University of Maryland

Department of Economics

Economics 630
Computational Methods in Macroeconomics

Fall 2022

Instructor : Professor Borağan Aruoba

Email : aruoba@umd.edu

Office Hours : Wednesdays 12:30-1:30 or by appointment

Time and Location : Mondays and Wednesdays 11:00-12:15 in Tydings 0101

Course Webpage : http://www.elms.umd.edu (Canvas)

OBJECTIVE OF THE COURSE

This course covers some of the essential computational methods frequently used in macroeconomics. The topics range from solving and estimating representative-agent models, some useful methods in time-series econometrics such as structural VARs to solving heterogenous-agent models. At the end of this course, you will be able to solve and/or estimate most models that are widely used in macroeconomics, or at least you will know where to start!

PREREQUISITES

ECON 601 and ECON 602. Students who have not taken these courses and/or students from other departments must talk to me before taking this course.

GRADING

Problem Sets (60%)

Throughout the course I will assign **six** problem sets. You will have about one to two weeks to work on each of these. You will work in groups of two that will rotate. These problem sets will require you to write codes in MATLAB and/or work with Eviews. See below for how you can access these.

Problem Set 1: Assigned on 8/31. Due on **9/7 by 5 pm** via email.

Problem Set 2: Assigned on 9/19. Due on **10/3 by 5 pm** via email.

Problem Set 3: Assigned on 10/3. Due on **10/21 by 5 pm** via email.

Problem Set 4: Assigned on 10/26. Due on **11/2 by 5 pm** via email.

Problem Set 5: Assigned on 11/9. Due on **11/23 by 5 pm** via email.

Problem Set 6: Assigned on 11/30. Due on **12/14 by 5 pm** via email.

Final Project (40%)

You will complete a final project, which will be substantially longer than a problem set and will involve replicating the results of a paper. There will be two explicit deadlines, one for producing intermediate results and a final deadline which is the day before classes start in the Spring.

Attendance in Fall Department Seminars

You are required to attend the student brown bag (ECON 709) on Tuesdays at 12:30 and the Macro/International Finance Seminar on Wednesdays at 3:30. I will take attendance and consistent non-attendance will gave consequences on your grade in ECON 630.

TEXTBOOKS AND OTHER READING MATERIAL

Most of the course will be based on articles which are listed on the course outline and these will be available electronically on the course webpage.

The following books may be useful in certain parts of the course.

Numerical Methods in Economics, Judd, MIT Press, 1998

Bayesian Estimation of DSGE Models, Herbst and Schorfheide, Princeton University Press, 2015

Dynamic Economics: Quantitative Methods and Applications, Adda and Cooper, MIT Press, 2003

Handbook of Computation Economics (Vol.3), edited by Schmedders and Judd, North-Holland, 2014

Time Series Analysis, Hamilton, Princeton University Press, 1994

Computational Methods for the Study of Dynamic Economies, Marimon and Scott , Oxford University Press, 1999

Recursive Methods in Economic Dynamics, Stokey and Lucas, Harvard University Press, 1989

SOFTWARE

There are two key software that you will need access to for this class, MATLAB and Eviews. You can get MATLAB for your personal computer. See

https://terpware.umd.edu/Linux/title/1849

For Eviews, you can use the computers in the computer lab, or, you can obtain your own license for $110. This is only available for Windows machines. It is available through this link (select Academic Enterprise Edition, Stand-alone): (be sure to use your UMD email address)

https://store.eviews.com/collections/software/products/academic-eviews-13-enterprise-edition

Please see the University's website for graduate course-related policies at: https://gradschool.umd.edu/course-related-policies

READING LIST

Papers with (*) are required readings. Paper with (x) are important papers that apply the methods discussed. They are also required. The others are optional. All papers are available on the course website and more material may be posted there as we make progress. **Don't print all these papers immediately**. As we progress, it will become clear which ones you will study in greater detail.

Lecture 1 – Tools and Software Engineering for Economists

(*) Aruoba, S. Boragan and Jesus Fernandez-Villaverde (2015), "A Comparison of Programming Languages in Economics", *Journal of Economic Dynamics and Control*, 58, 265-273.

Lecture 2 – Basic Numerical Methods

Chapters 1, 2, 5, and 7.7 in Judd (1998). [If you need a reference]

Chapter 3 in Adda and Cooper (2003). [If you need a reference]

Tauchen, George (1986), "Finite State Markov-Chain Approximations to Univariate and Vector Autoregressions", *Economic Letters,* 20, 177-181

Lecture 3 – Value Function Iteration

(*) Barillas, Francisco, and Jesus Fernandez-Villaverde (2007), "A Generalization of the Endogenous Grid Method", *Journal of Economic Dynamics and Control,* 31.8, 2698-2712.

Carroll, Christopher D (2006), "The Method of Endogenous Grid points for Solving Dynamic Stochastic Optimization Problems," *Economics letters*, 91.3, 312-320.

Maliar, Lilia, and Serguei Maliar (2001), "Heterogeneity in Capital and Skills in a Neoclassical Stochastic Growth Model", *Journal of Economic Dynamics and Control* 25.9, 1367-1397.

Maliar, Lilia, and Serguei Maliar (2013), "Envelope Condition Method versus Endogenous Grid Method for Solving Dynamic Programming Problems," *Economics Letters*, 120.2 (2013): 262-266.

Lecture 4 – Local Approximation Methods and Dynare

Dynare User Guide by Tommaso Mancini Griffoli.

(*) Schmitt-Grohe, S. and M. Uribe (2004), "Solving dynamic general equilibrium models using a second-order approximation to the policy function," *Journal of Economic Dynamics and Control*, 28, 755-775

Judd, Kenneth L. and Sy-Ming Guu (1997), "Asymptotic Methods for Aggregate Growth Models", *Journal of Economic Dynamics and Control,* 21, 1025-1042

Lecture 5 – Global Approximation Methods

(*) Judd, Kenneth L. (1992), "Projection Methods for Solving Aggregate Growth Models", *Journal of Economic Theory,* 58, 410-452

(*) Maliar, Lilia and Serguei Maliar, (2014) "Numerical Methods for Large-Scale Dynamic Economic Models," *Handbook of Computational Economics*, Volume 3.

Judd, Kenneth L., Lilia Maliar and Serguei Maliar, (2010), "A Cluster-Grid Projection Method: Solving Problems with High Dimensionality," NBER Working Paper 15965

McGrattan, Ellen R. (1999), "Application of Weighted Residual Methods to Dynamic Economic Models", in *Computational Methods for the Study of Dynamic Economies,* R. Marimon and A. Scott eds., Oxford University Press

Lecture 6 – Comparison of Methods

(*) Aruoba, S. Boragan, Jesus Fernandez-Villaverde and Juan F. Rubio-Ramirez (2006), "Comparing Solution Methods for Dynamic Equilibrium Economies", *Journal of Economic Dynamics and Control,* 30*,* 2477-2508

Lecture 7 – Solving Models with Occasionally Binding Constraints

(*) Christiano, Lawrence J. and Jonas D.M. Fisher. (2000), "Algorithms for solving dynamic models with occasionally binding constraints," *Journal of Economic Dynamics and Control*, 24, 1179-1232

(*) Aruoba, S. Boragan, Pablo Cuba-Borda, Kenji Higa-Flores, Frank Schorfheide and Sergio Villalvazo (2020), "Piecewise-Linear Approximations and Filtering for DSGE Models with Occasionally-Binding Constraints", *mimeo*

(*) Guerrieri, Luca, and Matteo Iacoviello (2015), "OccBin: A Toolkit for Solving Dynamic Models with Occasionally Binding Constraints Easily," *Journal of Monetary Economics*, vol. 70, pp. 22-38.

(x) Aruoba, S. Boragan, Pablo Cuba-Borda, and Frank Schorfheide (2018) "Macroeconomic Dynamics Near the ZLB: A Tale of Two Countries," *Review of Economic Studies*, Volume 85, Issue 1, p.87-118.

Lecture 11 - Identifying Effects of Shocks

(*) Ramey, V (2016), "Macroeconomic Shocks and their Propogation," in *Handbook of Macroconomics Volume 2*.

(*) Stock, J.H. and M.W. Watson (2016), "Factor Models and Structural Vector Autoregressions in Macroeconomics," in *Handbook of Macroconomics Volume 2*.

(*) Christiano, Lawrence J., Martin Eichenbaum and Charles Evans (1999), "Monetary Policy Shocks: What Have We Learned and to What End?", *Handbook of Macroeconomics*.

(*) Uhlig, Harald (2005), "What are the effects of monetary policy on output? Results from an agnostic identification procedure," *Journal of Monetary Economics,* 52, 381-419

(x) Gertler, Mark, and Peter Karadi (2015) "Monetary Policy Surprises, Credit Costs, and Economic Activity," *American Economic Journal: Macroeconomics*, 7 (1): 44-76.

(x) Jarociński, Marek, and Peter Karadi (2020) "Deconstructing Monetary Policy Surprises—The Role of Information Shocks," *American Economic Journal: Macroeconomics*, 12 (2): 1-43.

(*) Romer, Christina, D., and David H. Romer (2004) "A New Measure of Monetary Shocks: Derivation and Implications," *American Economic Review*, 94 (4): 1055-1084.

Christiano, Lawrence J., Martin Eichenbaum and Robert Vigfusson (2003), "What Happens After a Technology Shock?", *mimeo*.

Gali, Jordi (1999), "Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?", *American Economic Review*

Kehoe, Patrick J. (2006), "How to Advance Theory with Structural VARs: Use the Sims-Cogley-Nason Approach", *NBER Macroeconomics Annual*

Lecture 12 – State Space Methods and the Kalman Filter

(x) Aruoba, S. Boragan (2020), "Term Structures of Inflation Expectations and Real Interest Rates," *Journal of Business and Economic Statistics,* 38:3, 542-553.

Durbin, J. and S.J. Koopman (2012), *Time Series Analysis by State Space Methods*

Stock, J.H. and M.W. Watson (1991), "A Probability Model of the Coincident Economic Indicators," *NBER Working Paper 2772*.

Stock, J.H. and M.W. Watson (2016), "Factor Models and Structural Vector Autoregressions in Macroeconomics," in *Handbook of Macroconomics Volume 2*.

Lecture 13 – Estimation of DSGE Models (Linear)

(*) An, Sungbae and Frank Schorfheide (2007), "Bayesian Analysis of DSGE Models", *Econometric Reviews*, 26, 113-172

(x) Smets, Frank and Rafael Wouters (2007), "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach", *American Economic Review,* 97(3), 586-606.

Del Negro, Marco and Frank Schorfheide (2011), "Bayesian Macroeconometrics," in *The Oxford Handbook of Bayesian Econometrics*, J. Geweke, G. Koop, and H. van Dijk (eds.), Oxford University Press, 293-389.

Fernandez-Villaverde, J., J. Rubio-Ramirez and F. Schorfheide (2016), "Solution and Estimation Methods for DSGE Models," in *Handbook of Macroeconomics Volume 2*.

Lecture 14 – An Introduction to the Particle Filter and Estimation of DSGE Models (Nonlinear)

(x) Fernandez-Villaverde, Jesus and Juan F. Rubio-Ramirez (2008) "How Structural are Structural Parameters?", *2007 NBER Macroeconomics Annual,* 83-137.

Fernandez-Villaverde, J., J. Rubio-Ramirez and F. Schorfheide (2016), "Solution and Estimation Methods for DSGE Models," in *Handbook of Macroeconomics Volume 2*.

Fernandez-Villaverde, Jesus and Juan F. Rubio-Ramirez (2007) "Estimating Macroeconomic Models: A Likelihood Approach", *Review of Economic Studies,* 74, 1059–1087.

Creal, D. (2009), "A survey of sequential Monte Carlo methods for economics and finance"

Lecture 15 – Solving Heterogenous-Agent Models without Aggregate Uncertainty

(*) Aiyagari, S. Rao. (1994), "Uninsured idiosyncratic risk and aggregate saving," *The Quarterly Journal of Economics*, 659-684.

(*) Huggett, Mark (1993), "The Risk-Free Rate in Heterogeneous-Agent Incomplete-Insurance Economies," *Journal of economic Dynamics and Control* 17.5, 953-969.

Huggett, Mark. (1996), "Wealth Distribution in Life-Cycle Economies," *Journal of Monetary Economics*, 38.3, 469-494.

Carroll, Christopher, and Nathan Palmer (2015), "The Heterogeneous-Agent Computational toolKit: An Extensible Framework for Solving and Estimating Heterogeneous-Agent Models"

Lecture 16 – Solving Firm-Dynamics Models without Aggregate Uncertainty

(*) Hopenhayn, Hugo A, (1992) "Entry, Exit, and Firm Dynamics in Long Run Equilibrium," *Econometrica*, 1127-1150.

(*) Hopenhayn, Hugo, and Richard Rogerson, (1993), "Job Turnover and Policy Evaluation: A General Equilibrium Analysis," *Journal of Political Economy*, 915-938.

Lecture 17 – Solving Heterogenous-Agent Models with Aggregate Uncertainty

(*) Krusell, Per, and Anthony A. Smith, Jr. (1998), "Income and Wealth Heterogeneity in the Macroeconomy," *Journal of Political Economy,* 106.5, 867-896.

(*) Terry, Stephen J. (2017), "Alternative Methods for Solving Heterogeneous Firm Models", *Journal of Money, Credit and Banking,* 49(6), 1081-1111.

(x) Clementi, Gian Luca, and Berardino Palazzo, (2020), "Entry, Exit, Firm Dynamics, and Aggregate Fluctuations," *American Economic Journal: Macroeconomics,* forthcoming.

Lecture 18 – Solving Heterogenous-Agent Models with Aggregate Uncertainty Redux (With An Application to Heterogenous-Agent New Keynesian Models)

(*) Reiter, Michael (2009), "Solving heterogeneous-agent models by projection and perturbation," *Journal of Economic Dynamics and Control,* Volume 33, Issue 3, pages 649-665.

(*) Winberry, Thomas. (2018), "A Toolbox for Solving and Estimating Heterogeneous Agent Macro Models," *Quantitative Economics,* 9, 1123-1151.

(*) Bayer, Christian and Ralph Luetticke (2020), "Solving discrete time heterogeneous agent models with aggregate risk and many idiosyncratic states by perturbation," *Quantitative Economics,* forthcoming

(x) Auclert, Adrien, Matthew Rognlie and Ludwig Straub (2020), "Micro Jumps, Macro Humps: Monetary Policy and Business Cycles in an Estimated HANK Model," *mimeo*

COURSE OUTLINE

Lecture	Dates	Topic
1	Aug 29	Tools and Software Engineering for Economists
2	Aug 31	Basic Numerical Methods
3	Sep 7-12-14-19	Value Function Iteration
4	Sep 21-26-28	Local Approximation Methods and Dynare
5	Oct 3-5-10-12	Global Approximation Methods
6		Comparison of Approximation Methods
7	Oct 17-19	Solving Models with Occasionally Binding Constraints
8	Oct 24	Crash Courses in Classical (Frequentist) and Bayesian Econometrics
9	Oct 26	Introduction to Eviews
10	Oct 31	Vector Autoregressions (VARs) and Bayesian VARs
11	Nov 2-7-9-14	Identifying Effects of Shocks
12	Nov 16	State Space Methods and the Kalman Filter
13	Nov 21-28	Estimation of DSGE Models (Linear)
14		An Introduction to the Particle Filter and Estimation of DSGE Models (Nonlinear)
15	Nov 30	Solving Heterogenous-Agent Models without Aggregate Uncertainty
16	Dec 5	Solving Firm-Dynamics Models without Aggregate Uncertainty
17	Dec 7	Solving Heterogenous-Agent Models with Aggregate Uncertainty
18	Dec 12	Solving Heterogenous-Agent Models with Aggregate Uncertainty Redux (With An Application to Heterogenous-Agent New Keynesian Models)