

1 Economics 853 and 953: Applied Time Series

Dunning Hall 350 Thursday: 2:30-5:30

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2 Background

The era of the fixed X (fixed in repeated samples) world with empirical studies using time series data is gone and researchers are now compelled to understand the econometrics of time dependent processes. While the tools of classical econometrics continue to be extremely useful in advancing in this direction, there are many important departures in time series that require additional theoretical and computational machinery.

The intention of this course is to learn and to use the basic tools of applied time series analysis. Our emphasis will be on application; that is, taking the concepts developed in the lectures and employing them in an extended time series project. However, there will inevitably be a great deal of theory in the lectures given the nature of the topic.

Notes (in pdf format) and computer programs, examples etc. can be obtained directly via a Stata command (`do econ853.do` in the `C:\course\econ853` directory).

These notes are intended to serve as the barebones basis of the theory and those interested may follow up with more detailed readings. Since I am constantly adding (deleting) certain parts of my notes, I would suggest printing them only as you need them. Remember you can follow along in the lab with the pdf files. Where possible, I give the original source of the material, together with some additional references.

- The course will consist of 8 weeks of lectures with 4 weeks to work on your own in the laboratory (Dunning 350).
- The work in the course can serve as an MA essay and students are encouraged to discuss with me how this might be accomplished.

3 Grading

The good news is again that there is no exam. The bad news is that there is no exam. The project is worth 100% of the course mark and it will be submitted in stages through-out the term. **All stages should be no longer than 10-15 typed double spaced pages (including figures and tables).** Each stage is viewed as a two or three week assignment, and the **deadline is taken as given.** No exceptions.

4 Computing

There are two ways to use Stata

- 1. In Dunning 350 and use our machines
- 2. Purchase your own (both Windows and Mac versions are available but Stata works slightly differently in Mac) at <http://www.stata.com/coursegp.html> and specify MBEC10 for the GRADPLAN ID. Most students only need the small version (cleverly named Small Stata) with a limitation of 99 variables, 1200 observations and no 64 bit for \$29 U.S. or for the keener who might want more variables (2047) with unlimited number of observations (limited by size of your computer memory) there is Stata/IC \$65)

Since so much of this course is computer oriented, we have arranged to make Dunning 350 available to Economics 853/953 students during the work week (Monday-Friday 8:30-10 pm). If there is not a class or tutorial scheduled (check the web or door for the times posted), you are welcome to do your work there.

Dunning 350 has 16 Pentium IV personal computers (2.4 GHz or 2.0 GHz) with the most current version of STATA (Release 10). Dunning 350 has a laser printer but you are to supply the paper for your work.

For remote access, we have UNIX machines in Dunning 211. Finally, keep in mind that any file left in a public site is in jeopardy of being erased without notice. Therefore **do not leave your stuff in our machines.**

While there are other software applications like RATS, TSP, GAUSS, MATLAB, OX and so on, I insist that you use STATA (Release 11), since my sample programs are in STATA and are available for downloading. STATA is web-aware, has extensive drop down dialogue boxes for all commands, web search capabilities and a complete pdf manual for help (online). This is only the third year I have taught this course using STATA. I am constantly adding to the computer library used here in 853/953 and this year will be no different. Please be patient with me as there are inevitable mess ups.

Economics 853/953 has a WEB page on QED. I believe in sharing computer programs, data sources, tips, and general information so you should communicate with one another and not reinvent the wheel.

Both the TA and I are available to assist you along the way, please come by –we get lonely.

5 Stages for Project

Before discussing the four stages, it is worthwhile discussing a few concerns. A common question:

Exactly what is required for each project?

Unfortunately, there is no simple outline or template to mimic, since each student's project is different, requiring different analysis. **Creativity is rewarded**, so blindly following my examples does not necessarily lead to first-class grades. Students work in this class has served as the basis for many MA essays and led to the occasional publication in peer reviewed journals.

The stages are to be written up formally. This means that each of the stages will have such organizing lists as: Introductions, Model, Data, Results, and Concluding Remarks sections. I want you to learn how to do *formal academic writing*. Such writing will assist not only those that are continuing or are in the Ph.D. program but also those students entering the labour force. Indeed applied econometrics is as much about writing up your results as it is creating software and calculating things. You need to be able to explain your work.

6 853 and 953 Requirements

We have divided the Econ 853 and Econ 953 with the aim of having different standards and content demands for evaluation of MA and Ph.D. students. See departmental rules regarding the credit system for 953.

6.1 853 Requirement

1. Stage 1 and 2 and one of the other stages (each worth 30% for a total of 90%)
2. Class Participation 10% (so it adds to 100%!)

6.2 953 Requirement

1. All 4 stages each worth 25%
- OR**
2. 2 stages (Stage 1 and 2 worth 25% each) and 1 major new project on applied time series worth 50% which is marked on 2 occasions (March 19 with a meeting with me and final hand-in date with each being worth 25%). **Any student following this option should see me first.**

6.3 Final Hand-in Date (usually Monday before the final marks are out)

Stage 3 for the MA's and Stage 4 for the PhD's must be in the Monday before the marks meetings. There is a mark meeting this week and I need to have your grades

in then. No exceptions. If you are not back that week, e-mail me what you have. I intend to hand-in a grade for you.

6.4 Projects in Teams

You are to work in teams of 2 people and the team will hand-in one paper for all stages. In this case, you and your partner receive the same grade. Choose your partners wisely!

6.5 Stage 1: Empirical Writing (due February 4)

There are two choices for this stage. There is the traditional one that mimics the role of a referee in reviewing a paper (with more attention to literature and background as explained) and a new one this year based on forecasting some important economic variable.

6.5.1 Summarizing and Critiquing an Empirical Paper (Due: February 4)

- This part needs to be started immediately if you are going to deliver the goods. You should see yourself in the role of a **referee showing that you understand the paper and can explain the research strengths and weaknesses.**
- Select an empirical article in economics, formally write-up a model (not every equation—summarize), collect the data relevant for it, and provide some descriptive statistics that perhaps can get at some of the testable implications of this model.
- When choosing a paper look for one in which the emphasis is on a substantive economic problem rather than one that is just advancing a new technique in econometrics. The latter tend to use ‘soft’ rehashed and tired economic examples.
- For this stage, **I do not want you to attempt anything more sophisticated than general descriptive statistics.**
- One good source for the papers and the data is the **Journal of Applied Econometrics** (data archive: <http://qed.econ.queensu.ca/jae/>). The Web is another since many authors have data on their home page to accompany their paper. For example, you might want to check-out a site maintained by Christian Zimmerman at the University of Connecticut (<http://ideas.repec.org/>). There are a great number of links to working papers and economists. Below we also list some data sources.

- Your chosen model will comprise a set of time series observations on a dependent variable (or variables) and some set of explanatory variables. **Do not choose univariate projects!** You are **not** going to estimate this model (often this requires specialized programs and techniques-most of which we don't have yet).
- A project should include:
 1. A clear statement of the economic problem and or model.
 2. A complete description of the data used.
 3. Is the data sources complete?
 4. Could you have replicated the study?
 5. Why did the author write this paper and what were the major findings.
 6. Is the paper any good?
 7. Provide graphs of the appropriate data and interpret. For instance, does the simple time series graph suggest anything in respect to the theory.
 8. Provide Summary Statistics. Same question. Does these statistics shed any light on the theory.
 9. A copy of the original paper

The paper should be no more than 10 pages and there should be a formal write-up.

6.5.2 Forecasting (Due Feb. 4)

I have recently become interested in the release and or anticipation of economic or firm data that has substantial impact on world equity markets. This stage will appeal to those studying finance, information transmission or monetary policy.

As you may know there exists financial web pages with economic or market calendars giving the release time ad data of various information. This includes such things as CPI, unemployment rates, confidence indexes, and earnings. Perhaps the most well know one is at Bloomberg (<http://www.bloomberg.com/markets/ecalendar/index.html>), the Wall St. Journal (<http://online.wsj.com/mdc/public/page/marketsdata.html#calandeco>) and Globe and Mail (<http://www.globeinvestor.com/servlet/Page/document/v5/data/events/>)

For this stage which can be continued easily in the next stages is to choose one of these variables that is available as a time series (preferably do not choose CPI, unemployment, GDP and the like since these have been studied to death). Next over the course of the term you will develop a forecasting model for this. If you need assistance on this I would be happy to help. Queen's Business School has a Bloomberg terminal to access individual forecasts from various forecasters and this would greatly assist this work.

For this stage you will need to

1. Find the data (see data sources below)
2. A discussion of the nature of the variable discussing the what forecasts are available and perhaps if there are any records of what variables are favoured?
3. Investigate empirical literature (which includes popular press) as to why this is a critical variable that moves markets. Here we are thinking of some variable that has more broad impact on the markets than say the release of one stocks earning on its stock performance
4. Some evidence that markets have responded to the release either through investigation of market data that you conduct or empirical studies of others.
5. Provide graphs of the appropriate data and interpret. For instance, does the simple time series graph suggest anything in respect to the theory.
6. Provide Summary Statistics. Same question. Does these statistics shed any light on the issues you have discussed.

6.6 Stage 2: Univariate Time-Series Models (Due: March 4)

This will essentially be a classic univariate (often associated with Box-Jenkins) exercise to determine the appropriate time series model to estimate. The dependent variable is one of the variables you downloaded in the first project. This stage will include autocorrelation and partial autocorrelation functions and a consideration of various model selection, testing and forecasting strategies. This material will be covered in the first 3 or 4 weeks of class.

I will provide further details of this in class later in the term.

6.7 Stage 3 & 4 for PhD's: Options (Due: End of April for MA's and March 25 and end of April for PhD's)

MA students are to choose one (1) and Ph.D's are two choose two (2) of the of the following options or they can develop a more ambition project (discussed with me) . Note the PhD's first due date is March 25.

6.7.1 Vector Autoregressive Modeling (VAR)

For this part, a system approach to the model is required. While it is possible to do some vector ARMA model, it is more likely that the analysis will be a VAR. For this exercise, I would want included:

1. An identification methodology using a variety of selection and testing procedures.

2. A Granger causation study
3. Innovation accounting (impulse response)
4. Systems versus univariate forecasting comparison
5. VAR structural modeling

6.8 Kalman Filtering or Dynamic Factor Models -(Stata can now do this)

We have now moved Kalman filtering forward in the lectures since it is used in the estimation of ARMA models in Stata. In this stage what I would like is a dynamic common factor model. This is another way to look at VAR relations and there is specifically a set of commands to do this. I am going to teach this (By the way the Bank of Canada seems especially interested in developing models along these lines. These kinds of models are often associated with so-called "now time" forecasting .

6.8.1 ARCH Models

Conditional heteroskedasticity models have become extremely popular in empirical finance. Such conditional volatility models have been used as proxies for unobservable risk premiums. For Stage 3, students can investigate various *ARCH* models in either a multivariate or univariate setting. I would expect such a stage to motivate the modelling strategy and describe the empirical findings in some detail.

6.8.2 Nonstationarity, Cointegration and Inference

Recent tests and estimation methods for nonstationary time series are to be analyzed. Topics include tests for unit roots, cointegration, estimation, inference, and testing for regime shifts when the break point is unknown.

In addition I will discuss various new topics in nonstationary econometrics. I will not be covering all of these in formal lectures but each student will pick one (or more) of these topics and write a paper discussing and implementing the tests or estimation method. The scope for this stage is wide open and just about anything is welcome.

6.8.3 Spectral Analysis

Using some of the information gained in Stage 2 students choosing this stage will conduct some frequency decomposition exercise. This exact topic is open so long as it involves some aspect of spectral methods. Students should consult me before starting on this topic. Please keep in mind that while the notes include detailed information on this, it is quite unlikely that this topic is covered in class.

6.8.4 STATA Program of a new time series test or estimator

This is a stage introduced a few years ago which many students found attractive. By this time, students will have developed considerable programming skills in STATA and should be able to write some general code on a new time series test or estimator. We will post these to a Economics 853/953 bulletin board. Students doing this stage are graded on the econometric problem, the quality of the program, and the clarity of the documentation. No written work other than the code and a successful application are required. *T*

6.8.5 Any Other Time Series Topic

During the course, students may discover other topics which interest them and that they wish to pursue. I encourage such independence and you can follow such interests in this stage. However, I would ask you to see me *before* starting on this. This work has often served as an MA essay!

7 Auditors

All auditors are expected to complete one of the stages (1-4).

8 Course Outline

We will essentially develop the topics in the order that they are required for the projects. In addition there will be some special topics such as estimating heteroskedastic-autocorrelation consistent variance-covariance matrices, generalized method of moments and regime shifting that may be included.

8.1 Textbook and References

There are many fine time series books available (some of which I list below). Unfortunately the books tend to be all theory with little insight for practical application. For the stationary part of the course, we will draw heavily on Harvey and Fuller. The newer nonstationary time series comes from Hamilton and directly from the literature. In addition, some of the lecture material is drawn from other sources not necessarily identified as time series readings.

- Harvey, A.C. (1994) **Time Series Models**, Philip Allan Publishers Limited. Second Edition
- Fuller W.A. (12nd edition 1996) **Introduction to Statistical Time Series**, Wiley Publishers. (good for the spectral stuff)
- Hamilton, J. D. (1994) **Time Series Analysis**, Princeton Publishers.

- C. Chatfield (1989) **The Analysis of Time Series: An Introduction**, 4th edition, Chapman and Hall.
- C.W. J. Granger and P. Newbold (1986) **Forecasting Economic Time Series**, Academic Press, 2nd edition.
- Box, G.E.P. and Jenkins, G.M. (1976) **Time Series Analysis: Forecasting and Control** Holden-Day Publishers.
- Judge, G.G; Griffiths, W.E.; Hill, R.C.; Lütkepohl, H. and Lee, T. (1985) **The Theory and Practice of Econometrics**, second edition, Wiley and Sons Publishers. This is the advanced Judge et al
- Judge, G.G; Hill, R.C.; Griffiths, W.E.; Lütkepohl, H.; and Lee, T. (1987) **Introduction to the Theory and Practice of Econometrics**, second edition, Wiley and Sons Publisher. (The junior version).
- Hannan E.J. (1960) **Time Series Analysis**, Methuen and Co. This is hard.
- Spanos, A. (1986) **Statistical Foundations of Econometric Modelling**, Cambridge Press.
- Cramer, J.S. (1986) **Econometric Applications of Maximum Likelihood Methods**, Cambridge Press. This is a good review of MLE.
- Jenkins, G.M. and Watts D.G. **Spectral Analysis and its Applications**, Holiday Press.
- Dhrymes, Phoebus (1998) **Time Series, Unit Roots, and Cointegration**, Academic Press.
- Banerjee, A., Dolado, J., Galbraith, J. and D. Hendry (1993) **Co-integration, Error-Correction, and the Econometric Analysis of Non-stationary Data**, Oxford University Press.
- Davidson R. And J. G. MacKinnon (new addition) **Estimation and Inference in Econometrics**, Oxford University Press.

8.2 Course Content

- Chapter 1 - Background on Time Series
- Chapter 2 - Stationary Processes
- Chapter 3 - The Box-Jenkins Time Series Model
- Chapter 4 - Estimating Time Series Models
- Chapter 5 - Asymptotics, Estimation of Covariance Matrices and Hypothesis Testing

- Chapter 6 - Model Building: Model Selection Criteria and Prediction
- Chapter 7 - Multivariate or Vector Time Series Models
- Chapter 8 - Spectral Analysis (not covered anymore but notes available free of charge)
- Chapter 9 - Dynamic Common Factor Models and Kalman Filtering: An Introduction
- Chapter 10 - Unit Roots
- Chapter 11 - Cointegration (this section is getting huge)
- Chapter 12 - Heteroskedastic-Autocorrelation Consistent Covariance Matrix Estimation
- Chapter 13 -ARCH Models
- Chapter 14 -Endogenous Regime Shifting (if time)

9 Queen's Contacts for Data

A list of financial data sources available at Queen's is here:

1. <http://library.queensu.ca/research/guide/business/economic-statistical>
2. A good source is from WRDS at <http://wrds.wharton.upenn.edu/>
3. Account request info is available here: http://library.queensu.ca/db_access/compustat.htm
4. The WRDS reps at Queen's (contacted directly from WRDS when you register.)
 - (a) Annette Lilly, alilly@business.queensu.ca, (613)553-6502
 - (b) Amy Marshall, amarshall@business.queensu.ca, (613)533-6421

10 Data Sources

1. St Louis Federal Reserve Economic data (fred) <http://research.stlouisfed.org/fred2/> can be directly downloaded into Stata (U.S.)
2. U.S. Bureau of Economic Analysis <http://www.bea.gov/index.htm> (U.S.)
3. Bank of Canada <http://www.bankofcanada.ca/en/rates/index.html> (Canada)
4. Statistics Canada <http://www40.statcan.ca/l01/cst01/> (Canada-these do not tend to be long time series but for a minimal price the data can be downloaded by searching through files)

5. Yahoo Finance *<http://finance.yahoo.com>* (Good for prices and quotes of a variety of US and World stocks)
6. Health data bases *<http://www.ihe.ca/publications/health-db/>* (usually very short time series)
7. U.S. Bureau of Labor Statistics *<http://www.bls.gov/data/>*
8. OECD data *<http://titania.sourceoecd.org/vl=10567317/cl=14/nw=1/rpsv/home.htm>*
9. inGeneas Database *<http://www.ingeneas.com/ingeneas/index.html>* (contains Canadian passenger, Canadian immigration, Canadian census, Canadian vital statistic (birth, marriage and death), Canadian land, Canadian military and miscellaneous records from the 18th, 19th and early 20th centuries.-costs money)

11 Exercise: Obtaining A Time Series Variable from U.S. Data Base in Stata

1. Open up Stata by double clicking on it . We want to keep two kinds of logs of our session
 - (a) A full log file that records everything that happens (our commands as well as the execution of those commands)
 - (b) A command log file that records the commands we issue and can be used to construct programs (a series of commands conducted sequentially in a do file)
2. Open log file by going to log bar and following directions
3. Type: cmdlog using `c:\temp\freduse`
4. Type: search freduse. You will be directed to a screen that lets you instal the program *freuse*.
5. Click install. You now have a program that accesses all the data stored on the St. Louis Federal Reserve . We will use this database a lot in this course so be sure you understand how to get variables. Keep in mind the variable has to be spelt exactly the same way as in the data set. Including capital letters.
6. We will retrieve Real Gross Domestic Product US by typing: *freduse GDPC1*. Note that the capital letters for the name must be used and it has to be the exact same way as it is listed in the menu pages of the Reserve.
7. Look at the Reference Manager in drop down dialog and see that 3 variables have been defined and notice their format

8. The variable *daten* is a Stata time variable (*%td*), in a daily format. This data is actually quarterly (notice the dates are the first of each quarterly month, i.e. January 1, April 1 and so on)
9. Create a quarterly variable by typing: `gen time = q(1947q1) + _n - 1`
10. Define this time variable to be the reference one from which all lags (leads) can be defined by typing: `tset time`
11. Go to reference Manager and format the variable and notice the Stata commands are issued from these drop down menus. we will make extensive use of these over the term. Also they can serve as ways to try various things, see what the results are and if you like them, keep the commands for later use.
12. Explore the Graph Bar to see how you can create a graph of real GDP on time, title it, change features of graph.
13. Explore Summarize in Statistics drop down program
14. Type `cmdlog close`
15. Open log file by going to the logfile bar
16. Find `freduse` in the `c:\temp` file using the Stata do file editor, clean up the errors that you made and try to execute all the commands at once.
17. Save the commands to USB key or a temporary file and E-mail them to yourself
18. Welcome to Stata: once you know the commands it is this easy!