MACRO-LINKAGES, OIL PRICES AND DEFLATION WORKSHOP

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GPM for Dummies: Structure, Applications, and a Friendly Front-End

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Presentation at the IMF Research Department Macro Modeling Workshop on Macro-Financial Linkages, Oil Prices, and Deflation, January 6-9, 2009

Outline of the Presentation

1. Background and motivation

2. Stages in model building

3. Models and Bayesian estimation

4. Forecasting

5. Addition of more countries

6. Next steps

7. Use in WEO (Marianne)

8. Friendly front-end (Marianne)

Background and motivation

- Two types of models developed by IMF and used in central banks and in area desks at IMF

- First is small quarterly projection model (QPM) with 4 or 5 key equations (Berg, Karam and Laxton)

- Typically calibrated to give reasonable properties for the country under study

- Small models especially helpful in central banks with little experience of macro modeling

- But while use of calibration rather than estimation gives reasonable properties, such models have been criticized for reflecting little more than modelers' judgment

- Second is DSGE models – based on theoretical underpinnings and optimization by agents

- More sophisticated, but much more complex

- GPM project aimed at developing global projection model based on small QPMs that can be used for explanation of past developments and forecasting

- While DSGE models may eventually be used in this way, at present we are a long way from that possibility

- So we are beginning with smaller macro models

- Among other objectives of GPM project, want to assist central banks in forecasting external environment

- Some central banks make use of forecasts for external environment that are produced by IMF (WEO) or OECD (Economic Outlook)

- But full forecasts appear only semi-annually at annual frequencies or for limited range of countries, limiting their usefulness for quarterly forecasts

- So problem is how to update these forecasts

- Other central banks make use of forecasts of different countries provided by investment banks and/or Consensus Economics

- But combining forecasts from different sources could lead to inconsistencies

- For example, assumptions as to US forecast underlying forecasts by participants in Canadian survey of Consensus Economics will typically not be the same as forecasts by participants in US surveys

- Moreover, they do not provide any way of dealing with the "what if" question posed by members of MPC

- Ideally, want to have ability to run alternative simulations (e.g., what if US economy is stronger/weaker than in base-case projection, allowing for endogenous monetary policy response)

- GPM aims at providing consistent international forecast (with confidence bands), allowing users to input their own judgments and to run alternative simulations as needed

Stages in model building

- Number of stages in approach used to develop GPM
- First, built closed economy model (US)
- Second, estimated model using Bayesian techniques
- Third, added financial variable (BLT)
- Fourth, expanded model to three economic areas (US, Euro area, Japan)

- Fifth, added oil sector

- Sixth, added five Latin American IT countries (one at a time) and the aggregate of these five countries

- Seventh, added Indonesia

- Eighth, imposed nonlinearities such as zero lower bound on interest rates in the model and difference between effects of excess demand and excess supply

Behavioral equations in model

- Five key behavioral equations in multicountry models

- Output gap equation

$$
\begin{aligned}
y_{i,t} \;&=\; \beta_{i,1} y_{i,t-1} + \beta_{i,2} y_{i,t+1} - \beta_{i,3} r_{i,t-1} + \beta_{i,4} \sum_j \omega_{i,j,4} z_{i,j,t-1} \\
&\quad + \beta_{i,5} \sum_j \omega_{i,j,5} y_{j,t-1} + \varepsilon_{i,t}^{y}
\end{aligned}
$$

- Inflation equation

$$\begin{aligned}\pi_{i,t} &= \lambda_{i,1}\pi 4_{i,t+4} + (1-\lambda_{i,1})\pi 4_{i,t-1} + \lambda_{i,2} y_{i,t-1} \\ &\quad + \lambda_{i,3}\sum_j \omega_{i,j,3}\Delta Z_{i,j,t} - \varepsilon^{\pi}_{i,t}\end{aligned}$$

- Interest rate equation

$$I_{i,t} = (1-\gamma_{i,1})\left[\bar{\bar{R}}_{i,t} + \pi 4_{i,t+3} + \gamma_{i,2}(\pi 4_{i,t+3} - \pi_i^{tar}) + \gamma_{i,4} y_{i,t}\right] + \gamma_{i,1} I_{i,t-1} + \varepsilon^{I}_{i,t}$$

- Exchange rate determination

$$4(Z^e_{i,t+1} - Z_{i,t}) = (R_{i,t} - R_{us,t}) - (\bar{\bar{R}}_{i,t} - \bar{\bar{R}}_{us,t}) + \varepsilon^{Z-Z^e}_{i,t}$$

- Expected exchange rate equation

$$Z^e_{i,t+1} = \phi_i \ Z_{i,t+1} + (1 - \phi_i) \ Z_{i,t-1}$$

- Unemployment rate equation

$$u_{i,t} = \alpha_{i,1} u_{i,t-1} + \alpha_{i,2} y_{i,t} + \varepsilon^u_{i,t}$$

- Note way in which potential output and NAIRU are determined

Potential output

$$\bar{Y} = \bar{Y}_{i,t-1} + g_{i,t}^{\bar{Y}}/4 + \varepsilon_{i,t}^{\bar{Y}}$$

$$g_{i,t}^{\bar{Y}} = \tau_i g_i^{\bar{Y}ss} + (1 - \tau_i) g_{i,t-1}^{\bar{Y}} + \varepsilon_{i,t}^{g^{\bar{Y}}}$$

NAIRU

$$\bar{U}_{i,t} = \bar{U}_{i,t-1} + g_{i,t}^{\bar{U}} + \varepsilon_{i,t}^{\bar{U}}$$

$$g_{i,t}^{\bar{U}} = (1 - \alpha_{i,3}) g_{i,t-1}^{\bar{U}} + \varepsilon_{i,t}^{g^{\bar{U}}}$$

Bayesian Estimation

- Bayesian estimation has a number of advantages

- Puts some weight on priors and some weight on the data

- Incorporates theoretical insights to prevent incorrect empirical results (such as interest rate movements having perverse effects on inflation), but also confronts model with the data to some extent

- Allows use of small samples without concern about incorrect estimated results

- Allows estimation of many coefficients and latent variables (e.g., output gap, NAIRU, equilibrium real interest rate) even in small samples

- By specifying tightness of distribution on priors, researcher can change relative weights on priors and data in determining posterior distribution for parameters

- Number of criteria to evaluate success of Bayesian estimated models

- Closeness of posterior to priors when considerable weight is placed on the data

- Plausibility of impulse response functions

- Log data density (in some cases) and root mean squared errors

- Out of sample forecasting

Impulse Response Functions

Figure 1: Demand shock in the US (1)

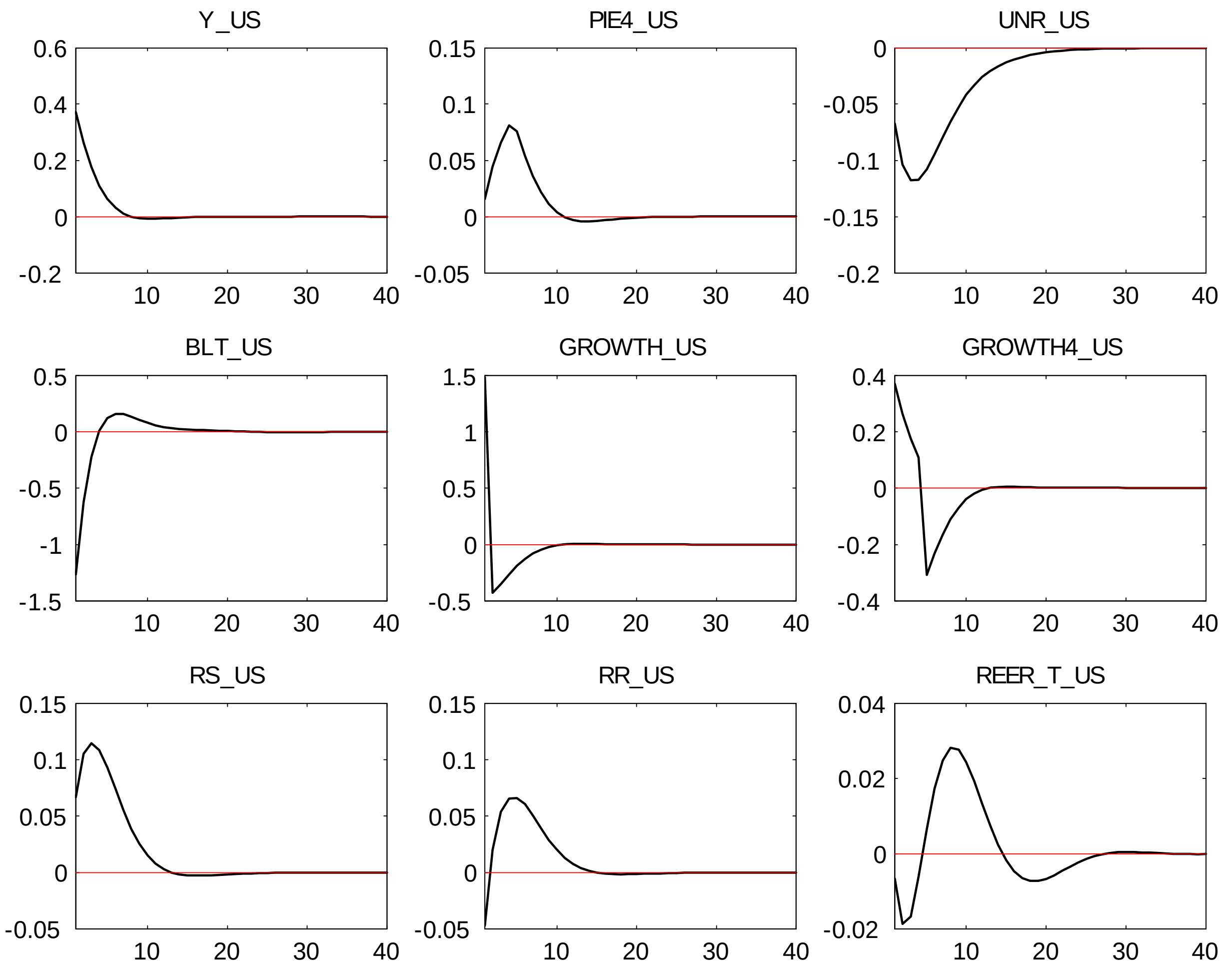


Figure 2: Demand shock in the US (2)

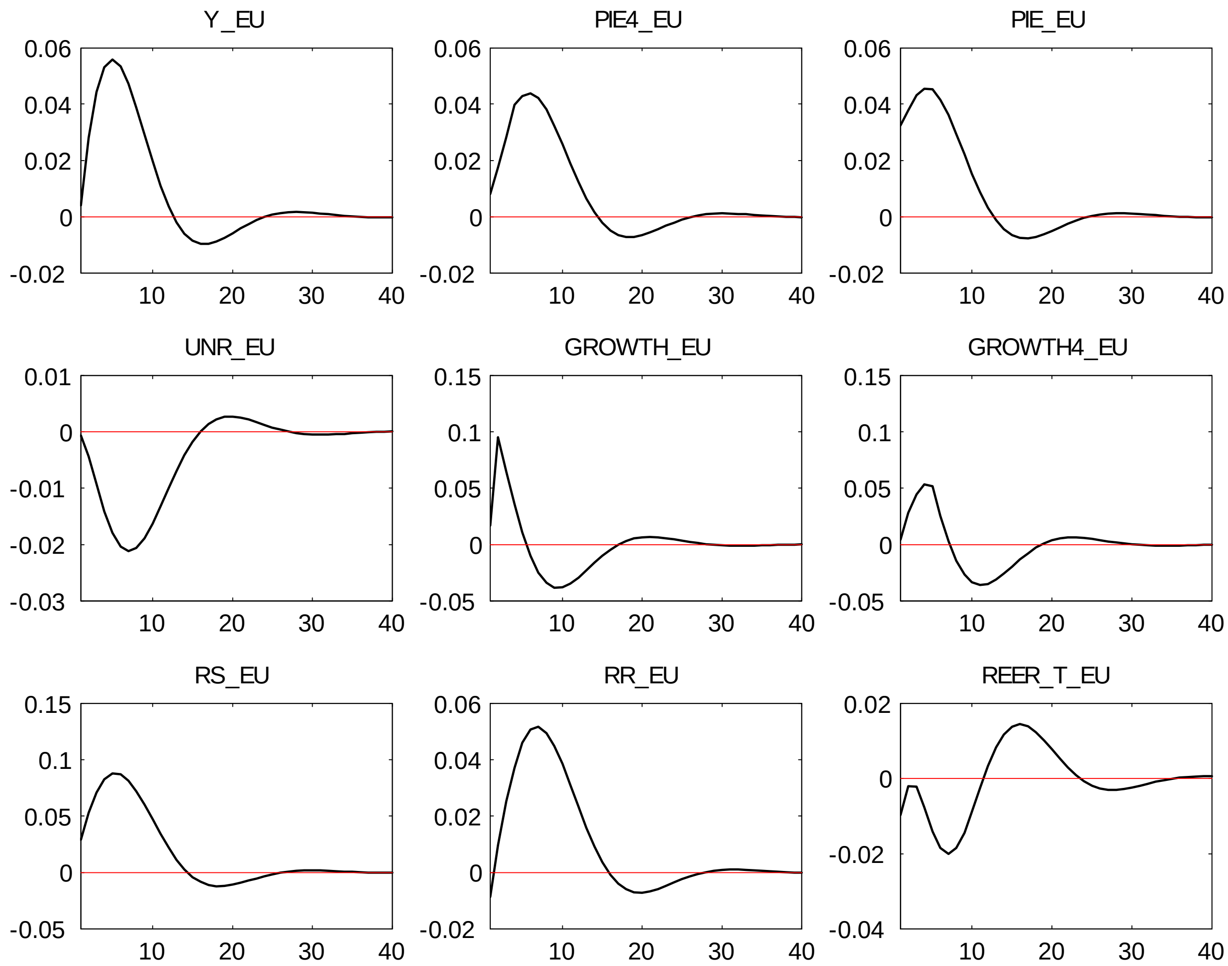
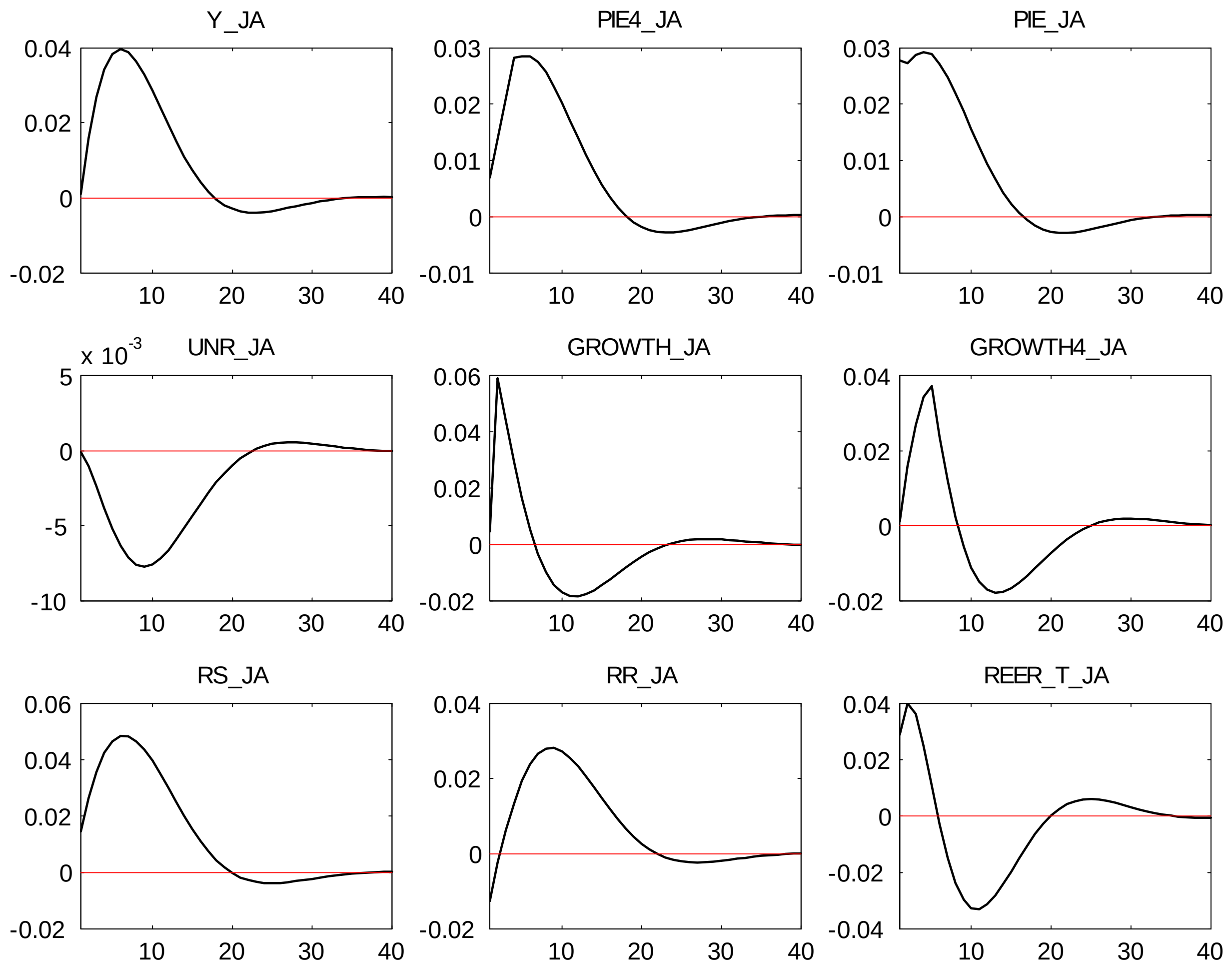


Figure 3: Demand shock in the US (3)



Introduction of bank lending tightening variable

- Variable based on Senior Loan Officer Opinion Survey on Bank Lending Practices – unweighted average of balance of opinion of four tightening questions

- Effectively use residual from regression of BLT on future output gap

$$BLT_{US,t} = \bar{BLT}_{US,t} - \kappa_{US} y_{US,t+4} - \varepsilon^{BLT}_{US,t}$$

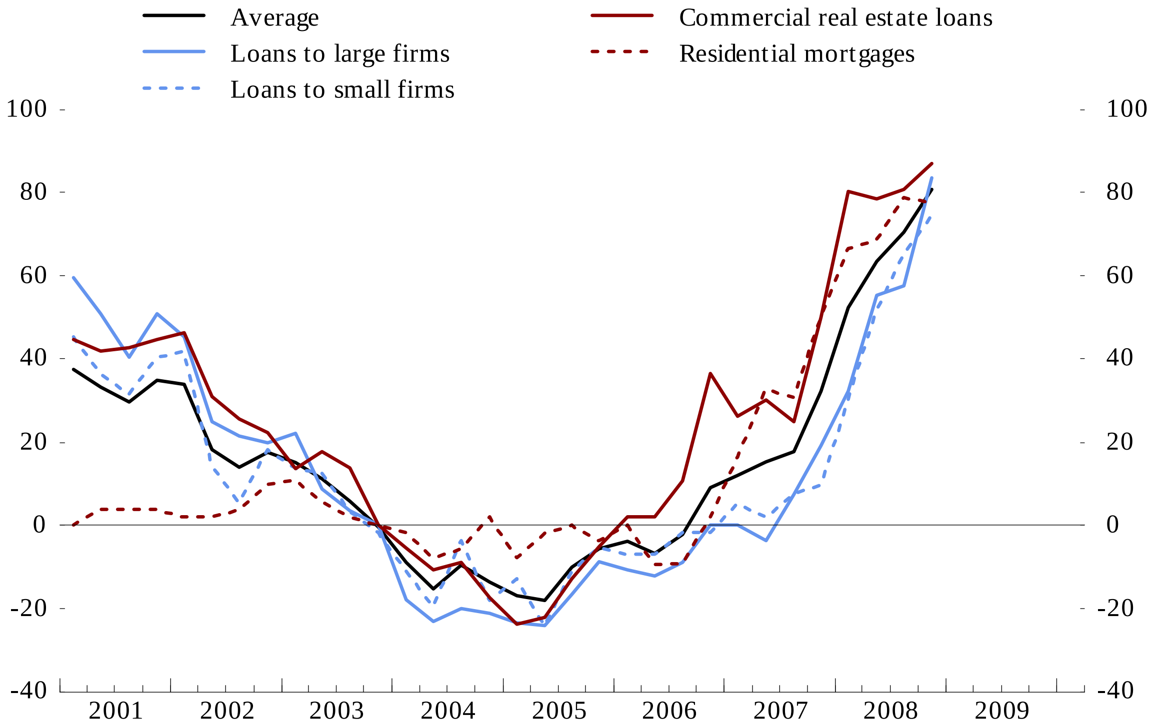
$$\bar{BLT}_{US} = \bar{BLT}_{US,t-1} + \varepsilon^{\bar{BLT}}_{US,t}$$

$$
\begin{aligned}
y_{US,t} \;=\;& \beta_{US,1} y_{US,t-1} + \beta_{US,2} y_{US,t+1} - \beta_{US,3} r_{US,t-1} \\
& + \beta_{US,4} \sum_j \omega_{US,4,j} z_{US,j,t-1} \\
& + \beta_{US,5} \sum_j \omega_{US,j,5} y_{j,t-1} + \theta_{US} \eta_{US,t} + \varepsilon^{y}_{US,t}
\end{aligned}
$$

$$
\begin{aligned}
\eta_{US,t} \;=\;& 0.04\varepsilon^{BLT}_{US.t-1} + 0.08\varepsilon^{BLT}_{US,t-2} + 0.12\varepsilon^{BLT}_{US,t-3} + 0.16\varepsilon^{BLT}_{US,t-4} + 0.20\varepsilon^{BLT}_{US,t-5} \\
& + 0.16\varepsilon^{BLT}_{US,t-6} + 0.12\varepsilon^{BLT}_{US,t-7} + 0.08\varepsilon^{BLT}_{US,t-8} + 0.04\varepsilon^{BLT}_{US,t-9}
\end{aligned}
$$

U.S. Bank Lending Tightening

(In percent)



U.S. Output Gaps Based on a U.S. Model

(In percent)

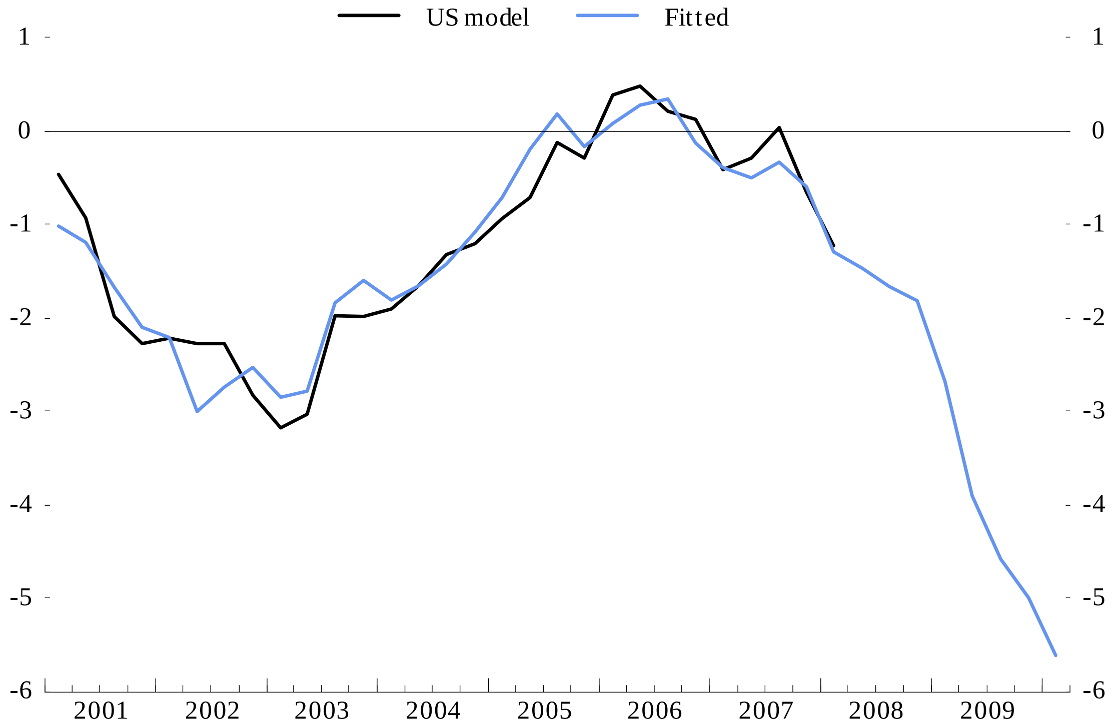


Figure 4: Financial (BLT) shock in the US (1)

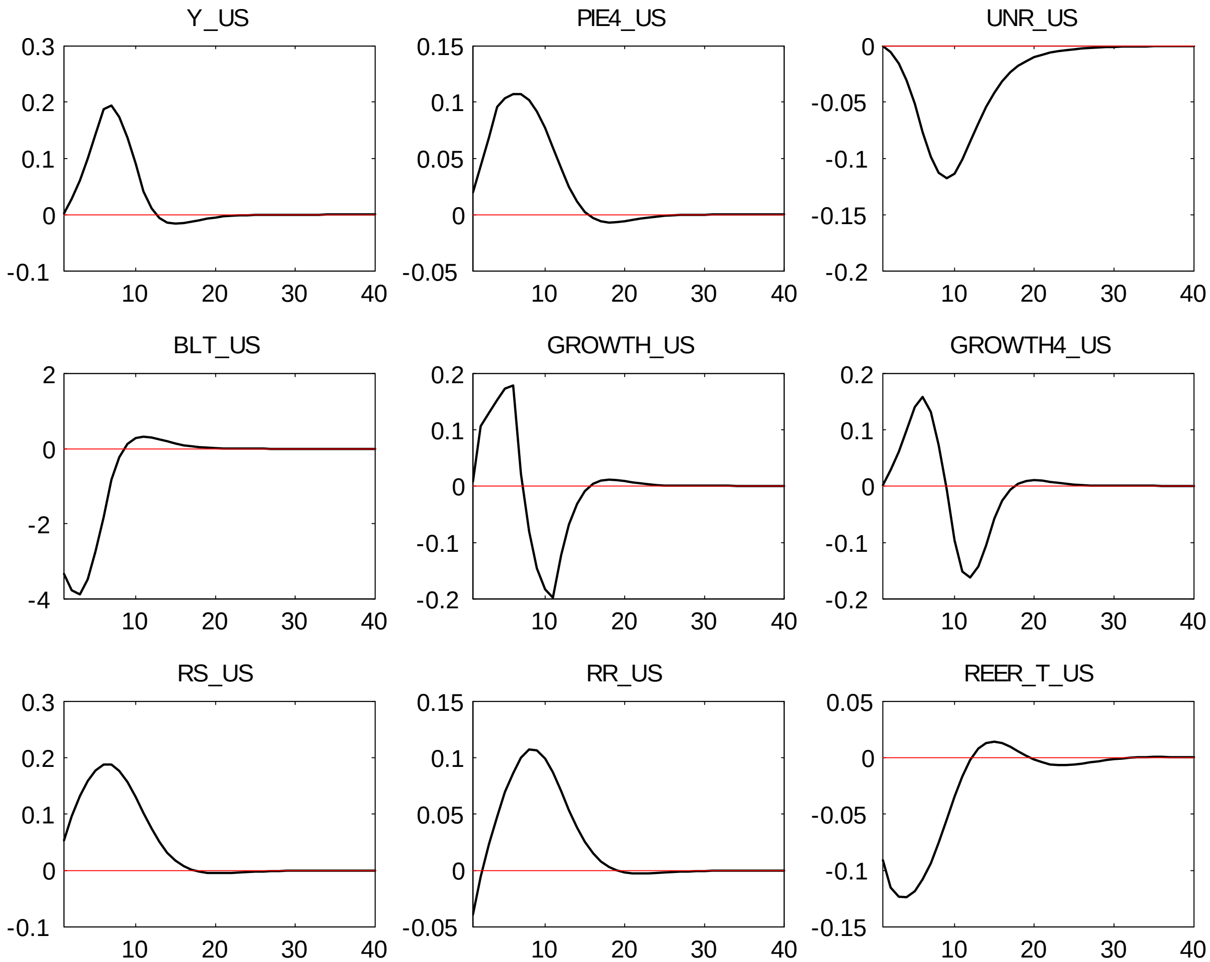


Figure 5: Financial (BLT) shock in the US (2)

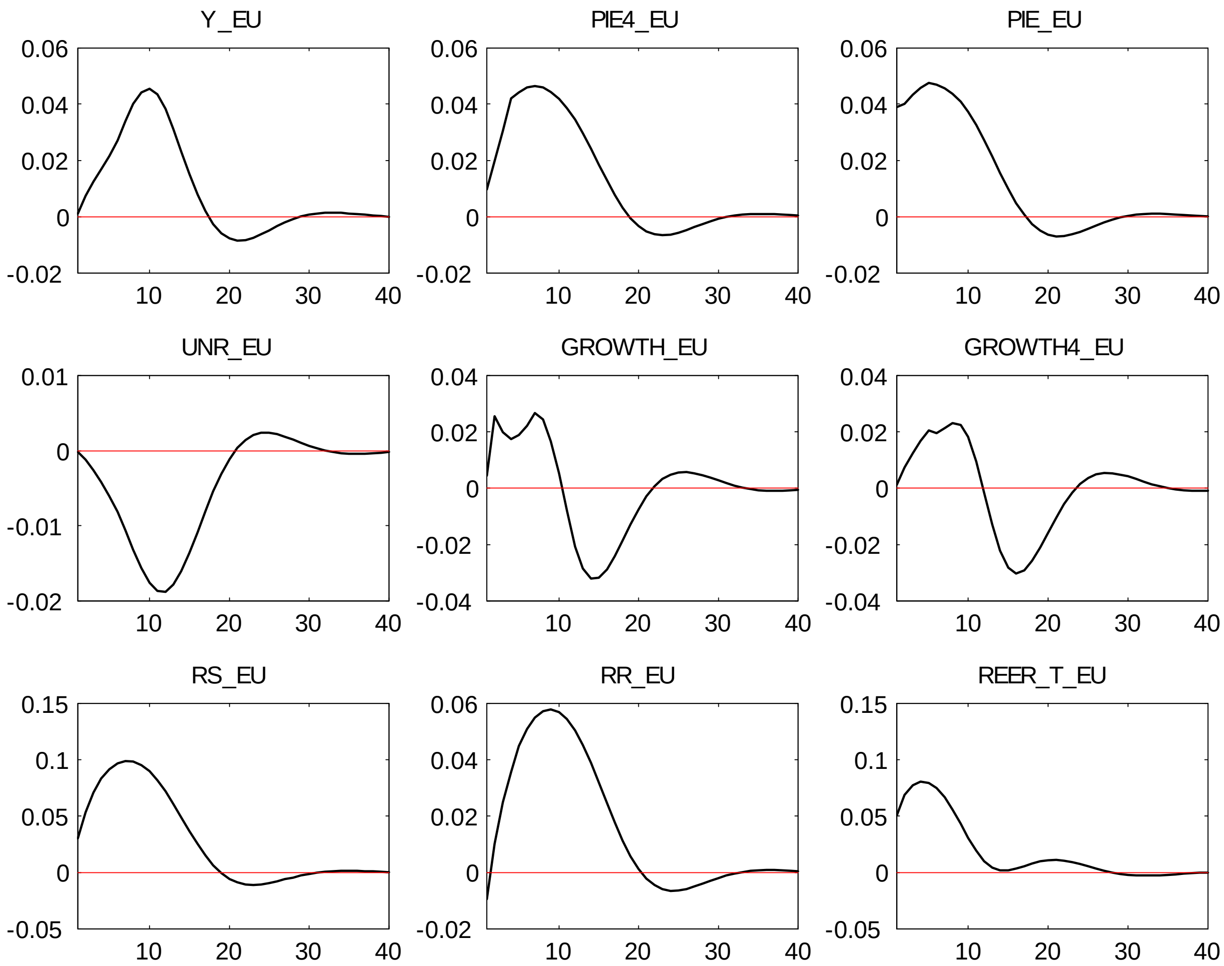
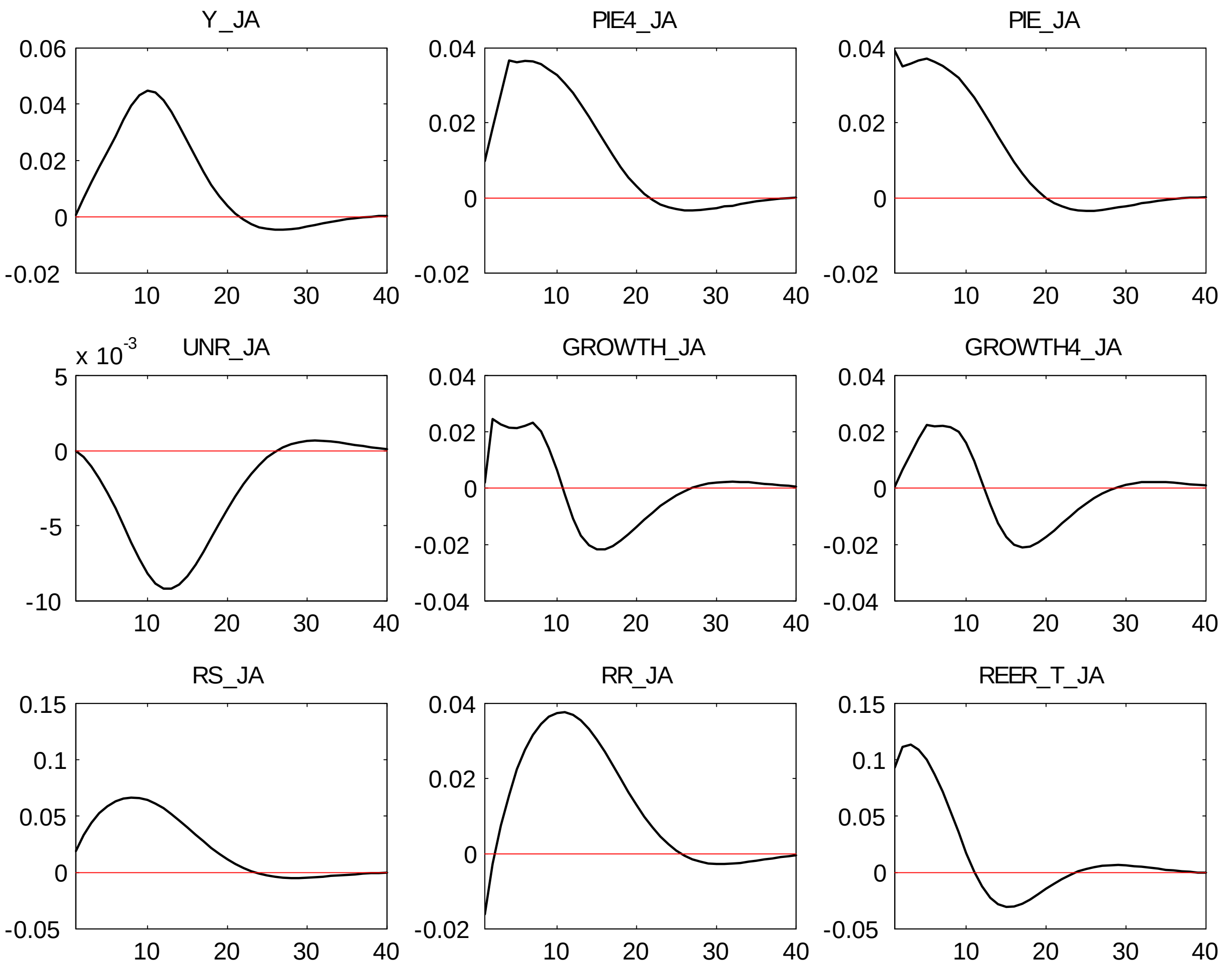


Figure 6: Financial (BLT) shock in the US (3)



Introduction of oil price variable

- Because of the importance of oil in the recent period and for purposes of forecasting, we subsequently added a simple model of oil prices to the open economy model

- Determination of oil prices in the model very simple; in future, intend to expand model to include global demand and supply for oil

$$\overline{RPOIL}_{US,t} = \overline{RPOIL}_{US,t-1} + g^{\overline{RPOIL}}_{US,t} + \varepsilon^{\overline{RPOIL}}_{US,t}$$

$$g^{\overline{RPOIL}}_{US,t} = (1 - \rho_{g,US})g^{\overline{RPOIL}}_{US,t-1} + \varepsilon^{g^{\overline{RPOIL}}}_{US,t}$$

$$rpoil_{US,t} = \rho_{rpoil,us} rpoil_{US,t-1} + \varepsilon^{rpoil}_{US,t}$$

- Potential output is affected by the average inflation in the real price of oil over the past year

- In effect, the level of potential output in any country is inversely related to the level of real prices in that country

$$\bar{\bar{Y}}_{i,t} = \bar{\bar{Y}}_{i,t-1} + g^{\bar{\bar{Y}}}_{i,t}/4 - \sigma_i\left(\sum_{j=0}^{3} \pi^{RPOIL}_{i,t-j}\right) + \varepsilon^{\bar{\bar{Y}}}_{i,t}$$

- Current and lagged increases in the real price of oil are added to the inflation equation

$$\begin{aligned}\pi_{i,t} &= \lambda_{i,1}\pi 4_{i,t+4} + (1-\lambda_{i,1})\pi 4_{i,t-1} + \lambda_{i,2} y_{i,t-1} + \lambda_{i,3}\sum_j \omega_{i,j,3}\Delta Z_{i,j,t} \\ &\quad + \upsilon_{i,1}\pi_{i,t}^{RPOIL} + \upsilon_{i,2}\pi_{i,t-1}^{RPOIL} - \varepsilon_{i,t}^{\pi}\end{aligned}$$

Figure 7: Oil Price Shock (1)

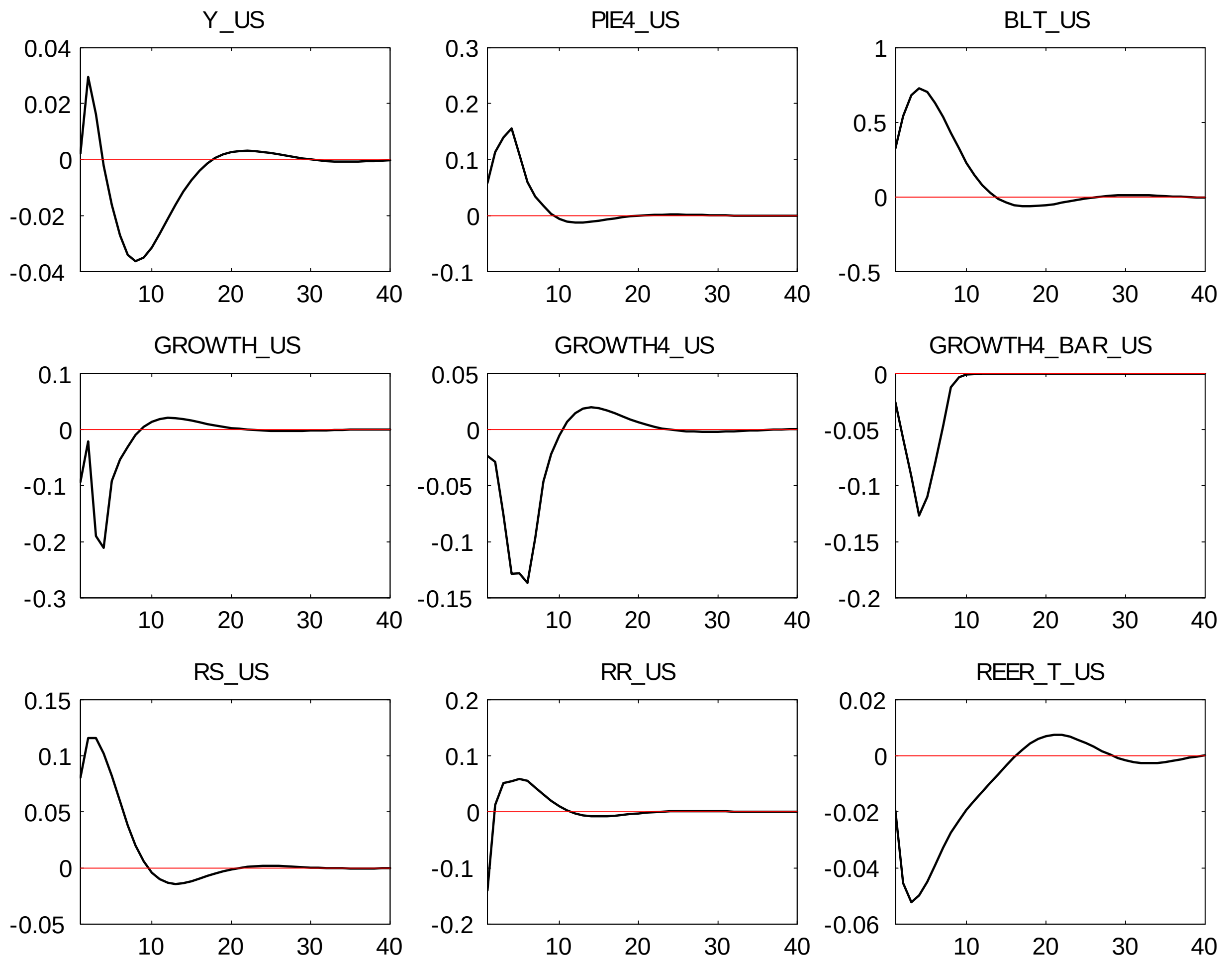


Figure 8: Oil Price Shock (2)

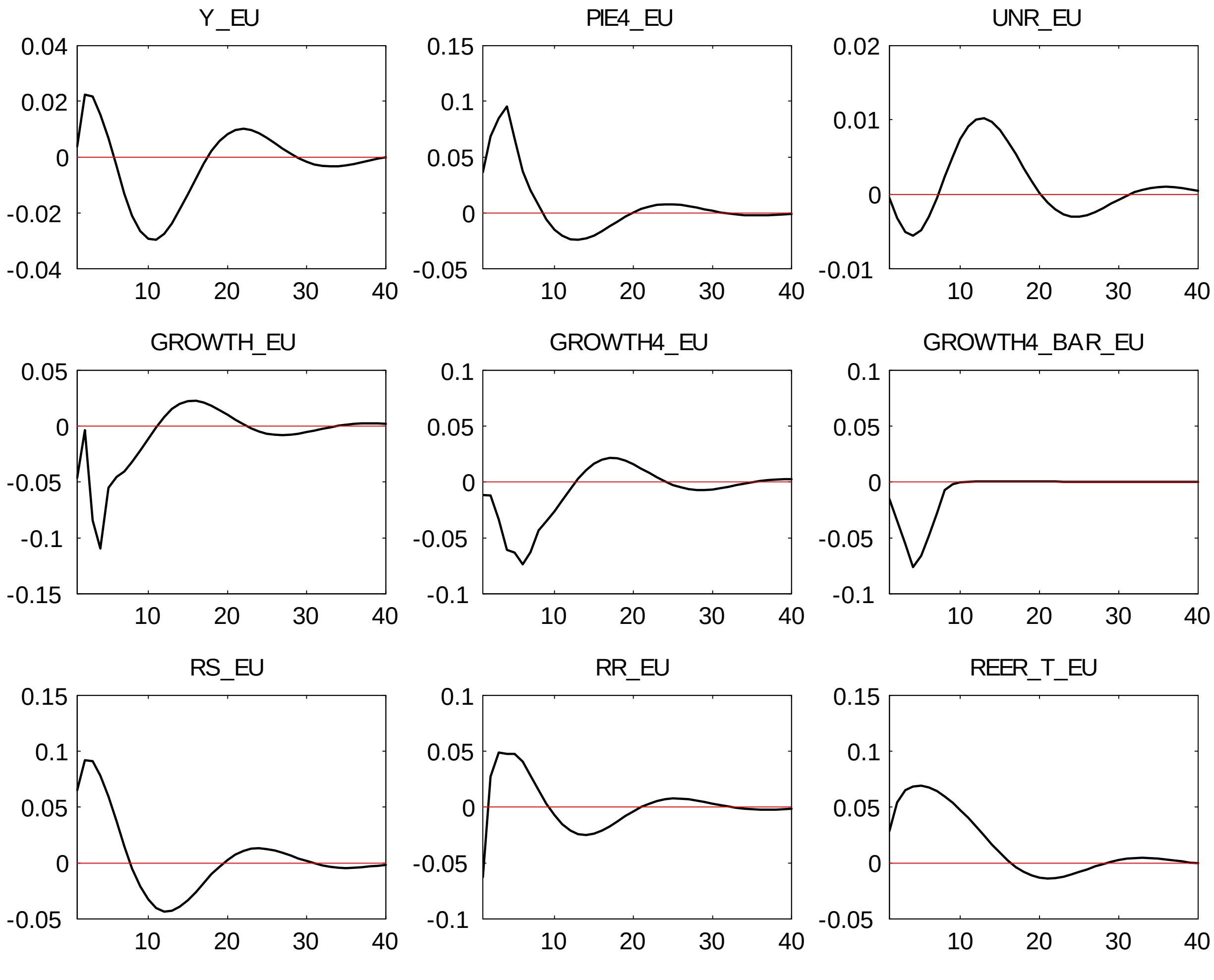
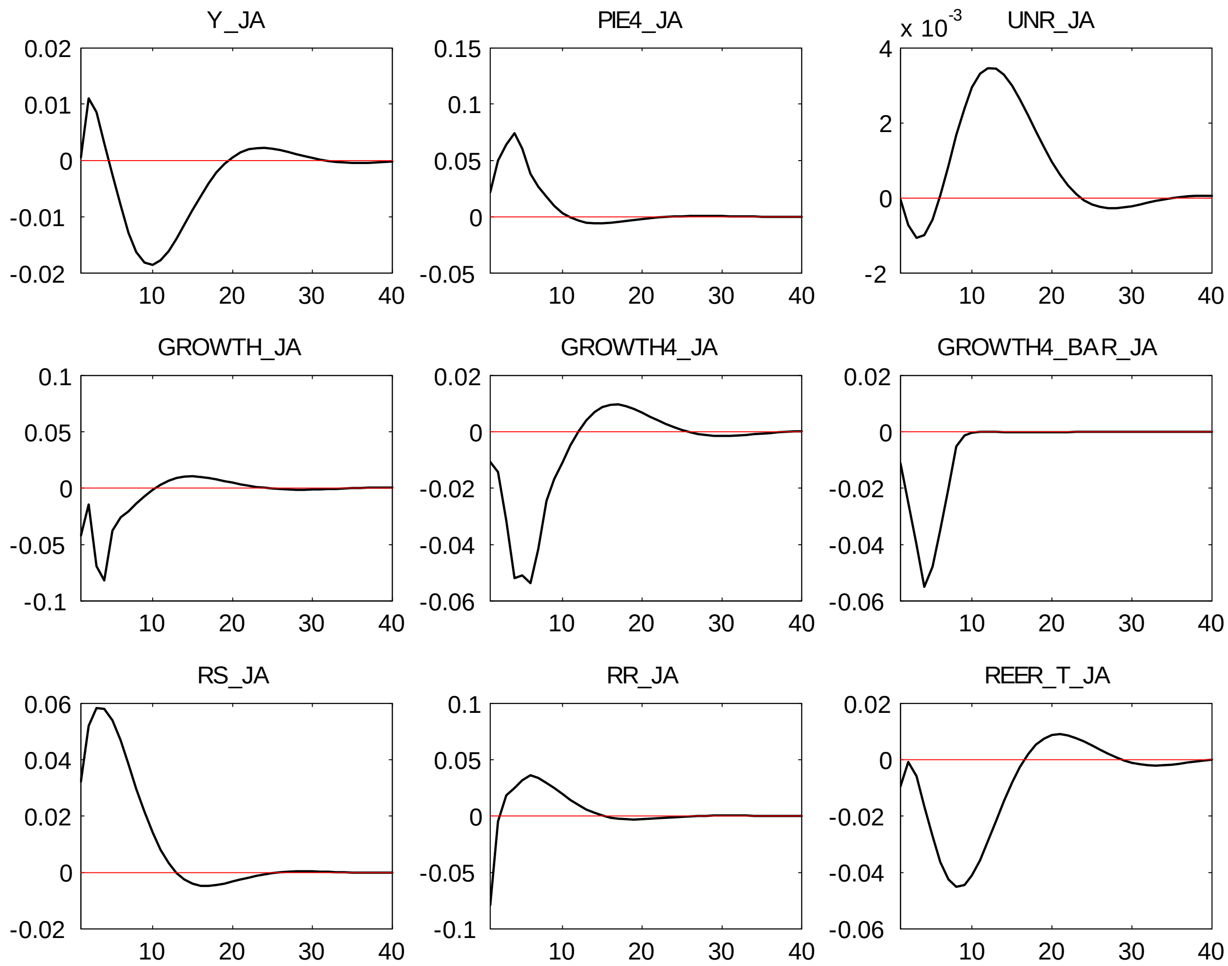


Figure 9: Oil Price Shock (3)



Forecasting with Bayesian estimates

- Various ways in which models can be used for out of sample forecasting
- Simplest, but least useful, allows model to forecast without any judgmental input
- More sophisticated approach, used in central banks and IMF, makes use of judgment of country experts to forecast endogenous variables for first two quarters or so ("nowcasting")
- Can easily replicate latter approach by tuning first couple of quarters

- In forecasts recently made with GPM plus oil model, used futures markets for oil prices and tuned first couple of quarters for conditional forecasts

- Also did almost-unconditional forecasts (dashed lines) and compared them with conditional

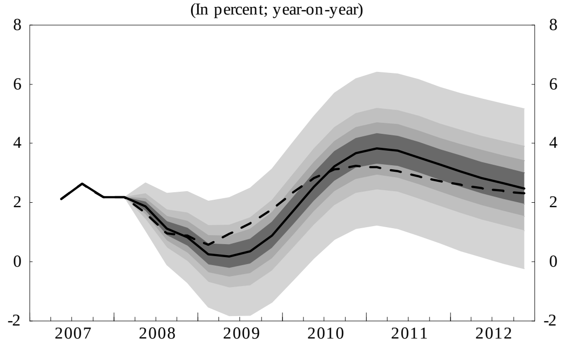
- Following figures are based on July 18 forecast. Marianne will present updated forecast shortly, based on more recent information.

Figure 10: Forecast Results [1]

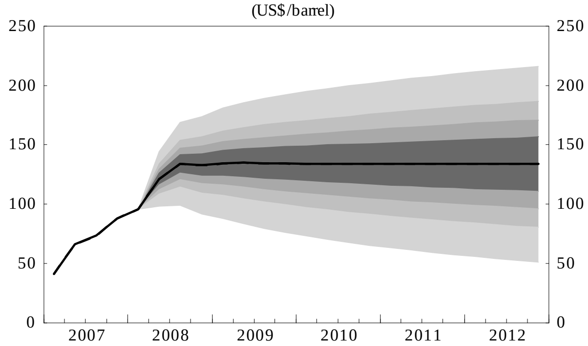
Summary: July 18 2008 Conditional Compared to July 18 2008 Unconditional

(Solid line=July 18 Conditional with 30%, 50%, 70% and 95% confidence bands; dashed line=July 18 Unconditional)

G3 Growth
(In percent; year-on-year)



Price of Oil
(US$/barrel)

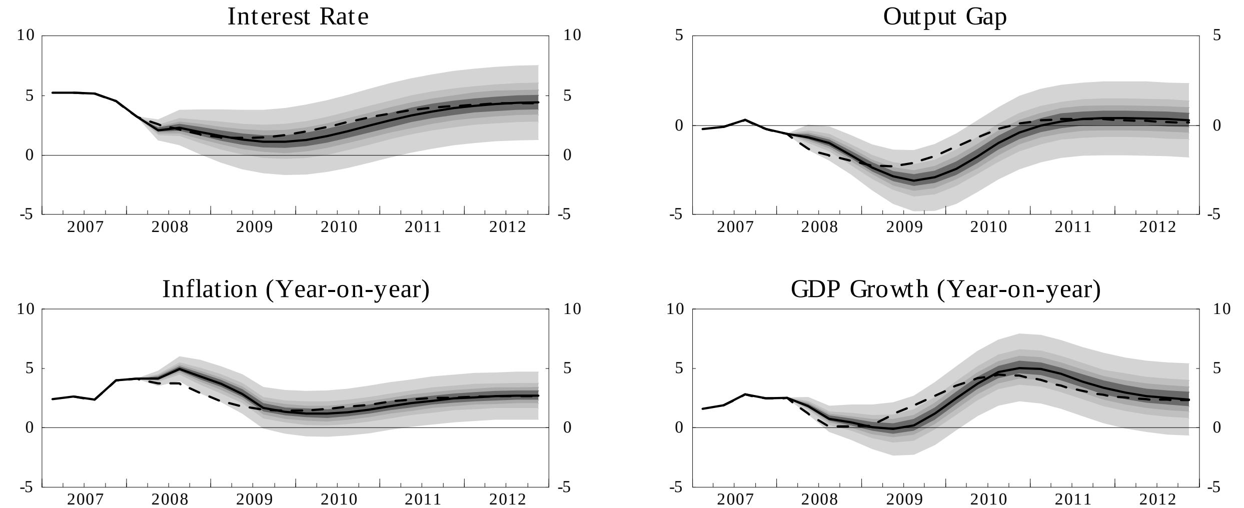


	Quarterly								Annual					
	2007		2008				2009							
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	2007	2008	2009	2010	2011	2012
Real GDP Growth (% y-o-y)														
G3 Growth	2.6	2.2	2.2	1.9	1.1	0.8	0.3	0.2	2.3	1.5	0.4	2.8	3.6	2.7
	[+0.0]	[+0.0]	[+0.0]	[+0.2]	[+0.2]	[-0.1]	[-0.3]	[-0.8]	[+0.0]	[+0.1]	[-0.7]	[-0.1]	[+0.6]	[+0.3]
United States	2.8	2.5	2.5	1.8	0.7	0.4	0.1	-0.1	2.2	1.4	0.3	4.0	4.2	2.6
	[+0.0]	[+0.0]	[+0.0]	[+0.6]	[+0.7]	[+0.3]	[-0.1]	[-1.2]	[+0.0]	[+0.4]	[-1.1]	[-0.2]	[+0.8]	[+0.2]
Euro Area	2.7	2.1	2.2	2.0	1.5	1.3	0.4	0.2	2.6	1.7	0.3	1.6	3.3	3.2
	[+0.0]	[+0.0]	[+0.0]	[-0.1]	[-0.3]	[-0.3]	[-0.5]	[-0.5]	[+0.0]	[-0.2]	[-0.5]	[-0.1]	[+0.5]	[+0.5]
Japan	1.9	1.4	1.1	1.6	1.5	1.0	0.5	1.0	2.0	1.3	1.0	1.6	2.1	2.0
	[+0.0]	[+0.0]	[+0.0]	[-0.4]	[-0.5]	[-0.5]	[-0.4]	[+0.1]	[+0.0]	[-0.4]	[+0.1]	[+0.0]	[+0.1]	[+0.1]
CPI Inflation (% y-o-y)														
United States	2.4	4.0	4.2	4.2	5.1	4.4	3.7	2.9	2.9	4.5	2.4	1.3	2.2	2.7
	[+0.0]	[+0.0]	[+0.0]	[+0.4]	[+1.3]	[+1.4]	[+1.4]	[+1.0]	[+0.0]	[+0.8]	[+0.6]	[-0.4]	[-0.3]	[+0.0]
Euro Area	1.9	2.9	3.4	3.6	3.9	3.6	3.0	2.4	2.1	3.6	2.0	0.4	0.9	1.9
	[+0.0]	[+0.0]	[+0.0]	[+0.2]	[+0.3]	[+0.7]	[+0.6]	[+0.4]	[+0.0]	[+0.3]	[+0.2]	[-0.6]	[-0.5]	[-0.0]

Figure 11: Forecast Results [2]

United States: July 18 2008 Conditional Compared to July 18 2008 Unconditional

(Solid line=July 18 Conditional with 30%, 50%, 70% and 95% confidence bands; dashed line=July 18 Unconditional)



	Quarterly								Annual					
	2007		2008				2009							
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	2007	2008	2009	2010	2011	2012
Short-term Interest Rate	5.2	4.5	3.2	2.1	2.3	1.9	1.6	1.3	5.0	2.4	1.3	1.8	3.5	4.3
	[+0.0]	[+0.0]	[+0.0]	[-0.5]	[+0.1]	[+0.2]	[+0.1]	[-0.1]	[+0.0]	[-0.0]	[-0.3]	[-0.8]	[-0.4]	[-0.0]
Bank Lending Tightening	17.8	32.2	52.4	63.6	67.9	64.0	53.9	40.1	19.4	62.0	33.1	0.5	-1.6	2.0
	[+0.0]	[+0.0]	[+0.0]	[+12.2]	[+20.4]	[+24.5]	[+24.4]	[+21.3]	[+0.0]	[+14.3]	[+18.0]	[+1.6]	[-2.5]	[-1.7]
Real GDP Growth														
% y-o-y	2.8	2.5	2.5	1.8	0.7	0.4	0.1	-0.1	2.2	1.4	0.3	4.0	4.2	2.6
	[+0.0]	[+0.0]	[+0.0]	[+0.6]	[+0.7]	[+0.3]	[-0.1]	[-1.2]	[+0.0]	[+0.4]	[-1.1]	[-0.2]	[+0.8]	[+0.2]
% q@ar	4.9	0.6	0.9	1.0	0.5	-0.6	-0.6	0.4						
	[+0.0]	[+0.0]	[+0.0]	[+2.5]	[+0.1]	[-1.5]	[-1.7]	[-1.8]						
Potential GDP Growth														

Addition of more countries

- In principle, could simply add more countries to model and estimate it in the normal way

- Unfortunately, time needed to estimate model increases very rapidly as size of model increases

- Full re-estimation of three country model with oil and with additional country takes 4-6 hours

- Needed alternative way of handling additional countries, at least initially

- Three approaches – do not allow additional country to affect estimation or simulation; allow additional country to affect simulation but not estimation; allow additional country to affect both estimation and simulation

- First way is to freeze results of three country model without oil (i.e., treat the output of the three country model as exogenously given) and then estimate extra country by itself

- Not unreasonable, if one thinks that addition of another small country unlikely to have much effect on estimates of parameters and variance of disturbances of large countries, or feedback to large countries in simulation

- Second approach is to allow feedback in part but not totally

- For example, might allow increase in demand in additional country to affect aggregate demand in large countries (IRF), but still in context of frozen coefficients of large countries

- Both of these much faster than full re-estimation and therefore facilitate experimentation with coefficients of additional country

- Third, when additional country is large, or important in a certain way (e.g., oil-producing countries can affect oil market), may want to allow additional country to influence coefficient estimates in large countries or in certain sector (e.g., oil sector)

- So far, we have used second approach to add the five IT Latin American countries individually and a Latin American aggregate based on weighted average of the five countries

- Also, initially used second approach to add Indonesia to three country model

- But ran into problems of ZLB in Japan because of magnification of weight of Indonesia in Japanese exports in simulations with only four countries in model

- Switched to first approach

- "How-to" paper will be prepared to facilitate addition of SOEs to the system by central banks

Future steps

1. introduction of more financial variables (e.g., bond spreads, CDS spreads, swap spreads, etc.) to help account for financial-real linkages and country risk premiums

2. use of both total CPI and core CPI in model

3. more articulated oil price sector; possible introduction of other commodity prices

4. more countries (individual and regions or groups, e.g., China, rest of emerging Asia, ROW, possibly oil exporters)

5. integration of model with imperfect credibility models

6. increased use of nonlinearities such as ZLB

7. comparison of forecast with other competitor models