This document covers the first half of the Fall Term. The remainder of the semester will be taught by Robert Barro.

Note: Enrollment is strictly limited to PhD students in the Economics Department, Business Economics program, and PEG program. Qualified Harvard undergraduates may also enroll. No other students may take the course for credit or as auditors. This is the policy of the department of economics and I am obligated to enforce it.

Course Concept: The first half of this course will cover dynamic optimization methods (i.e., Dynamic Programming) in discrete time and continuous time. To illustrate these concepts, we will study applications in asset pricing, consumption, investment, and search. This course is intended for graduate students although advanced undergraduates with appropriate mathematical training (multivariable calculus and real analysis) are encouraged to attend.

Problem Sets: I will assign six short *weekly* problem sets. The problem sets will be posted on the course web site. The posting dates will be Tuesdays. The first problem set will be posted September 2 (the first day of class). Problem sets are due in class one week after they are posted. Solution sets will be posted on the course web site the same day that problem sets are due. Problem sets will be graded within one week after they are turned in. Graded problem sets will be handed out in class. If a student is not present to pick them up in class, they will be left with my assistant, Emily De Puy (Littauer M-13).

Office hours: Email Emily De Puy edepuy@fas.harvard.edu for office hours appointments. If you prefer, you can also come to walk-in office hours (no appointment needed). To find the time of my next office hours, please email Emily.

Sections: We will have two kinds of sections. Teaching fellows (TF's) will hold sections every week. Over the course of the semester, I will hold an additional five sections (at a time to be arranged with the class) designed to discuss how to develop your research program.

Special dates:
- September 2: First day of class
- September 25: Rosh Hashanah (class will be held and videotaped).
- October 2: section will be held in class this week.
- October 16: Beginning of second half of the semester. Robert Barro takes over.
- November 27: Thanksgiving (no class).
- December 3: Reading period begins (Wednesday).

Texts (at COOP):

Avinash Dixit and Robert Pindyck, *Investment Under Uncertainty*, (1994)

Nancy Stokey and Robert Lucas, *Recursive Methods in Economic Dynamics* (1989)

(Optional) Lars Ljungqvist and Thomas J. Sargent, *Recursive Macroeconomic Theory*, (3rd Edition, 2012)

(Optional) David Romer, *Advanced Macroeconomics,* (4th Edition, 2011)

Unless otherwise noted, readings listed below are required.

Lecture 1: Introduction to Dynamic Programming
- Stokey and Lucas chapter 1-2.
- (Optional) Richard Rogerson, Robert Shimer, and Randall Wright ["Search-Theoretic Models of the Labor Market: A Survey,"](#) *Journal of Economic Literature*, Vol XLIII (December 2005), pp. 959-988.

1. Introduction to dynamic programming
2. The Bellman Equation
3. Three ways to solve the Bellman Equation
4. Application: Search and stopping problem

Lecture 2: Iterative Methods
- Stokey and Lucas chapter 3.
- (Optional) Stokey and Lucas chapter 4.
- (Optional) Ljungqvist and Sargent chapters 2-3.

1. Functional operators
2. Iterative solutions for the Bellman Equation
3. Contraction Mapping Theorem
4. Blackwell's Theorem
5. Application: Search and stopping problem

Lecture 3: Classical consumption models

- Romer, Chapter 7
- Robert E. Hall "Stochastic Implications of the Life Cycle-Permanent Income Hypothesis: Theory and Evidence." *Journal of Political Economy*. Vol. 86 (6), pp. 971-87, 1978.
- Martin Browning and Tom Crossley, "The Life Cycle Model of Consumption and Saving" *Journal of Economic Perspectives,* Vol. 15, No. 3 (Summer, 2001), pp. 3-22.
- Jonathan Skinner, 2007. "Are You Sure You're Saving Enough for Retirement?," *Journal of Economic Perspectives*, Vol. 21(3), pages 59-80, Summer.
- (Optional) John Campbell and N. Gregory Mankiw, "Consumption, Income, and Interest Rates: Reinterpreting the Time Series Evidence," *NBER Macroeconomics Annual: 1989.* Blanchard, Olivier Jean Fischer, Stanley, eds, Cambridge, Mass. and London: MIT Press, pp. 185-216, 1989.
- (Optional) John Shea, "Union Contracts and the Life-Cycle/Permanent-Income Hypothesis" *American Economic Review*, Vol. 85 (1), pp. 186-200, 1995.

1. Consumption: Basic model and the early theories
2. Linearization of the Euler Equation
3. Empirical tests without "precautionary savings effects"
4. The Marginal Propensity to Consume

Lecture 4: Consumption with liquidity constraints
- Angus Deaton, "Saving and Liquidity Constraints." *Econometrica*. Vol. 59 (5). p 1221-48. September 1991.
- Christopher Carroll, **"A Theory of the Consumption Function, with and without Liquidity Constraints"** *Journal of Economic Perspectives*, Vol. 15, No. 3 (Summer, 2001), pp. 23-45
- Jonathan Parker and C. Broda, 2014. "The Economic Stimulus Payments of 2008 and the Aggregate Demand for Consumption" mimeo. Supplementary Materials

1. Precautionary savings motives
2. Liquidity constraints
3. Application: Numerical solution of a problem with liquidity constraints
4. Comparison to "eat-the-pie" problem
5. Discrete numerical analysis

Lecture 5: Non-stationary dynamic programming and the lifecycle
- Orazio Attanasio, "Consumption," *Handbook of Macroeconomics Vol. 1B*, pp. 741-812, 1999.
- Pierre-Olivier Gourinchas and Jonathan Parker **"Consumption over the Lifecycle,"** *Econometrica*, January 2002, 70(1), pp. 47-91.

1. Non-stationary dynamic programming
2. Lifecycle problem with liquidity constraints
3. Simulated Euler equation tests with liquidity constrained households

Lecture 6: Empirical implementation of consumption models.

- Marios Angeletos, David Laibson, Andrea Repetto, Jeremy Tobacman, and Stephen Weinberg, "The hyperbolic buffer stock model: calibration, simulation, and empirical validation." *Journal of Economic Perspectives*, Vol. 15, No. 3 (Summer, 2001), pp. 47-68.
- Mian, Atif R. and Rao, Kamalesh and Sufi, Amir, "Household Balance Sheets, Consumption, and the Economic Slump" (June 7, 2013). Chicago Booth Research Paper No. 13-42; Fama-Miller Working Paper.
- (Optional) David Laibson, Andrea Repetto, Jeremy Tobacman "Estimating Discount Functions from Lifecycle Consumption Choices."
- (Optional) Mark Aguiar and Erik Hurst, "Consumption vs. Expenditure", *Journal of Political Economy,* October 2005, Vol 113 Number 5, 919-948.
- (Optional) John Karl Scholz, Ananth Seshadri, and Surachai Khitatrakun, "Are Americans Saving 'Optimally' for Retirement?" *Journal of Political Economy*, 114(4), August 2006, 607-643.
- (Optional) Mian, Atif R. and Sufi, Amir, "What Explains the 2007-2009 Drop in Employment?" (February 2014). Fama-Miller Working Paper ; Chicago Booth Research Paper No. 13-43.

    1. Quasi-hyperbolic Discounting
    2. Hyperbolic Euler Equation
    3. Lifecycle simulations
    4. Method of Simulated Moments (MSM)

Lecture 7: Asset pricing and consumption.

- John Campbell, "Asset Prices, Consumption, and the Business Cycle," *Handbook of Macroeconomics Vol. 1C*, Elsevier B.V., pp. 1231-1303, 1999.
- Ravi Bansal, Dana Kiku, and Amir Yaron. "Long run risks, the macroeconomy, and asset prices." *American Economic Review* (2010): 542-546.
- Andreas Fuster, Benjamin Hebert, David Laibson. "Natural Expectations, Macroeconomic Dynamics, and Asset Pricing." *NBER Macroeconomics Annual 2011*;26:1-48.
- (Optional) N. Gregory Mankiw and Stephen Zeldes, "The consumption of stockholders and non-stockholders," *Journal of Financial Economics*, 29, pp. 97-112, 1991.
- (Optional) Narayana Kocherlakota, "The equity premium, it's still a puzzle." *Journal of Economic Literature*, 34(1), pp. 42-71, 1996.
- (Optional) Robert E. Lucas, Jr., "Asset Prices in an Exchange Economy," *Econometrica*, 46(6), pp. 1429-1446, 1978.
- (Optional) Rajnish Mehra and Edward C. Prescott, "The Equity Premium: A Puzzle." *Journal of Monetary Economics*. Vol. 15(2), pp. 145-161, 1985.
- (Optional) Xavier Gabaix and David Laibson "The 6D Bias and the Equity Premium Puzzle" in eds. Ben Bernanke and Kenneth Rogoff, *NBER Macroeconomics Annual,* Vol. 16, pp. 257-312, 2001.

1. Equity premium puzzle
2. Calibration of risk aversion
3. Resolutions of the equity premium puzzle

Lectures 8: Intro to Continuous Time Dynamic Programming.

- Dixit and Pindyck chapter 3.

1. Continuous time random walks: Wiener Process
2. Ito's Lemma
3. Continuous time Bellman Equation

Lectures 9-10: Applications of Continuous Time Dynamic Programming

- Dixit and Pindyck chapters 4 and 5
- (Optional) S. Bentolila and Giuseppe Bertola, "Firing Costs and Labor Demand: How Bad is Eurosclerosis?," *Review of Economic Studies*, 57(3), pp. 381-402, 1990.
- (Optional) Ricardo Caballero, Eduardo Engel, and John Haltiwanger, "Aggregate Employment Dynamics: Building from Microeconomic Evidence," *American Economic Review*, 87(1), pp. 115-137, 1997.
- (Optional) Avinash Dixit, "Entry and Exit Decisions under Uncertainty," *Journal of Political Economy*, 97(3), pp. 620-638, 1989.
- (Optional) Robert C. Merton, "Lifetime Portfolio Selection under Uncertainty: The Continuous-Time Case," *Review of Economics and Statistics*, Vol. 51(3), pp. 247-257, 1969.
- (Optional) Sanford Grossman and Guy Laroque, "Asset Pricing and Optimal Portfolio Choice in the Presence of Illiquid Durable Consumption Goods," *Econometrica*, 58(1), pp. 25-52, 1990.

1. General Solutions
     a. Boundary Conditions
2. Application: Merton's consumption problem
3. Application: Stopping Problems
     a. Boundary condition: Value Matching
     b. Boundary condition: Smooth Pasting
     c. Solving second order ODE's

Lecture 11: Classical Investment Models.
- Dixit and Pindyck chapter 1
- Ricardo J. Caballero, "Aggregate Investment," *Handbook of Macroeconomics Vol. 1B,* Elsevier Science B.V., pp. 813-862, 1999.
- Romer, chapter 8
- (Optional) Robert Hall and Dale Jorgensen "Tax Policy and Investment Behavior," *American Economic Review*, 57(3), pp. 391-414, 1967.
- (Optional) James Tobin, "A General Equilibrium Approach to Monetary Theory," *Journal of Money, Credit, and Banking,* 1(1), pp.15-29, 1969.

1. Introduction to investment
2. Static model
3. Dynamic model: q-theory of investment
4. Phase diagrams

Lecture 12: Investment under uncertainty with non-convexities.
- Dixit and Pindyck chapter 2
- Giuseppe Bertola and Ricardo Caballero, "Kinked Adjustment Costs and Aggregate Dynamics," *NBER Macroeconomics Annual 1990*, pp. 237-288, 1990.
- Nicholas Bloom, 2009, "The Impact of Uncertainty Shocks," *Econometrica*, 77(3), pp. 623-685.
- (Optional) Ricardo Caballero and Eduardo Engel, "Explaining Investment Dynamics in U.S. Manufacturing: A Generalized (S,s) Approach," *Econometrica*, 67(4), pp. 783-826, 1999.
- (Optional) Mike Golosov and Robert Lucas "Menu Costs and Phillips Curves" *Journal of Political Economy*, 2007, pp.171-199.

1. Empirical evidence on investment
2. Lumpy investment introduction
3. Lumpy investment models: Bertola and Caballero (1990)
4. Lumpy investment and delayed responses
5. Lumpy decisions across economics
6. Optional: Analytic example of q-model
7. Optional: Ergodic distributions and the Kolmogorov Equation

Additional Five Lectures Given in Section: How to Optimize Your Time as a Doctoral Student

1. Can Brenda tell me if I was admitted by mistake?
2. Why does David assign more than 168 hours of readings and problem sets per week?
3. Where can you purchase alarm clocks without snooze buttons?
4. Where can I get a pirated copy of Civilization V?
5. Is marijuana legalized in Massachusetts?
6. Is it possible to graduate if you only do 50% of the reading assignments?
7. What if you do 20%? 10%?
8. Do the faculty believe that we understand their lectures?
9. When should I start research?
What makes a research project successful?
10. How should I manage a portfolio of research projects?
11. What does the theory of option value say about optimal stopping times for partially finished research projects?