Dynamic Models for Computational Social Science
ECON GA 4004

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3 credits

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Office Hours: TBD — Class Hours: TBD

Course Description

This course introduces dynamic processes, both deterministic and stochastic, as tools for answering questions in the social sciences. We apply these tools to a variety of current research questions.

Course Materials

- **An Introduction to Difference Equations** by Saber Elaydi
- **All of Statistics** by Wasserman
- **Recursive Macroeconomic Theory** (RMT) by Ljunqvist and Sargent
- **QuantEcon** Various lectures from QuantEcon available at **https://quantecon.org**

Prerequisites

The main prerequisite for this course are a solid mastery of the concepts covered in the Mathematical Foundations for Computational Social Science and the Data Skills for Computational Social Sciences courses. See the corresponding course syllabi for lists of the material covered in these courses.

A willingness to consult Wikepedia for math and statistics concepts will be helpful for students.

Course Objectives

The key objective in this course is to expose students to mathematical tools that will allow them to:

- Analyze questions involving dynamic systems in the social sciences by using time-series analysis, Markov chains, and dynamic decision making
- Use these tools to solve problems in the social sciences that may not have otherwise had good answers
- Allow students themselves to answer questions in the social sciences using one or more of the dynamic computational tools covered in class
- Teach students how to apply Leontief's adage that "dynamics is a special case of statics" and to understand how that adage aptly captures key insights that were the foundations of path breaking work in social dynamics by John R. Hicks and Kenneth Arrow

Course Structure

Class Structure

This course will meet once a week for 3 hours.

Class will be treated as a mixture of lecture time and lab time. Students should bring, and expect to use, their laptops every time the class meets.

Assessments

This course will use a mixture of homework assignments, in-class quizzes, exams, and a final project to evaluate students.

Homework: At the beginning of the course, homework will be assigned almost every week. Later in the course, there will be less frequent assignments in order to assure that you have time to work on your class project. Your two lowest homework grades will be dropped.
In-class quizzes: There will be 4 in-class quizzes during the semester. These quizzes will be open book and the lowest score will be dropped.
Exams: There will be 2 take-home exams.
Project: There will be a class project aimed at helping you apply the tools that you have learned to a "real-world problem."

Other than for quizzes and exams, we highly encourage students to work together. We have found that groups of 3-4 seem to work best. We believe that collaborative work is the best way to learn the type of material that we cover. We advise students not to rely on others to do work that you do not understand.

Grading Policy

The assignments just described will be the main inputs to the grade for the course. Assignments will be weighted evenly within groups and overall according to the following decision rule:

- Homework assignments: 25%
- In-class quizzes: 15%
- Tests: 20%
- Project: 40%

This weighting reflects our opinion that the most important skills to be acquired in this class are communicated by one's ability successfully to apply the tools that you learn to an interesting question in the social sciences.

Grading policy: A =100-90%; A- = 90-85%; B+ = 84-80%; B = 79 - 70%; C = 69 - 50%; D = 49 and lower

Schedule and weekly learning goals

The schedule is tentative and subject to change. Several of the modules below will occupy more than one week. The learning goals target key concepts to be mastered after each module. Successive modules build on early modules.

Week 01: Deterministic Dynamic Processes

Sources and tools:

- Chapters 1-4 of Saber Elaydi's text.
- https://python.quantecon.org/scalar_dynam.html

Topics to be mastered:

- Dynamics of first-order difference equations
- Linear difference equations of higher order
- Systems of linear difference equations
- Differential equations
- Stability and stationarity of deterministic processes

Week 02: Stochastic Processes, I

Sources and tools:

- https://python.quantecon.org/finite_markov.html
- https://python.quantecon.org/stationary_densities.html
- `quantecon.MarkovChain`

Topics to be mastered:

- Discrete Markov chains
- Continuous state Markov processes
- Irreducibility and aperiodicity
- Stability and stationarity of Markov processes
- Ergodicity of Markov processes
- Look-ahead estimator

Week 03: Stochastic Processes, II

Sources and tools:

- https://python.quantecon.org/linear_models.html
- `quantecon.LinearStateSpace`

Topics to be mastered:

- Linear state space models
- Stability and stationarity of linear state space models
- Ergodicity of linear state space models
- Prediction for linear state space systems

Week 04: Dynamic programming, I

Sources and tools:

- Chapters 3-4 of RMT
- https://python.quantecon.org/short_path.html

Topics to be mastered:

- Sequential problems
- Euler equations
- Stochastic control problems
- Contraction mapping theorem
- Computational methods
- Howard improvement algorithm

Week 05: Dynamic programming, II

Sources and tools:

- Chapter 5 of RMT
- https://python.quantecon.org/lqcontrol.html
- https://python.quantecon.org/perm_income.html
- https://python.quantecon.org/markov_jump_lq.html
- `quantecon.LQ`
- `quantecon.LQMarkov`

Topics to be mastered:

- LQ dynamic programming
- Discrete-time Riccati difference equations
- The permanent income model
- Markov jump LQ dynamic programming

Week 06: Dynamic programming, III

Sources and tools:

- Chapter 6 of RMT
- https://python.quantecon.org/mccall_model.html
- https://python.quantecon.org/mccall_model_with_separation.html
- https://python.quantecon.org/mccall_fitted_vfi.html
- https://python.quantecon.org/odu.html

Topics to be mastered:

- The McCall search model
- Search model with separation
- Fitted value function iteration
- Search model with Bayesian learning

Week 07: Time series modeling, I

Sources and tools:

- Chapter 2 of RMT
- https://python.quantecon.org/ar1_processes.html

Topics to be mastered:

- Autoregressive processes
- Autoregressive Conditional Heteroskedasticity
- Vector autoregression
- Poisson process
- Survival analysis

Week 08: Time series modeling, II

Sources and tools:

- **Statistical Rethinking**
- https://python.quantecon.org/exchangeable.html

Topics to be mastered:

- Bayesian time series analysis
- Exchangeablity
- Bayesian updating
- The Bayesian method of maximum likelihood

Week 09: Hidden state models, I

Sources and tools:

- Chapter 2 of RMT

Topics to be mastered:

- Gaussian mixture models (GMM)
- Hidden state models
- Introduction of Kalman filter
- EM algorithm

Week 10: Hidden state models, II

Sources and tools:

- Chapter 2 of RMT
- https://python.quantecon.org/kalman.html
- `quantecon.Kalman`

Topics to be mastered:

- Elaboration on Kalman filter
- Innovations representation
- Convergence of filtering and forecasting
- Computation of time-invariant Kalman filter
- Factorization of likelihood function

Week 11: Case studies, I

Sources and tools:

- Chapter 13 of RMT
- https://python.quantecon.org/markov_asset.html
- https://python.quantecon.org/lucas_model.html

Topics to be mastered:

- Asset pricing with finite states
- Asset prices in the risk-neutral case
- Asset prices under risk aversion
- The Lucas asset pricing model

Week 12: Case studies, II

Sources and tools:

- Chapter 13 of RMT
- https://python.quantecon.org/harrison_kreps.html
- https://python.quantecon.org/black_litterman.html

Topics to be mastered:

- Asset pricing with incomplete markets
- Mean-variance portfolio theory
- Hansen-Jagannathan bounds

Week 13: Case studies, III

Sources and tools:

- https://python.quantecon.org/smoothing.html
- https://python.quantecon.org/smoothing_tax.html

Topics to be mastered:

- Consumption smoothing with complete markets
- Consumption smoothing with incomplete markets
- Tax smoothing with complete and incomplete markets

Week 14: Case studies, IV

Sources and tools:

- https://python.quantecon.org/tax_smoothing_1.html
- https://python.quantecon.org/tax_smoothing_2.html
- https://python.quantecon.org/tax_smoothing_3.html

Topics to be mastered:

- Extensions of tax-smoothing model

Week 15: Case studies, V

Sources and tools:

- RMT
- https://python.quantecon.org/mle.html

Topics to be mastered:

- Markov models for text analysis
- MLE of DSGE models

Course Policies

Professional Behavior

Attend class. They say "eighty percent of success is just showing up." We have found that those who show up perform systematically better.

Arrive to class on time and stay until the end of class. Chronically arriving late or leaving class early is unprofessional and disruptive to the rest of the class.

We understand that the electronic recording of notes will be important for class and so computers will be allowed in class. Please refrain from using computers for anything but activities related to the class. Phones are prohibited as they are rarely useful for anything in the course. Eating and drinking are allowed in class but please refrain from it affecting the course. Try not to eat your lunch in class as the classes are typically active.