MathWorks
FINANCE CONFERENCE 2023

Nonlinear Confidence Bands Computation in MATLAB

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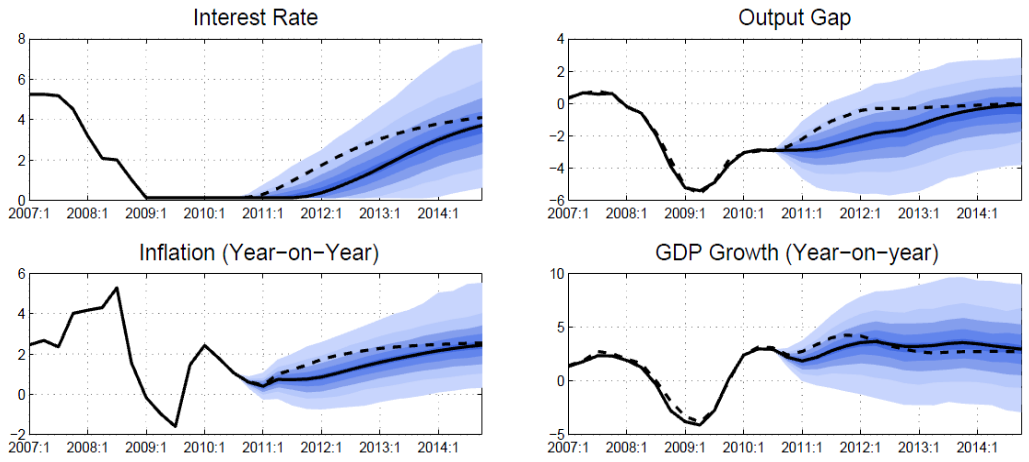
Motivation

- After calculating forecasts of main macro-economic variables, like GDP, inflation and unemployment, there is a strong rationale to compute confidence bands around the projections
  - to establish the uncertainty about them
  - to detect escalated up and down risks
  - to calculate useful statistics like recession and deflation probabilities.



Requirements

- A suitable non-linear macro-economic model.
  - A non-linear DSGE model developed.
- A platform to solve the model efficiently.
  - Matlab offers great combination of tools for estimation, filtering, forecasting and simulation.
- Data on observable variables.
  - Matlab has functions to clean and transform panel data efficiently.
- Running big number of simulations over the baseline.
  - An efficient solver needed for large number of simulations.
- Computing power to do all these within a tight timeline.
  - Need to reduce the computation time from multiple perspectives.

Model Setup

- Designed and implemented the model that will cover all relevant macro-economic dynamics in a modeling platform that is most suitable for the methods to be used.

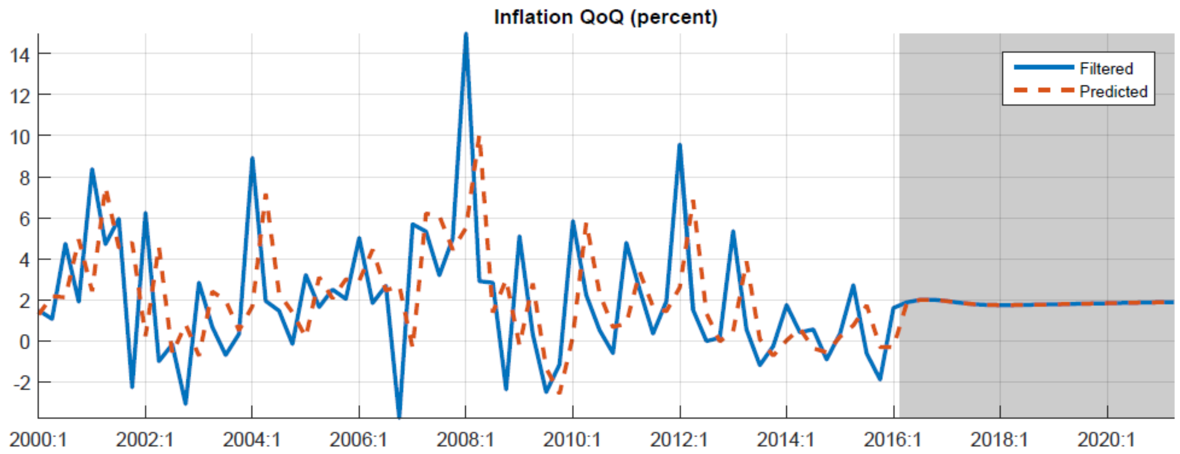
Inflation
$\pi_t = \lambda_1 * \pi 4_{t+4} + (1 - \lambda_1) * \pi 4_{t-1} + \lambda_2 * y_{t-1} + \lambda_3 * \Delta z_t + \varepsilon_t^{\pi}$

- Inflation is a function of inflation expectations ($\pi 4_{t+4}$), lagged inflation ($\pi 4_{t-1}$), the lagged output gap (y_{t-1}) and the change in the real exchange rate (Δz_t).
- The model includes a convex function for the output gap $\lambda_2 \left(\frac{y_{t-1}}{y_{\text{max}} - y_{t-1}} y_{\text{max}} \right)$, suggesting that excess demand raises inflation by more than what excess supply reduces it. We need this because we are considering model solutions with some fairly large negative output gaps.
- For small variation in the output gap the model is approximately linear ($\lambda_2 * y_{t-1}$), which is what is used for estimation.

Data

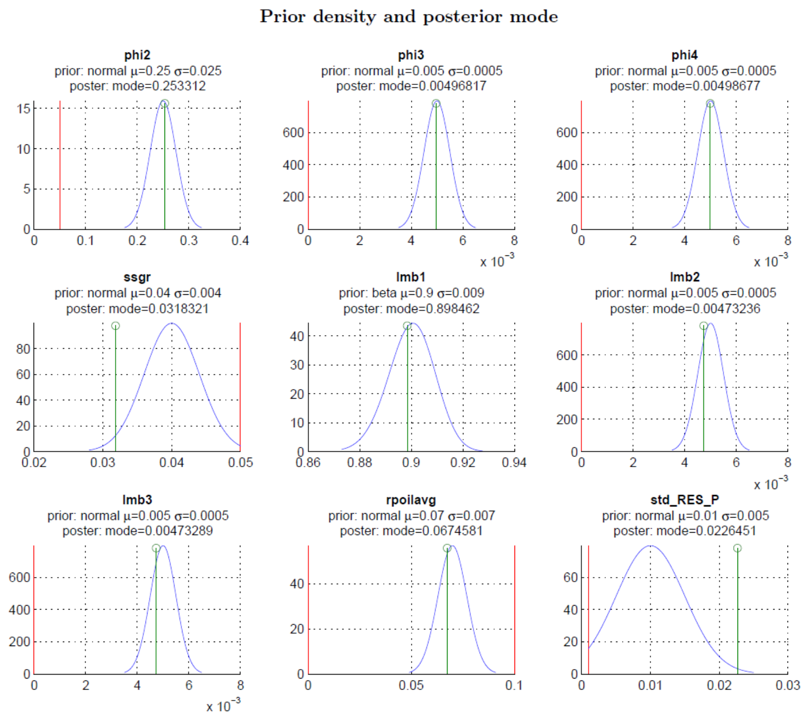
- The data required is identified and coded to be collected just-in-time when the model is run. All necessary clean-up and transformation is done in the code.

Inflation



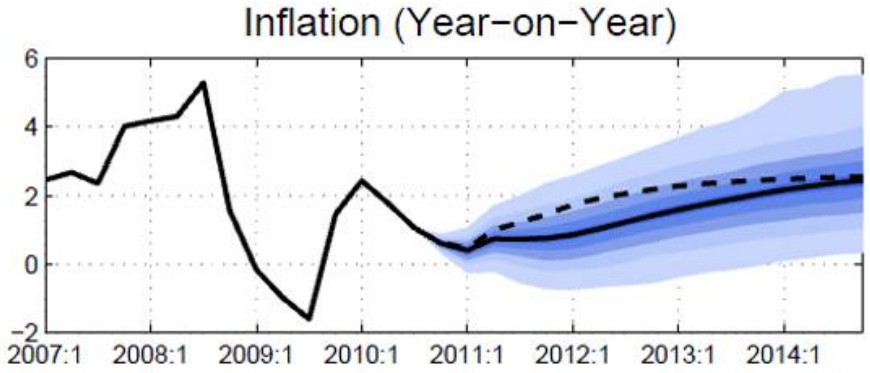
Model Solution

- The model solution includes estimation of model parameters, filtering noisy data and running baseline forecast.



Confidence Bands Simulations

- Since the model is non-linear, we must simulate many draws of shocks to get estimates of the confidence bands.
- The standard method, Monte-Carlo Sampling, is not practical due to the enormous number of drawings needed.
  - high dimensionality of the problem (number of shocks, number of periods and number of state variables)
- Simulations are made by drawing samples from the estimated distributions of exogenous shock terms.



Latin Hypercube Sampling

- We opted for a more structured way of drawing the shocks to more evenly sweep the high dimensional space.
- This sampling technique implies a faster convergence; a smaller number of simulations is needed to obtain good estimates of the confidence bands.
- Latin Hypercube sampling algorithm draws points from unit hypercube $(0,1)^D$, where D is the dimension.
- Let's say, D = 20 x 84 = 1680, where 20 corresponds to periods, and 84 to the number of shocks.
- We simulate K = 3600 simulations, so we obtain by the Latin Hypercube algorithm K draws each having D = 1680 coordinates.
- These draws are from uniform distribution, so we need to transform each 84-tuple to the Gaussian distribution and then multiply with a Cholesky factor of the variance-covariance matrix.

Distributed Computing

- Sampling methodology brings us from >100,000 down to ~3600 simulations. Or from >100 days to about 4 days of computation.
- To be able to bring it down to an “overnight process” we need to use parallel processing.
- We create a cluster of 4 servers with 32 cores on each, or 128 workers in Matlab.

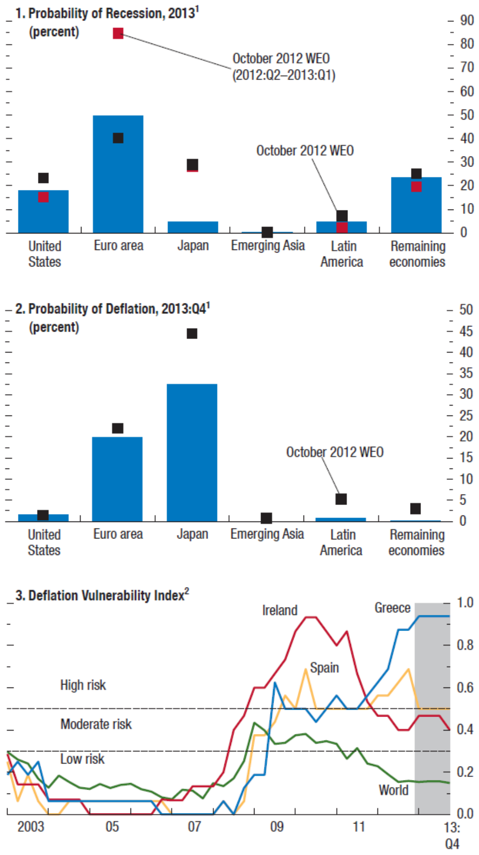
```
bs_baseline = 'Dec09';
md ='wld.mod';
numworkers=128;
numperworker=30; %  3840 draws
numshockper=20;
numper=100;
forecastdd='2011Q1';

run_nonlinear_confbands('PP', PP,...
                        'basename', bs_baseline,...
                        'model', md,...
                        'database', [bs_baseline '_forecast.csv'],...
                        'numworkers', numworkers,...
                        'numperworker', numperworker,...
                        'numshockper', numshockper,...
                        'numper', numper,...
                        'forecastdate', forecastdd,...
                        'resourcename','jmemdc','resourcelookup', 'emdc',...
                        'clev',[0.90 0.70 0.50 0.30 0.10],...
                        'srng',qq(2009,4):qq(2009,4)+12-1,...
                        'statoutfile','Shock_statistics.pdf');
```

Results

Figure 1.13. Recession and Deflation Risks

Risks for recessions during 2013 have stayed broadly unchanged or receded. They remain relatively high in the advanced economies. The same holds for deflation risks. Deflation vulnerabilities are particularly elevated in some euro area periphery economies.



Source: IMF staff estimates.
¹Emerging Asia: China, Hong Kong SAR, India, Indonesia, Korea, Malaysia, Philippines, Singapore, Taiwan Province of China, Thailand; Latin America: Brazil, Chile, Colombia, Mexico, Peru; remaining economies: Argentina, Australia, Bulgaria, Canada, Czech Republic, Denmark, Estonia, Israel, New Zealand, Norway, Russia, South Africa, Sweden, Switzerland, Turkey, United Kingdom, Venezuela.
²For details on the construction of this indicator, see Kumar (2003) and Decressin and Laxton (2009). The indicator is expanded to include house prices.