Macro Model Comparison and Forecast Competition: New Tools and Results

Goethe University – Macroeconomics Seminar
January 21, 2021

Volker Wieland
IMFS, Goethe University Frankfurt

Sources for seminar talk

New model comparison tools in Macro Macro Model Data Base (MMB) 3.1 just released (www.macromodelbase.com)


1. New tools in MMB 3.1 just released

Make macro modeling
more reproducible
more collaborative
more comparative
The Macroeconomic Model Comparison Initiative

The MMB is developed by contributors around the world under the auspices of the Macroeconomic Model Comparison Initiative (MMCI), a joint project of the Hoover Institution at Stanford University and the Institute for Monetary and Financial Stability (IMFS) at Goethe University Frankfurt, which is supported financially by the Alfred P. Sloan Foundation. The MMCI aims to facilitate the comparison of macroeconomic models, enable the reproducibility of macroeconomic research and bring together researchers in this area.

Learn more about project and initiative
Long tradition in monetary policy: Bryant, Hooper & Mann (Brookings 1993), Taylor (NBER 1999), Levin, Wieland & Williams (AER 2003).

Also in fiscal policy: For example, IMF project - Coenen, Erceg, Freedman, Furceri, Kumhof, Lalonde, Laxton, Lindé, Mourougane, Muir, Mursula, Resende, Roberts, Roeger, Snudden, Trabandt, in't Veld, AEJ-Macro, 2012.

9 models: IMF, OECD, ECB, FRB (2), BoC, EU Commission, 2 academic.

Similarly ECB on fiscal consolidation, 2015, 15 models.
A systematic approach to model comparison

Model(-specific) elements

Table 1: Model-Specific Variables, Parameters, Shocks and Equations

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x^m_t$</td>
<td>endogenous variables in model $m$</td>
</tr>
<tr>
<td>$x^m_{t,s}$</td>
<td>policy variables in model $m$ (also included in $x^m_t$)</td>
</tr>
<tr>
<td>$\eta^m_t$</td>
<td>policy shocks in model $m$</td>
</tr>
<tr>
<td>$\epsilon^m_t$</td>
<td>other economic shocks in model $m$</td>
</tr>
<tr>
<td>$g_m(\cdot)$</td>
<td>policy rules in model $m$</td>
</tr>
<tr>
<td>$f_m(\cdot)$</td>
<td>other model equations in model $m$</td>
</tr>
<tr>
<td>$\gamma^m$</td>
<td>policy rule parameters in model $m$</td>
</tr>
<tr>
<td>$\beta^m$</td>
<td>other economic parameters in model $m$</td>
</tr>
<tr>
<td>$\Sigma^m$</td>
<td>covariance matrix of shocks in model $m$</td>
</tr>
</tbody>
</table>
A particular model: Policy rules and other equations

(1) \[ E_t[g_m(x_t, x_{t+1}, x_t, \eta_t^m, \gamma^m)] = 0 \]

(2) \[ E_t[f_m(x_t^m, x_{t+1}, x_t^m, \varepsilon_t^m, \beta^m)] = 0 \]

Innovations/shocks

(3) \[ E(\eta_t^m \varepsilon_t^m) = 0 \]

(4) \[ E(\eta_t^m \varepsilon_t^m | \eta_t^m \varepsilon_t^m) = \Sigma^m = \begin{pmatrix} \Sigma_{\eta\eta}^m & \Sigma_{\eta\varepsilon}^m \\ \Sigma_{\eta\varepsilon}^m & \Sigma_{\varepsilon\varepsilon}^m \end{pmatrix} \]
Introducing common ingredients

Table 2: Comparable Common Variables, Parameters, Shocks and Equations

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$z_t$</td>
<td>common variables in all models</td>
</tr>
<tr>
<td>$z_t^g$</td>
<td>common policy variables in all models (also included in $z_t$)</td>
</tr>
<tr>
<td>$\eta$</td>
<td>common policy shocks in all models</td>
</tr>
<tr>
<td>$g(.)$</td>
<td>common policy rules</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>common policy rule parameters</td>
</tr>
</tbody>
</table>

Augmented model

\[
E_t[g(z_t, z_{t+1}, z_{t-1}, \eta_t, \gamma)] = 0 \quad (5) \\
E_t[h_m(z_t, x_t^m, x_{t+1}^m, x_{t-1}^m, \theta^m)] = 0 \quad (6) \\
E_t[f_m(x_t^m, x_{t+1}^m, x_{t-1}^m, \xi_t^m, \beta^m)] = 0 \quad (7)
\]

$h_m(., \theta^m)$: model-specific equations defining common variables in terms of model-specific variables.
Solution

\[ z_t = k_z(z_{t-1}, x^m_t, \eta_t, \varepsilon^m_t, \kappa_z) \quad (8) \]
\[ x^m_t = k_x(z_{t-1}, x^m_{t-1}, \eta_t, \varepsilon^m_t, \kappa_x) \quad (9) \]

- Numerical approximation,
- Compute comparable objectives
  - IRF's of z's to η's, variances and correlations of z's given all shocks, etc.
- Compute metric measuring distance between different models.
A comparison across model types

Policy Rules
- Christian et al. (2014)
- Coenen et al. (2012)
- Levin et al. (2003)
- Orphanides & Wieland (2008)
- Orphanides & Wieland (2013)
- Smets & Wouters (2007)
- Taylor (1993)

Shocks
- Monetary Policy Shock
- Fiscal Policy Shock

Variables
- Inflation
- Interest
- Output
- Output Gap
- Inflation

Options
- Plot autocorrelation functions
- Plot variances

Horizon: 20
- DGP 0.0
- DGP 0.5
- DGP 1.0
- DGP 2.5
- DGP 5.0
- DGP 10.0
- DGP 15.0
- DGP 20.0

Comparison (5 Models, 1 Policy Rule, 1 Shock)
A comparison across economies
Note to Table 1: $i_t$ is the nominal federal funds rate, $\pi_t$ is the inflation rate, for which the Fed uses core PCE inflation, $u_t$ is the unemployment rate, $\pi^*$ is the Fed’s longer-run inflation objective of 2%, $r_t^*$ is the Fed’s estimate level of the neutral real federal funds rate in the longer-run, $u^*_t$ is the Fed’s estimate of rate of unemployment in the longer run, $Z_t$ is the cumulative sum of past deviations from the Taylor rule forced by the zero bound, and $PL_{gap_t}$ is the price level gap, defined as the percent deviation of the actual level of prices from a price level that rises 2 percent per year from its level in a specified starting period.

**First 3 rules nested in**

$$i_t = \varphi_{\pi} \pi_t + \varphi_y y_t + \varphi_{yi} y_{t-4} + \varphi_i i_{t-1} + \mu$$

<table>
<thead>
<tr>
<th>Rule</th>
<th>Parameter Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR93:</td>
<td>1.5</td>
</tr>
<tr>
<td>BA:</td>
<td>1.5</td>
</tr>
<tr>
<td>FD:</td>
<td>0.5</td>
</tr>
<tr>
<td>NPP:</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Also, we consider an inflation-tilting rule as suggested by Nikolsko-Rzhevskyy, Papell, Prodan (2019)
Use models to evaluate rules

**Small New-Keynesian Model (NK):**

\[ y_t = E_t y_{t+1} - 1.59(i_t - E_t \pi_{t+1} - r_t^*) \]
\[ r_t^* = 0.35r_{t-1} + \eta_t \]
\[ \pi_t = 0.99E_t \pi_{t+1} + 0.096y_t + \varepsilon_t \]

**Small Old-Keynesian Model (OK):**

\[ y_t = 1.16y_{t-1} - 0.25y_{t-2} - 0.1(i_{t-1}^q - \pi_{t-1}) + \eta_t \]
\[ \pi_t^q = 0.7\pi_{t-1}^q - 0.1\pi_{t-2}^q + 0.28\pi_{t-3}^q + 0.12\pi_{t-4}^q - 0.14y_{t-1} + \varepsilon_t \]

**Medium-Scale New Keynesian Model (SW):**

\[ \pi_t^q = 0.7\pi_{t-1}^q - 0.1\pi_{t-2}^q + 0.28\pi_{t-3}^q + 0.12\pi_{t-4}^q - 0.14y_{t-1} + \varepsilon_t \]

---

**Table 2**

<table>
<thead>
<tr>
<th>Rules/Models</th>
<th>OK</th>
<th>NK</th>
<th>SW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inflation</td>
<td>Output Gap</td>
<td>Inflation</td>
</tr>
<tr>
<td>T93</td>
<td>3.45</td>
<td>2.27</td>
<td>0.90</td>
</tr>
<tr>
<td>BA</td>
<td>3.49</td>
<td>1.99</td>
<td>0.96</td>
</tr>
<tr>
<td>NPP</td>
<td>2.65</td>
<td>2.59</td>
<td>0.84</td>
</tr>
<tr>
<td>FD</td>
<td>\infty</td>
<td>\infty</td>
<td>0.88</td>
</tr>
<tr>
<td>E</td>
<td>2.33</td>
<td>2.80</td>
<td>0.86</td>
</tr>
</tbody>
</table>

**Note to Table 2:** The models are the small old-Keynesian (OK), small new-Keynesian (NK) and the medium-size policy model (SW). The rules are the Taylor (1993) rule (T93), the balanced approach rule (BA), the inflation-tilting Taylor rule proposed by Nikolsko-Rzhevskyy, Papell, and Prodan rule (NPP), the first-difference rule (FD). E refers to the outcome under the model’s estimated rule with its residuals, when that rule and residual covariance matrix is available, or to sample standard deviations when not available.
Four more models

TMCM: A multi-country model due to Taylor (1993), which is a first-generation New Keynesian model. It is a model with rational expectations, nominal rigidities based on staggered contracts, and an interest-rate policy rule.

CCTW10: A model due to Cogan, Cwik, Taylor and Wieland (2010), which extends the SW model. It includes including Keynesian rule-of-thumb consumers. This modification affects, for example, the size of the fiscal multipliers, and improves fit a little bit.

CMR14: A model due to Christiano-Motto-Rostagno (2014), which adds financial frictions and considers post-crisis data.

IN10: A model of Iacoviello and Neri (2010), which adds a housing market as well as financial frictions.

---

Figure 1. Standard deviation of inflation and output gap
Note: The figure shows the standard deviations of inflation and the output gap of each of the rules relative to the Taylor 1993 rule in 7 different models. The rules shown are the balanced approach rule (BA), the first difference rule (FD) and the inflation-tilting rule (NPP). The models are as follows: (1) OK Model – specification from Rudebusch and Svensson (1999), (2) NK Model - specification from Levin, Wieland and Williams (2003), (3) SW Model from Smets and Wouters (2007)), (4) TMCM Model from Taylor (1993), (5) CCTW10 Model from Cogan, Cwik, Taylor and Wieland (2010), (6) CMR14 Model from Christiano, Motto and Rostagno (2014), and (7) IN10 Model from Iacoviello and Neri (2010).
How close to optimal?

We find optimal response coefficients that solve in a given model:

\[
\begin{align*}
\text{Min} & \quad \phi \left( \text{Var}(\pi) + \lambda \text{Var}(y) + \text{Var}(\Delta i) \right) \\
\text{s.t.} & \quad i_t = \phi_{\pi} \pi_t + \phi_y y_t + \phi_{yl} y_{t-1} + \phi_i i_{t-1}
\end{align*}
\]
Would new post-crisis macro-financial models have performed better in forecasting the recession of 08/09?


- Benchmark: Survey of professional forecasters in 2008/09
- Data: Quarterly real-time data vintages for U.S. economy
- Models:
  - Bayesian Vector Autoregressions (B-VARs)
  - Pre-crisis structural models
  - Post-crisis structural models

**SPF Forecasts 2008:Q3 and 2008:Q4**
**SPF Forecasts 2009:Q1 and 2009:Q2**

**Pre-Crisis Models**

<table>
<thead>
<tr>
<th>Model</th>
<th>Formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Del Negro and Schorfheide (2004)</td>
<td>NK-DS04</td>
</tr>
<tr>
<td>Wieland and Wolters (2011)</td>
<td>NK-WW11</td>
</tr>
<tr>
<td>Smets and Wouters (2007)</td>
<td>DSGE-SW07</td>
</tr>
<tr>
<td>Edge et al. (2008)</td>
<td>DSGE-FRBEDO</td>
</tr>
<tr>
<td>Giannone et al. (2015)</td>
<td>BVAR3, BVAR7, BVAR11, CC-F18</td>
</tr>
<tr>
<td>Fair (2018)</td>
<td></td>
</tr>
</tbody>
</table>

3: output growth, inflation, interest rate
7: output growth, consumption growth, investment growth, wages, hours, interest rate
11: output growth, inflation, interest rate, consumption of non and services, consumption of durables, residential investment, investment, hours, wages, inflation for consumer nondurable vices, inflation for consumer durables
3, 7 or 11
more than 100
Post-Crisis Macro-Financial Models

<table>
<thead>
<tr>
<th>Bernanke et al. (1999)</th>
<th>FF-BGG99</th>
</tr>
</thead>
<tbody>
<tr>
<td>Del Negro and Schorfheide (2013), Del Negro et al. (2015)</td>
<td>FA-SW07</td>
</tr>
<tr>
<td>Kolasa and Rubaszek (2015)</td>
<td>FF-DSSW07-FA1</td>
</tr>
<tr>
<td>Kolasa and Rubaszek (2015)</td>
<td>FF-DSSW07-CC</td>
</tr>
<tr>
<td>Carabenciov et al. (2008)</td>
<td>FF-IMFQP</td>
</tr>
</tbody>
</table>

5: output growth, inflation, interest rate, investment, credit spread
8: output growth, consumption growth, investment growth, wages, hours, interest rate, credit spread
9: output growth, consumption growth, investment growth, wages, hours, interest rate, credit spread, loan growth
11: output growth, consumption growth, investment growth, wages, hours, interest rate, residential investment, mortgage house prices, mortgage loan spread
6: unemployment rate, output growth, inflation, interest rate, lending tightness

Model-based forecasts: 4 different information sets

Scenarios:
(1) Forecast based exclusively on information from preceding quarter
(2) Condition on current quarter SPF nowcasts of output growth, unemployment rate, non-residential investment, residential investment
(3) Condition on current quarter data: interest rates, credit spreads, mortgage spreads, and monthly observations such as inflation, unemployment, hours.
(4) Condition on (2) and (3).
Pre-Crisis Models: Forecast 2008:Q4, Scenario 1, 2 & 3

Pre-Crisis Models: Forecast 2009:Q1, Scenario 1, 2 & 3
Post-Crisis Models: Forecast 2008:Q4, Scenario 1, 2 & 3

Post-Crisis Models: Forecast 2009:Q1, Scenario 1, 2 & 3
Conclusions

New model comparison tools in Macro Macro Model Data Base (MMB) 3.1 just released (www.macromodelbase.com)
