

MathWorks
FINANCE CONFERENCE 2023

BEAR Toolbox for Estimating Economic Relationships

October 11-12 | Online



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BEAR 5.2

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October 12, 2023

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<https://github.com/european-central-bank/BEAR-toolbox>

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- 1 BEAR - Introduction
- 2 BEAR - VAR models
- 3 BEAR - types of identification
- 4 BEAR 5.2 - what is new?
- 5 Conditional forecasts with BEAR
- 6 BEAR 6 - plans



Introduction to BEAR

- BEAR is a comprehensive (Bayesian) (Panel) VAR toolbox (based on MATLAB) for forecasting and policy analysis.
- BEAR includes a user-friendly graphical interface which allows the tool to be used by country desk economists and non-technical users.
- BEAR includes state-of-the art applications such as sign and magnitude restrictions, proxy VARs, conditional forecasts, Bayesian forecast evaluation measures.
- BEAR is specifically developed for transparently supplying a tool for state-of-the-art research. It is constantly further developed to always be at the frontier of economic research.
- BEAR is easy to understand, augment and adapt.



Gary Koop, Professor University Strathclyde

- Bayesian VAR analysis is made easy using the BEAR toolbox. It is a powerful tool for academics, central bankers and policymakers.

Fabio Canova, Professor Norwegian Business School

- A toolbox built by policymakers for policymakers. A must!

Giorgio E Primiceri, Professor Northwestern

- BEAR is an invaluable, user-friendly toolbox for the Bayesian estimation of state-of-the-art multivariate time-series models. Not only it is accessible to less-technical users, but also extremely useful to more advanced researchers.



User and Technical guide and excel data input

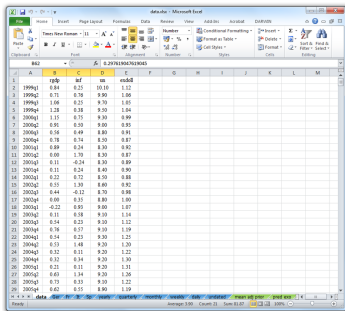
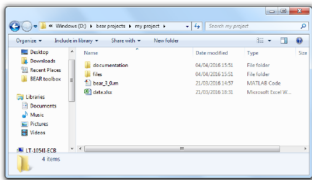
CHAPTER 2. PREPARING YOUR PROJECT

guide providing the mathematical derivations for the models and applications implemented by the toolbox.

- the 'files' folder. This folder contains the set of matlab functions run by the code. Except in a few specific cases indicated in this guide, you should not alter nor delete any elements in this folder. Doing so may result in the code not working properly anymore.
- the 'bear_3_0.m' matlab file. This file is used to start the toolbox and run the estimation. Further details can be found in [chapter 3: Running your project](#).
- the 'data.xlsx' Excel file. This file contains the data that will be used by the toolbox to run the estimation.

By default, the toolbox folder is called 'bear toolbox 3.0'. However, it is possible to rename the folder to suit your particular project, for instance 'project Japan', or 'BVAR US'. You may then place the folder in any directory of your choice. For example, you may create a new project, and for this project change the folder name from 'bear toolbox 3.0' to 'my project'. Assume that for convenience you also create a new folder on your D drive called 'bear projects' that gathers all your different projects. You may then move 'my project' into 'bear projects'. Your project folder will then look as follows:

Figure 2.2.: Project folder



	A	B	C	D	E	F	G	H	I	J	K	L	M
1		1999q1	inf	un	end01								
2	1999q1	0.84	0.25	1010	1.52								
3	1999q2	0.72	0.76	930	1.60								
4	1999q3	1.06	0.25	930	1.65								
5	1999q4	1.28	0.38	930	1.64								
6	2000q1	1.15	0.75	930	0.89								
7	2000q2	0.91	0.59	900	0.95								
8	2000q3	0.56	0.69	880	0.91								
9	2000q4	0.78	0.74	850	0.87								
10	2001q1	0.89	0.24	830	0.82								
11	2001q2	0.69	1.39	830	0.87								
12	2001q3	0.11	-0.24	830	0.89								
13	2001q4	0.11	0.24	840	0.90								
14	2002q1	0.22	0.72	850	0.88								
15	2002q2	0.52	1.39	860	0.82								
16	2002q3	0.44	-0.12	830	0.88								
17	2002q4	0.69	0.35	880	1.00								
18	2003q1	-0.22	0.90	850	1.07								
19	2003q2	0.11	0.58	830	1.14								
20	2003q3	0.54	0.25	830	1.12								
21	2003q4	0.36	0.57	830	1.19								
22	2004q1	0.54	0.25	830	1.25								
23	2004q2	0.57	1.48	830	1.20								
24	2004q3	0.32	0.11	820	1.22								
25	2004q4	0.32	0.34	830	1.30								
26	2005q1	0.21	0.11	820	1.31								
27	2005q2	0.40	1.34	820	1.26								
28	2005q3	0.75	0.33	830	1.22								
29	2005q4	1.62	0.15	830	1.19								



Many estimation types of VAR models

- 1 Bayesian VARs
 - Many priors including block exogeneity, mean-adjusted, Dummy observations
 - FAVARs
- 2 OLS
- 3 Panel VARs
- 4 Stochastic Volatility
- 5 Time Varying Parameters
- 6 Mixed Frequency



BEAR - types of identification

Sign and magnitude restrictions

- Over different time periods

Long run zero restrictions (Blanchard and Quah 1989)

- Enter '1000 1000' in the periods for the zero restrictions

Correlation restrictions (Ludvigson et al. 2017)

- Enter the external variable in the sheet 'IV'.

Relative magnitude restrictions (Caldara et al. 2016)

- S1 for stronger and W1 for weaker in sheet 'relmagn res value'.

FEVD restrictions (Weale and Wieladek 2016)

- Enter .Absolute or .Relative in sheet 'FEVD res value'.

Applications

- Impulse response functions
- Unconditional forecasts
- Forecast error variance decomposition
- Historical decomposition
- Conditional forecasts (Waggoner and Zha, 1999)
- Tilting of predictive distribution (relative entropy)



Classical (maximum likelihood) criteria

- model: sum of squared residuals, (adjusted) R-squared
- forecasts: RMSE, MAE, MAPE, Theil's U
- Rolling window estimations with density and forecast evaluation

Bayesian-specific criteria:

- model: marginal likelihood
- forecasts: continuous ranked probability score, log score, DIC



- Hyperparameter optimisations - speeded up
- Variable specific priors for the AR coefficient
- IRFs and priors for exogenous variables
- Sign restrictions for panel VAR models (pooled and hierarchical)
- Parallelisation for some procedures (sign restrictions, tilting)
- Option to suppress figures and excel output (efficiency gains)



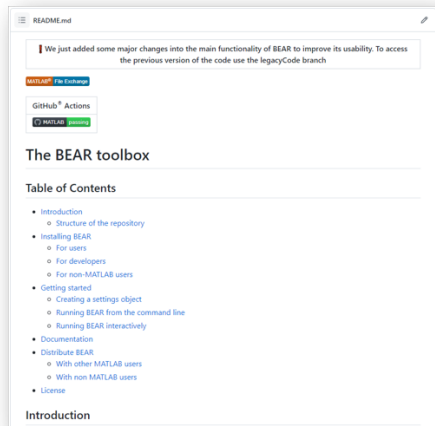
BEAR 5.2: what's new?

Improvements

- 1 BEAR Infrastructure upgraded
 - Facilitate running multiple estimations simultaneously
 - Allow working in arbitrary folders
- 2 BEAR inputs are now objects to enable easy adjustments
 - Provide a set of default values on each property
 - Easier tracking of models
- 3 Created a new modern interface
 - Works with the new BEAR settings objects
 - Provide easy-to-discover examples that help the users get started
- 4 BEAR in a source control system
 - Facilitate development and testing
 - Easier for the community to provide feedback

Automated testing and packaging

- Add a project for path control and a first set of unit tests including the replications of old papers
- Added numerical testing to track changes respect to older BEAR versions
- Added source control via GitHub
- We packaged the code as a toolbox and made it available through GitHub releases
- Makes it easier for people to report issues and contribute changes



The screenshot shows the README file for the BEAR toolbox. At the top, there is a notification box stating: "We just added some major changes into the main functionality of BEAR to improve its usability. To access the previous version of the code use the legacyCode branch". Below this, there are badges for "MATLAB File Exchange" and "GitHub Actions". A section titled "The BEAR toolbox" is followed by a "Table of Contents" with the following items:

- Introduction
 - Structure of the repository
- Installing BEAR
 - For users
 - For developers
 - For non-MATLAB users
- Getting started
 - Creating a settings object
 - Running BEAR from the command line
 - Running BEAR interactively
- Documentation
- Distribute BEAR
 - With other MATLAB users
 - With non MATLAB users
- License

The word "Introduction" is also visible at the bottom of the screenshot.



BEAR settings class (II)

BEAR allows you to run 7 generic model types, with many options each:

- This enabled running BEAR in batch mode or even parallel

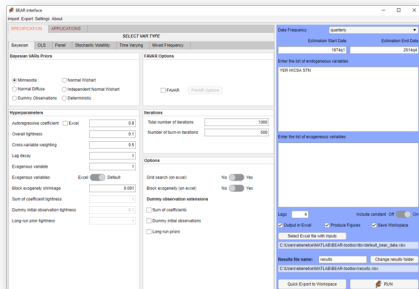
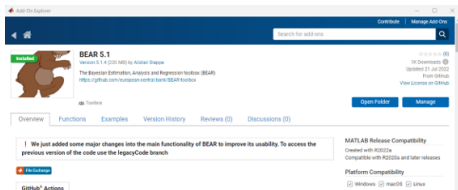
```
for lambda = 1:0.1:2
    s = BEARsettings('BVAR', ExcelFile = 'data.xlsx', lambda1 = lambda);
    BEARmain(s)
end
```

- It facilitates bug tracking a lot, because odd errors due to invalid or incorrect inputs are not a lot harder to run at all
- It is now easier to save, send or replicate a set of settings



New app

- Builds on top of the previous settings object, easier to add updates, new models, or import settings
- Includes new BEAR types
- Directly installable from MATLAB
- Standalone version available



BEAR 5.2 has replication files

- Banbura and van Vlodrop (2018)
- Caldara and Herbst (2019)
- Amir-Ahmadi and Uhlig (2015)
- Bernanke, Boivin and Eliasz (2004)
- Wieladek and Garcia Pascual (2016)

BEAR 5.2 is open source

- BEAR will be regularly updated on Github:
<https://github.com/european-central-bank/BEAR-toolbox>
- Also available from ECB website:
<https://www.ecb.europa.eu/pub/research/working-papers/html/bear-toolbox.en.html>

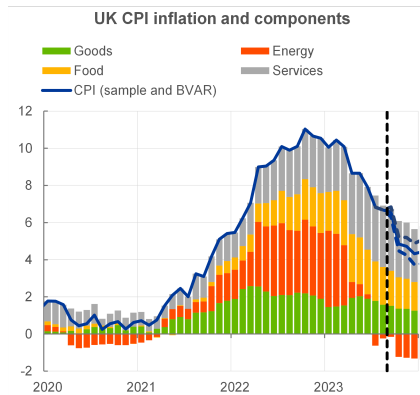
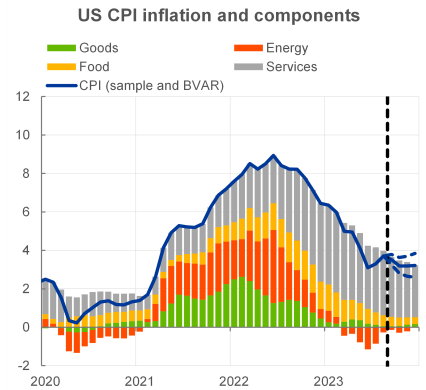
For variables available, use it for the condition in the next quarters

- Set up external and domestic variables
- Set conditions on external assumptions, select shock specific conditional forecasts or tilting
- If shock specific is selected, come up with an identification (e.g. slow and fast moving variables)
- Compare conditional and unconditional forecast



Application of conditional forecasts with BEAR (I)

Example application to US and UK inflation



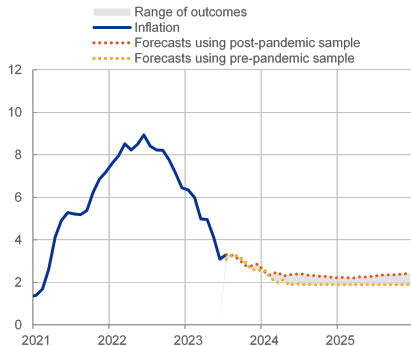
Illustrative conditional forecasts for headline CPI and its components in annual percentage changes and percentage points contributions. This should not be reported as representing the views of the ECB.



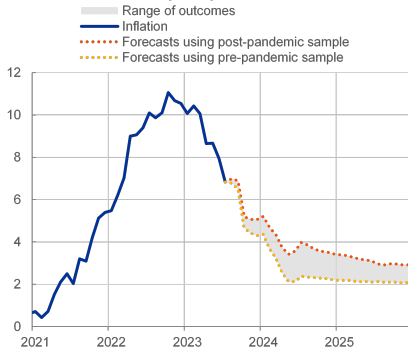
Application of conditional forecasts with BEAR (II)

Example application to US and UK economies

BVAR forecasts of US inflation with and without post pandemic era



BVAR forecasts of UK inflation with and without post pandemic era



Conditional forecasts for headline CPI in annual percentage changes using parameters from samples with and without the post-pandemic era. This should not be reported as representing the views of the ECB.



Developing new models

- Add new approaches to deal with **large shocks**
- Incorporate **new prior** approaches such as narrative restrictions
- Incorporating new approaches for **structural change**
- Add new **non-linearities** in undertaking economic analysis
- Add the ability to combine models

Improving current infrastructure

- **Modernization** of the code
- New **data management**
- Improved **interface**
- **Speed up** the code through parallel computation or vectorization
- Take into account high-frequency data



Requests and suggestions are welcome



Factor Augmented VARs

Motivation

- "... small number of variables is unlikely to span the information sets used by actual central banks, which are known to follow literally hundreds of data series..." Bernanke et al. 2005
- Extract factors from (very) large "information" data sets

Pro

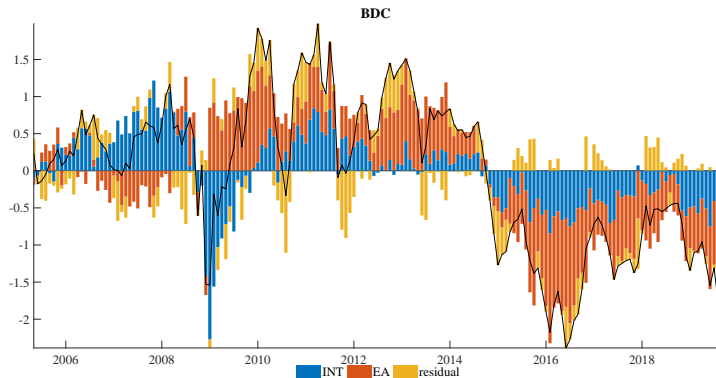
- Few factors summarise a large amount of information
- Better representation of economic concepts (e.g. price pressure, trade tensions, uncertainty)

Con

- Factors are hard to interpret

Factor Augmented VARs

Example output: What is driving long-term inflation expectations?



(Bayesian) Proxy SVARs

Motivation

- "... the instrument is constructed as a partial measure of the shock of interest: [...] the part of a monetary shock revealed during a monetary policy announcement window." Stock & Watson (2018)
- Identifies the shock based on covariance restrictions with a suitable proxy variable.

Pro

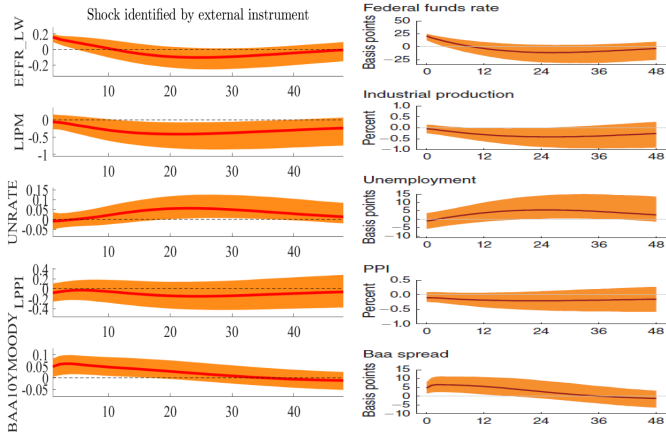
- Identifies the shock without imposing any theoretical structure
- Avoids drawbacks of conventional identification schemes
- Combination with sign/magnitude restrictions

Con

- Limited amount of suitable proxy variables

(Bayesian) Proxy SVARs

Example output: Replication of Caldara and Herbst (2019)



Motivation

- "The slowly changing mean can account for a number of secular developments such as changing inflation expectations, slowing productivity growth or demographics." Banbura, Van Vlodrop (2018)
- time-varying unconditional mean is anchored to off-model information, i.e. survey forecasts

Pro

- Increased forecasting performance by reducing uncertainty about the uncond. mean

Con

- Suitable survey forecast not available for all variables of interest

Trend-Cycle Bayesian VARs

Example output Banbura and Van Vlodrop (2018)

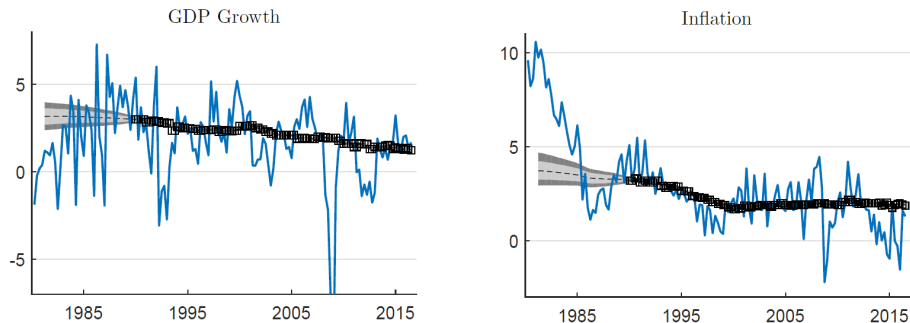


Figure 1: Posterior distributions for the end-of-sample local and unconditional means



Motivation

- ”Modern Big Data analytics, often referred to as the three “Vs”: the large number of time series continuously released (Volume), the complexity of the data covering various sectors of the economy, published in an asynchronous way and with different frequencies and precision (Variety), and the need to incorporate new information within minutes of their release (Velocity). ... BVARs are able to effectively handle the three Vs ...”, (Cimadomo et al. 2020).

Pro

- Flexible to use big data in real time for nowcasting

Con

- Computationally intensive

Mixed-Frequency Bayesian VARs

Example output

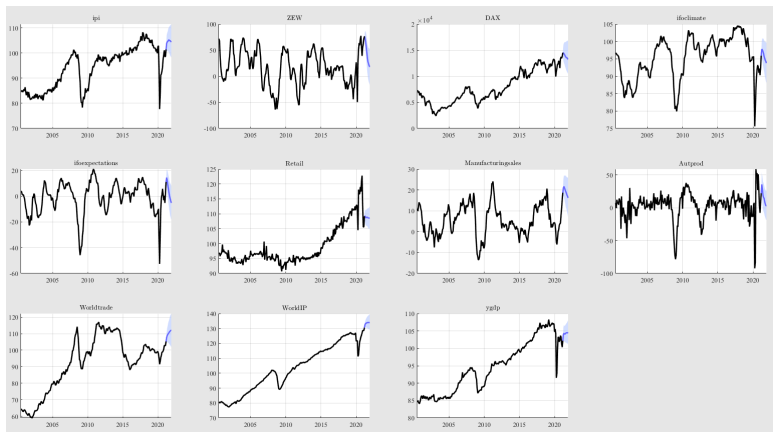


Figure 2: Nowcasting German GDP with a MF Bayesian VAR



Mixed-Frequency Bayesian VARs

Example output

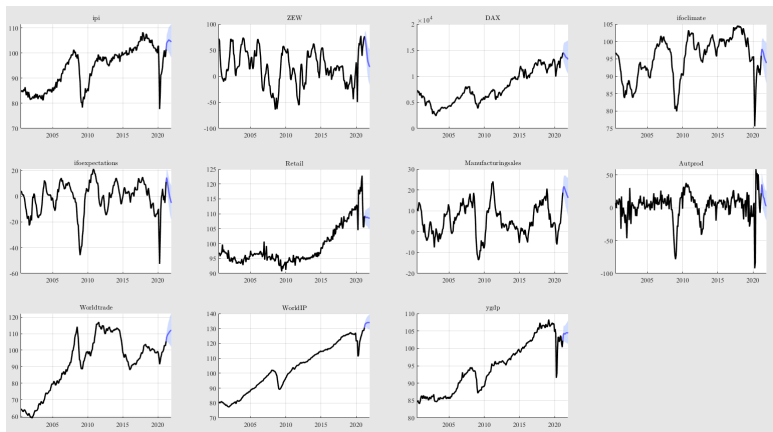


Figure 3: Nowcasting German GDP with a MF Bayesian VAR



Stochastic Volatility

Motivation

Motivation

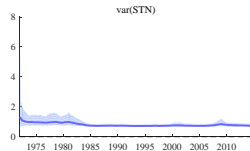
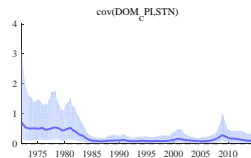
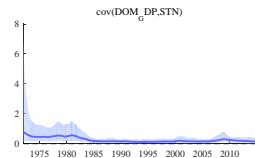
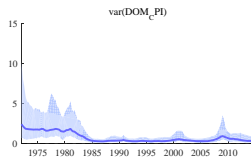
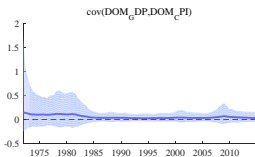
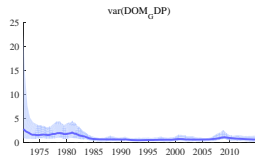
- A data-generating process of economic variables often seems to have drifting coefficients and shocks of stochastic volatility.
- In particular, VAR innovation variances change over time (Bernanke and Mihov 1998, Kim and Nelson 1999, MacConnell and Perez Quiros 2000).

Setup in BEAR

- Cogley and Sargent (2005)
- Sparse matrix approach (Chan and Jeliazkov 2009)
- Three options: 1.) Standard, 2.) Random inertia, 3.) Large BVARs (Carriero, Clark and Marcellino 2012)

Stochastic Volatility

Example output



Time Varying Parameters

Motivation and setup in BEAR

Motivation

- "There is strong evidence that U.S. unemployment and inflation were higher and more volatile in the period between 1965 and 1980 than in the last 20 years." (Primiceri 2005, RES).
- Typical questions in ECB policy analysis: Has the Phillips curve flattened? Has the monetary policy transmission channel changed?

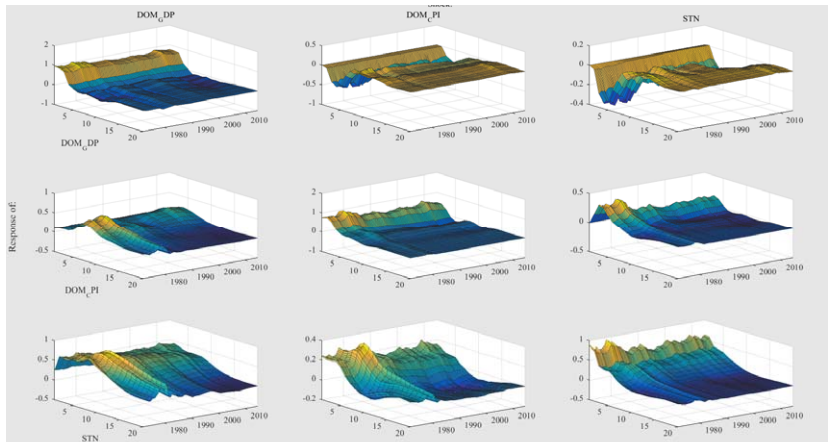
Set-up in BEAR

- Sparse matrix approach (Chan and Jeliazkov 2009)
- Two options: 1.) Time varying VAR coefficients 2.) General (Time varying VAR coefficients and Stochastic Volatility)



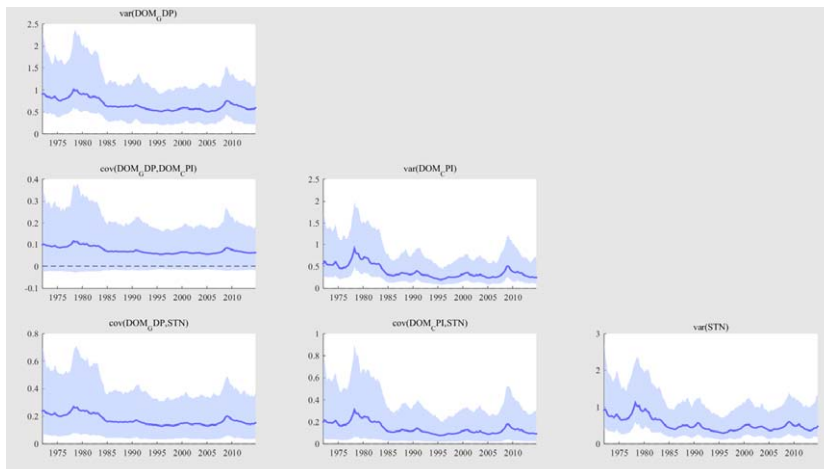
Time Varying Parameters

Example output



Time Varying Parameters

Example output



Equilibrium VARs

Motivation and setup in BEAR

Motivation

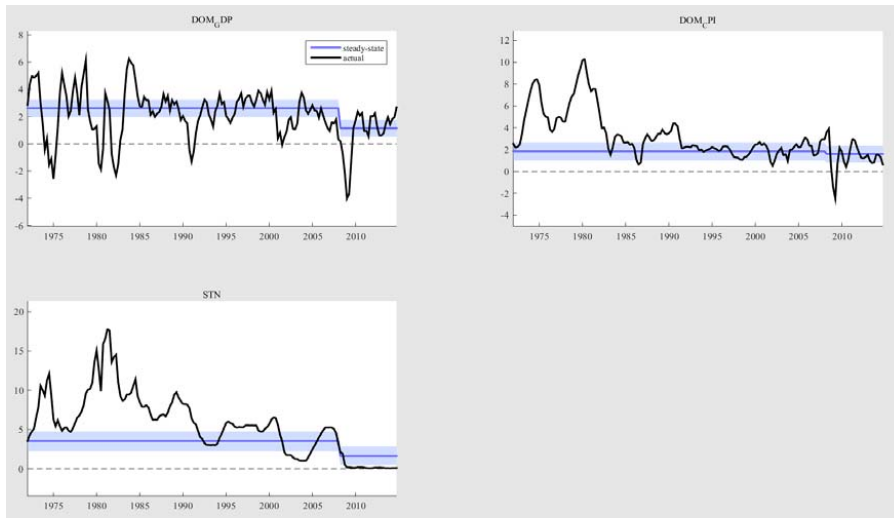
- Usually we are interested in trend-cycle decompositions.
- For historical decompositions we want to calculate deviations from "steady-state".
- So we have to take into account the "long-run", the "equilibrium", "steady-state", "trends" or "fundamentals".

Set-up in BEAR

- We extend the methodology of Villani (2009).
- In Version 4.0 it is possible to have a prior on the deterministic part (constant, linear trend, quadratic trend).
- A generalization to stochastic trends will be part of the next version.

Equilibrium VARs

Example output



Priors for the long-run

Motivation and setup in BEAR

Motivation

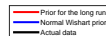
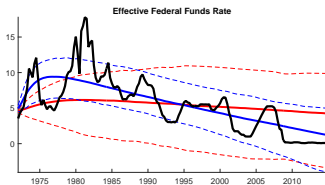
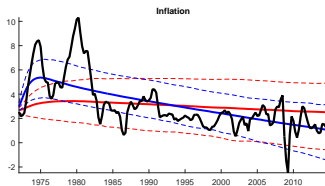
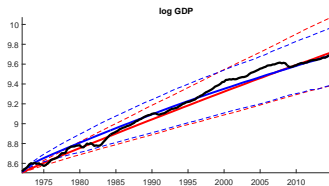
- Disciplinates the long-run predictions of VARs.
- "Flat-prior VARs tend to attribute an implausibly large share of the variation in observed time series to a deterministic—and thus entirely predictable—component." (Giannone et al. 2017)
- Priors can be naturally elicited using economic theory, which provides guidance on the joint dynamics of macroeconomic time series in the long run.

Set-up in BEAR

- Giannone, Lenza and Primiceri (2017).
- Conjugate prior, easily implemented using dummy observations and combined with other popular priors.

Priors for the long-run

Example output



Forecasting evaluation procedures

Motivation and setup in BEAR

Motivation

- Assess forecasting performance of our VAR.
- Large literature has provided important insights on how to test whether forecasts are optimal / rational.
- Traditional tests that are based on stationarity assumptions should not be used in the presence of instabilities.

Set-up in BEAR

- Rossi and Sekhposyan (2016, 2017) and Loria and Rossi (2017).
- Rolling window estimations with density and forecast evaluation.



Forecasting evaluation procedures

Example Output

