministic Time Trends</td>
<td>242</td>
</tr>
<tr>
<td>28.2. Regressions of one I(1) Variable on an Unrelated I(1) Variable</td>
<td>243</td>
</tr>
<tr>
<td>28.3. Regressions of an I(0) Variable on an I(1) Variable</td>
<td>245</td>
</tr>
<tr>
<td>29. Cointegration</td>
<td>248</td>
</tr>
<tr>
<td>29.1. Implications of Cointegration for the Vector MAR</td>
<td>250</td>
</tr>
<tr>
<td>29.2. Implications of Cointegration for the VAR Representation</td>
<td>251</td>
</tr>
<tr>
<td>29.3. The VEC Representation of Cointegrated VAR Models</td>
<td>253</td>
</tr>
<tr>
<td>29.4. Cointegration Tests</td>
<td>254</td>
</tr>
<tr>
<td>29.4.1. Single-Equation Methods</td>
<td>254</td>
</tr>
<tr>
<td>Known Cointegrating Vector</td>
<td>254</td>
</tr>
<tr>
<td>Unknown Cointegrating Vector</td>
<td>254</td>
</tr>
<tr>
<td>29.4.2. Systems Methods</td>
<td>255</td>
</tr>
<tr>
<td>Known Cointegrating Vector</td>
<td>255</td>
</tr>
<tr>
<td>Unknown Cointegrating Vector</td>
<td>255</td>
</tr>
<tr>
<td>29.4.3. Other Tests</td>
<td>264</td>
</tr>
<tr>
<td>29.5. Summary of the Estimation Methods for Cointegrated VAR Models</td>
<td>264</td>
</tr>
<tr>
<td>29.6. Pitfalls in Interpreting Estimates of Cointegrating Vectors</td>
<td>265</td>
</tr>
<tr>
<td>29.7. Model Selection</td>
<td>266</td>
</tr>
<tr>
<td>29.8. Identification of Structural Shocks</td>
<td>267</td>
</tr>
<tr>
<td>29.9. Cointegrated VAR(∞) Models</td>
<td>267</td>
</tr>
<tr>
<td>29.10. Inference in Possibly Cointegrated VAR Models</td>
<td>267</td>
</tr>
<tr>
<td>Part 7: Nonrecursive Structural VAR Models</td>
<td>270</td>
</tr>
<tr>
<td>30. Identification</td>
<td>270</td>
</tr>
<tr>
<td>30.1. Short-Run Identifying Restrictions</td>
<td>270</td>
</tr>
<tr>
<td>30.1.1. Exactly Identified Models</td>
<td>270</td>
</tr>
<tr>
<td>30.1.2. Overidentified Models</td>
<td>271</td>
</tr>
<tr>
<td>30.1.3. Where Do the Restrictions Come From?</td>
<td>271</td>
</tr>
<tr>
<td>30.2. Long-Run Identifying Restrictions</td>
<td>272</td>
</tr>
<tr>
<td>30.2.1. Overview</td>
<td>272</td>
</tr>
<tr>
<td>30.2.2. Examples</td>
<td>274</td>
</tr>
</tbody>
</table>
30.2.3. Caveats about Long-Run Restrictions ........................................ 277
31. Structural VAR Critiques .................................................................. 278
32. Selected Alternative Structural VAR Approaches ............................. 280
   32.1. Financial Market Shocks .......................................................... 280
   32.2. Identification by Heteroskedasticity ......................................... 280
   32.3. Sign Restrictions .................................................................... 281
      32.3.1. Interpretation ................................................................. 282
      32.3.2. Extensions ................................................................. 283
      32.3.3. Inference ................................................................. 283

Part 8: Nonlinear Time Series Models
33. Overview ...................................................................................... 286
   33.1. Nonlinear Dynamics in the Conditional Mean ............................ 286
   33.2. Testing Nonlinearities in the Conditional Mean ......................... 287
   33.3. Nonlinear Impulse Responses and Forecasts ............................... 289
      33.3.1. Estimation of Asymmetric Impulse Responses .................... 289
      33.3.2. Testing for Asymmetric Impulse Responses ....................... 291

Appendix 1: Advice on Writing the Research Paper ................................. 292
Appendix 2: Examples of Ideas for Paper Topics ..................................... 294