ECON 8873: Empirical Methods in Macroeconomics
Syllabus

Basic Information

- **Schedule**: MW 10:30PM - 11:45AM, Room: Maloney Hall 330
- **Contact Information**: Pablo A. Guerron-Quintana, Office: Maloney 325, Email: guerron@bc.edu
- **Office Hours**: by appointment only.

Course Description

In this course, we will learn numerical methods to solve and estimate nonlinear dynamic general equilibrium models (DSGE). Although the target audience is macro/international economics students, the class will be taught in a very general format so students from other fields may find beneficial to take the course. The material is mostly based on lecture notes jointly developed with Jesus Fernandez-Villaverde (U. Penn). They will be available before each class.

In the first part of the course, the student will be introduced to tools in software engineering and numerical analysis. The second part of the course is devoted to global methods to solve DSGE models. Some of these methods may be familiar to you because of economic examples in other Ph.D. courses. We will go into the details of why these methods work and how to apply them to a variety of situations.

In the final part, you will be introduced to techniques to estimate models displaying nonlinear dynamics. Most of this part will concentrate on the particle filter and estimation using likelihood-based methods.

Because of its nature, this course is highly applied. It means that you will have to spend a lot of time implementing algorithms and learning new software. This is error/trial so keep doing it! By this point, you should be proficient in Matlab (and Julia and Python and R). If you don't know a lower level language such as C/C++, it is a great moment to start doing so. Two excellent references are (Pitt-Francis and Whiteley, 2012) and (Lippman, Lajoie, and Moo, 2013). Fortran is a good option but is falling behind. Ron Gallant and Grey Gordon have excellent online material for C/C++ and Fortran, respectively. The site https://www.cplusplus.com/ offers excellent tutorials for C++. QuanEcon offers nice tutorials for Julia and Python. Sergei Maliar and Lilia Maliar have also code for different tasks and languages.

Grade Composition

The final grade will be based on homework assignments (30% of the grade), very proactive class participation including a presentation (20%) and a final project (50%). Homework is individual but you may cooperate with one of your classmates. You need to acknowledge the cooperation on the first page of your submitted solution. The final project will involve replicating a recent paper in the literature. You need to look for options and discuss them with me.

Topics

Some Preliminaries

In this section, the student will be introduced to selected topics in software engineering and numerical methods needed in the second and third parts of the class. For the first and second parts, we will rely heavily on the lecture notes joint with Jesus Fernandez-Villaverde.

- Intro to high-performance computing.
- Basic software utilities: Operating systems, Shell, Editors, IDEs, Version control.
- Scientific computing languages: C++, Java, Matlab, Julia, CUDA, Thrust, Mathematica, Python (Aruoba and Fernandez-Villaverde, 2015), (Deng, Guerron-Quintana, and Tseng, 2021), (Guerron-Quintana, 2016), (Coleman, Lyon, Maliar, and Maliar, 2018).
- Numerical/automatic differentiation and integration (Judd, 1998), (Robert and Casella, 2005), (Judd, Maliar, and Maliar, 2016), (Martin, Frazier, and Robert, 2021), (Neidinger, 2010), (Yoon, 2021), (Kochenderfer and Wheeler, 2019), (Dick, Kuo, and Sloan, 2013) https://alexey.radul.name/ideas/2013/introduction-to-automatic-differentiation/.
- Optimization: derivative, non-derivative, simulation based (Judd, 1998), (Bartholomew-Biggs, 2008), (Arnoud, Guvenen, and Kleineberg, 2019), (Kochenderfer and Wheeler, 2019).
- Parallel programming: OpenMP, MPI, GPU–CUDA/Thrust, OpenACC, std++ (Kirk and Hwu, 2017).

Solving Nonlinear Models

The student will be exposed to methods to solve models that cannot be solved with traditional linearization methods. Examples of such cases are models with occasionally binding constraints (zero lower bound, non-negative investment, collateral constraints), default models, models with time varying risk. In addition, you will be exposed to a formal exposition of dynamic programming, which is a critical tool to work on models of search and matching or default.

- Introduction to Dynamic Programming — Contraction mapping theorem, envelope theorem, Benveniste-Scheikman theorem Chapters 3 - 5 in (Sargent and Ljungqvist, 2018), chapters 3 - 6 in (Stokey and Lucas, 1999), chapter 3 in (Powell, 2011) provides a tractable exposition, chapter 5 in (Aguiar and Amador, 2021).

- Value function iteration (Judd, 1998), (Sargent and Ljungqvist, 2018), (Heer and Maussner, 2009).

- Alternatives/extensions to value function iteration (Arellano, Maliar, Maliar, and Tsyrennikov, 2016), (Gordon and Qiu), (Cao, Luo, and Nie, 2022), chapter 12 in (Judd, 1998), chapter 4 in (Heer and Maussner, 2009).

- Heterogeneous agent models – OLG (Gordon, 2018), (Krusell and Smith, 1998), (Heer and Maussner, 2009), (Rios-Rull, 1997), (Nakajima, 2007), (Maliar, Maliar, and Winant, 2019).

- Perturbation methods, pruning, generalized impulse responses (Schmidtt-Grohe and Uribe, 2016), (Judd, 1998), (Koop, Pesaran, and Potter, 1996), (Andreasen, Fernandez-Villaverde, and Rubio-Ramirez, 2016), (Fernandez-Villaverde and Guerron-Quintana, 2020),(de Groot, Durdu, and Mendoza, 2020), (Bianchi, Kung, and Tirskikh, 2022), (Dew-Becker, 2012), (Goncalves, Herrera, Kilian, and Pesavento, 2021), (Coeurdacier, Rey, and Winant, 2011), (de Groot, 2013), (Lopez, Lopez-Salido, and Vazquez-Grande, 2022).

- Projection Methods (Judd, 1998), (Heer and Maussner, 2009), (Fernandez-Villaverde, Rubio-Ramirez, and Schorfheide, 2016), (Maliar and Maliar, 2015), (Levintal, 2018), (Fernandez-Villaverde, Gordon, Guerron-Quintana, and Rubio-Ramirez, 2015a), (Kruger and Kubler, 2004), (Cai and Guerron-Quintana, 2023).

Estimation of Nonlinear Models

Now that you know how to solve nonlinear models, we turn the issue of how we take these models to the data.

- Refresher Kalman filtering.

- Extended and Unscented Kalman filtering (Särkkä and Svensson, 2023).

- Particle filtering (Herbst and Schorfheide, 2016), (Doucet, Freitas, and Gordon, 2001), (Lindsten, Jordan, and Schon, 2014), (Fernandez-Villaverde, Guerron-Quintana, and Rubio-Ramirez, 2015c), (Fernandez-Villaverde and Guerron-Quintana, 2021), (Chopin and Papaspiliopoulos, 2020), (Tulsyan, Gopaluni, and Khare, 2016).

- Other filtering approaches: Partial information filtering; Simulated method of moments and particle filtering (Drautzburg, Fernandez-Villaverde, and Guerron-Quintana, 2021), (Gordon and Guerron-Quintana, 2021).

- Metropolis Hasting meets Particle Filter (P-MCMC) (Herbst and Schorfheide, 2016), (Fernandez-Villaverde et al., 2015c), (Fernandez-Villaverde et al., 2016), (Fernandez-Villaverde and Rubio-Ramirez, 2007), (Robert and Casella, 2005), (Chopin and Papaspiliopoulos, 2020).[1]

- Impulse-Response Matching (Christiano, Eichenbaum, and Trabandt, 2016), (Christiano, Trabandt, and Walentin, 2010), (Guerron-Quintana, Inoue, and Kilian, 2017), (Forneron and Ng, 2018).

- Recent advances: Variational inference, Hamiltonian Monte Carlo, Approximate Bayesian Computation, Bayesian Synthetic Likelihood, Machine learning in macro (Fernandez-Villaverde and Guerron-Quintana, 2021), (Koop and Korobilis, 2020), (Smidl and Quinn, 2006), (Forneron and Ng, 2018), (Maliar et al., 2019), (Maliar, Maliar, and Winant, 2021), (Fernandez-Villaverde, 2021), (Martin et al., 2021), (Goodfellow, Bengio, and Courville, 2017), (Childers, Fernandez-Villaverde, Perla, Rackauckas, and Wu, 2022), (Kahou, Fernandez-Villaverde, Perla, and Sood, 2021), (Kase, Melosi, and Rottner, 2022), (Azinovic, Gaegauf, and Scheidegger, 2022), (Chen, Didisheim, and Scheidegger, 2023), (Friedl, Kubler, Scheidegger, and Usui, 2023).

- Topics on VARs: Bayesian Estimation and Gibbs Sampling (Canova, 2007), (Kilian and Lutkepohl, 2017), (Chan, Koop, Poirier, and Tobias, 2019) Identification (Antolin-Diaz and Rubio-Ramirez, 2018), (Ludvigson, Ma, and Ng, Forthcoming), (Miranda-Agrippino and Ricco, Forthcoming), Heterogeneity (Chang, Chen, and Schorfheide, 2021), Nonlinear (Guerron-Quintana, Khazanov, and Zhong, 2021), (Aruoba, Mlikota, Schorfheide, and Villalvazo, 2022).[2]

- Applications: stochastic volatility — interest rate and fiscal uncertainty, time-varying parameters — good luck or good policy, smooth transition AR — productivity in Detroit, zero lower bound (Fernandez-Villaverde, Guerron-Quintana, Kuester, and Rubio-Ramirez, 2015b), (Fernandez-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe, 2011), (Herbst and Schorfheide, 2016), (Fernandez-Villaverde et al., 2015c), (Fernandez-Villaverde et al., 2015a), (van Dijk, Terasvirta., and Franses, 2002)

Potential papers for presentations. Consult with me before choosing one:

- (Saijo, 2020)
- (Childers, 2018)
- (Mlikota and Schorfheide, 2022)
- (Kahou et al., 2021)
- (Childers et al., 2022)

[1]Excellent resource website on SMC and particle filters: https://www.stats.ox.ac.uk/~doucet/smc_resources.html

[2]Gary Koop has lots of Bayesian code for VARs: https://sites.google.com/site/garykoop/home/computer-code-2.

- (Azinovic et al., 2022)
- (Eftekhari and Scheidegger, 2022)
- (Kase et al., 2022)
- (Maliar et al., 2021)
- (Chang and Schorfheide, 2021)
- (Fernandez-Villaverde, Hurtado, and Nuno, 2020)
- (Lui and Plagborg-Moller, 2020)
- (Aruoba, Cuba-Borda, Higa-Flores, Schorfheide, and Villalvazo, 2021)
- (Bilbiie, Primiceri, and Tambalotti, 2023)

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