

# Computational Macroeconomics

(Optional Course, 4 credits)

## Course Description

This is a hands-on course on a computational approach to macroeconomic modelling, offered to the Masters' and the doctoral students. The course equips students with skills in using computer programming languages such as *Python*, *MATLAB* and *Julia* to develop, calibrate and solve (both analytically and numerically) several contemporary macroeconomic models. The course begins with programming basics, and covers several standard computational tools which are part of the toolbox of modern macroeconomists. It also introduces students to responsible AI-assisted computational workflows for generating pseudocode, debugging, documenting and verifying numerical codes. We use contemporary macroeconomic models, including neoclassical models with both representative and heterogeneous agents, search and matching, as well as some behavioral and Post Keynesian models. Many of these models are analytically intractable, requiring numerical methods, which will be taught in this course. We will also learn how to process and interpret some standard macroeconomic datasets.

## Software

The course will equip you with basic skills in at least three programming languages: *Python*, *Julia* and *MATLAB / Octave*. In addition, by the end of the course you will also be expected to independently use at least one of these languages to write your own codes to solve various computational problems. The macroeconomic models will be typically developed using one of these languages. In addition, you will learn to use the MATLAB-based package *Dynare* to specify, solve, calibrate, simulate and estimate dynamic general equilibrium models, including an introduction to Bayesian estimation using MCMC methods and parallel computation. The course will also introduce the responsible use of agentic AI coding tools, especially *Codex* and *Claude Code*, for generating pseudocode, debugging and documenting codes, translating across programming languages, and verifying computational results.

## Prerequisites

No prior background in programming is required, as programming basics will be taught as part of this course. However, the course assumes familiarity with basic concepts in dynamical systems, including dynamic optimization, and with standard general equilibrium models in macroeconomics, such as the Arrow-Debreu, Ramsey-Cass-Koopmans and overlapping generations models. For students in the two-year MA program, these topics have been covered in the Macroeconomics II course.

## Computational Requirements

Several components of the course involve computationally intensive numerical work, including iterative solution of dynamic programming problems, simulation of stochastic and heterogeneous-agent models, repeated solution and sensitivity analysis of DSGE models, and Bayesian estimation using MCMC

algorithms. These tasks can require substantial processing time, memory and parallel computation, particularly when using fine state-space grids, large simulated populations, multiple parameter configurations or multiple MCMC chains. These computationally intensive components may involve access to a well-equipped computer laboratory and, for selected exercises and student projects, to multi-core and high-performance computing facilities.

## Evaluation

Problem sets / Projects: 20%, Mid-semester Examination (in-person with computer): 40%, End-semester Examination (in-person with computer): 40%.

## Course Outline\*

### 1 The Computational Experiment

A big picture of what we cover in this course, and why do we do this.

Reference: Lucas (1980), Kydland and Prescott (1996).

### 2 Computational Tools and Workflows

#### 2.1 Programming Basics: Python, MATLAB & Julia

Introduction to programming, algorithms and pseudocodes. Setting up the computational environment. Introduction to Python using Jupyter Lab / Notebook. Scripts, variables, data types, arrays, loops, conditionals, functions, structures and classes. Basic principles of writing readable, modular and reproducible codes. Numerical precision, vectorization and computational efficiency. Using scientific libraries in Python: NumPy, Matplotlib, SymPy, SciPy, Numba and Pandas. Introduction to MATLAB / GNU Octave. Introduction to Julia using Jupyter Lab / Notebook. Managing, processing and visualizing macroeconomic data. Linear algebra through numerical and symbolic computation. Introduction to Dynare as a specialized tool for specifying, solving and simulating dynamic general equilibrium models. Basic project organization, documentation and version control for computational research.

Reference: [Sargent and Stachurski's Python lectures](#), MATLAB User guides, \*[Perla, Sargent and Stachurski's Julia lectures](#), \*[Stachurski \(2009\)](#), \*[Novales, Fernández, and Ruiz \(2014\)](#), documentation for various softwares.

#### 2.2 AI-Assisted Computational Workflows

Responsible use of agentic AI coding tools in computational macroeconomics. Introduction to *Codex* and *Claude Code* for generating pseudocode, translating codes across Python, MATLAB/Octave and Julia, debugging numerical programs, writing documentation, and improving reproducibility. Limitations of AI-assisted coding: hallucinated packages, incorrect timing conventions, wrong state variables, convergence errors, and economically incorrect simulations. Verification of AI-assisted codes through model equations, convergence diagnostics, Euler-equation errors, simulation checks, and economic interpretation.

Reference: Course handouts; documentation for *Codex* and *Claude Code*.

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\*Starred readings are optional

### 3 Economic Dynamics using Python / MATLAB / Julia

Dynamic models in discrete and continuous time; deterministic and stochastic time-series models. Analytical and numerical solution/simulation of difference and differential equations. Approximation methods: Newton's method; differential-equation solvers and the Runge-Kutta algorithm in Python and MATLAB. AR(1) processes and measurement of business cycles from data.

Reference: [Sargent and Stachurski's Python lectures](#), MATLAB User guides, [Perla, Sargent and Stachurski's Julia lectures](#), Judd (2023) chapt. 5-7, \*Stachurski (2009).

### 4 Dynamic Programming

Deterministic finite and infinite horizon problems, value functions, Bellman equation and policy functions, existence and uniqueness of value functions, solving by sequential method vs. dynamic programming using value function iteration, introduction to stochastic processes and Markov chains, optimal stopping problems, stochastic dynamic programming.

Reference: [Sargent and Stachurski's Python lectures](#), Adda and Cooper (2003) chapt. 2, Ljungqvist and Sargent (2012) chapt. 2 & 3, Judd (2023) chapt. 5-7.

### 5 Representative Agent Models

#### 5.1 DSGE models and Real Business Cycles

Arrow-Debreu Competitive Equilibrium, Sequential Trading Competitive Equilibrium, Recursive Competitive Equilibrium. Moving from theory to data. Calibration techniques. Simulation of artificial economy using Dynare (MATLAB) / linearsolve (Python). Generating impulse response from a technology shock.

Reference: Adda and Cooper (2003) chapt. 5, Cooley (1995) chapt. 1, Heer and Maußner (2024), \*Brock and Mirman (1972), \*Uribe and Schmitt-Grohé (2017) chapt. 4, \*McCandless (2008) chapt. 4 to 7, \*Summers (1990), \*Kydland and Prescott (1982), \*King and Rebelo (1999).

#### 5.2 New Keynesian Model

Nominal rigidities, New Keynesian model, simulations using Dynare / linearsolve, computational experiments with exogenous shocks, policy applications. Introduction to likelihood-based and Bayesian estimation of DSGE models using Dynare, including Kalman filtering and Markov Chain Monte Carlo (MCMC) methods.

Reference: Galí (2008) chapt. 3, Heer and Maußner (2024), chapt. 2, Smets and Wouters (2003).

### 6 Heterogeneous Agent Models & Wealth Inequality

Models with infinitely-lived agents subject to uninsurable idiosyncratic risks: Bewley-Aiyagiri models, income and wealth inequality and distribution dynamics, limited asset market participation, HANK / TANK models with poor hand-to-mouth agents.

Reference: Heer and Maußner (2024), \*Ljungqvist and Sargent (2012), \*Krueger, Perri, Pistaferri, and Violante (2010), \*Aiyagiri (1994), \*Krusell and Smith Jr. (1998), \*Bilbiie (2008).

### 7 Search and Matching in Labor Markets

Search frictions and non-Walrasian labor markets. Revisiting the Diamond-Mortensen-Pissarides model as a computational application: matching function, job creation condition, Beveridge curve, wage determination and labor-market dynamics. Numerical simulation of unemployment and vacancies, and comparison with labor-market data.

Reference: Pissarides (2000) chapt. 1.

## 8 Alternative Approaches: Behavioral Macroeconomics and Post Keynesian Models

Departure from REH: limits to cognitive abilities, computations of models with heuristics, limits of arbitrage, fundamentalists vs. chartists, applications in foreign exchange markets. Post Keynesian & stock-flow consistent models: computation of solution path in high-dimensional models.

Readings: Grauwe (2012) chapt. 1, \*Shleifer and Vishny (1997), \*Chiarella, He, and Zheng (2013), Blecker (2002).

## References and Further Readings

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