Lecture 1: Introduction

FIE463: Numerical methods in Macroeconomics and Finance using Python

Richard Foltyn

Norwegian School of Economics (NHH)

January 9, 2025

Contents

About me

- Undergraduate studies in software engineering (& economics), PhD in Economics
- Research fields: Quantitative Macroeconomics & Household Finance
- 20+ years of programming experience:
  - Previously (and mostly forgotten): C/C++, Visual Basic, Java, Java Script, PHP, Perl, SQL, Matlab, R
  - These days: Python, Fortran, Unix shell scripts, Stata

Introduction to Python

Why Python? ... and why not?

Why Python?

- Free and open source
- Easy to learn, yet powerful and flexible syntax
- General-purpose language that can be used to solve many different problems
- Huge ecosystem of libraries and tools
- By now the most popular language overall
  - Most popular in machine learning
  - One of the two most popular in data science (together with R)
- May not be the fastest, but offers easy way to accelerate things (Cython, Numba, JAX, ML libraries)

What can you do with Python?

- Everything. The question is whether you should be using Python!

Why not Python?

- You already know another language that solves your problem well
- You want to use an estimator/algorithm that is implemented somewhere else (Stata, R), but not in Python

Python popularity (1)

Since its creation in the 1990s, Python has climbed to the top of almost any programming language ranking.

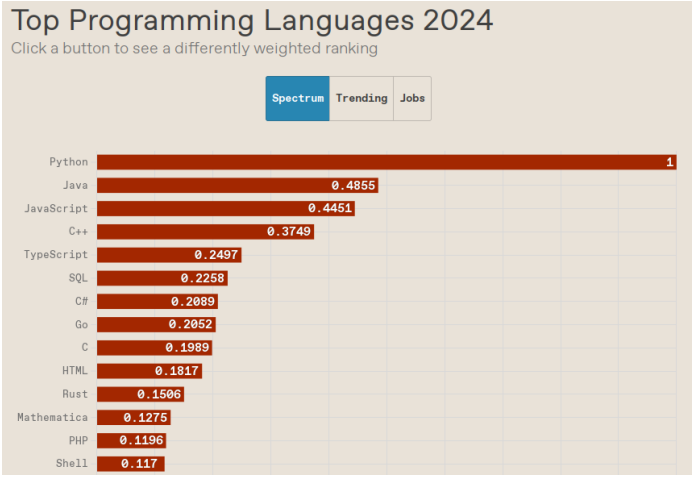


Figure 1: Source: IEEE The Top Programming Languages 2024

Python popularity (2)

"Which programming, scripting, and markup languages have you done extensive development work in over the past year?"

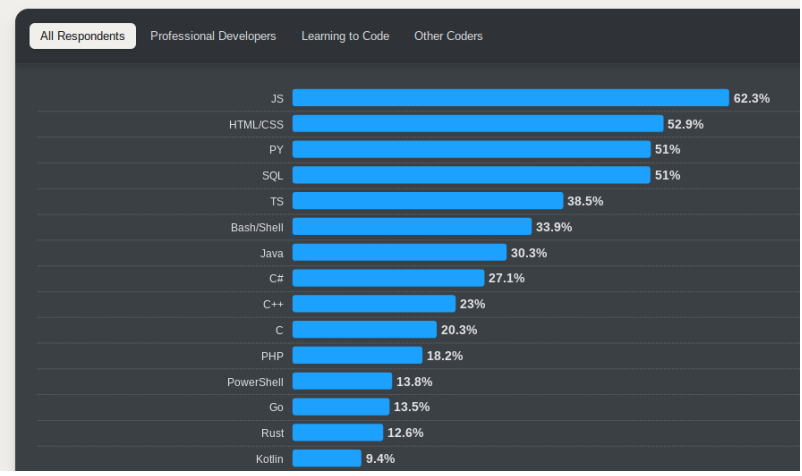


Figure 2: Source: StackOverflow Developer Survey 2024

Python popularity (3)

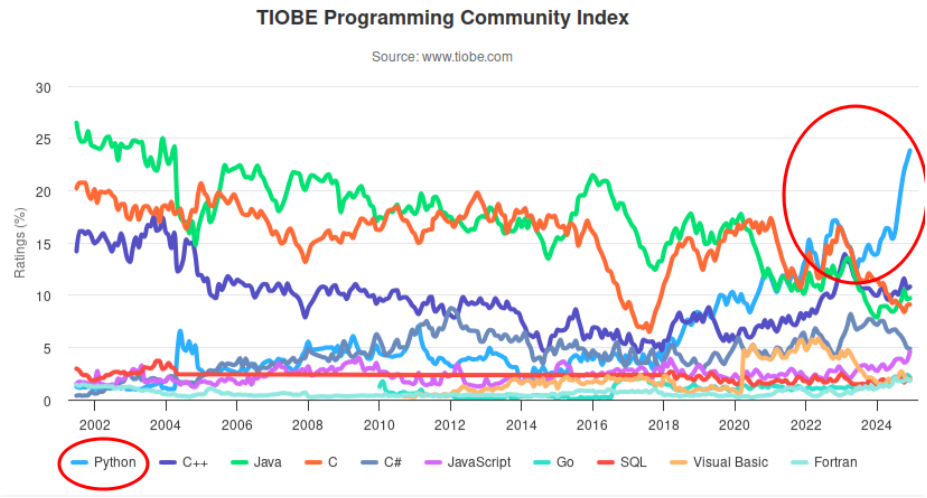


Figure 3: Source: TIOBE Index for December 2024

Python popularity (4)

GitHub: *"AI leads Python to top language as the number of global developers surges"*

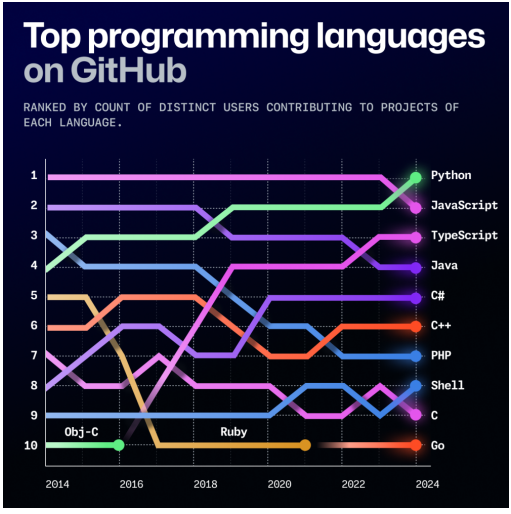


Figure 4: Source: GitHub Blog

Examples of Python in economics & finance

Solving dynamic programming problems with Python + Numba

- Olsson (2024): Solves Aiyagari model + extensive margin labour supply choice for single and couple households
- Foltyn (2024): Household finance model with portfolio choice and learning from experience

Econometrics (custom estimators with Python + Numba or JAX)

- Foltyn and Olsson (2024): Custom Maximum Likelihood Estimator (MLE)
- Foltyn (2024): Custom MLE, uses JAX to run it on GPUs

Dynamic economic models solved with Python + ML

- Maliar, Maliar, and Winant (2021): Solve dynamic problems with TensorFlow; [code]
- Duarte, Duarte, and Silva (2024): Continuous-time finance models with TensorFlow
- Duarte et al. (2021): Solve HH portfolio choice problem with 22 states using JAX

Python vs. other languages (1)

Matlab

- Proprietary, quite expensive
- Shipped as complete software package from one vendor (plus optional toolboxes)
- (Legacy) industry standard, widely used
- Substantially less powerful syntax
- Pure Matlab is somewhat faster than pure Python, but Python is easier to accelerate

R language

- Free, open source
- Focus on statistics, less on general-purpose computing
- Large ecosystem of packages focus on statistics, econometric modelling, machine learning

Python vs. other languages (2)

Julia

- Free, open source
- Focused on numerical computations, less on general-purpose computing
- Popular among younger academics doing quantitative work
- Substantially faster than Python, but Python can be accelerated to similar speed (using Numba)
- Smaller ecosystem, still under rapid development

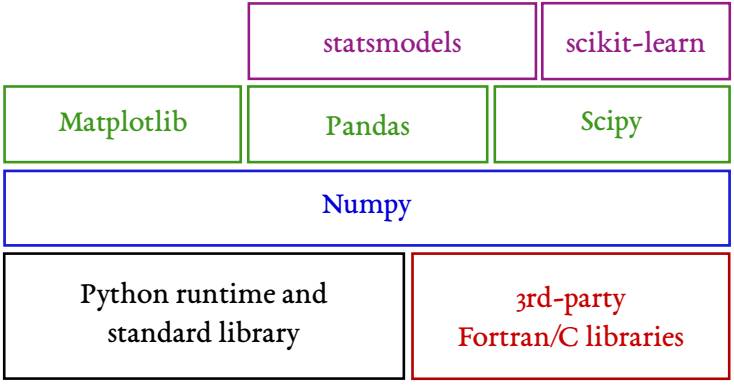
Stata

- Proprietary, quite expensive
- Focused on econometrics, in particular econometrics using large micro data sets
- Syntax was designed to run built-in commands, very inflexible for anything else
- If what you need is implemented, great! If not, it's very tedious to do it yourself (Mata is not great either).

Python ecosystem

Python software stack

How things fit together



Python software stack (used in this course)

Core libraries for quantitative work

- Python language, runtime and standard libraries ("Python")
- NumPy: implements n-dimensional arrays, linear algebra routines, random number generators
- Matplotlib: High-level plotting routines for visualization
- Pandas: Containers to handle heterogeneous data & routines for data analysis
- SciPy: Optimization routines, sparse matrices, integration, interpolation, linear algebra, statistics
- scikit-learn: routines used for machine learning (Ridge regression, Lasso, elastic net, etc.)

Python software stack (**not** covered in this course)

Econometrics & Machine learning

- statsmodels: routines for estimating many (linear) models
- TensorFlow: ML library maintained by Google with Python API
- JAX: Low-level API for automatic differentiation and accelerated linear algebra used to build ML models, developed by Google
- PyTorch: Python interface to ML libraries originally developed by Facebook

Frameworks to speed things up

- Numba: compiles Python code to machine code using LLVM
- Cython: converts pseudo-Python to C code (advanced, don't use this)

Jupyter notebooks vs. Python files

This course often uses Jupyter notebooks, not “regular” Python scripts.

Jupyter notebooks

- File extension: `.ipynb`
- Interactive, dynamic notebooks
- Good for exploratory work
- Easy to share work with others, in particular if they are *not* data analysts or programmers
- Can be exported to other formats, e.g., PDFs, LaTeX

Python scripts

- File extension: `.py`
- Interactive only in debugger
- For “serious” programming
- For libraries, reusable code
- Not useful to share with others who don’t know Python

Tools:
Git, GitHub, and VS Code

Software & tools

Goal: learn to use industry-standard tools for programming in Python

- Python distribution: Anaconda
- Version control: git
- Code hosting: GitHub
- Editor: Visual Studio Code

Why git? (and GitHub)

- Because everyone uses it: almost completely replaced all other version control systems over the last 19 years

  Examples:

  - Python: https://github.com/python/cpython
  - NumPy: https://github.com/numpy/numpy
  - SciPy: https://github.com/scipy/scipy
  - Pandas: https://github.com/pandas-dev/pandas
  - Matplotlib: https://github.com/matplotlib/matplotlib
  - PyTorch (Meta's ML library): https://github.com/pytorch/pytorch
  - TensorFlow (Google's ML library): https://github.com/tensorflow/tensorflow
- Keeps history of **your** code changes (and can restore previous versions)
- Keeps history of **other's** code changes
- Allows for decentralized coding in teams
- Allows synchronizing of code across devices

GitHub

Why GitHub?

- Everyone uses it!
- Alternatives (less popular):
  - GitLab
  - BitBucket
- Offers many other services besides version control (issue tracking, Wiki, etc.)
- Register for free at https://github.com/signup

Visual Studio Code

Why Visual Studio Code?

- Has become the most widely used editor for most languages (see StackOverflow Developer Survey 2024)
- Free & open source
- Good support for almost any programming language and file format (e.g., Jupyter Notebooks) via extensions
- Natively supports git & GitHub (unlike older editors)

- Alternative: PyCharm by JetBrains (free community edition is available, free professional edition for students)

- Note: Visual Studio Code completely independent of Visual Studio, a commercial IDE from Microsoft for Windows development

VS Code is the most popular editor

"Which development environments did you use regularly over the past year?"

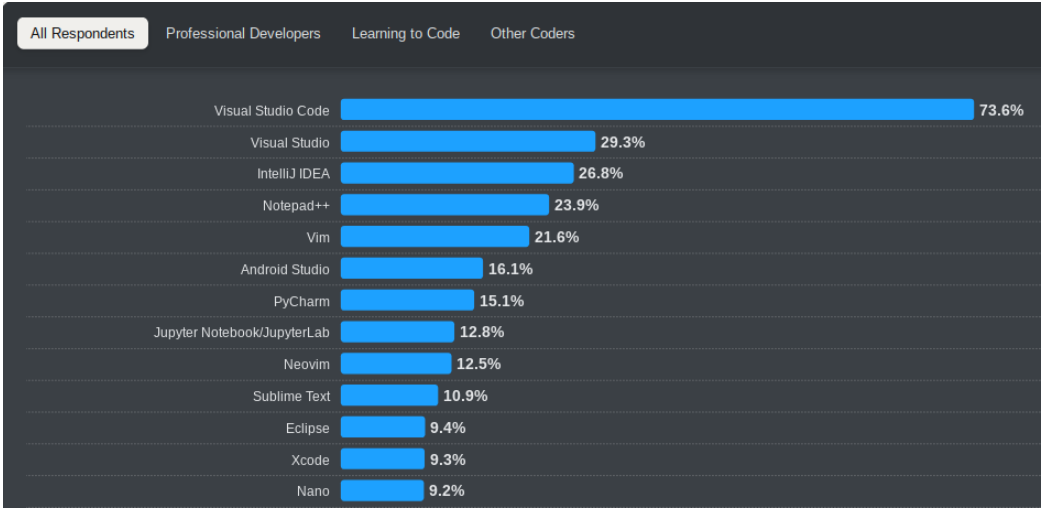


Figure 5: Source: StackOverflow Developer Survey 2024

Course outline & assessment

Course details

Teaching approach

1. Lectures: introduce new concepts [Tuesday, 12:15–14:00]
2. Workshops: practice concepts from previous lecture [Thursday, 8:15–10:00]

Prerequisites

- No Python knowledge required
- Previous exposure to other programming languages (R, Julia, Matlab) is helpful

Course material

- Available on GitHub: https://github.com/richardfoltyn/FIE463-V25

Course outline (preliminary!)

Part 1: Introduction to Python [≈ 4 weeks]

- Setting up a working environment
- Working with Visual Studio Code, Jupyter notebooks, git (optional)
- Basic programming concepts (syntax, data types, NumPy arrays)
- Control flow (conditional execution, loops)
- Functions and modules
- Plotting with matplotlib
- Applications:
  - Two-period consumption-savings problems
  - Static portfolio choice

Course outline (preliminary!)

Part 2: Applications to models in macroeconomics & finance [≈ 4 weeks]

- Advanced NumPy and SciPy
- Random number generation, simulation, and statistics with SciPy
- Applications:
  - Finite and infinite-horizon consumption-savings problems
  - Stochastic processes: AR(1) and Markov Chains
  - Solving models with uncertainty (income risk)
  - Simple asset pricing models

Course outline (preliminary!)

Part 3: Working with financial data [≈ 4 weeks]

- Introduction to pandas
- Processing data from various sources
- Introduction to unsupervised and supervised learning with scikit-learn
- Applications:
  - Obtaining macroeconomic & financial data from the internet
  - Predicting house prices, stock prices, or similar

Assessment

Course approval

1. Individual programming assignment to be handed in after part 1 of the course

Assessment

1. Group project #1 (“term paper”) to be handed in after part 2 of the course [40%]
2. Individual peer review of another group’s project #1 [5%]
3. Group project #2 (“term paper”) to be handed in the end of the course [50%]
4. Individual peer review of another group’s project #2 [5%]

The peer reviews are intended to give students additional feedback on code style, structure and efficiency in a respectful, constructive manner.

Additional Resources

Additional resources

- Numpy quick start tutorial
- Numpy tutorial for Matlab users
- QuantEcon lectures: python programming for economics & finance
- QuantEcon library: collection of routines and tools for economics
- QuantEcon repository: contributed code for solving economic problems in Python
- scikit-learn user guide

Additional resources — Books

- Think Python by Allen B. Downey
  General intro to Python, chapters are available as Jupyter notebooks.
- Python for Everybody by Charles R. Severance
  General intro to Python with a focus on data analysis, available as PDF.

Additional resources — Videos

Introduction to the command line / terminal:

- Absolute BEGINNER Guide to the **Mac OS** Terminal [17 min]
  https://youtu.be/aKRYQsKR46I
- Git Bash - Simplest command line program for **Windows** [7 min]
  https://youtu.be/yoZ910JQzrg

Introduction to using git

- Git for dummies [20 min] https://youtu.be/mJ-qvsxPHpY
- Git and GitHub Tutorial for Beginners [46 min] https://youtu.be/tRZGeaHPoaw
- Git Essentials in VS Code [30 min] https://youtu.be/twsYxYaQikI
  Focuses on interacting with git and GitHub through VS Code

References

Duarte, Victor, Diogo Duarte, and Dejanir H Silva. 2024. Machine learning for continuous-time finance. **The Review of Financial Studies** 37 (11): 3217–3271.

Duarte, Victor, Julia Fonseca, Aaron S Goodman, and Jonathan A Parker. 2021. **Simple Allocation Rules and Optimal Portfolio Choice Over the Lifecycle.** Working Paper, Working Paper Series 29559. National Bureau of Economic Research.

Foltyn, Richard. 2024. Experience-based Learning, Stock Market Participation and Portfolio Choice.

Foltyn, Richard, and Jonna Olsson. 2024. Subjective life expectancies, time preference heterogeneity, and wealth inequality. **Quantitative Economics** 15 (3): 699–736.

Maliar, Lilia, Serguei Maliar, and Pablo Winant. 2021. Deep learning for solving dynamic economic models. **Journal of Monetary Economics** 122:76–101.

Olsson, Jonna. 2024. Singles, couples, and their labor supply: long-run trends and short-run fluctuations. **American Economic Journal: Macroeconomics.**