Econ 5725 Quantitative Macroeconomics

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Lecture location and times: Seigle 348 Tue 1730-2030

I Course Description

This course follows the first year PhD macro sequence: 501 and 502. Our goal in this course is to learn tools that help us relate models to data. We will learn numerical methods (and algorithms) to solve for the equilibrium allocations of representative agent models, heterogeneous agents economies, and overlapping generations models taking good care of distributions and aggregate consistency in stationary and non-stationary environments such as business cycles or development processes. We will pose quantitative questions and learn how to answer them by doing. This will require intensive computational work by students.

You should check the course website regularly at:

http://r-santaeulalia.net/Quantitative-Macro-SP16.html.

There I will post announcements, homeworks, additional references and a class diary that keeps track of what we are doing.

II Grades and Requirements

This course is demanding and I expect you to be engaged continuously. The grade will be some weighted average of homeworks and presentations. In this course we are learning methods, and we learn them by using them. You should expect one homework per foreseeable Tuesday and all homeworks are mandatory. One of you (not necessary at random) will present his/her homework solutions at the beginning of each class for 10-15 minutes.

You are definitely encouraged to work in groups but you will submit your homeworks individually: you will place the solution to the homeworks (and to possibly other requirements) in electronic form in /XXX/QMSpring15 in subdirectories that each student should have under his/her own name. You will have access to /XXX/QMSpring15 and your own subdirectory, for example, /XXX/QMSpring15/BettyGrable. You will place the solutions with your name and the homeworks name there, that is

/XXX/QMSpring15/BettyGrable/HWK-1/Readme.pdf

In order to gain access to your subfolder at /XXX/QMSpring15 on the Wash. U. Computron server, email Lucas, <heberlie[at]wustl.edu>, and become members of the /XXX/QMSpring15 family.

III Computer Skills

It helps if you have had previous programming experience but it is not a pre-requisite. However, in order to solve the homeworks in this class it is definitely a requisite to learn how to program. To learn so, you are on your own. That is, I am not going to teach you how to declare variables, generate random numbers, call intrinsic functions, link external subroutines, etc., but I am assuming that you are gaining—for those who do not have it yet—expertise on programming by yourselves as we go along. In other words, this is not a computer science course; instead, what we learn in this class are tools and algorithms that, making use of some programming language, help us to solve modern macroeconomic models with heterogeneous agents.

The programming language you use is at your discretion. If you are planning to do serious computational work in your research, I encourage you to learn Fortran (good alternatives are C or C++). This requires an initial fixed cost but I think it pays off. When it comes to numerical work, the scientific community speaks Fortran and most large-scale scientific computer programs are written in Fortran. One good reason to do so is that Fortran is faster than other available alternatives, and you will care a lot about the speed when you increase the scale of your work—the second half of this course with heterogeneous agents will approach that boundary. Two good sources to learn how to program in Fortran are Chapman (1998) and http://www.cs.mtu.edu/~shene/COURSES/cs201/NOTES/fortran.html.

Matlab is more user-friendly than Fortran and very popular in economics. It is particularly useful if you are used to think in vector-matrix operations. This application has a large amount of toolkits available to solve representative-agent business cycle models via (log- and) linearizations around steady states (see Uhlig's toolkit, Dynare, etc.) that you may find useful. Some alternatives are Gauss, R, Scilab and Octave.

To do serious data work when you are 'fishing for facts', Stata is a good application that allows you to upload and manipulate many large data sets at once. SAS or Eviews may work fine as well.

You will have to contact our IT team to learn how to access all these packages in Wash.U.

Finally, by the end of the semester, if time permits, we will learn the basics of parallel programming either through message passing interface or the use of GPUs.

IV Textbooks

A relevant set of important and excellent references—in addition to standard macroeconomic textbooks such Stokey and Lucas (1989) and Sargent and Ljungqvist (2004)—that a graduate student that plans to use computational methods in his/her research should have is:

1. Cooley (1995)
2. Marimon and Scott (1998)

3. Judd (1998)

4. Press et al. (1992) (you can find this available and free online).

5. Heer and Maussner (2005)

We will also use a large set of the graduate lecture notes by Dirk Krüger (UPenn), and the graduate lecture notes by Gianluca Violante (NYU). Further, some of the empirical macroeconomic methods that we will discuss are comprehensively described in Canova (2007).

Though we will not strictly follow any of the previous references, you sill see many obvious intersections between what we cover in class and the material presented in those books—I will try to refer you to the relevant, with respect to this course, parts of them. Also, note that References 4 and 5 provide code online.

The set of reference papers below for the course outline are yet to be tuned and will grow with the semester.

V Course Outline

1. **Discrete Time Stochastic Dynamic Programming**

   (a) Finite Horizon and the Theorem of the Maximum

   (b) Infinite Horizon and the Contraction Mapping Theorem

   References: Harris (1987), Stokey and Lucas (1989), Sargent and Ljungqvist (2004), and Heer and Maussner (2005).

2. **Macro and Micro Data: Some Useful Sources and Tools**

   (a) Macro data: PWT, WDI, NIPA, etc.

   - Growth and Business Cycle Measurement; Detrending and the use of Filters; Recovering some objects of interest (productivity residuals, factor shares, real price of investment...); Vector ARs; SVARs.

   References: Prescott (1986), Kydland and Prescott (1988), Cooley and Prescott (1995), Canova (2007), Galí (1999), Fisher (2006), Fernald (2007), Erceg et al. (2005), Christiano et al. (2007), Francis and Ramey (2005), Canova et al. (2010), Chari et al. (2008), Basu et al. (2006), Chang and Hong (2006), Chari et al. (2007), Ríos-Rull and Santaeulàlia-Llopis (2010), Ríos-Rull et al. (2011), and Santaeulàlia-Llopis (2011b)

   (b) Micro Data [cross-sections, panels of cross-sections, and panel data]: DHS, LSMS-ISA, MLSFH, CPS and (-MORG), SCF, PSID, etc.

   - Examples of Trouble: Identifying Age, Cohort, and Time Effects
   - Examples of Trouble: Selection Issues

   References: Krusell et al. (2000), Card and Lemieux (2001) Carneiro and Lee (2011), Hong and Santaeulàlia-Llopis (2012), Díaz-Giménez et al. (2011), Krüger and Perri (2006),Castro and Coen-Pirani (2006), Heathcote et al. (2009), Meghir and Pistaferri

(2010), Krueger et al. (2010), Guvenen (2009), Deaton (2000), Ameriks and Zeldes (2004), Heathcote et al. (2005), Fernández-Villaverde and Krüger (2007), and Olivetti and Petrongolo (2009).

3. **Numerical Methods**

   (a) Function Approximation (one- and multi-dimensional)
      - Local Methods: Taylor (and Padé)
      - Global Methods
         - Discretization
         - Spectral Methods: Polynomial Interpolation
            * Linear, kth-Order Polynomials, Chebyshev and other Orthogonal Basis
         - Finite Element Methods: Piecewise Polynomial Splines
            * Linear, Quadratic, Cubic Splines
            * Shape-Preserving Schumaker Splines
            * B-Splines
         - Weighted residuals methods: Collocation, Least Squares, Garlekin

   (b) Numerical Differentiation

   (c) Numerical Integration
      - Newton-Cotes Methods, Trapezoid Rule, Simpson's Rule
      - Gaussian quadrature
      - Monte Carlo Methods and Quasi-Monte Carlo Methods

   (d) Root Finding (solving systems of equations):
      - Bisection, Secant Method, Newton's Method, Fixed-Point Iteration
      - Gauss-Jacobi, Gauss-Seidel, Fixed-Point Iteration, Newton's Method, Secant (Broyden) Method, Enhancing Global Convergence: Powell's Hybrid, Homotopy Continuation Methods

   (e) Numerical Optimization

   References: Marimon and Scott (1998), Judd (1998), Heer and Maussner (2005), and Press et al. (1992).

4. **Representative Agent Models**

   Neoclassical growth model with stand-in households, the workhorse of modern macroeconomics; real business cycle (RBC) models; and, additional cases with a large state space.

   (a) Value Function Methods
      - Value function iteration (VFI): Discretization
      - Linear quadratic methods, Linearization and Log-linearization
      - Finite element methods and Collocation
      - Weighted residuals methods

   (b) Euler Equation Methods

- Policy function iteration (PFI)
- Linearization
- Finite element methods and Collocation
- Weighted residuals methods

References: Tauchen (1986), Marimon and Scott (1998), Judd (1998), Klein (2000), Heer and Maussner (2005), Aruoba et al. (2006), Kydland and Prescott (1982), Prescott (1986), Hansen (1985), Cooley and Prescott (1995), Greenwood et al. (2000), and Boldrin et al. (2001). See also the online linearization notes by F. Perri; J. Heathcote; and M. Nakajima.

5. **Heterogeneous Agents Models**

   (a) **Heterogeneous Agents with Complete Markets**

      i. When heterogenous agents economies behave as representative agent economies.
         - The Negishi method
      ii. When heterogenous agents economies do NOT behave as representative agent economies.
      iii. The case of Hybrid OLGs Economies.

      References: Chatterjee (1994), Caselli and Ventura (2000), Maliar and Maliar (2001), Maliar and Maliar (2003), Koulovatianos (2005), and Santaeulàlia-Llopis (2011a).

   (b) **Heterogeneous Agents with Incomplete Markets**

      i. Solution methods to Aiyagari-Bewley ($T = \infty$) economies
         - Transitional dynamics
      ii. Solution methods to Aiyagari-Bewley-Hugget (Life-Cycle) economies
         - Transitional dynamics
      iii. Solution methods to overlapping generations (OLGs) economies

      References: Huggett (1993), Aiyagari (1994), Hopenhayn and Prescott (1992), Ríos-Rull (1995), Ríos-Rull (1998), Castañeda et al. (2003), Flodén (2008), Huggett (1996), Conesa and Krüger (1999), Cubeddu and Ríos-Rull (2003), Hong and Ríos-Rull (2007), Hong (2008), Hong and Ríos-Rull (2009), Storesletten et al. (2004a), Hugget et al. (2011), Guvenen (2007), Guvenen and Smith (2010), and Chatterjee et al. (2007).

   (c) **Heterogeneous Agents with Incomplete Markets and Aggregate Risk**

      i. Solution Methods to Krusell-Smith ($T = \infty$) Economies
      ii. Solution Methods to Storesletten-Telmer-Yaron (OLGs) Economies

      References: Imrohoroglu (1989), Díaz-Giménez et al. (1992), Ríos-Rull (1996), Krusell and Smith (1998), Castañeda et al. (1998), Krusell et al. (2009), and Storesletten et al. (2004b).

6. **Methods versus Substance: A Discussion on Identification**

   (a) Calibration

(b) Structural (DSGE) Estimation

(c) SVARs

References: Canova and Sala (2009), Komunjer and Ng (2009), Guerron-Quintana (2010), Iskrev (2010), Ríos-Rull et al. (2011), Cooley and Prescott (1995), Christiano et al. (2005), and Justiniano and Primiceri (2008).

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