University of Pennsylvania **Economics 706, Spring 2021**

Time-Series Econometrics

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Office Hours: right after Zoom sessions and by appointment

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Office Hours: TBA

Course Organization: The course will be offered online through CANVAS and comprise asynchronous recorded lectures as well as real-time video conferencing sessions. In addition, lecture slides and notes will be posted on CANVAS. Here is how the mechanics of this online course will work:

1. On the scheduled class dates, I will hold 45 minute Zoom sessions (Tu & Thu from 10:30-11:15am) so that you can ask questions about the asynchronous lecture materials that you are supposed to study prior to the session. We can adjust the length of the Q&A sessions as needed and I am happy to stay on for some "office hours" to discuss additional questions that you feel are not suitable to be asked in front of the full class.

2. On each Zoom session day, starting on January 21, I will post recorded lectures and MATLAB tutorials for the next meeting day. I will also post a sheet with questions that serve as the basis for the discussion during the next Zoom session.

3. You are expected to view the lecture recordings prior to the next video conferencing session and prepare answers to the questions (you don't have to submit them). I will call on you during these sessions to answer the questions.

4. During the video conferencing sessions you have the opportunity to ask additional questions that you would normally ask in the classroom during the lectures. Note that I will not simply repeat the recorded lectures. You do have to view the recordings prior to the online meetings to be able to engage and follow the discussions.

5. In addition the teaching assistant will offer asynchronous recitation sessions as well as virtual office hours. Details will be announced on CANVAS.

Course Description:

The course provides an introduction to modern time series econometrics. The first part of the course deals with properties of dependent processes. This includes laws of large numbers and central limit theorems as well as properties of autoregressive (AR), moving average (MA), and ARMA processes. Most of the analysis will be conducted in the time domain, but the course also includes a brief excursion into the frequency domain. The second part focuses on statistical inference. We begin with the Bayesian estimation of AR models. After the midterm we will consider the analysis of linear state-space models, which encompass ARMA models, time-varying coefficient models, and factor models. Finally, we consider models with time-varying heteroskedasticity and extensions to vector processes.

Prerequisites: Economics 705 or equivalent graduate level econometrics.

Courseware: You can access the course materials via CANVAS. You can log-in from *http://upenn.instructure.com/*.

Course Requirements:

- **Problem Sets**: There will regular problem sets, assigned throughout the semester. The problem sets are designed to give you the opportunity to review and enhance the material learned in class. You are encouraged to form small study groups, however, each member of a study group has to submit his or her own write-up of the solution. These solutions must be submitted on the specified due dates. [60%]
- **Final Exam**: will take the form of a 24 hour take-home exam and take place in early May. The first-year Ph.D. instructors will coordinate the dates. [40%]

Course Readings: There is no one textbook that exactly matches the material covered in class. I will make my lecture notes available on CANVAS and post recommended readings. The book *Econometrics* by Fumio Hayashi (2000) provides background reading for the material covered in lectures 2-7. It is actually based on Econ 706 lecture notes from when Hayashi was a professor at Penn. Some classic references for time series analysis are:

Brockwell, P.J. and R.A. Davis (1991): "*Time Series: Theory and Models*," Springer-Verlag.

Granger, C.W.J. and P. Newbold (1987): "*Forecasting Economic Time Series*," Academic Press.

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

Harvey, A.C. (1990): "*The Econometric Analysis of Time Series*," MIT Press.

Kim, C.-J. and C.R. Nelson (1999): "*State-Space Models with Regime Switching*," MIT Press, Cambridge.

Throughout this course, we will focus on Bayesian inference. In this regard, some useful reference are:

Gelman, Andrew, John B. Carlin, Hal S. Stern, and Donald B. Rubin (1995): *"Bayesian Data Analysis,"* Chapman & Hall, New York.

Koop, Gary (2003): *"Bayesian Econometrics,"* John Wiley & Sons.

Geweke, John (2005): *"Contemporary Bayesian Econometrics and Statistics,"* Wiley, New York.

Robert, Christian P. (1994): *"The Bayesian Choice,"* Springer-Verlag, New York,

Finally, here are three books with a specific focus on macroeconomic and financial applications:

Canova, Fabio (2007): *Methods for Applied Macroeconomic Research,* Princeton University Press.

DeJong, David and Chetan Dave (2007): *Structural Macroeconometrics,* Princeton University Press.

Campbell, J.Y., A.W. Lo, and A.C. MacKinlay (1997): "*The Econometrics of Financial Markets*," Princeton University Press.

Course Outline

- **Dependent Processes:** empirical measures of temporal dependence, covariance stationarity, WLLNs and CLTs for MA processes, strict stationarity, Martingales, deterministic trend model.
- **Stationary ARMA Processes:** AR models, autocovariance functions, infinite-order MA processes, Wold decomposition, ARMA models, prediction.
- **Frequency Domain Analysis:** spectral representation for linear cyclical model, spectral representation for stationary processes, filters, the spectrum of some common models.
- **Trend and Difference Stationarity:** trend stationary processes, difference stationary processes, functional central limit theorem and unit root asymptotics.
- **Estimation of AR Models:** likelihood function, frequentist analysis of the conditional MLE, Bayesian analysis.
- **Vector Autoregressions:** theoretical properties, Granger causality, likelihood function, Bayesian analysis, structural VARs.
- **Model Selection:** posterior model probabilities and model selection, consistency, hyperparameter selection, decision making with multiple models.
- **Reduced-Form VARs:** direct sampling from posterior, Minnesota prior, data-driven hyperparameter selection, forecasting, extensions.
- **State-space Models:** specification, filtering, smoothing, data augmentation and Gibbs sampling.
- **Topics:** dynamic factor models, Markov switching models, cointegration, heteroskedasticity.