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Course description

This course will survey mathematical and statistical modeling methods widely used in economic research, organized around the "info-metric" meta-theory developed by Amos Golan and his associates, based on the principle of constrained entropy maximization. The topics will include: review of conventional econometric data-modeling techniques, such as linear regression; Bayesian inference based on the principle of inverse probability; constrained maximization in convex and non-convex problems; information theory; entropy and constrained entropy maximization in underdetermined systems; data compression through modeling; linear dynamic models; non-linear dynamic models; Markov models including agent-based models; equilibrium concepts from general equilibrium theory and game theory; Bowles' program of explanation in social science; maximum entropy statistical equilibrium models. In each case the relevant mathematical and statistical formalisms will be explained and illustrated by examples from current political economy, together with a critical review of recent published and working paper research.

Learning goals

Students will review and extend their knowledge of the central methods of modeling research in economics and political economy through problems discussed in a lab meeting each week. Close reading of key research papers in economics and political economy and student presentation of critical evaluations of published research will help students to read the professional literature with critical judgment. Students will undertake two, possibly linked, original data-based research projects using the methods presented in the course.

Trigger Warning

Learning the material in this course may change the way you understand political economy and the interpretation of economic data irreversibly, and make it impossible for you to maintain the views you now hold. Learning can be a painful and stressful process that is traumatic to those who cling uncritically to received ideas.

Prerequisites:

Advanced Microeconomics I and Advanced Macroeconomics 1, or permission of the instructor.

Required Work:

- 2 5-page writing exercises each presenting a data-based research project. The two projects may be linked into a single joint project where suitable. A detailed list of possible topics will be available at the beginning of the course. Exercises will be due one week before scheduled oral presentations.

- 2 in-class oral presentations of these critical reviews. Presentations will be scheduled starting in the fourth week of the term.
- Two portfolios of 3 problems each selected from problems assigned and discussed. The portfolios will be due March 26 and May 7.

Readings

Readings will be based on journal articles, working papers and preprints, and will be available through Canvas.

Books

We will use Amos Golan's *Foundations of Info-Metrics* as a basic text, supplemented by other readings and notes.

Topics and readings

The background readings are intended primarily as a resource for students interested in pursuing those topics in depth.

Topics

1. (January 23) What do we talk about when we talk about a model?
   (a) Review of linear regression as a joint frequency distribution
   (b) Error specification
2. (January 30) Bayesian inference
   (a) Bayes' Theorem: Prior and Posterior Probabilities, Likelihood, and Evidence
   (b) Linear regression as an example of Bayesian inference
   (c) Other common applications of Bayesian inference
   (d) The Bayesian philosophy
   (e) Examples from traditional statistical methods
   (f) Advanced Bayesian applications
   Jaynes, E. T. (1978). Where do we stand on maximum entropy? (pp. 1–74).
   (g) The likelihood problem
3. (February 6) Information theory
   (a) Shannon's theorem and entropy
   (b) Kullback-Leibler divergence

(c) Data compression and Bayes' Theorem

Shannon, Claude E. (1948). A Mathematical Theory of Communication. Bell System Technical Journal.

Kullback, S.; Leibler, R.A. (1951). On information and sufficiency. Annals of Mathematical Statistics.

Mckay, David. (2003). Information theory, Inference, and Learning Algorithms. Cambridge University Press. (Chapter 1)

4. (February 13, 20, 27, March 5) Statistical equilibrium models

   (a) Maximum entropy

   Golan ch 1-3

   (b) Jaynes' lessons from the Wolf dice data

   Jaynes, E. T. (1978). Where do we stand on maximum entropy? (pp. 1–74).

   (c) Constraints

   Golan ch 4, 8, 9

   (d) Purposive behavior and constraints

   Scharfenaker, Ellis and Duncan Foley (2017). Quantal Response Statistical Equilibrium in Economic Interactions: Theory and Estimation. Entropy

   Foley, Duncan. (2017). Information theory and behavior. The New School for Social Research, Working Paper 31/2017.

   (e) Examples of statistical equilibrium

   Scharfenaker, Ellis and Paulo dos Santos. (2015). The distribution and regulation of Tobin's q, Economics Letters, vol. 137(C), pages 191-194.

   Yang, Jangho (2017). Information theoretic approaches to economics, Journal of Economic Surveys.

   Yang, Jangho (2017). A Quantal Response Statistical Equilibrium Model of Induced Technical Change in an Interactive Factor Market: Firm-Level Evidence in the EU Economies, Entropy (forthcoming).

   Reddy, Foley et al - Email correspondence on statistical physics, https://reddytoread.com/2017/04/26/statistical-physics-and-the-social-sciences-what-potential-contribution.

   (f) What counts as a good theoretical explanation of data?

5. (March 12) Artificial Intelligence and Neural Networks

   (a) "Why does deep and cheap learning work so well?" Henry W. Lin and Max Tegmark Why does deep and cheap learning work so well?.

   (b) Henry W Lin and Max Tegmark.

      i. We show how the success of deep learning depends not only on mathematics but also on physics: although well-known mathematical theorems guarantee that neural networks can approximate arbitrary functions well, the class of functions of practical interest can be approximated through "cheap learning" with exponentially fewer parameters than generic ones, because they have simplifying properties tracing back to the laws of physics. The exceptional simplicity of physics-based functions hinges on properties such as symmetry, locality, compositionality and polynomial log-probability, and we explore how these properties translate into exceptionally simple neural networks approximating both natural phenomena such as images and abstract representations thereof such as drawings. We further argue that when the statistical process generating the data is of a certain hierarchical form prevalent in physics and machine-learning, a deep neural network can be more efficient than a shallow one. We formalize these claims using information theory and discuss the relation to renormalization group procedures. Various "no-flattening theorems" show when these efficient deep networks cannot be accurately approximated by shallow ones without efficiency loss - even for linear networks. arXiv, 2016 vol. cond-mat.dis-nn. http://arxiv.org/abs/1608.08225v1

6. (March 12) Static optimization
   (a) Lagrange multipliers and complementary slackness
   (b) Optimization in convex models
   Notes on optimization Duncan K. Foley
   (c) Optimization in non-convex models; annealing methods
7. (March 26, April 2) Deterministic dynamic models
   (a) Difference and differential equations
   (b) Linear difference and differential equations
   (c) Non-linear difference and differential equations
   (d) Bifurcations
   (e) Limit cycles and chaos
   Notes on Dynamical Systems Theory Duncan Foley
   Nonlinear Dynamics: A Primer by Alfredo Medio, Marji Lines Cambridge University Press, 2014
   Nonlinear Dynamical Systems in Economics by Marji Lines Springer 2005
8. (April 9, 16) Markov models
   (a) Ergodic and non-ergodic models
   (b) Multiple equilibria
   (c) Entropy functions and Lyapunov functions
   (d) Social interaction models
   (e) Agent-based models
   Notes on Social Interaction, Duncan Foley.
   Notes on Markov Processes, Duncan Foley.
9. (April 23) Equilibrium concepts
   (a) Cournot-Nash equilibrium
   (b) Market-clearing equilibrium
   (c) Social interaction equilibrium
   Notes on Social Interaction, Duncan Foley.
   (d) Dynamic equilibrium and stability

(e) Statistical equilibrium

Golan, ch 10, Modeling and Theories

Duncan K. Foley (1994). A statistical equilibrium theory of markets. Journal of Economic Theory,

Duncan Foley (2017), Crisis and theoretical methods: equilibrium and disequilibrium once again, Working Paper 03/2017, Economics Department, NSSR.

(f) Bowles' program of explanation in social science

Bowles, S. *Microeconomics* ch 1

10. (May 3) Priors and uncertainty in constraints

    (a) Golan, ch 8,9

11. (May 10)

    (a) Review

Bibliography