

SOLVING MACROECONOMIC MODELS ON LARGE SCALE COMPUTING INFRASTRUCTURES

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OUTLINE

- 1 FAILURE OF INTEREST PARITY
- 2 RESEARCH PROJECT
- 3 WORK FLOW
- 4 RESULTS

INTEREST PARITY

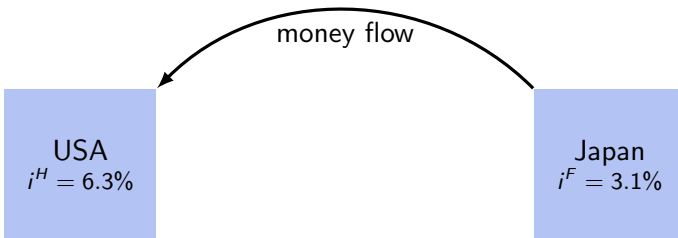
USA

$$i^H = 6.3\%$$

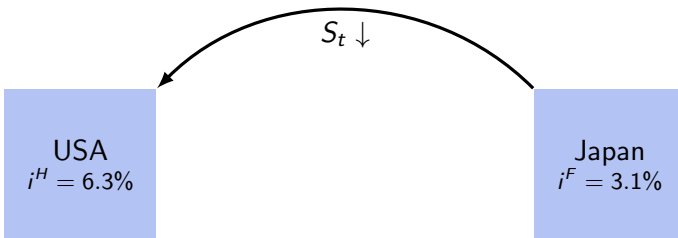
Japan

$$i^F = 3.1\%$$

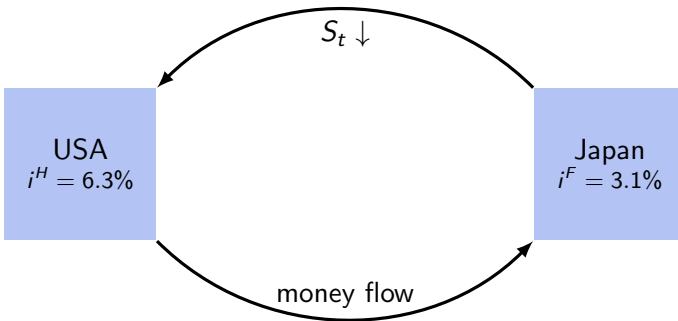
INTEREST PARITY



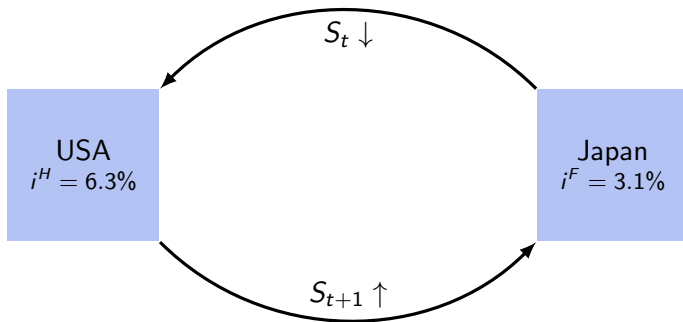
INTEREST PARITY



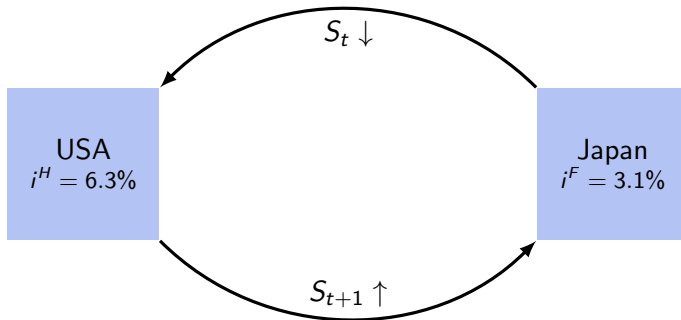
INTEREST PARITY



INTEREST PARITY



INTEREST PARITY



$$S_{t+1} - S_t = \alpha + \underset{\approx 1}{\beta} (i_t^H - i_t^F) + \epsilon_{t+1}$$

CROSS-COUNTRY UIP REGRESSION

| Ctry1 | Ctry2 | beta | [s.e.] |
|-------|-------|--------|---------|
| DE | AU | 0.254 | [0.207] |
| JP | AU | 0.103 | [0.268] |
| JP | DE | 0.109 | [0.297] |
| UK | AU | -0.192 | [0.229] |
| UK | DE | 0.282 | [0.190] |
| UK | JP | -1.169 | [0.409] |
| US | AU | -0.058 | [0.168] |
| US | DE | -0.041 | [0.221] |
| US | JP | -0.632 | [0.258] |
| US | UK | -0.050 | [0.196] |

$$s_{t+1} - s_t = \alpha + \underset{\approx 1}{\beta} (i_t^H - i_t^F) + \epsilon_{t+1}$$

GOAL/RESEARCH METHODOLOGY

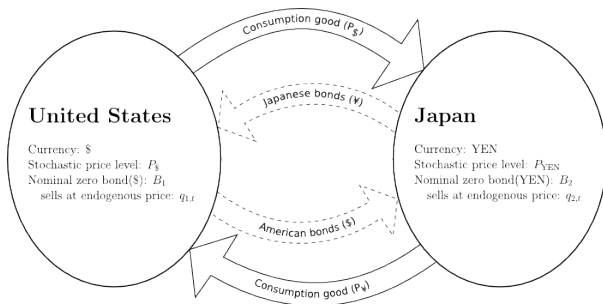
Goal:

- Attribute the phenomenon to peoples' hedging motives.

Research methodology:

- Set up a theoretical model to explain the relation between interest rates and exchange rates.
- Calibrate the observable parameters (GDP growth, Exchange rate movements)
- Pick values for unobservable preference parameters.
- Solve the model
- Simulate the model economy and compare to the real world data.
- Ultimately need to show that $norm(\beta^{Th} - \beta^{Em})$ small.

MARKET SETUP



PARAMETER SPACE (ρ, η)

- Agents' preferences have to be pinned down for the computation.
- Utility function for each agent:

$$u(c_t, h_t) = \frac{2}{1-\gamma} (c_t - h_t)^{1-\gamma}$$

- Habit process:

$$h_{t+1} = \rho h_t + \eta c_t.$$

- Thus 2 parameters per country.

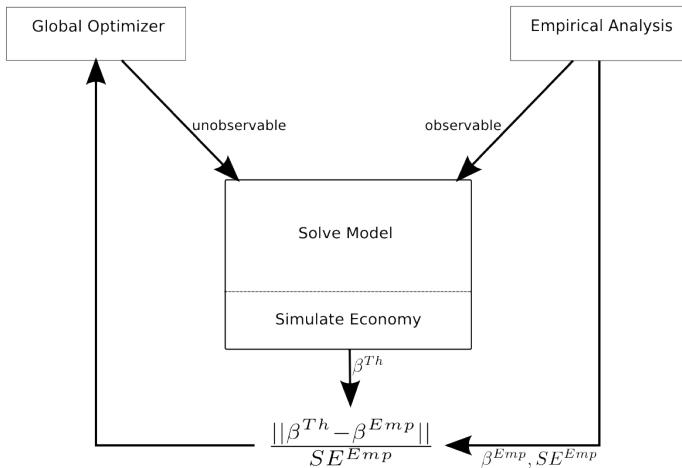
CROSS COUNTRY ANALYSIS

- Idea: Perform this analysis for N countries.
- Multi-country analysis in a two-country model.
- We choose five countries: AU, DE, JP, UK, US resulting in 10 ctry pairs.
- Find parameter combination that replicates empirical results from previous slide.

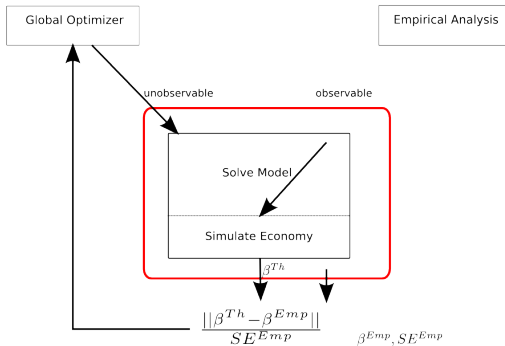
CROSS COUNTRY CALIBRATION

- Want to generate three tables for the paper:
 - ① Separate calibration — one habit parameterization per country pair, i.e.
 $\mathbb{E}[h_1] = \mathbb{E}[h_2]$ and $\sigma[h_1] = \sigma[h_2]$
 - ② Joint calibration — the same habit parameterization for everybody, i.e.
 $\mathbb{E}[h], \sigma[h]$
 - ③ Simultaneous calibration — one habit parameterization per country, i.e.
 $\mathbb{E}[h_{ctry}], \sigma[h_{ctry}], ctry = [AU, DE, JP, UK, US]$

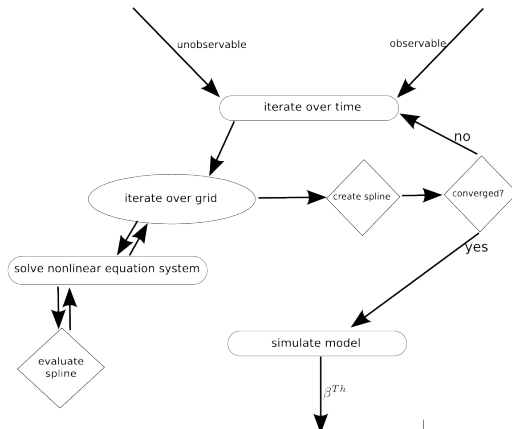
ANALYSIS OVERVIEW



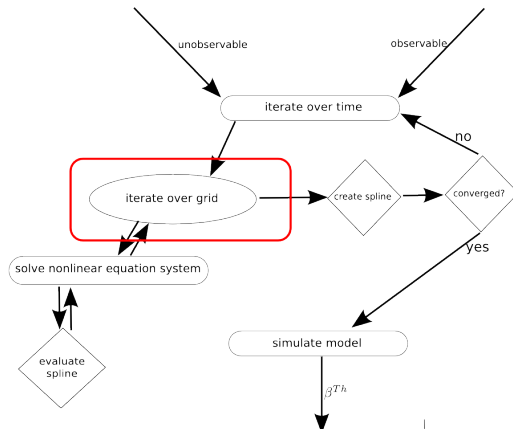
ANALYSIS OVERVIEW



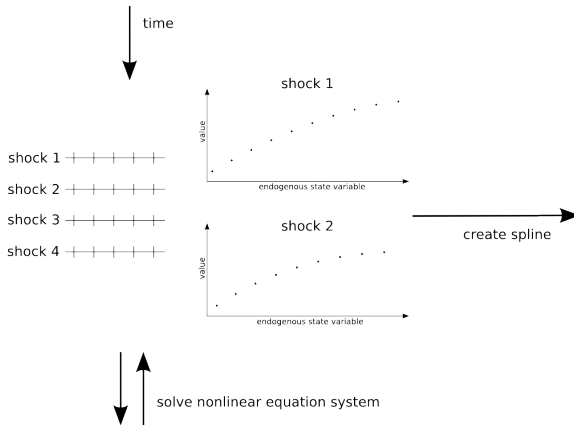
POLICY ITERATION



POLICY ITERATION



INTERPOLATION GRID



LOOP SCRIPT: GPREMIUM.PY

- Starting point is a Python script that automates evaluation of user specified parameter combinations.
- Script reads a *file* specifying the parameters to loop over:

| Var | ParaFile | group | groupRestrs | vals | paraFileRegex |
|--------|---------------------|-------|-------------|-------------|-----------------|
| Ctry | input/markovA.in | 0 | lowerTr | AU,DE,JP | space-separated |
| Ctry | input/markovB.in | 0 | lowerTr | AU,DE,JP | space-separated |
| EA | input/parameters.in | 1 | diagnol | 0.7,0.8,0.9 | bar-separated |
| EB | input/parameters.in | 1 | diagnol | 0.7,0.8,0.9 | bar-separated |
| sigmaA | input/parameters.in | 2 | None | 0.001,0.002 | bar-separated |
| sigmaB | input/parameters.in | 2 | None | 0.001,0.002 | bar-separated |

para.loop

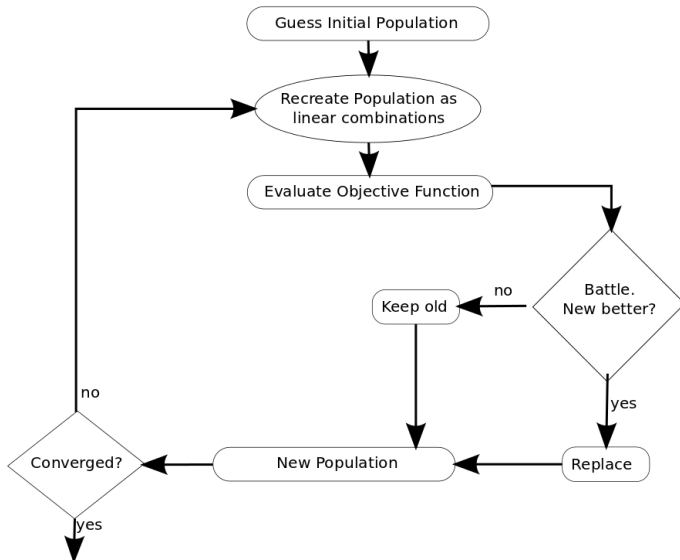
- From this, script derives a list of all jobs to be executed and their properties (i.e. jobname, input files, input file adjustments).
- The script delegates the job execution to the programming library GC3Pie. Library allows starting processes locally but also on SMSCG infrastructure for example.

OPTIMIZATION SCRIPT - GPARASEARCH.PY

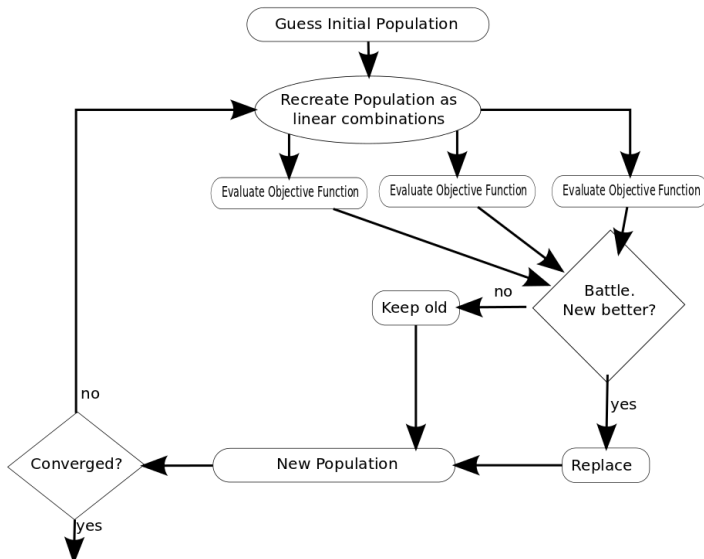
- Global optimization algorithm chooses parameter combinations.
- Script writes parameter combinations into a “para.loop” file and calls “loop script” to generate list of jobs.
- Evaluation is again done in parallel using GC3Pie.
- When all jobs have returned, results are collected, evaluated and send back to optimizer.
- Potential problem: Some jobs might not return:
 - ① Because the execution of our model failed.
 - ② There was a problem on the grid.

In this case we simply assign the parameter combination a large value and move on.

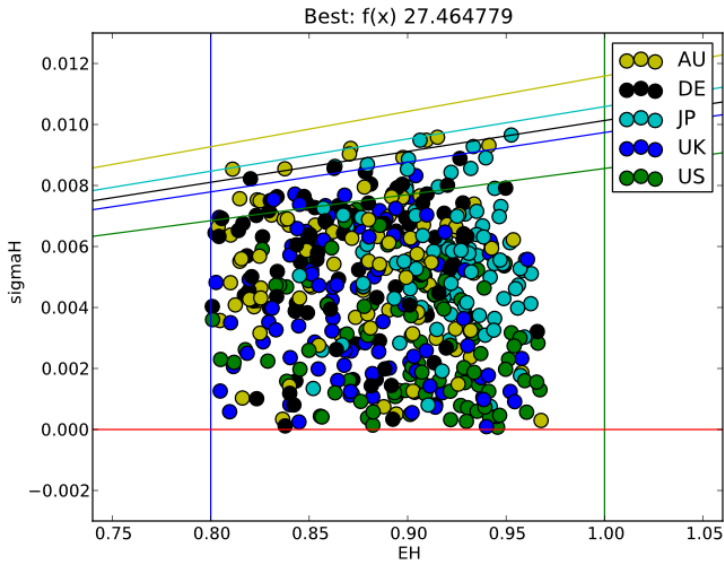
DIFFERENTIAL EVOLUTION ALGORITHM



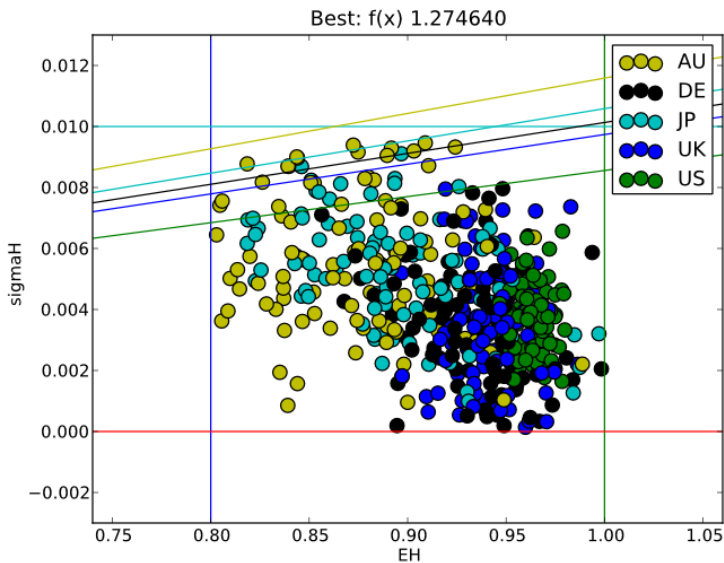
PARALLEL DIFFERENTIAL EVOLUTION ALGORITHM



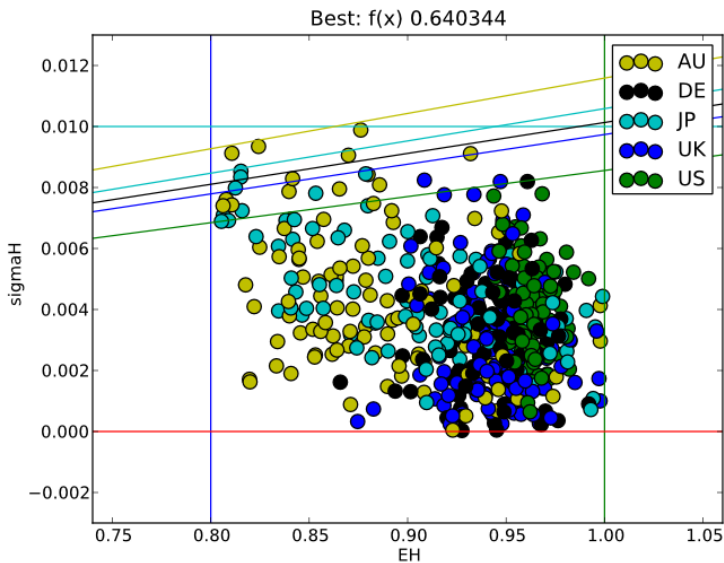
GLOBAL OPTIMIZER - INITIAL POPULATION



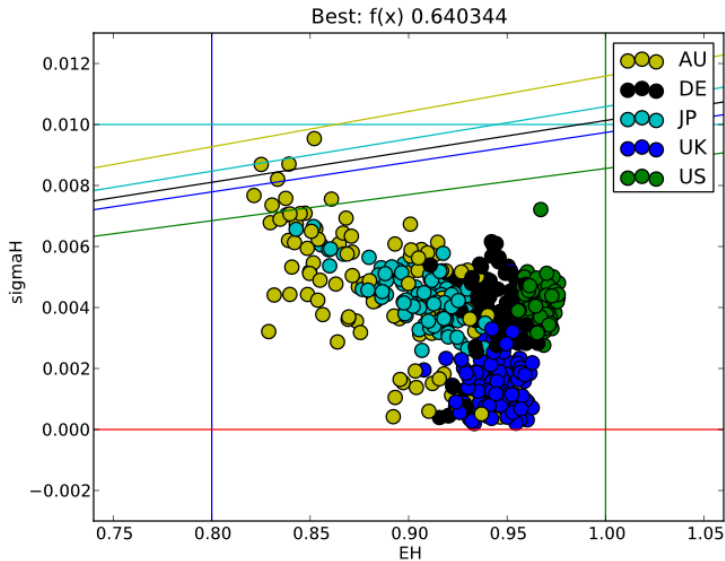
GLOBAL OPTIMIZER - POPULATION AFTER 40



GLOBAL OPTIMIZER - POPULATION AFTER 120



GLOBAL OPTIMIZER - POPULATION AFTER 240



SIMULTANEOUS CALIBRATION

SEPARATE HABIT PROCESS PER COUNTRY

| Ctry1 | Ctry2 | $\mathbb{E}[H_1]$ | $\sigma[H_1]$ | $\mathbb{E}[H_2]$ | $\sigma[H_2]$ | Model β | Emp. β | [s.e.] |
|-------|-------|-------------------|---------------|-------------------|---------------|---------------|--------------|--------|
| AU | DE | 0.83 | 0.0057 | 0.97 | 0.0010 | -0.09 | 0.25 | [0.21] |
| AU | JP | 0.83 | 0.0057 | 0.90 | 0.0054 | -0.02 | 0.10 | [0.27] |
| AU | UK | 0.83 | 0.0057 | 0.95 | 0.0025 | -0.10 | -0.19 | [0.23] |
| AU | US | 0.83 | 0.0057 | 0.95 | 0.0032 | 0.43 | -0.04 | [0.17] |
| DE | JP | 0.97 | 0.0010 | 0.90 | 0.0054 | -0.37 | 0.12 | [0.29] |
| DE | UK | 0.97 | 0.0010 | 0.95 | 0.0025 | -0.07 | 0.27 | [0.18] |
| DE | US | 0.97 | 0.0010 | 0.95 | 0.0032 | 0.41 | -0.03 | [0.21] |
| JP | UK | 0.90 | 0.0054 | 0.95 | 0.0025 | -0.38 | -1.05 | [0.38] |
| JP | US | 0.90 | 0.0054 | 0.95 | 0.0032 | -0.32 | -0.63 | [0.25] |
| UK | US | 0.95 | 0.0025 | 0.95 | 0.0032 | 0.76 | -0.04 | [0.19] |

CONCLUSIONS

- Calibrating macroeconomic models can require large computing power.
- Global optimization in connection with the GC3Pie library has worked well to solve our particular problem.
- Paper reference: Time-Varying International Diversification and the Forward Premium, Simon Scheuring, Benjamin Jonen