Computational Macroeconomics — Syllabus (draft as of July 28, 2025)
Econ xxx, Fall 2025 (October 20 — December 5)
Dr. Kanato Nakakuni

Time: Monday 13:45–15:15 and Friday 8:30–10:00
Room: xxx
Note: if any

Overview: The goal of this course is to provide an introduction to quantitative macroeconomic analysis and the computational techniques essential for solving modern macroeconomic models. Building on prior theory-based macroeconomics courses, *Computational Macroeconomics* is designed to equip students with practical skills and methods for computationally solving macroeconomic models.

A central focus of the course is the overlapping generations (OLG) model—one of the core frameworks in macroeconomics—and its extensions that incorporate household heterogeneity. We begin with a programming primer in Julia and a partial-equilibrium, two-period model to introduce key concepts and numerical methods for solving households' dynamic optimization problems. These methods are broadly applicable beyond the lifecycle context.

The course then progresses to a multi-period lifecycle model that incorporates consumption, savings, and labor supply decisions. This model is subsequently embedded in a general equilibrium framework. Students will learn how to calibrate the model, solve for equilibrium in both the long run and along the transitional path, and use it to analyze macroeconomic issues in which demographics and lifecycle decisions play a pivotal role—such as the effects of social security reforms or family policies. We will further extend the model to capture household heterogeneity—for example, in income, gender, and family structure.

Throughout the course, we will discuss real-world applications of the model and solve it hands-on. Example applications and questions include: What are the macroeconomic consequences of family policies, such as cash or in-kind transfers to households with children? What are the macroeconomic and welfare implications of social security reforms, such as increasing social security premiums, reducing the public pension benefits, or increasing the retirement age? By the end of the course, students will acquire practical skills in computationally solving dynamic optimization problems, calibrating macroeconomic models, and simulating the models tailored to their own research questions.

Course Material: We will not rely on a single textbook; instead, I will provide lecture notes tailored to the course content. However, the following textbook and website will serve as important references:

- Heer, B., & Maussner, A. (2024). *Dynamic general equilibrium modeling*. Berlin, Heidelberg: Springer Berlin Heidelberg.
- QuantEcon. (n.d.). *Quantitative Economics with Julia*. Retrieved June 24, 2025, from https://julia.quantecon.org/intro.html

Grading: Final exam (90 min, 50%) + assignments (5 – 10 pages, 50%)

Prerequisites: Students are expected to have completed intermediate-level courses in microeconomics and macroeconomics.

<u>Schedule (draft)</u>:

Lecture 1: Introduction and a programming primer (in Julia)
I will begin with an overview of the course logistics, including its goals and motivation. I will then provide a programming primer using Julia. This will cover basic programming concepts necessary for solving economic models, such as iteration, function definition, data types, and the use of numerical libraries. Much of this material will be based on [QuantEcon's Julia Essentials](). Students are encouraged to install Julia and VS Code in advance. However, using a different programming language (e.g., MATLAB, Python, etc.) is also acceptable if they are more comfortable with it. If everyone is set up, we may do some hands-on exercises during the lecture. Otherwise, these can be assigned as optional (non-graded) homework. (questions through google forms?)

Part I: Solving lifecycle problems

Lecture 2: Two period model and basic algorithms
I will introduce the *grid search* method with discretization as a way to solve dynamic household problems. We will formulate a two-period model of consumption and saving to illustrate the core ideas behind this approach. The simplicity of the model enables a direct comparison between numerical and analytical solutions, helping us to understand the trade-off between computational speed and accuracy.I will also briefly discuss alternative solution methods, including the *endogenous grid method* and *projection methods*.

Lecture 3: Lifecycle model
We extend the two-period model to a multi-period one with consumption, savings, and labor supply choices. I will begin by formulating the problem and introducing the concept of *backward induction* for solving finite-horizon models like the lifecycle model. I will walk through example code and demonstrate several techniques to improve computational efficiency—such as exploiting the concavity of the utility function to simplify the search for optimal choices. Students will then replicate the model on their own. As a follow-up, we will run simple experiments by varying deep parameters—such as the time discount factor—and observe how the model's behavior changes.

Lecture 4: Coding session (1)
We will cover two topics. First is the inter-vivo transfer (IVT) and endogenous determination of initial asset distribution. In doing so, we cover a variant of the value function iteration. Second is labor supply and endogenous evolution of human capital. In doing so, we cover the concept of interpolation.

Part II: Solving for equilibrium

Lecture 5: General Equilibrium
We extend the model to a general equilibrium (GE) setting by introducing a representative firm and a government that provides social security benefits and taxes household income. I will formulate the model and explain the basic solution algorithm, which involves checking market-clearing conditions and government budget balance in an outer loop, while solving the household problem in an inner loop. I will also introduce the fundamentals of *calibration*, discussing how to choose model parameters to match empirical moments. As a hands-on exercise, students will write calibration

code to determine parameters (e.g., time discount factor) so that the model matches a target statistic (e.g., capital-output ratio).

Lecture 6: Experiments in the long-run equilibrium
We will use the GE model to conduct counterfactual experiments in the long-run equilibrium. For example, we will explore the effects of changes in social security benefits, increases in the retirement age, and shifts in the demographic structure. In doing so, I will introduce the concept of *consumption equivalent variation* (CEV), a measure used to quantify welfare changes for households. Throughout the lecture, I will emphasize the importance of clearly explaining the economic mechanisms behind the observed computational results—not just reporting numbers, but interpreting what they mean and why they arise.

Lecture 7: Transitional Dynamics
Building on Lecture 6, we will solve for the *transitional dynamics* following counterfactual changes in economic or policy environments. I will explain the basic algorithm, which involves guessing the entire time path of factor prices and tax rates, solving each cohort's problem along the transition, and aggregating their choices to compute the implied equilibrium prices. I will walk through example code to illustrate this procedure. Students will then simulate their own counterfactual policy experiments.

Lecture 8: Coding session (2)
We will work on additional counterfactual experiments, including those to examine the mechanism of macroeconomic and welfare effects of those policies in the long-run equilibrium (e.g., GE vs. PE).

Part III: Advanced topics

Lecture 9: Risk and ex-post heterogeneity: Aiyagari framework
I will introduce another key paradigm in macroeconomics: Aiyagari (1994) model, within the context of a lifecycle framework (e.g., Huggett 1996). This model incorporates idiosyncratic income risk, leading to ex-post heterogeneity in income and asset holdings across households. I will explain how to introduce a stochastic income process into the model using the Tauchen (1986) method to approximate an AR(1) process. I will then walk through example code implementing the model with this form of income risk.

Lecture 10: Application (1) Education choice and income inequality (Abbott et al., 2019 JPE)
Lecture 11: Application (2) Fertility (Kim et al., 2024 AER)
Lecture 12: Application (3) Female labor supply and family policy (Guner et al., 2020 REStud)

Lectures 10–12 will be dedicated to applying the models we have studied to real research papers. For each paper, I will begin with a 15-minute overview (research questions, key findings, contributions, what's new in the model), followed by a 15-minute walkthrough of a simplified version that captures the core mechanics of the model. Students will then have 45 minutes to work on solving the simplified problem, after which I will use the remaining 15 minutes to go over the solution and discuss insights. In doing so, I will cover new margin of choice and endogenous state variables (such as skill investments, fertility, and human capital accumulation) and household heterogeneity relevant to them.

List of potential papers for application:

- Abbott, B., Gallipoli, G., Meghir, C., & Violante, G. L. (2019). Education policy and intergenerational transfers in equilibrium. *Journal of Political Economy*, *127*(6), 2569-2624. (Replication package available in Fortran)
- Daruich, D., & Fernández, R. (2024). Universal basic income: A dynamic assessment. *American Economic Review*, *114*(1), 38-88. (Replication package available in MATLAB)
- Kim, S., Tertilt, M., & Yum, M. (2024). Status externalities in education and low birth rates in Korea. *American Economic Review*, *114*(6), 1576-1611. (Replication package available in MATLAB)
- Guner, N., Kaygusuz, R., & Ventura, G. (2020). Child-related transfers, household labour supply, and welfare. *The Review of Economic Studies*, *87*(5), 2290-2321. (Replication package available in Fortran)

Lecture 13: Coding session (3) (Application (4) by choice of Mingjie)

Lecture 14: Wrapping-up, Q&A, and final remarks:
In the final lecture, I will wrap up the course by reviewing the key concepts we've covered and highlighting how they are connected across topics. I will also share tips and guidance for the final exam and how to prepare effectively. This session will include time for open Q&A, where I will address any remaining questions related to both course content and logistics. Given the density of earlier sessions, this lecture may also serve as a buffer to catch up on any material we may not have fully covered.

Reference:

Programming primer in Julia

- Getting Started with Julia, Quantitative Economics with Julia, by Perla. J., Sargent. T. J., and Stachurski. J. https://julia.quantecon.org/intro.html

Overview of solution methods: Grid search, Projection methods, Endogenous grid methods,

- Carroll, C. D. (2006). The method of endogenous gridpoints for solving dynamic stochastic optimization problems. *Economics letters*, *91*(3), 312-320.
- Heer, B., & Maußner, A. (2024). Weighted residuals methods. In Dynamic General Equilibrium Modeling: Computational Methods and Applications (pp. 231-310). Cham: Springer International Publishing.

Calibration

- Cooley, T. F. (1997). Calibrated models. *Oxford Review of Economic Policy*, *13*(3), 55-69.

Overlapping generations model

- Auerbach, A. J., & Kotlikoff, L. J. (1987). Evaluating fiscal policy with a dynamic simulation model. *The American Economic Review*, *77*(2), 49-55.
- Heer, B., & Maußner, A. (2024). Overlapping Generations Models with Perfect Foresight. In *Dynamic General Equilibrium Modeling: Computational Methods and Applications* (pp. 543-625). Cham: Springer International Publishing.

A few applications

- Bick, A., & Fuchs-Schündeln, N. (2018). Taxation and labour supply of married couples across countries: A macroeconomic analysis. *The Review of Economic Studies*, *85*(3), 1543-1576.
- Guner, N., Kaygusuz, R., & Ventura, G. (2020). Child-related transfers, household labour supply, and welfare. *The Review of Economic Studies*, *87*(5), 2290-2321.
- Tertilt, M. (2005). Polygyny, fertility, and savings. *Journal of Political Economy*, *113*(6), 1341-1371.

Household heterogeneity: Introducing idiosyncratic risk:

- Aiyagari, S. R. (1994). Uninsured idiosyncratic risk and aggregate saving. *The Quarterly Journal of Economics*, *109*(3), 659-684.
- Huggett, M. (1996). Wealth distribution in life-cycle economies. *Journal of Monetary Economics*, *38*(3), 469-494.
- Heer, B., & Maußner, A. (2024). OLG Models with Uncertainty. In Dynamic General Equilibrium Modeling: Computational Methods and Applications (pp. 627-724). Cham: Springer International Publishing.