1. New tools and initiatives
   - model data base, comparison software, website, recent publications, initiative, network, conferences
2. Examples using MMB 2.3
3. A peek at recent research applications
   - Real equilibrium interest rates
   - Robustness of macroprudential policy rules
4. A proposal for a competition
Recent related publications and new work

**New Methods for Macro-Financial Model Comparison and Policy Analysis**

**Model Uncertainty in Macroeconomics: On the Implications of Financial Frictions**
- Chapter forthcoming in, Oxford Handbook of Central Banking.

Recent work on equilibrium real rates, fiscal stimulus and financial frictions, macroprudential & monetary policy rules, US tax reform.
MMCI: Make it easier to evaluate policy across models

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

Recently: Effects of Fiscal Stimulus in Structural Models

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

2 full days, keynote, 3 plenaries, 6 parallel sessions, 2 poster sessions, 37 papers, 11 posters, 20 discussants.
Next steps

• Full open source version of MMB (end of 2018)
  – Browser-based GUI, MMB using Dynare for Octave
• Online comparison database (end of 2018)
  – Browser-based GUI, drawing on simulation archive, possibility to include modeling approaches outside of Dynare
• More than 140 models end of 2019
Government purchases shock with SW rule

Autocorrelation functions: All shocks with SW Rule
NK-GK11: Gertler-Karadi (2011), Capital quality shock, Taylor rule, SW rule, Orphanides-Wieland 2013 rule


Real-time estimation and forecasting

- See also Wolters and Wieland (2013), Forecasting and policy making, in Elliott, Granger and Timmermann, Handbook of economic forecasting, vol 2.
- Recent application: Wieland and Wolters, Little decline in model-based estimates of the long-run equilibrium interest rate.

Recursive real-time estimation of long-run equilibrium rate with Smets-Wouter model

SW 2007 r* estimate

Average real rate for 20-year windows

R* for rolling 20-year window’s

95% confidence intervals
Contributions to the difference between average real interest rate and long-term \( r^* \) for the United States

<table>
<thead>
<tr>
<th>Shock</th>
<th>Contribution to difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>-0.09 %</td>
</tr>
<tr>
<td>Risk premiums</td>
<td>-0.48 %</td>
</tr>
<tr>
<td>Government expenditure</td>
<td>-0.04 %</td>
</tr>
<tr>
<td>Investment-specific</td>
<td>-0.24 %</td>
</tr>
<tr>
<td>Monetary policy</td>
<td>-0.83 %</td>
</tr>
<tr>
<td>Price markup</td>
<td>0.15 %</td>
</tr>
<tr>
<td>Wage markup</td>
<td>-0.01 %</td>
</tr>
</tbody>
</table>

Total difference: \(-1.75 \% = 0.45 \% - 2.2 \%\)

Macro-prudential policy rules

Binder, Lieberknecht, Quintana and Wieland (2017), Robust macroprudential policy rules under model uncertainty, working paper.

Three models with banking sector

1. Gertler-Karadi, JME 2011, NK_GK11
2. Meh-Moran, JEDC 2010, NK_MM10
3. Gerali-Neri-Sessa-Signori, JMCB 2010, EA_GNSS10

Models: banking sector

- Banks play a passive role in financial accelerator and housing finance models.
- By contrast, three models considered treat banks’ balance sheet and decision processes explicitly, banks’ financial conditions can affect credit supply.
- Shocks can originate from the banking sector, this sector plays an crucial role in the transmission of standard macroeconomic shocks.

Role for bank capital

Gertler-Karadi (JME 2011), NK_GK11
- Moral hazard problem between banks and depositors, endogenous capital constraint.

Meh-Moran (JEDC 2010), NK_MM10
- Double moral hazard, bank invests net worth with entrepreneur to mitigate moral hazard vs depositor. Bank capital influences ability to attract deposits.

Gerali-Neri-Sessa-Signoretti (JMCB 2010), EA_GNSS10
- Monopolistic banks set deposit and lending rates, capital out of retained earnings, quadratic cost if capital-asset ratio moves from (regulatory) target.
Benchmark monetary policy rule

- Central bank follows first-difference rule as in Orphanides and Wieland (2013)

\[ i_t = i_{t-1} + 0.5\pi_t + 0.5(x_t - x_{t-4}) \]

Bank capital shock

CTA Ratio: Minimum ratio of bank capital to the real value of bank assets

\[ \nu_t = \rho \nu_{t-1} + \chi (b_t - y_t) \]

Note: Impulse response functions for a five-percent fall in bank net worth. Monetary policy is modeled according to the rule in Orphanides and Wieland (2013). A period is a quarter and all variables are expressed in percentage deviations from their non-stochastic steady state value.
Policy regimes

- **Perfect cooperation:**
  - monetary policy and macroprudential policy jointly optimize a shared objective.
- **Leader-follower:**
  - Central bank implements first-difference interest rate rule (as in Orphanides and Wieland 2013),
  - macro-prudential policy authority optimizes conditional on central bank policy.

Perfect coordination regime

\[
\min_{\{\rho, \phi, \phi_x, \phi_d, \rho_x, \chi\}} L = \frac{\sigma^2_{b-y} + 0.5\sigma^2_x + 0.5\sigma^2_d + \sigma^2_{b-y} + 0.5\sigma^2_x + 0.5\sigma^2_{d\nu}}{\text{Central Bank Objective}} \quad \text{Macro Pru Objective}
\]

\[
s.t. \; i_t = \rho_i i_{t-1} + \phi_i \pi_t + \phi_x x_t + \phi_d (x_t - x_{t-4})
\]

\[
\nu_t = \rho_v \nu_{t-1} + \chi (b_t - y_t)
\]

Leader follower regime

\[
\min_{\{\rho, \chi\}} L^{mp} = \sigma^2_{b-y} + 0.5\sigma^2_x + 0.5\sigma^2_{d\nu}
\]

\[
s.t. \; \nu_t = \rho_v \nu_{t-1} + \chi (b_t - y_t)
\]

\[
i_t = i_{t-1} + 0.5\pi_t + 0.5 (x_t - x_{t-4})
\]

Perfect coordination lacking robustness under model uncertainty

<table>
<thead>
<tr>
<th>Model</th>
<th>GNSS</th>
<th>MM</th>
<th>GK</th>
</tr>
</thead>
<tbody>
<tr>
<td>% [CGP]</td>
<td>% [CGP]</td>
<td>% [CGP]</td>
<td></td>
</tr>
<tr>
<td>GNSS</td>
<td>-</td>
<td>186 [3.66]</td>
<td>191 [7.83]</td>
</tr>
<tr>
<td>Rule</td>
<td>MM</td>
<td>1484 [9.69]</td>
<td>-</td>
</tr>
<tr>
<td>GK</td>
<td>-</td>
<td>595 [13.83]</td>
<td>-</td>
</tr>
</tbody>
</table>

CGP: Credit Gap Premium, the increase in standard deviation of credit gap relative to the outcome under the model-specific optimized rule that is necessary to match the loss under the alternative rule.
Leader-follower regime more robust

<table>
<thead>
<tr>
<th>Model</th>
<th>GNSS</th>
<th>MM</th>
<th>GK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rule</td>
<td>MM</td>
<td>89 [2.54]</td>
<td>15 [4.17]</td>
</tr>
<tr>
<td>GK</td>
<td>330 [4.91]</td>
<td>17 [1.23]</td>
<td>-</td>
</tr>
</tbody>
</table>

Bayesian model averaging

- Bayesian perspective on models, with (probability-weighted) loss

\[ L = \sum_{m \in M} \rho_m L_m \]

where \( \rho_m \) is policymaker’s prior as to model \( m \).

\[
\min_{\{\rho_m, \chi\}} \sum_{m \in M} \left[ \frac{L_m^{mp} - \min L_m^{mp}}{\min L_m^{mp}} \right]
\]

s.t. \[ \nu_t = \rho_t \nu_{t-1} + \chi (b_t - y_t) \]
\[
i_t = i_{t-1} + 0.5 \pi_t + 0.5 (x_t - x_{t-4})
\]

Robustness

Optimized Model-Averaged Macroprudential Rules

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Average Loss</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Increase</td>
<td>GCP</td>
<td>Inflation</td>
</tr>
<tr>
<td>GNSS</td>
<td>28.23</td>
<td>1.44</td>
</tr>
<tr>
<td>MM</td>
<td>8.31</td>
<td>0.85</td>
</tr>
<tr>
<td>GK</td>
<td>23.74</td>
<td>5.32</td>
</tr>
<tr>
<td>Average</td>
<td>20.10</td>
<td>3.22</td>
</tr>
</tbody>
</table>

\[ \nu_t = 0.896 \nu_{t-1} + 1.883 (b_t - y_t) \]

4. A proposal for a competition: Explaining and forecasting the Great Recession.
Performance SPF versus model forecasts

1. Comparing models estimated on U.S. data:
   - What were the main drivers of the decline in GDP growth in 2008/9?
     For example, variance decomposition for GDP growth.

2. Forecasting competition based on real-time, historical data vintages:
   - Provide and share data. Compare forecasts and recession risks.
   - Checks: Public models, forecasts of other recessions and future.

What have we learned?
The MMCI forecasting competition

Interested? Contact wieland@wiwi.uni-frankfurt.de

Appendix: 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>$x_t^m$</td>
<td>endogenous variables in model m</td>
</tr>
<tr>
<td>$z_t^{m,g}$</td>
<td>policy variables in model m (also included in $x_t^m$)</td>
</tr>
<tr>
<td>$\eta_t^m$</td>
<td>policy shocks in model m</td>
</tr>
<tr>
<td>$\varepsilon_t^m$</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) \[ E_t[g_m(x_t^m, x_{t+1}^m, x_{t-1}^m, \eta_t^m, \gamma^m)] = 0 \]

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

**Innovations/shocks**

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

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

**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>$\xi$</td>
<td>common variables in all models</td>
</tr>
<tr>
<td>$\xi^*$</td>
<td>common policy variables in all models (also included in $\xi$)</td>
</tr>
<tr>
<td>$\eta$</td>
<td>common policy shocks in all models</td>
</tr>
<tr>
<td>$g(\cdot)$</td>
<td>common policy rules</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>common policy rule parameters</td>
</tr>
</tbody>
</table>
Augmented model

\[ E_t[g(z_t, z_{t+1}, z_{t-1}, \eta_t, \gamma)] = 0 \quad (5) \]

\[ E_t[h_m(z_t, x^m_t, x^m_{t+1}, x^m_{t-1}, \theta^m)] = 0 \quad (6) \]

\[ E_t[f_m(x^m_t, x^m_{t+1}, x^m_{t-1}, \varepsilon^m_t, \beta^m)] = 0 \quad (7) \]

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

Solution

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

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

- Numerical approximation,
- Compute comparable objectives
  - IRF’s of \( z \)'s to \( \eta \)'s, variances and correlations of \( z \)'s given all shocks, etc.
- Compute metric measuring distance between different models.

Common variables & policy rules

```
// Definition of Modelbase Variables in Terms of Original Model Variables /*
interest = r^4;            // *
inflation = pinfA;         // *
inflationq = 4*pinf;       // *
outputgap = y-yf;          // *
output = y;                // *
flspol = eg;               // *
/*
/**

// Policy Rule
/**
// Monetary Policy
/**
interest = cofintb1*interest(-1)    // */
+ cofintb2*interest(-2)    // */
+ cofintb3*interest(-3)    // */
+ cofintb4*interest(-4)    // */
+ cofinf0*inflationq    // */
+ cofinf01*inflationq(-1) // */
+ cofinf02*inflationq(-2) // */
+ cofinfmM*inflationq(-3) // */
```

Monetary policy shocks: model generations (U.S., SW rule)
Monetary policy shocks: Economies

Reproducibility of computational research

A topic in other fields:

- Stanford statistician Donoho (2010, Biostatistics): "an article about computation result is advertising, not scholarship. The actual scholarship is the full software, code and data, that produced the result."

\[ \text{Graph showing economic outputs for the United States and Euro Area} \]