# Computational Methods for Quantitative **Economics**

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#### **Topics**

- Discussion of scientific computing
- Overview of Python libraries
- Computing equilibria
- Google JAX
- Option pricing with Python
- High dimensional problems

### Assumptions:

- basic econ/computer/maths/stats
- some programming?

#### Aims:

- Discuss options
- Review trends
- Learn techniques

#### Resources

https://github.com/QuantEcon/kobe\_comp\_econ\_2023

What are the major trends in scientific computing?

- what's driving them?
- how can we benefit?

# Trend 1: Proprietary $\rightarrow$ Open Source

#### **Proprietary**

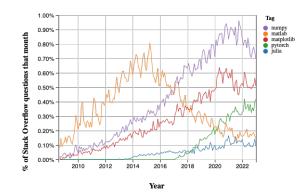
- Excel
- MATLAB
- Eviews, etc.

#### Open Source / Open Standard

- Python
- Julia
- R, etc.

closed and stable vs open and fast moving

#### Popularity:



# Trend 2: Low Level $\rightarrow$ High Level

#### Low level

- Fortran
- Assembly

### High level

- Python
- Javascript
- Ruby

### Low level languages give us tight control of hardware

- CPU
- memory, etc.

## High level languages give us

- abstraction
- automation
- flexibility, etc.

## Example. 1 + 1 in assembly

```
pushq
        %rbp
        %rsp, %rbp
movq
        $1, -12(%rbp)
movl
        $1, -8(\%rbp)
movl
        -12(\%rbp), %edx
movl
        -8(\%rbp), \%eax
movl
addl
        %edx. %eax
        \%eax, -4(\%rbp)
movl
Tvom
        -4(\%rbp), \%eax
        %rbp
popq
```

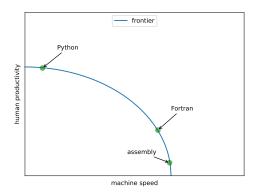
## Example. 1+1 in C

```
#include <stdio.h>
int main() {
    int x = 1 + 1;
    printf("1 + 1 = %d\n", x);
    return 0;
}
```

## Example. 1 + 1 in Fortran

```
PROGRAM ONE_PLUS_ONE
INTEGER :: X = 1 + 1
PRINT *, '1 + 1 = ', X
END PROGRAM ONE_PLUS_ONE
```

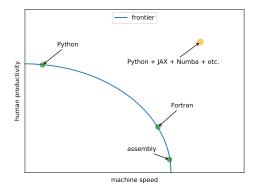
$$x = 1 + 1$$
  
print("1 + 1 = ", x)



Which Language?

New trend — a shifting frontier

#### Trade-offs:

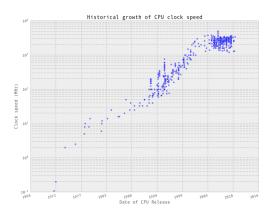


In order (according to repo stats):

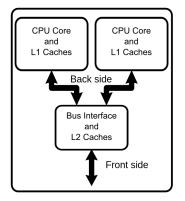
- 1. Python
- 2. C++
- 3. Javascript
- 4. Jupyter notebooks
- 5. Ruby

## Trend 3: Parallelization

### CPU frequency (clock speed) growth is slowing



### Chip makers have responded by developing multi-core processors



Source: Wikipedia

### GPUs are becoming increasingly important



Applications: machine learning, deep learning, etc.

While scientific computing environments best support parallelization?

- Most have some support
- but which make it easy to harness its power?

#### Current winner:

Google JAX (Python library)

#### How about R?

- Specialized to statistics
- Huge range of estimation routines
- Popular in academia
- Loosing some ground to Python (AI, machine learning)

#### Pros:

- Fast and elegant
- Many scientific routines
- Julia is written in Julia

#### Cons:

Low rates of investment in some important libraries

## Python

- Easy to learn, well designed
- Massive scientific ecosystem
- Heavily supported by big players
- Strong support for parallel computing
- Huge demand for tech-savvy Python programmers

## Accessing Python

Option 1: Via a service (remote option)

• https://colab.research.google.com

Option 2: Local install (Python + scientific libs)

- Install Anaconda from https://www.anaconda.com/
  - Select latest version
- Not plain vanilla Python

## How to Interact with Python?

#### Many options:

- write with VS Code / Emacs / Vim
- run with base Python, IPython, etc.

Or do both with Jupyter notebooks / Jupyter lab

for simplicity we focus only on the last option

# Jupyter Notebooks

A browser based interface to Python / Julia / R / etc.

Search for jupyter notebook

#### Useful for:

- getting started
- exploring ideas

# Working with Notebooks

- Entry and execution
- Markdown
- Getting help
- Copy paste
- Edit and command mode