A Small Quarterly Multi-Country Projection Model

IOAN CARABENCIOV
International Monetary Fund

IGOR ERMOLAEV
Bank of Russia

CHARLES FREEDMAN
International Monetary Fund

MICHEL JUILLARD
Paris School of Economics and CEPREMAP

ONDRA KAMENIK
International Monetary Fund

DMITRY KORSHUNOV
Bank of Russia

DOUGLAS LAXTON
International Monetary Fund

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Introduction

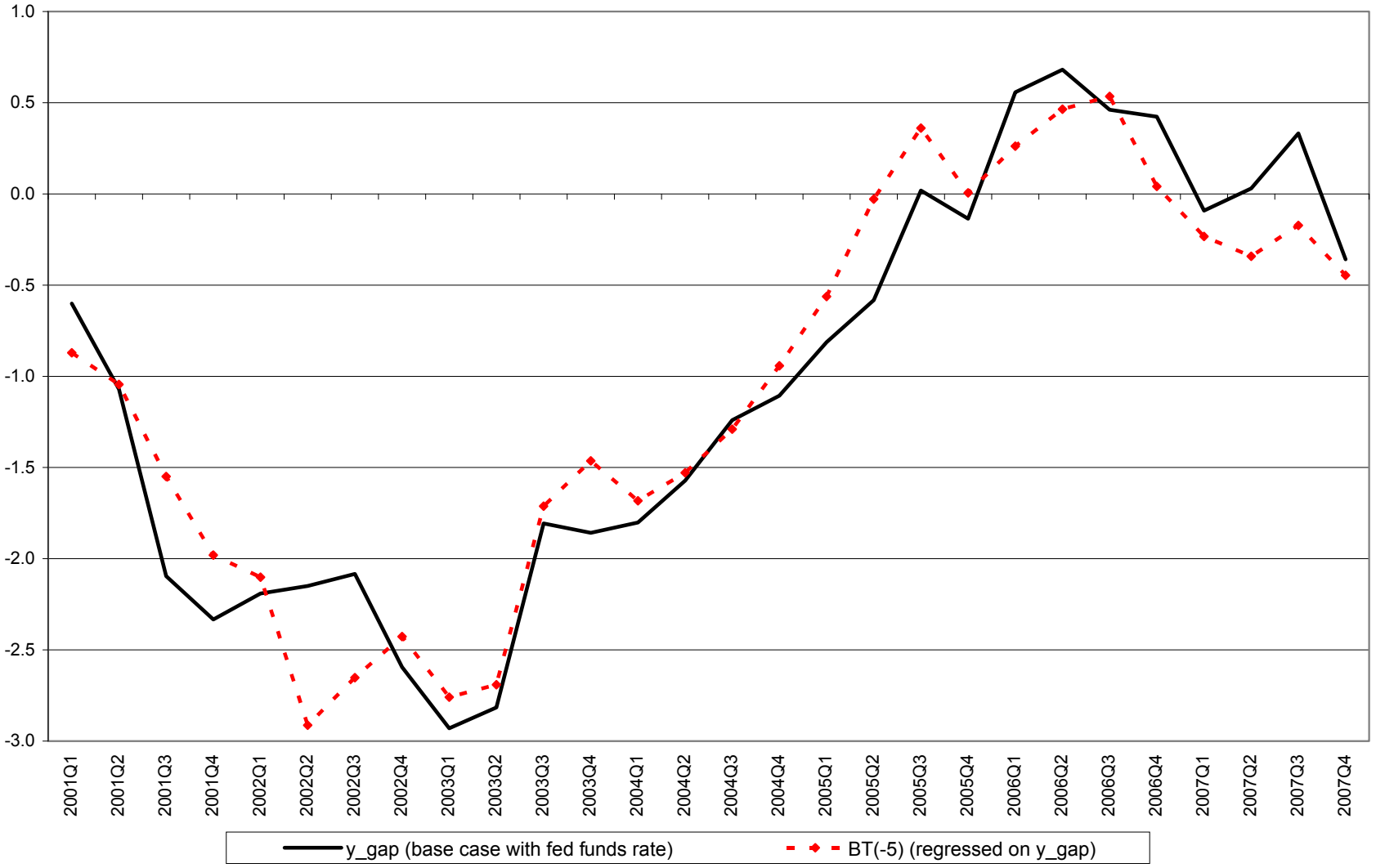
- Estimate a small Global Projection Model (GPM) that includes the United States, Euro Area and Japan using data on GDP, unemployment, inflation and the short-term interest rates

- Add information on Bank Lending Tightness (BLT) to the U.S. model

Main Results

- The model produces plausible forecasts and sensible IRFs
- BLT variable provides an important leading indicator role
- The model predicts significant weakness in the U.S., European and Japanese economies in 2008

Figure 1: BLT and the US Output Gap



The US economy over the sample period

- In 1994, as the economy completed its recovery from the recession of 1990-1991 the Fed raised its policy interest rate towards a more neutral, less stimulative level.

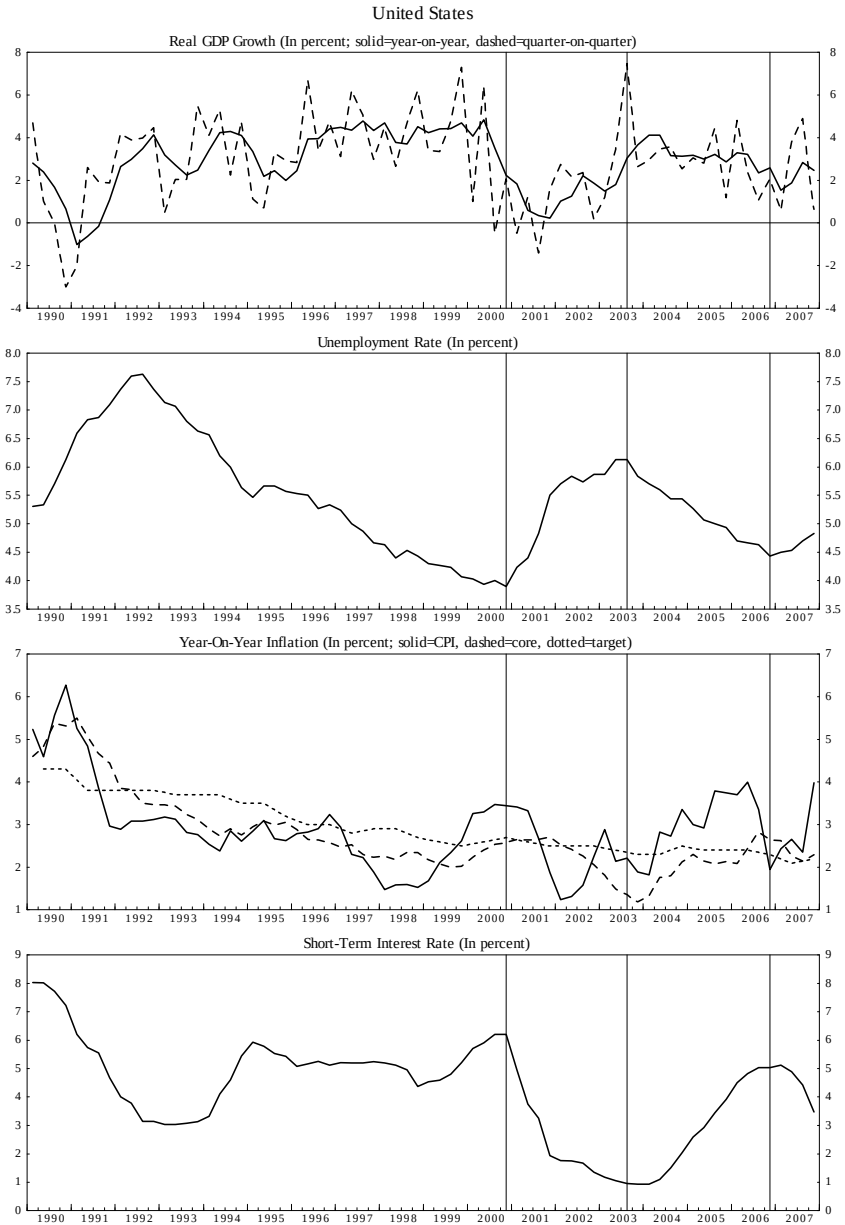
- Over the period 1996 to 1999, the economy continued to grow at a fairly rapid pace, with unemployment falling.

- In response to concerns about inflationary pressures the Fed began to raise interest rates gradually through 1999 and into 2000. GDP growth slowed partly in response to the high tech slowdown and the fall in the stock market.

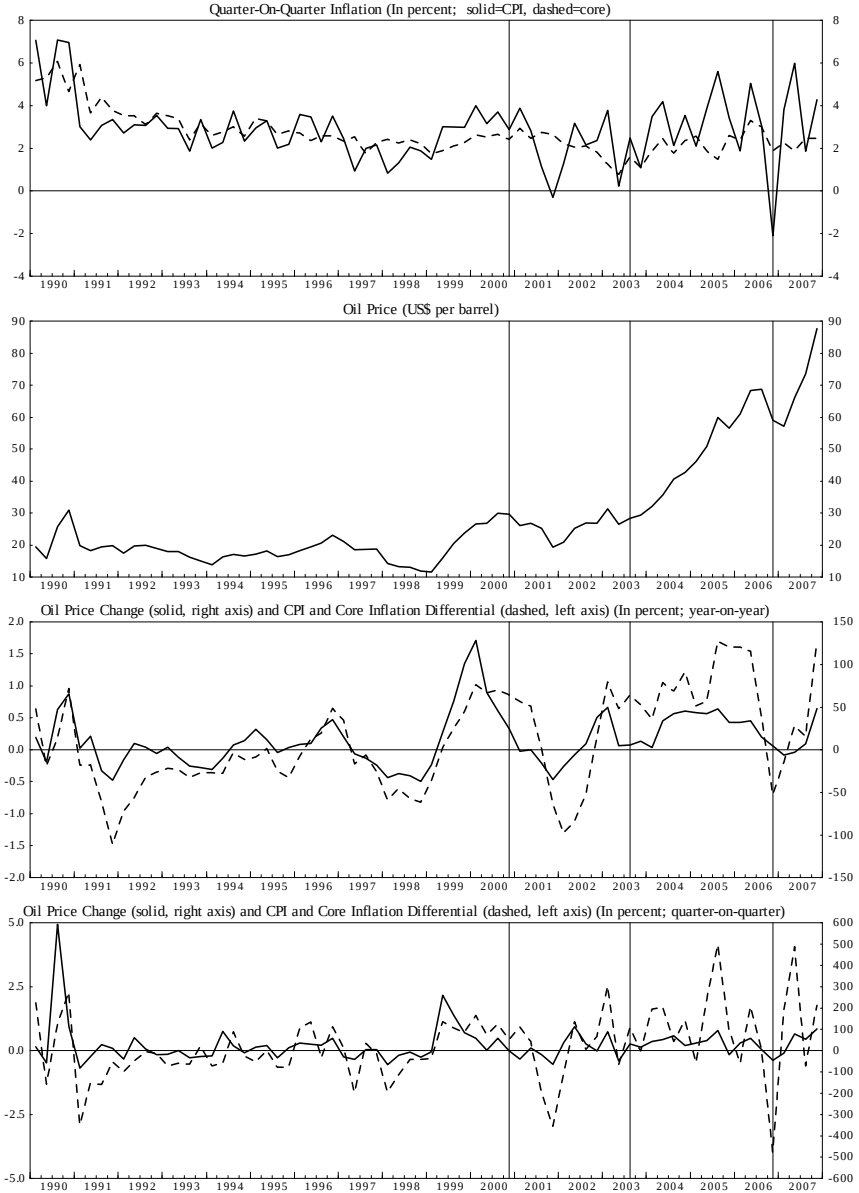
The US economy over the sample period (cont.)

- The Fed gradually reduced its policy interest rate with the decline of inflation to very low levels. The period of low interest rates was successful in reinvigorating the economy and causing unemployment to decline from a peak of about 6% in 2003 to a through of about 4.5% in 2006.

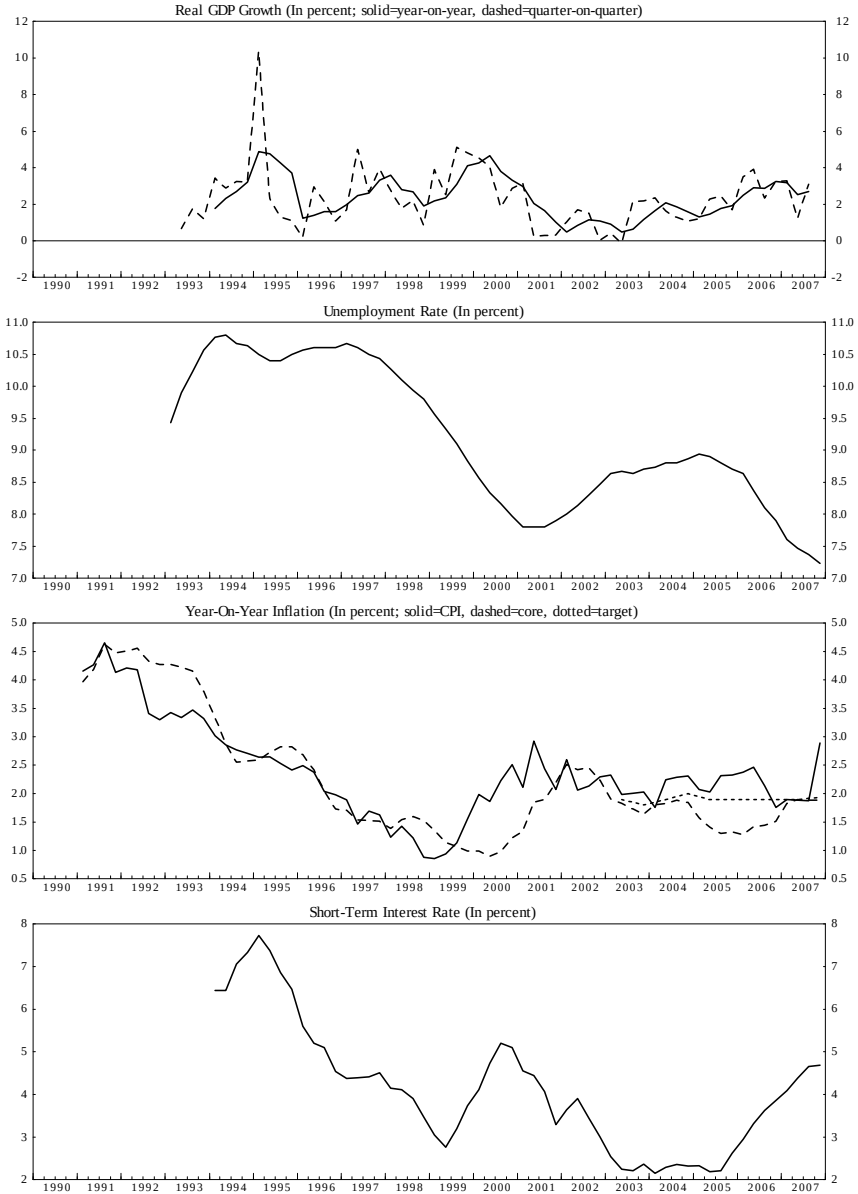
- Finally, over the past year, the end of the housing price boom, the liquidity problems in the asset-backed commercial paper market, and the problems faced by holders of structured financial instruments have together led to a negative outlook for the United States


United States
Real GDP Growth (In percent; solid=year-on-year, dashed=quarter-on-quarter)
Unemployment Rate (In percent)
Year-On-Year Inflation (In percent; solid=CPI, dashed=core, dotted=target)
Short-Term Interest Rate (In percent)

United States



Euro Area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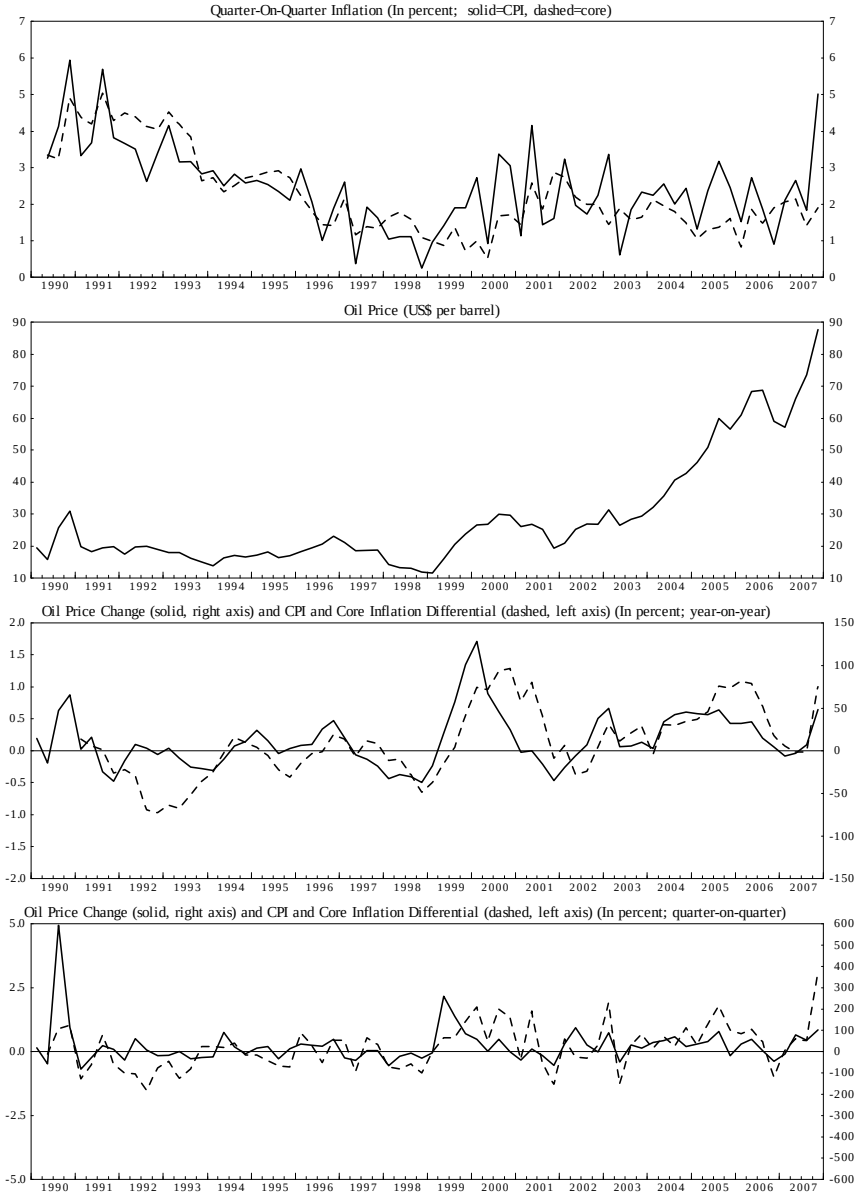
Unemployment Rate (In percent)
Year-On-Year Inflation (In percent; solid=CPI, dashed=core, dotted=target)
Short-Term Interest Rate (In percent)
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007

Euro Area


Quarter-On-Quarter Inflation (In percent; solid=CPI, dashed=core)
Oil Price (US$ per barrel)
Oil Price Change (solid, right axis) and CPI and Core Inflation Differential (dashed, left axis) (In percent; year-on-year)
Oil Price Change (solid, right axis) and CPI and Core Inflation Differential (dashed, left axis) (In percent; quarter-on-quarter)
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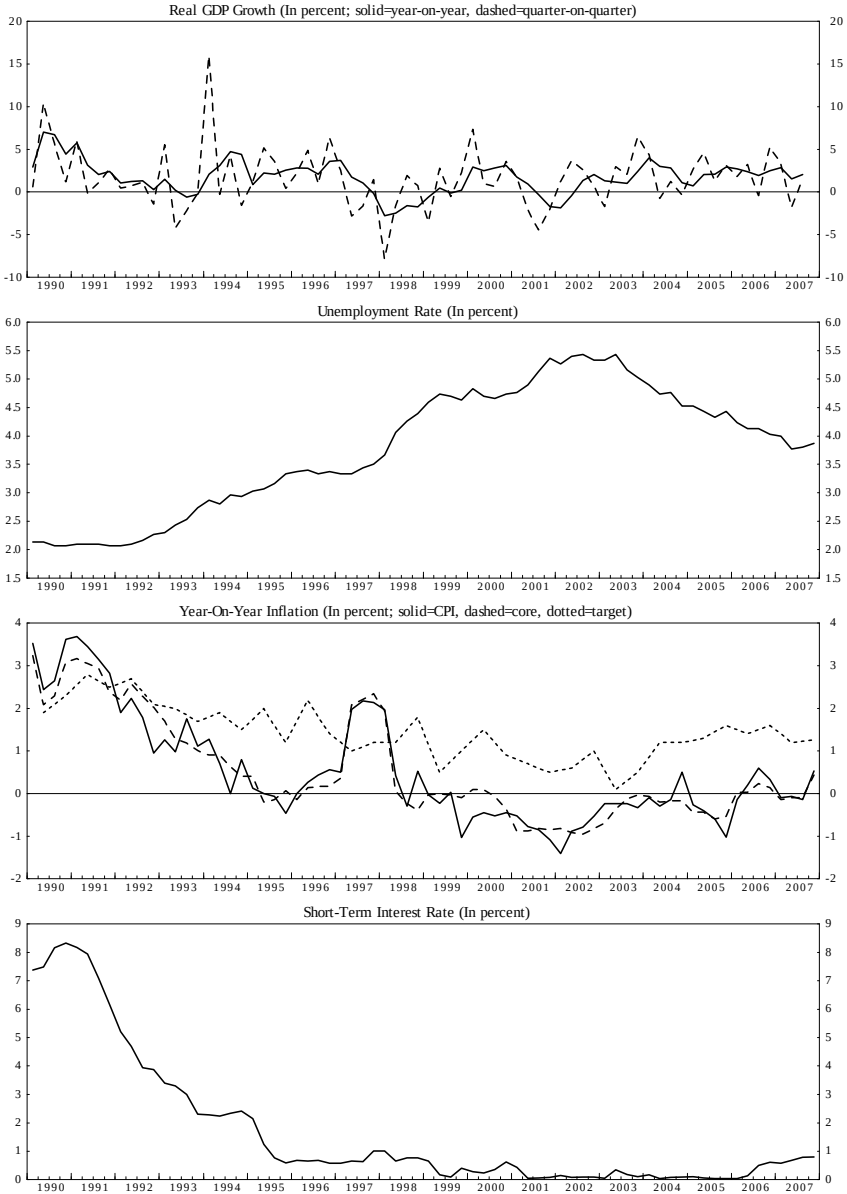
Japan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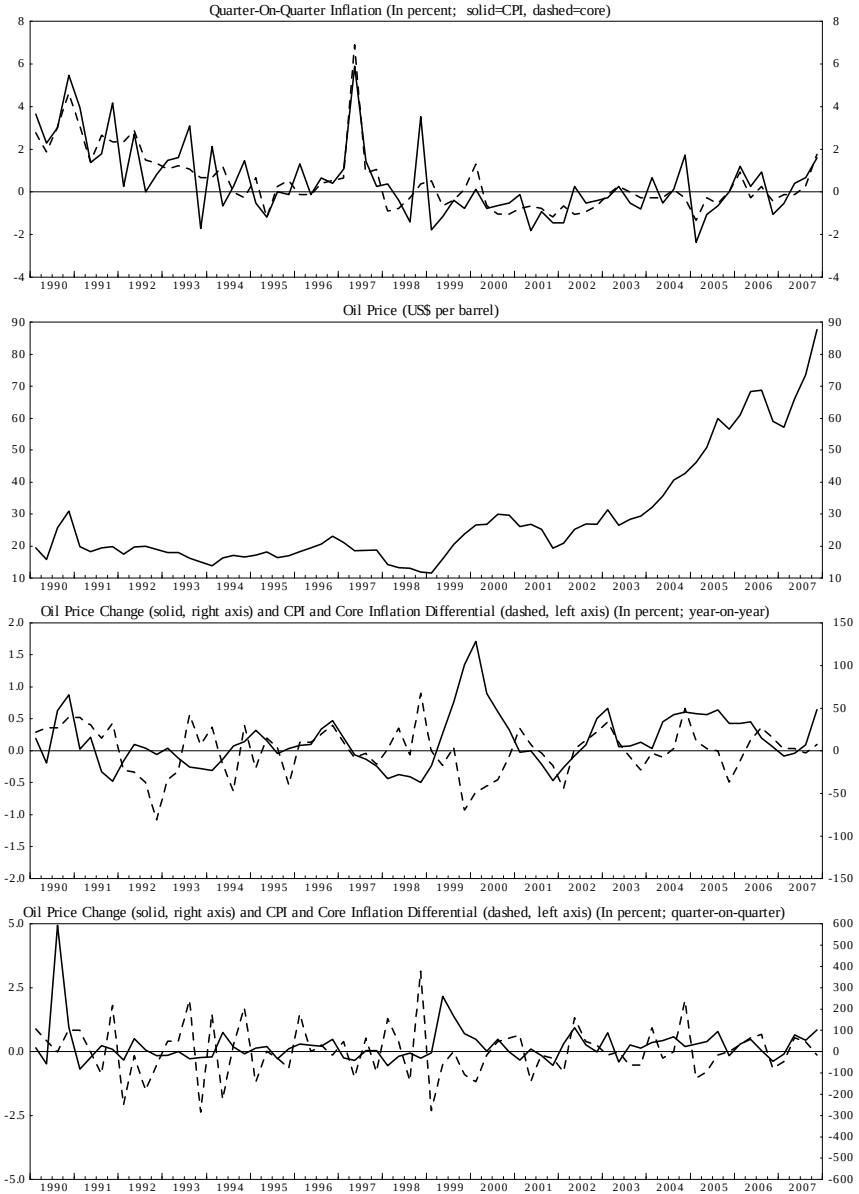
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1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007

The Model (US Part)

- Headline Inflation
- Output Gap
- Reaction Function
- Unemployment Gap

1. Inflation Equation

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

- Backward and Forward-Looking Components ($\lambda_1 \pi 4_{t+4} + (1 - \lambda_1)\pi 4_{t-1}$)
- Output Gap ($\lambda_2 y_{t-1}$)
- Change in Real Effective Exchange Rate ($\lambda_3 \Delta Reerm_t$)
- Supply Shock (ε_t^{π})

2. Output Gap Equation

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t+1} - \beta_3 r_{t-1} + \beta_4 \sum_j \omega_{j,4} z_{j,t-1} + \beta_5 \sum_j \omega_{j,5} y_{j,t-1} + \varepsilon_t^y \quad (2)$$

- Backward and Forward-Looking Components ($\beta_1 y_{t-1} + \beta_2 y_{t+1}$)
- Real Interest Rate Gap $\beta_3 \mathrm{r}_{t-1} = \beta_3(\mathrm{rr}_{t-1} - \overline{rr}_{t-1})$
- Effective Real Exchange Rate Gap ($\beta_4 \sum_j \omega_{j,4} z_{j,t-1}$)

- Foreign Output Gap ($\beta_5 \sum_j \omega_{j,5} y_{j,t-1}$)

- Demand Shock (ε_t^y)

3. Reaction Function Equation

$$\begin{aligned} rs_t &= (1-\gamma_1)\left[\overline{rr}_t + \pi 4_{t+3} + \gamma_2(\pi 4_{t+3} - \pi^{tar}) + \gamma_4 y_t\right] \\ &\quad +\gamma_1 rs_{t-1} + \varepsilon_t^{rs} \end{aligned}$$

- Expected 1-Year-Ahead Y-O-Y Inflation Gap $\gamma_2(\pi 4_{t+4} - \pi^{tar})$
- Inertia $\gamma_1(rs_{t-1})$
- Output Gap $\gamma_4(y_t)$
- Discretionary or Random Component of Monetary Policy (ε_t^{rs})

4. Unemployment Gap Equation (Dynamic Okun's Law)

$$(u_t - \overline{u}_t) = \alpha_1(u_{t-1} - \overline{u}_{t-1}) + \alpha_2 y_t + \varepsilon_t^{(u_t - \overline{u}_t)}$$

- Inertia $\alpha_1(u_{t-1} - \overline{u}_{t-1})$
- Output Gap $\alpha_2 y_t$
- Shock $\varepsilon_t^{(u_t - \overline{u}_t)}$

5. NAIRU Process

$$\begin{aligned} \overline{u}_t &= \overline{u}_{t-1} + ug_t + \varepsilon_t^{\overline{u}} \\ ug_t &= (1-\alpha_3)ug_{t-1} + \varepsilon_t^{ug} \end{aligned}$$

- Level shocks to NAIRU ($\varepsilon_t^{\overline{u}}$)

- Shock to NAIRU Growth (ε_t^{ug})

6. Potential Output Process

$$\begin{aligned} \overline{y}_t &= \overline{y}_{t-1} + g_t/4 + \varepsilon_t^{\overline{y}} \\ g_t &= \tau g^{ss} + (1-\tau) g_{t-1} + \varepsilon_t^{g} \end{aligned}$$

- Level shocks to potential output ($\epsilon_t^{\overline{y}}$)
- Persistence deviations in potential growth from long-run growth ($\tau g^{ss} + (1 - \tau) g_{t-1}$)
- Shock to Potential Growth (ε_t^{g})

7. Equilibrium Real Interest Rate Process

$$\overline{rr}_t = \rho \overline{rr}_t^{ss} + (1-\rho)\overline{rr}_{t-1} + \varepsilon_t^{\overline{rr}}$$

- Persistence deviations in equlibrium real interest rate ($\overline{rr}_t$) from its steady-state rate($\overline{rr}_t^{ss}$)

The Model with BLT

- Bank Lending Tightness (BLT) index

- Stronger Macro-financial linkages

Simple Measure of BLT Based on Fed's Senior Loan Officer Survey

$$BLT_t = 0.25(CILF_t + CISF_t + CR_t + RM_t)$$

- Commercial and industrial loans for large firms ($CILF_t$)
- Commercial and industrial loans for small firms ($CISF_t$)
- Commercial real estate loans (CR_t)
- Residential mortgage loans (RM_t)

Model Extensions for Macro-financial linkages(1)

$$\begin{aligned} BLT_t - \overline{BLT}_t &= -\kappa y_{t+4} + \varepsilon_t^{BLT} \\ \overline{BLT}_t &= \overline{BLT}_{t-1} + \varepsilon_t^{\overline{BLT}} \end{aligned}$$

- BLT gap ($BLT_t - \overline{BLT}_t$) depends on the expected output gap one year ahead

- BLT index depends on shifts in its equilibrium level ($\overline{BLT}_t$)

Model Extensions for Macro-financial linkages (2)

$$
\begin{aligned}
y_t &= \beta_1 y_{t-1} + \beta_2 y_{t+1} - \beta_3 (rr_{t-1} - \overline{rr}_{t-1}) - \theta(\eta_t^{BLT}) \\
\eta_t^{BLT} &= 0.04(\varepsilon_{t-1}^{BLT} + \varepsilon_{t-9}^{BLT}) + 0.08(\varepsilon_{t-2}^{BLT} + \varepsilon_{t-8}^{BLT}) \\
&\quad + 0.12(\varepsilon_{t-3}^{BLT} + \varepsilon_{t-7}^{BLT}) + 0.16(\varepsilon_{t-4}^{BLT} + \varepsilon_{t-6}^{BLT}) + 0.20\varepsilon_{t-5}^{BLT}
\end{aligned}
$$

- Effect of innovations in BLT equation on output gap ($\theta(\eta_t^{BLT})$)
- Distributed lags of innovations in BLT equation (ε_t^{BLT})

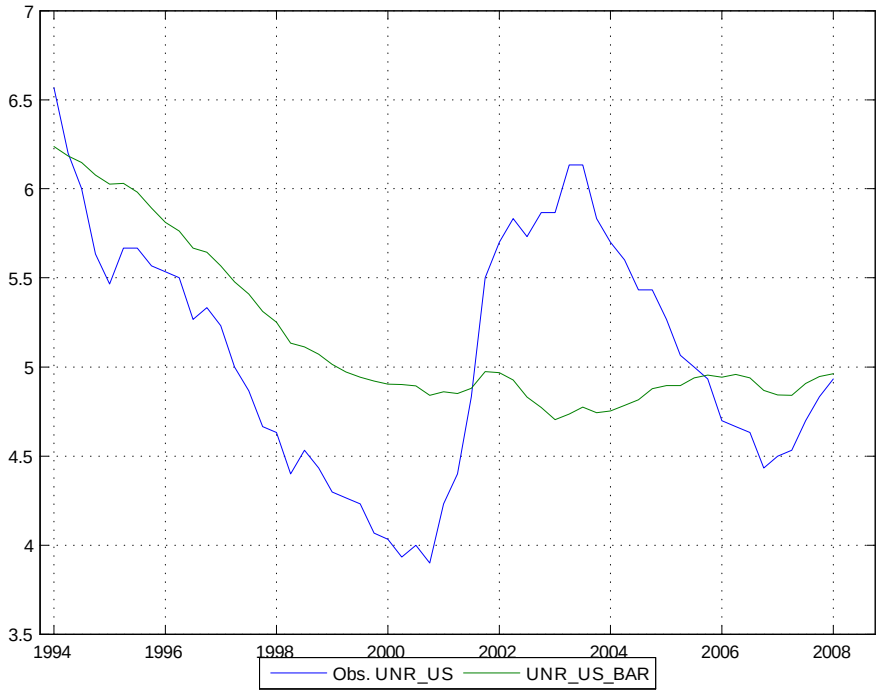
Observable Variables

- CPI, unemployment rate, Interest rate, real GDP, BLT index
- Sample without near-term judgment is 1994q1 to 2008q1
- Compare results with near-term judgment from 2008q2 and conditional forecast

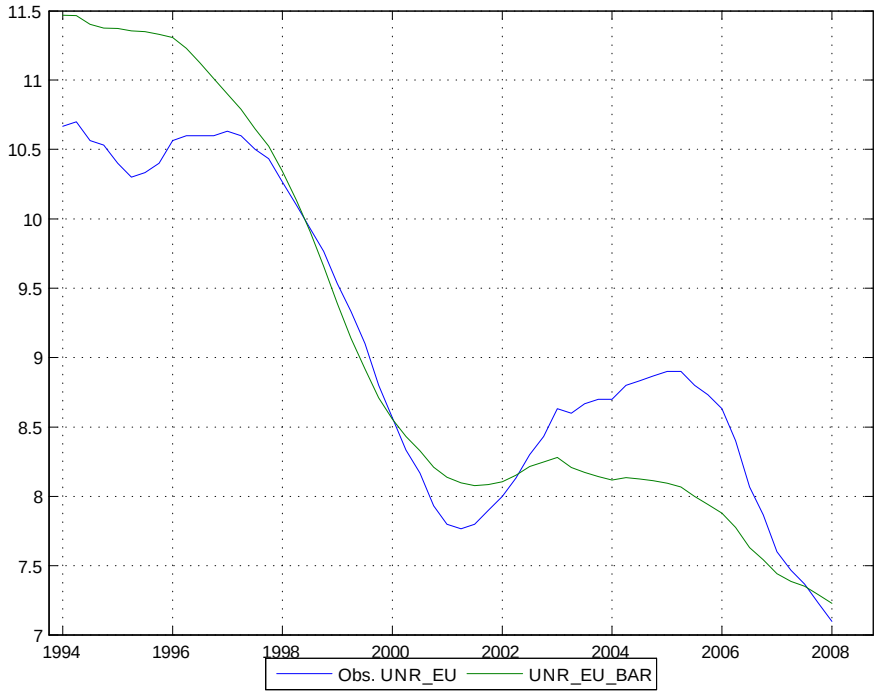
Summary of the Open-Economy Linkages

- Real exchange rate gap in the output gap equation: $\beta_4 \sum_j \omega_{j,4} z_{j,t-1}$
- Foreign output gaps in the domestic output equation: $\beta_5 \sum_j \omega_{j,5} y_{j,t-1}$
- Change in real exchange rate in the inflation equation: $\lambda_3 \Delta Reerm_t$
- UIP equation: $rr_t - rr_t^{us} = 4(lz_t^e - lz_t) + \overline{rr}_t - \overline{rr}_t^{us} + \varepsilon_t^{UIP}$
- Exchange Rate Expectations: $lz_t^e = \phi z_{t+1} + (1-\phi) z_{t-1}$

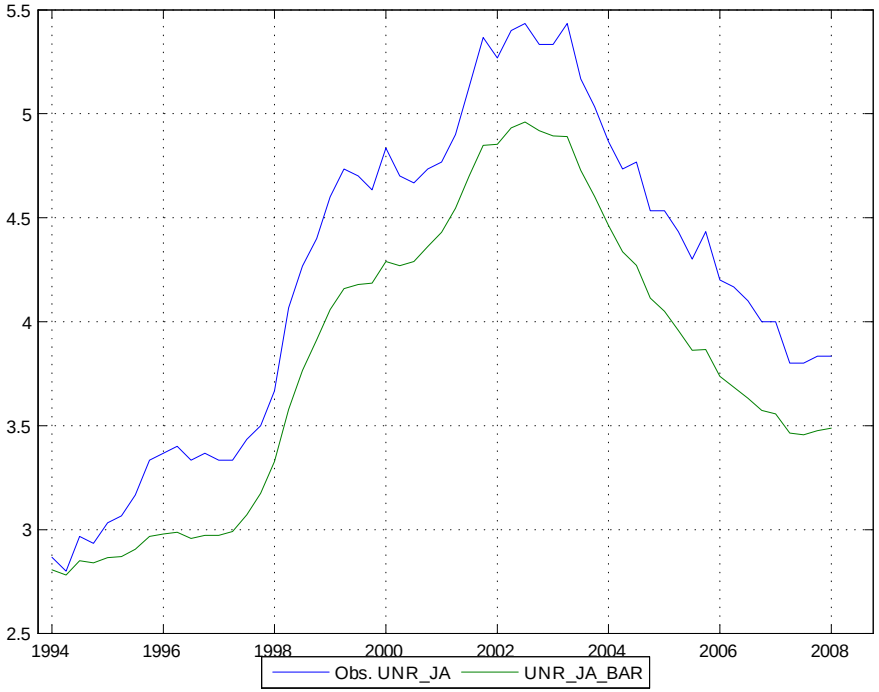
Unemployment and Model-Consistent NAIRU



U.S.

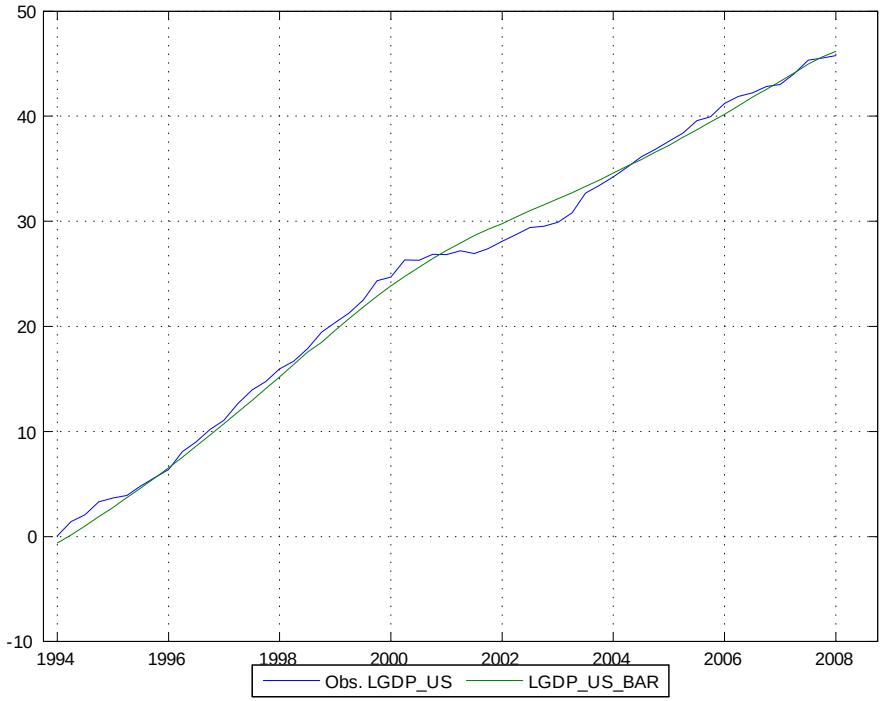


Europe

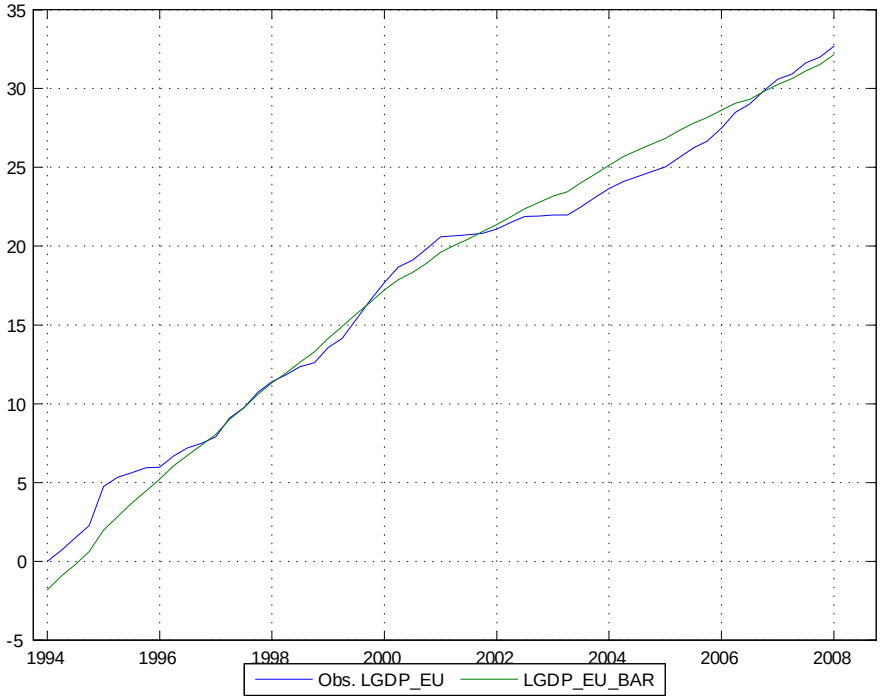

5.5
5
4.5
4
3.5
3
2.5
1994
1996
1998
2000
2002
2004
2006
2008
Obs. UNR_JA
UNR_JA_BAR

JA

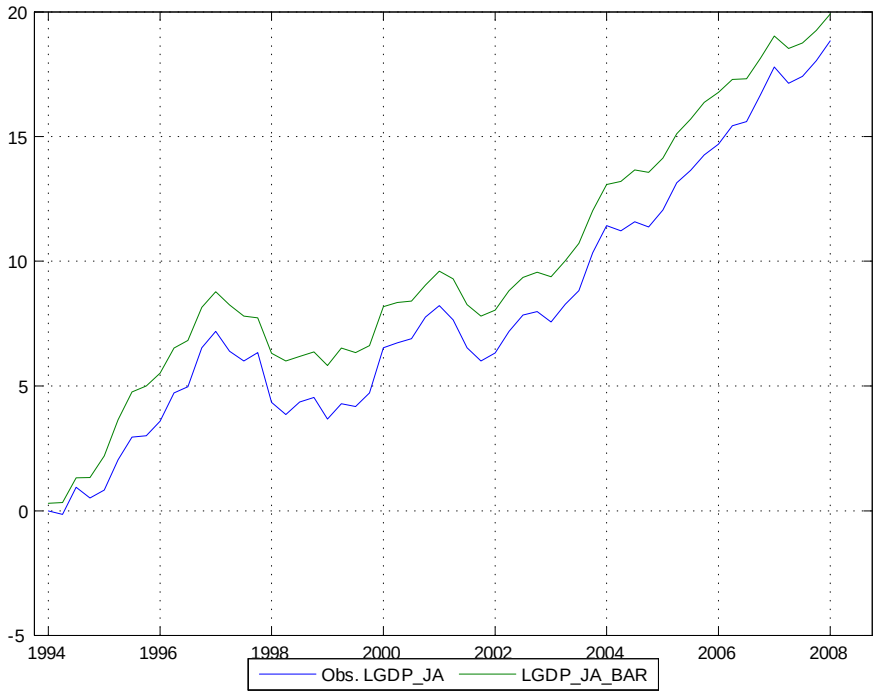
GDP and Model-Consistent GDP



U.S.



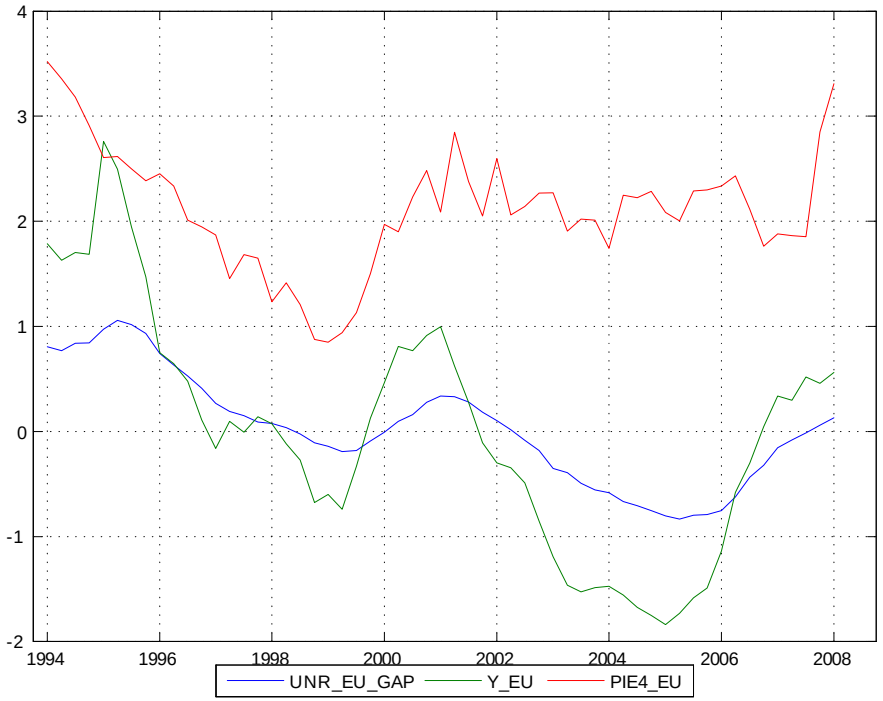
Europe


20
15
10
5
0
-5
1994
1996
1998
2000
2002
2004
2006
2008
Obs. LGDP_JA
LGDP_JA_BAR

JA

GDP Gap, Unemployment Gap, and Inflation

U.S.



Europe


2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1994
1996
1998
2000
2002
2004
2006
2008
UNR_JA_GAP
Y_JA
PIE4_JA

JA

The Properties of the Model

- Posterior Maximization (parameters and standard deviations of structural shocks)

- Analisys of Impulse Response Functions

Table 1: Results from posterior maximization [1]

	Prior distribution	Prior mean	Prior s.d.	Posterior mode	s.d.
$alpha1\_EU$	beta	0.750	0.1000	0.7313	0.0675
$alpha1\_JA$	beta	0.750	0.1000	0.7590	0.1102
$alpha1\_US$	beta	0.750	0.1000	0.7833	0.0574
$alpha2\_EU$	gamm	0.300	0.1000	0.1411	0.0273
$alpha2\_JA$	gamm	0.100	0.0500	0.0673	0.0297
$alpha2\_US$	gamm	0.300	0.1000	0.1913	0.0303
$alpha3\_EU$	beta	0.500	0.2000	0.1092	0.0495
$alpha3\_JA$	beta	0.500	0.2000	0.2158	0.1082
$alpha3\_US$	beta	0.500	0.2000	0.2553	0.1820
$beta\_fact\_EU$	gamm	0.052	0.0100	0.0527	0.0102
$beta\_fact\_JA$	gamm	0.045	0.0100	0.0423	0.0098
$beta\_fact\_US$	gamm	0.030	0.0100	0.0254	0.0089
$beta\_reergap\_EU$	gamm	0.104	0.0400	0.0527	0.0226
$beta\_reergap\_JA$	gamm	0.090	0.0400	0.0522	0.0318
$beta\_reergap\_US$	gamm	0.060	0.0200	0.0488	0.0165
$beta1\_EU$	gamm	0.750	0.1000	0.8927	0.0650
$beta1\_JA$	gamm	0.750	0.1000	0.8520	0.1533
$beta1\_US$	gamm	0.750	0.1000	0.6682	0.0599

Table 2: Results from posterior maximization [2]

	Prior distribution	Prior mean	Prior s.d.	Posterior mode	s.d.
$beta2\_EU$	beta	0.100	0.0500	0.1182	0.0592
$beta2\_JA$	beta	0.100	0.0500	0.0719	0.0416
$beta2\_US$	beta	0.100	0.0500	0.0784	0.0459
$beta3\_EU$	gamm	0.200	0.0500	0.2175	0.0482
$beta3\_JA$	gamm	0.200	0.0500	0.1473	0.0387
$beta3\_US$	gamm	0.200	0.0500	0.1909	0.0450
$gamma1\_EU$	beta	0.500	0.0500	0.6487	0.0383
$gamma1\_JA$	beta	0.500	0.0500	0.7549	0.0350
$gamma1\_US$	beta	0.500	0.0500	0.7162	0.0337
$gamma2\_EU$	gamm	1.500	0.2000	1.2183	0.1638
$gamma2\_JA$	gamm	1.500	0.2000	1.1154	0.1558
$gamma2\_US$	gamm	1.500	0.3000	0.8756	0.1841
$gamma4\_EU$	gamm	0.200	0.0500	0.1817	0.0468
$gamma4\_JA$	gamm	0.200	0.0500	0.1740	0.0452
$gamma4\_US$	gamm	0.200	0.0500	0.2076	0.0530
$growth\_EU\_ss$	norm	2.000	0.5000	2.2546	0.3410
$growth\_JA\_ss$	norm	1.700	0.5000	1.6001	0.3018
$growth\_US\_ss$	norm	2.500	0.2500	2.5661	0.2421

Table 3: Results from posterior maximization [3]

	Prior distribution	Prior mean	Prior s.d.	Posterior mode	s.d.
$kappa\_US$	gamm	20.000	0.5000	20.0200	0.4971
$lambda1\_EU$	beta	0.700	0.1000	0.8110	0.0684
$lambda1\_JA$	beta	0.700	0.1000	0.8922	0.0468
$lambda1\_US$	beta	0.700	0.1000	0.8458	0.0564
$lambda2\_EU$	gamm	0.250	0.0500	0.2326	0.0440
$lambda2\_JA$	gamm	0.250	0.0500	0.2001	0.0459
$lambda2\_US$	gamm	0.200	0.0500	0.1815	0.0389
$lambda3\_EU$	gamm	0.208	0.0500	0.1006	0.0211
$lambda3\_JA$	gamm	0.180	0.0500	0.0759	0.0206
$lambda3\_US$	gamm	0.120	0.0500	0.0660	0.0255
phi_EU	beta	0.500	0.2000	0.8360	0.0662
phi_JA	beta	0.500	0.2000	0.8288	0.0704

Table 4: Results from posterior maximization [4]

	Prior distribution	Prior mean	Prior s.d.	Posterior mode	s.d.
$pietar\_EU\_ss$	gamm	2.000	0.5000	2.3330	0.1740
$pietar\_JA\_ss$	gamm	1.000	0.3000	0.4541	0.1829
$pietar\_US\_ss$	gamm	2.500	0.5000	2.7285	0.2825
rho_EU	beta	0.500	0.1000	0.1903	0.0654
rho_JA	beta	0.500	0.1000	0.4946	0.1079
rho_US	beta	0.500	0.1000	0.2763	0.0667
$rr\_bar\_EU\_ss$	norm	2.000	0.3000	2.1660	0.2115
$rr\_bar\_JA\_ss$	norm	2.000	0.3000	0.9300	0.4457
$rr\_bar\_US\_ss$	norm	2.000	0.3000	1.9344	0.2489
tau_EU	beta	0.050	0.0300	0.0249	0.0169
tau_JA	beta	0.050	0.0300	0.0374	0.0251
tau_US	beta	0.050	0.0300	0.0425	0.0253
$theta\_US$	gamm	1.000	0.5000	1.0902	0.5582

Table 5: Results from posterior parameters (std deviation of structural shocks)

	Prior distribution	Prior mean	Prior s.d.	Posterior mode	s.d.
$RES\_BLT\_BAR\_US$	invg	0.200	Inf	0.0922	0.0377
RES_BLT_US	invg	0.400	Inf	0.9476	0.4595
RES_G_EU	invg	0.100	0.0500	0.1136	0.0346
RES_G_JA	invg	0.100	0.0500	0.0726	0.0226
RES_G_US	invg	0.100	Inf	0.2923	0.0672
$RES\_LGDP\_BAR\_EU$	invg	0.200	0.0500	0.1813	0.0339
$RES\_LGDP\_BAR\_JA$	invg	0.200	0.0500	0.6020	0.0736
$RES\_LGDP\_BAR\_US$	invg	0.050	0.0500	0.0291	0.0112
$RES\_LZ\_BAR\_EU$	invg	1.000	Inf	4.3397	0.5651
$RES\_LZ\_BAR\_JA$	invg	4.000	Inf	5.8132	0.8121
RES_PIE_EU	invg	0.500	Inf	1.0650	0.1205
RES_PIE_JA	invg	1.000	Inf	1.3529	0.1418
RES_PIE_US	invg	0.700	Inf	1.2537	0.1213
$RES\_RR\_BAR\_EU$	invg	0.200	0.0400	0.1890	0.0358
$RES\_RR\_BAR\_JA$	invg	0.100	0.0400	0.0795	0.0232
$RES\_RR\_BAR\_US$	invg	0.200	Inf	0.9459	0.1600

Table 6: Results from posterior parameters (std deviation of structural shocks) [2]

	Prior distribution	Prior mean	Prior s.d.	Posterior mode	s.d.
$RES\_RR\_DIFF\_EU$	invg	1.000	Inf	0.4615	0.1891
$RES\_RR\_DIFF\_JA$	invg	0.500	Inf	0.2302	0.0939
RES_RS_EU	invg	0.250	Inf	0.2507	0.0322
RES_RS_JA	invg	0.250	Inf	0.2334	0.0340
RES_RS_US	invg	0.700	Inf	0.2407	0.0439
$RES\_UNR\_BAR\_EU$	invg	0.100	Inf	0.0304	0.0065
$RES\_UNR\_BAR\_JA$	invg	0.100	Inf	0.0533	0.0322
$RES\_UNR\_BAR\_US$	invg	0.100	Inf	0.0474	0.0203
$RES\_UNR\_G\_EU$	invg	0.100	Inf	0.0398	0.0074
$RES\_UNR\_G\_JA$	invg	0.100	Inf	0.0516	0.0148
$RES\_UNR\_G\_US$	invg	0.100	Inf	0.0472	0.0175
$RES\_UNR\_GAP\_EU$	invg	0.200	Inf	0.0433	0.0061
$RES\_UNR\_GAP\_JA$	invg	0.100	Inf	0.0724	0.0230
$RES\_UNR\_GAP\_US$	invg	0.200	Inf	0.0967	0.0157
RES_Y_EU	invg	0.300	0.0500	0.2585	0.0323
RES_Y_JA	invg	0.500	0.1000	0.3922	0.0568
RES_Y_US	invg	0.250	Inf	0.3525	0.0410

Table 7: Results from posterior parameters (correlation of structural shocks)

	Prior distribution	Prior mean	Prior s.d.	Posterior mode	s.d.
$RES\_LGDP\_BAR\_US, RES\_PIE\_US$	beta	0.100	0.0300	0.0915	0.0292
RES_BLT_US, RES_G_US	beta	0.900	0.0500	0.8763	0.0564
$RES\_LGDP\_BAR\_EU, RES\_PIE\_EU$	beta	0.100	0.0300	0.0961	0.0304
RES_Y_EU, RES_G_EU	beta	0.250	0.1000	0.2519	0.1146
$RES\_LGDP\_BAR\_JA, RES\_PIE\_JA$	beta	0.100	0.0300	0.0917	0.0287
RES_Y_JA, RES_G_JA	beta	0.250	0.1000	0.2239	0.1053

Table 8: Root Mean Square Errors

	1 Q Ahead	4 Q Ahead	8 Q Ahead	12 Q Ahead
Output Gap US	0.495	0.681	0.947	1.12
GDP Quarterly Growth at annual rates US	1.88	2.08	2.38	2.16
GDP Year-on-Year Growth US	0.544	1.28	1.75	1.65
Unemployment Rate US	0.15	0.446	0.856	1.17
CPI Year-on-Year Inflation US	0.344	0.732	0.707	0.751
Short-term Interest Rate (RS) US	0.327	1.06	1.6	1.9
Bank Lending Tightness US	7.19	13.4	17.9	18.5
Output Gap EU	0.431	0.698	0.72	0.81
GDP Quarterly Growth at annual rates EU	1.6	1.69	1.38	1.42
GDP Year-on-Year Growth EU	0.439	1.14	1.05	1.1
Unemployment Rate EU	0.0664	0.28	0.651	1.08
CPI Year-on-Year Inflation EU	0.235	0.585	0.605	0.588
Short-term Interest Rate (RS) EU	0.31	0.883	1.1	1.3
Output Gap JA	0.544	0.953	1.14	1.17
GDP Quarterly Growth at annual rates JA	2.95	2.91	2.87	2.88
GDP Year-on-Year Growth JA	0.736	1.88	1.74	1.7
Unemployment Rate JA	0.12	0.365	0.697	0.934
CPI Year-on-Year Inflation JA	0.313	0.768	0.906	0.999
Short-term Interest Rate (RS) JA	0.254	0.663	0.968	1.1

Figure 2: Growth rate shock in the US (1)

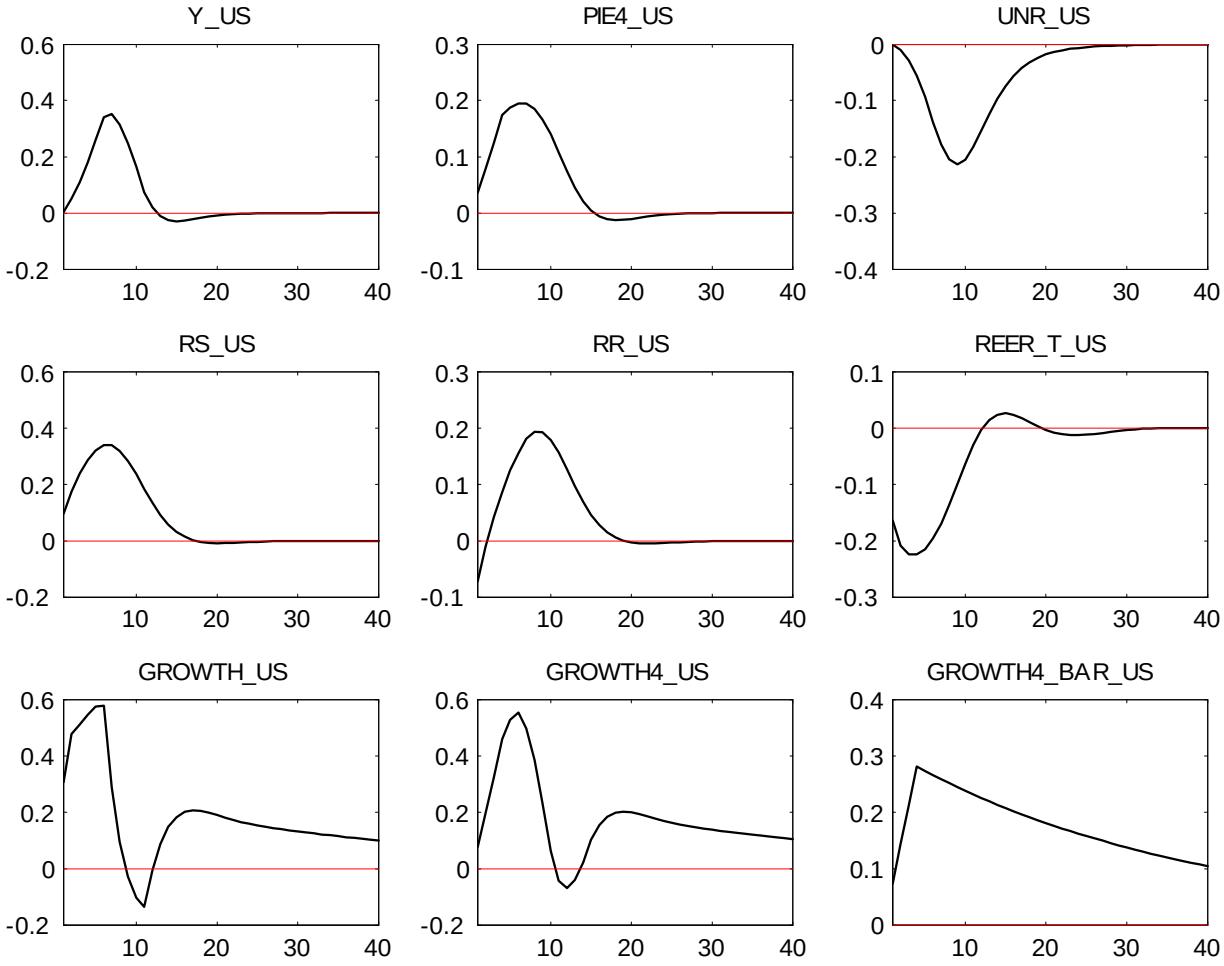


Figure 3: Growth rate shock in the US (2)

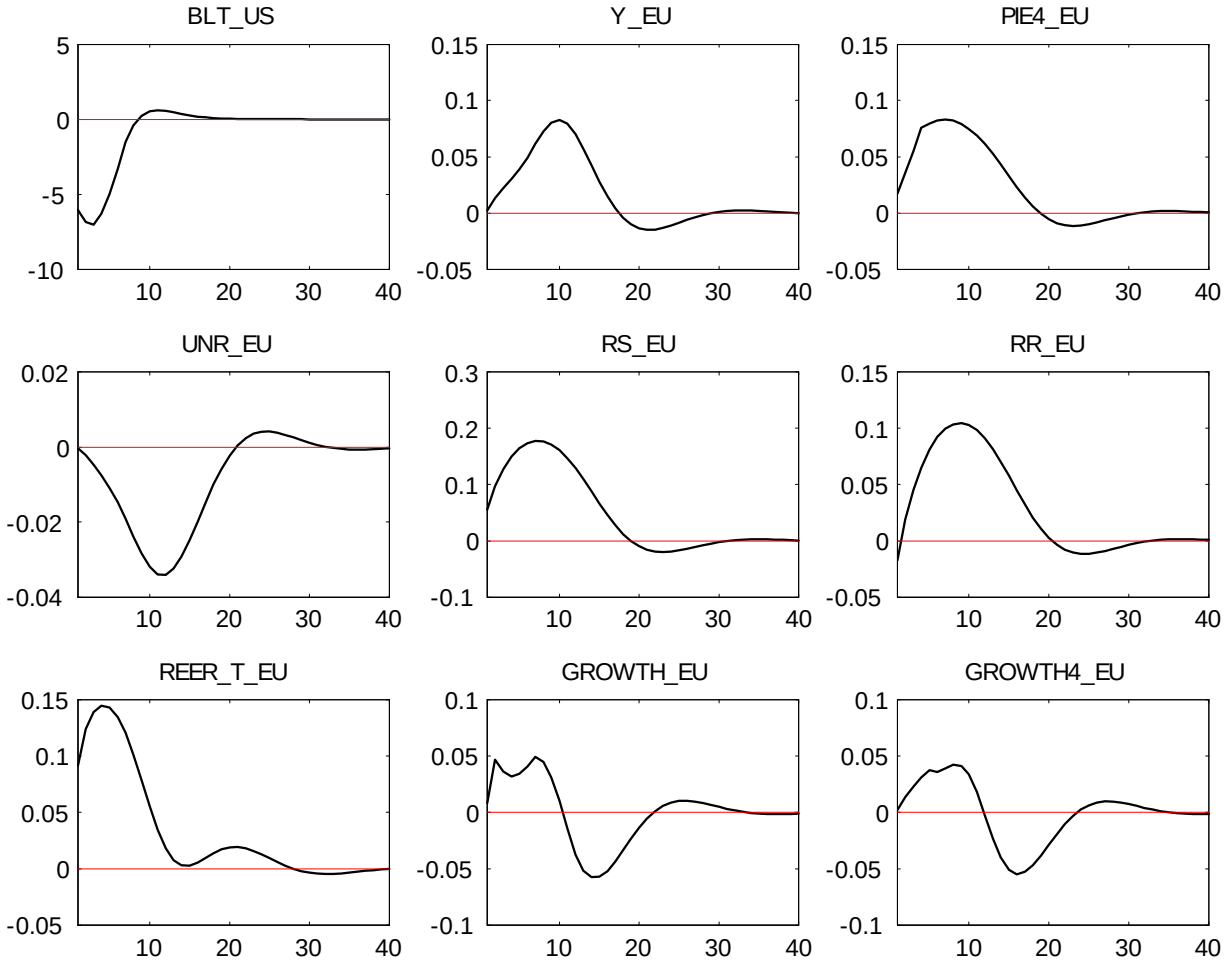


Figure 4: Growth rate shock in the US (3)

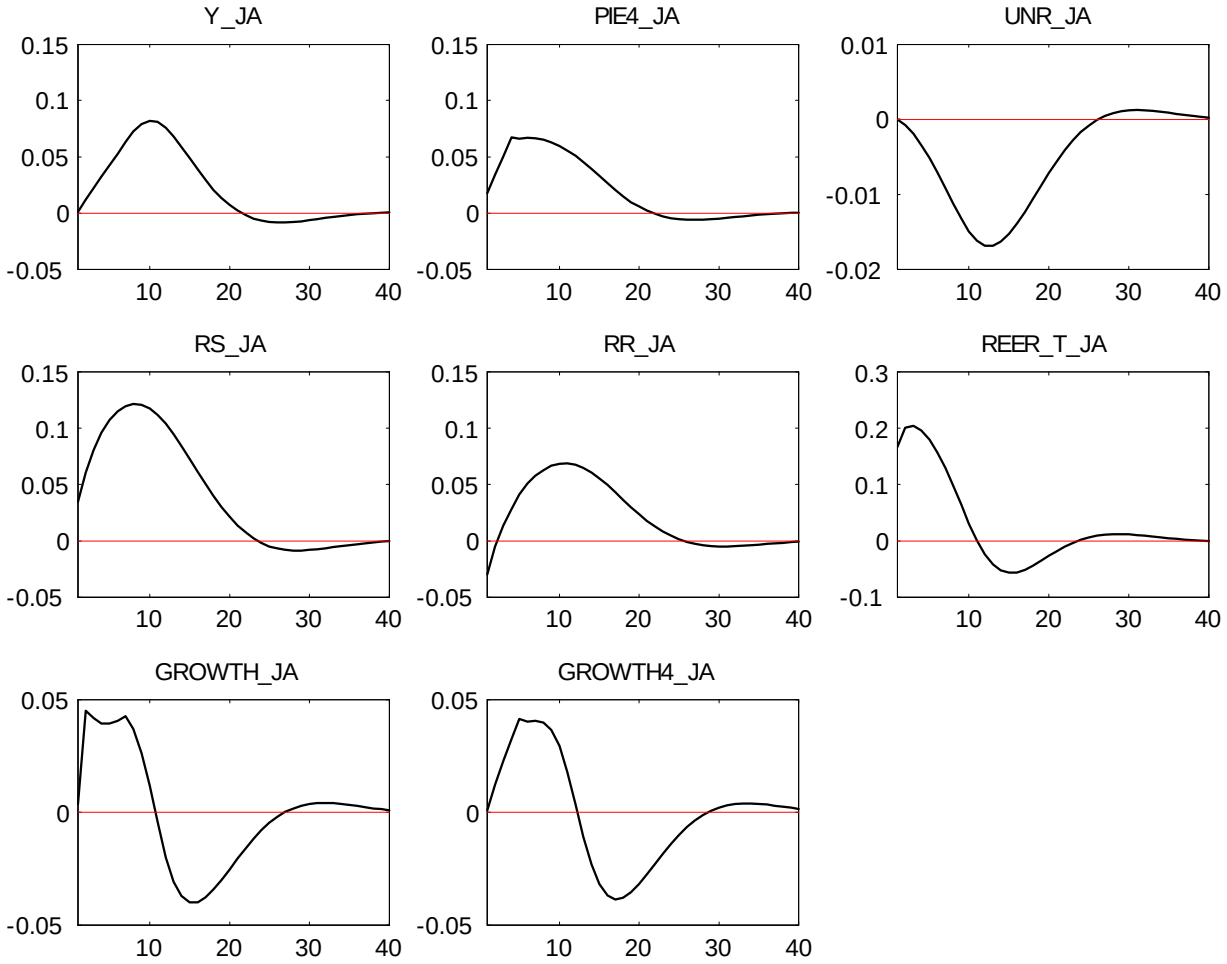


Figure 5: Demand shock in the US (1)

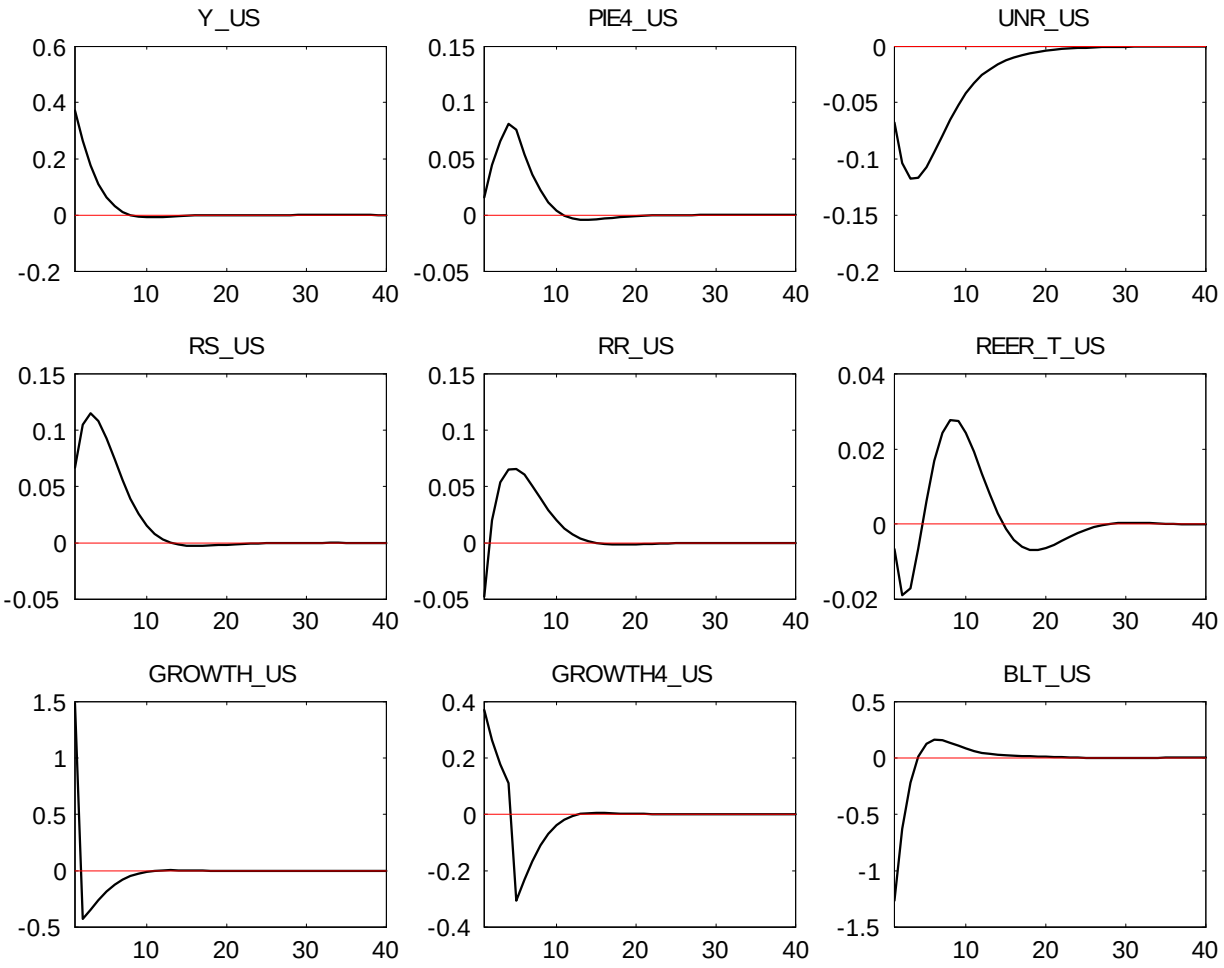


Figure 6: Demand shock in the US (2)

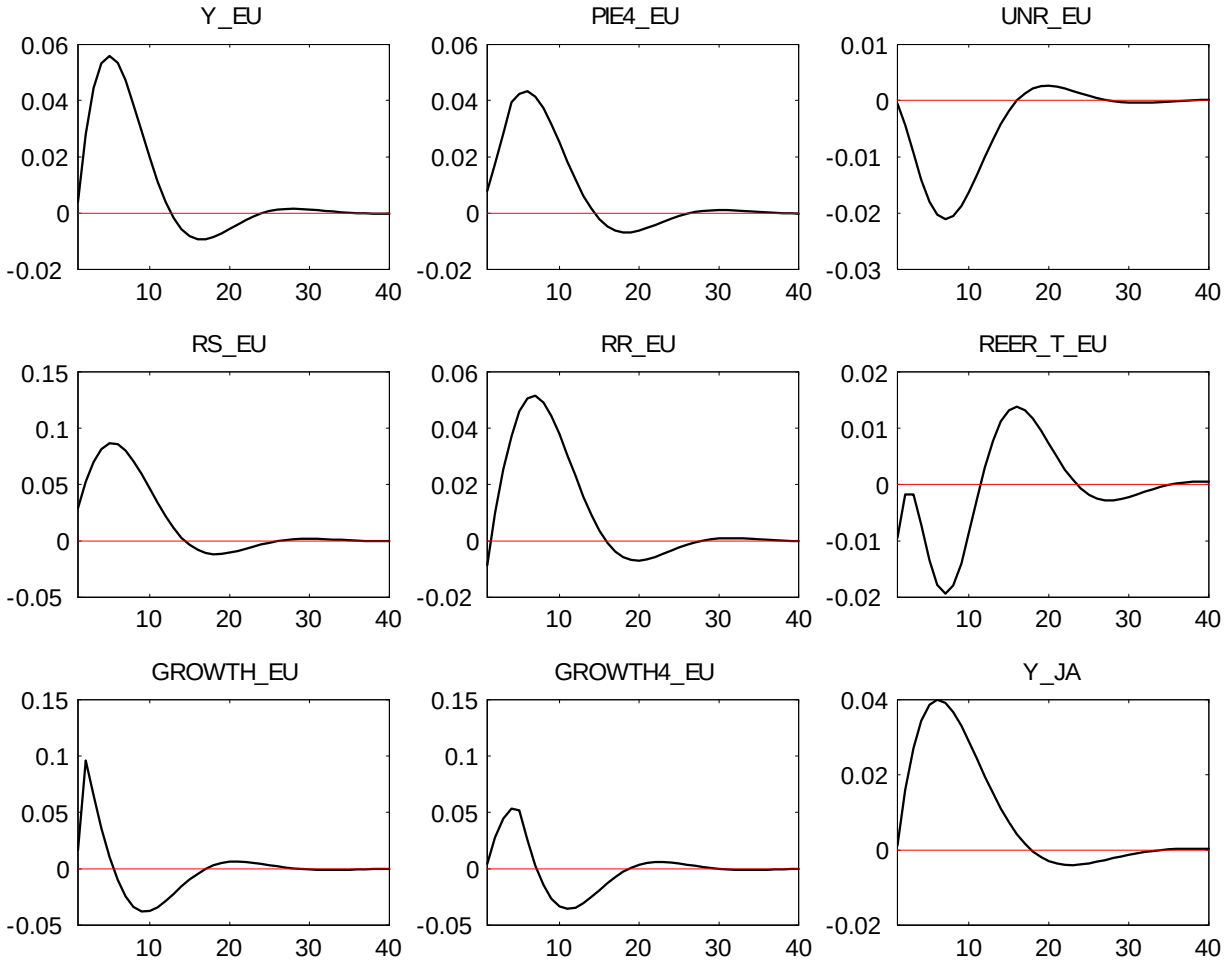


Figure 7: Demand shock in the US (3)

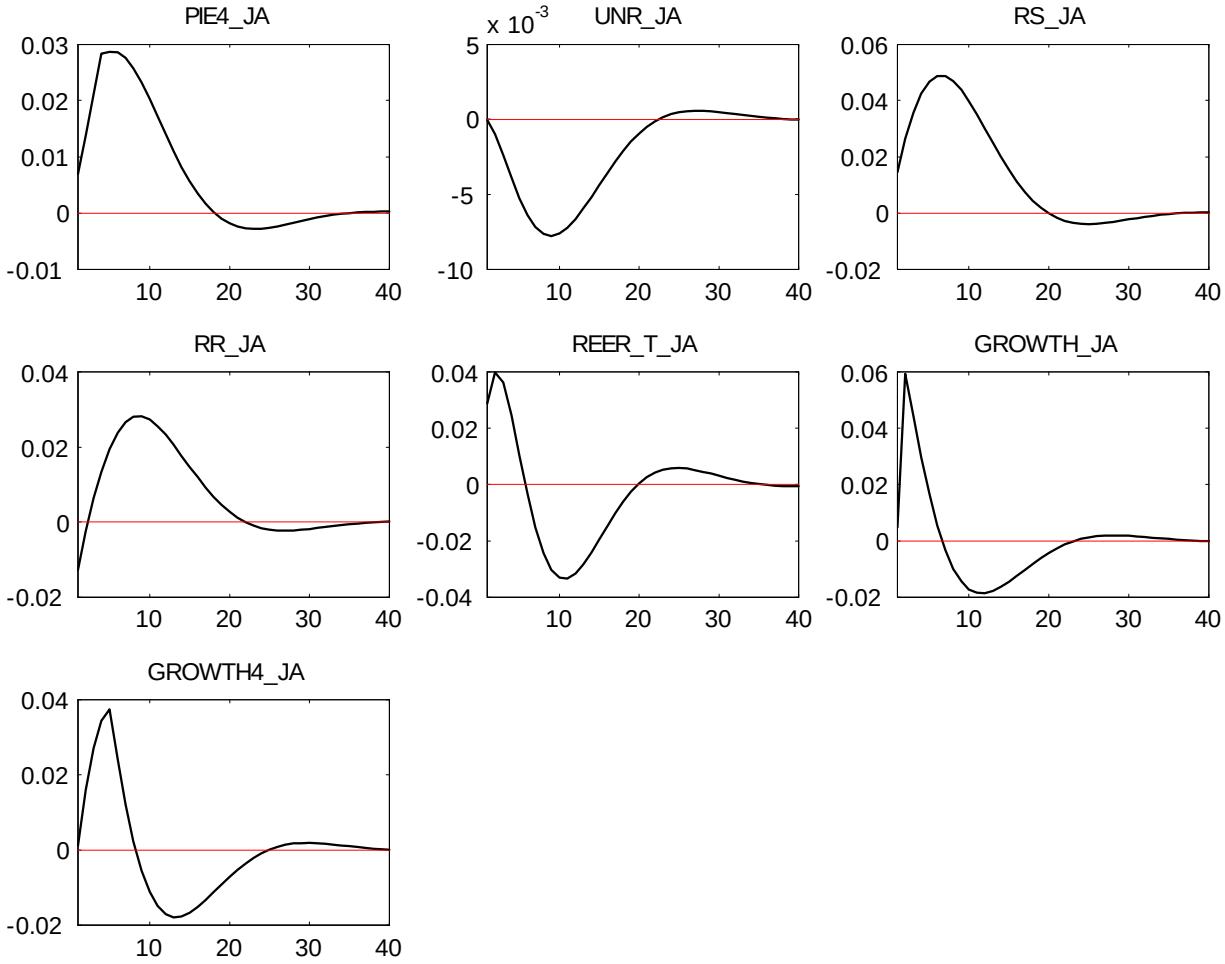


Figure 8: Demand shock in Europe (1)

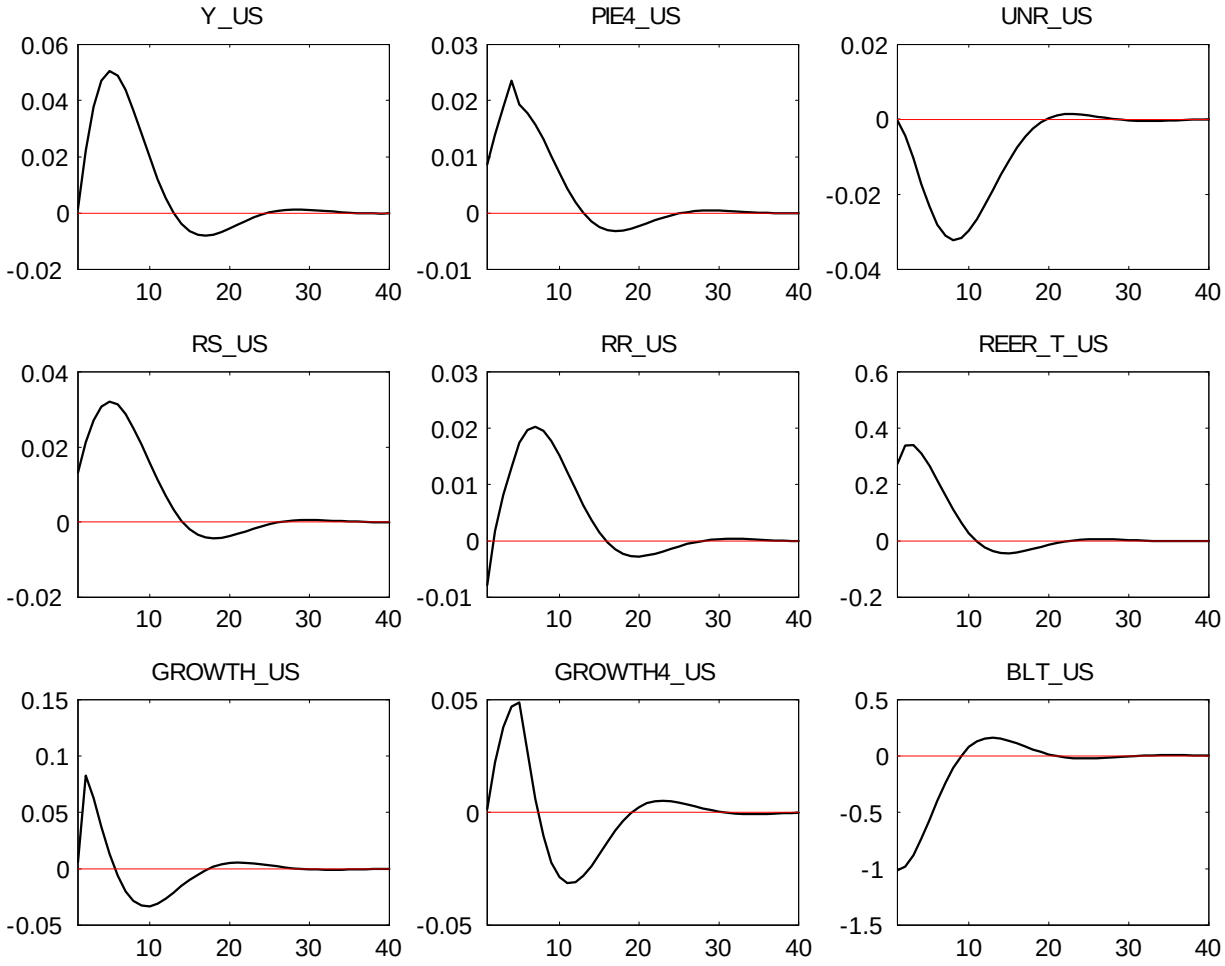


Figure 9: Demand shock in Europe (2)

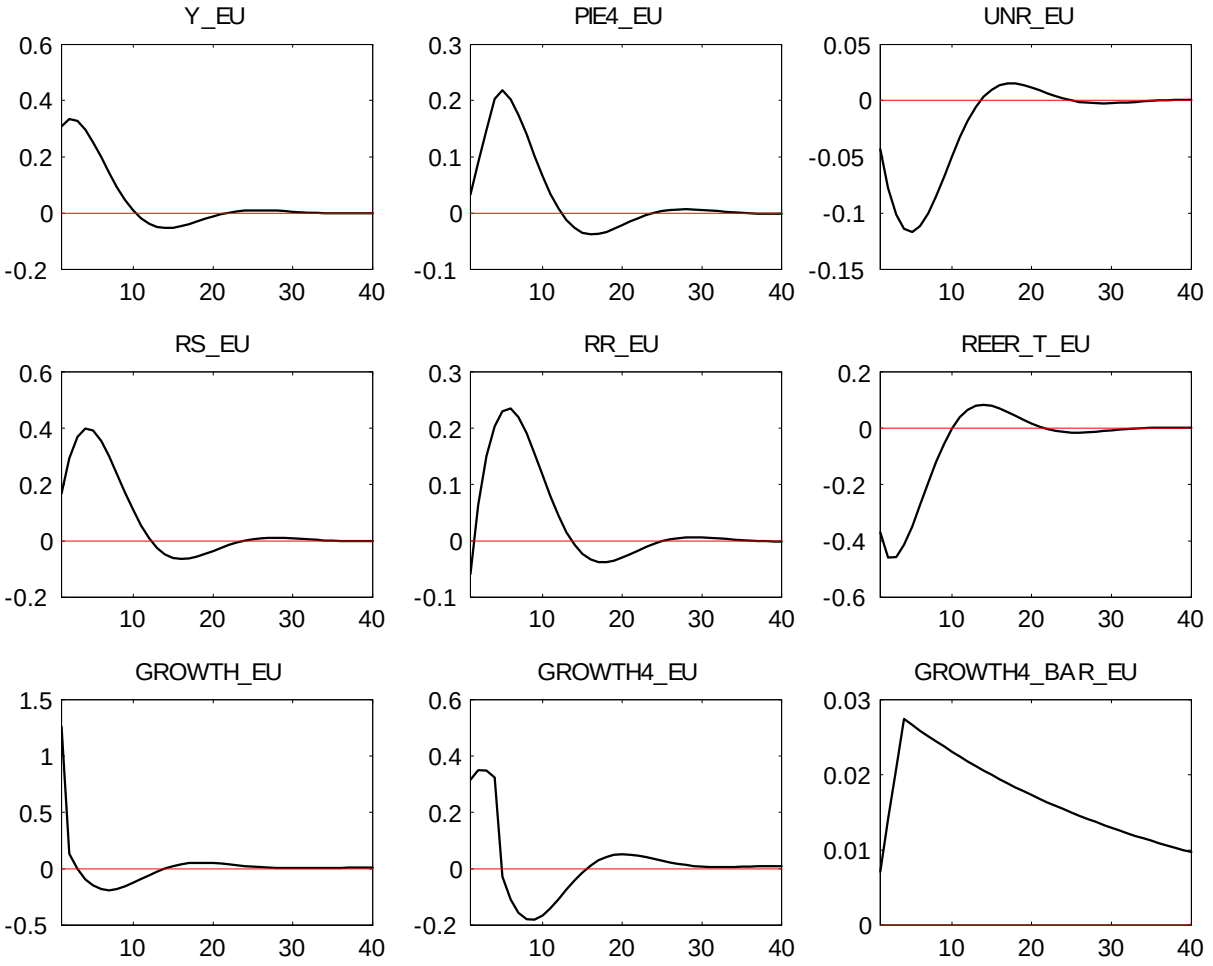


Figure 10: Demand shock in Europe (3)

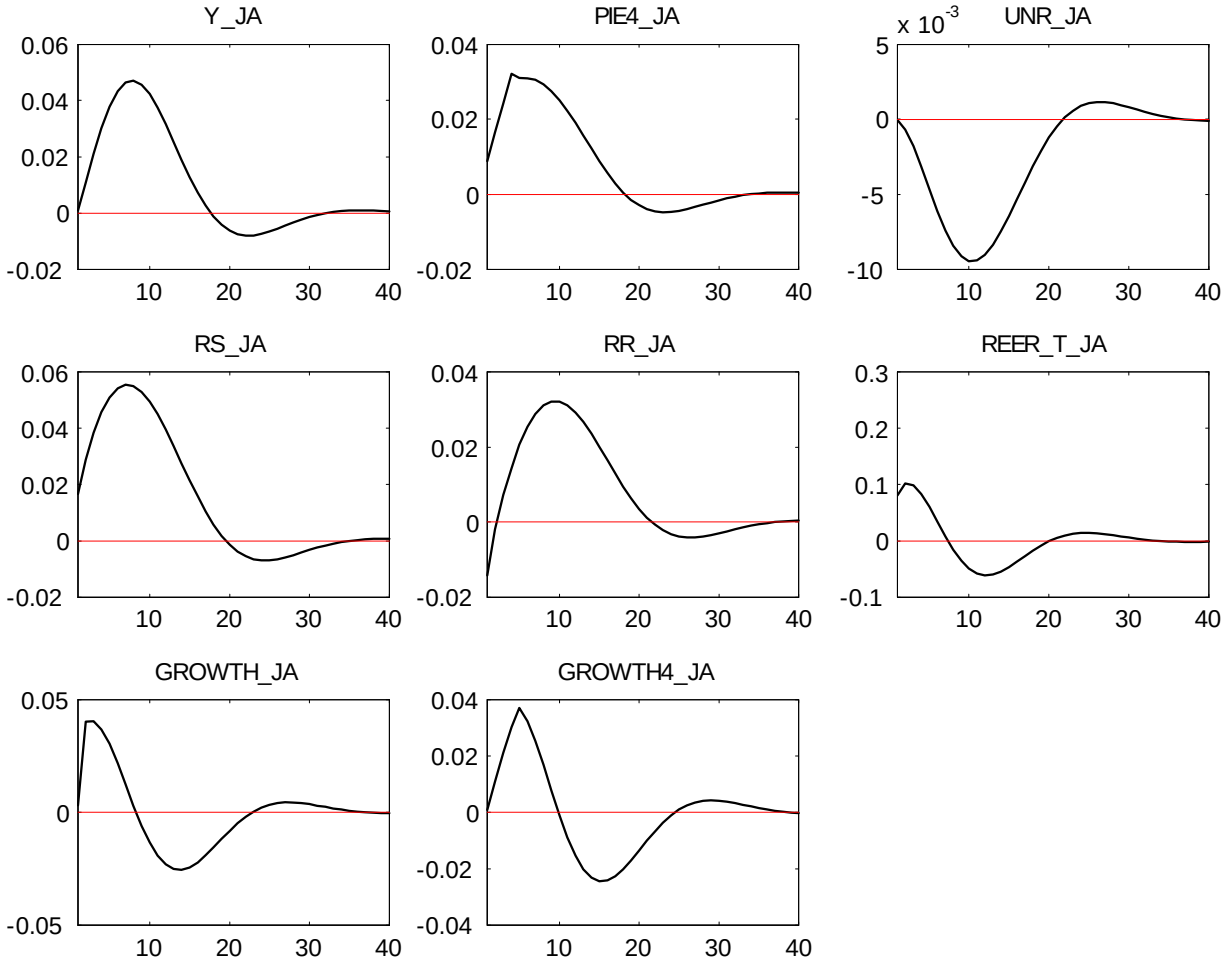


Figure 11: Demand shock in Japan (1)

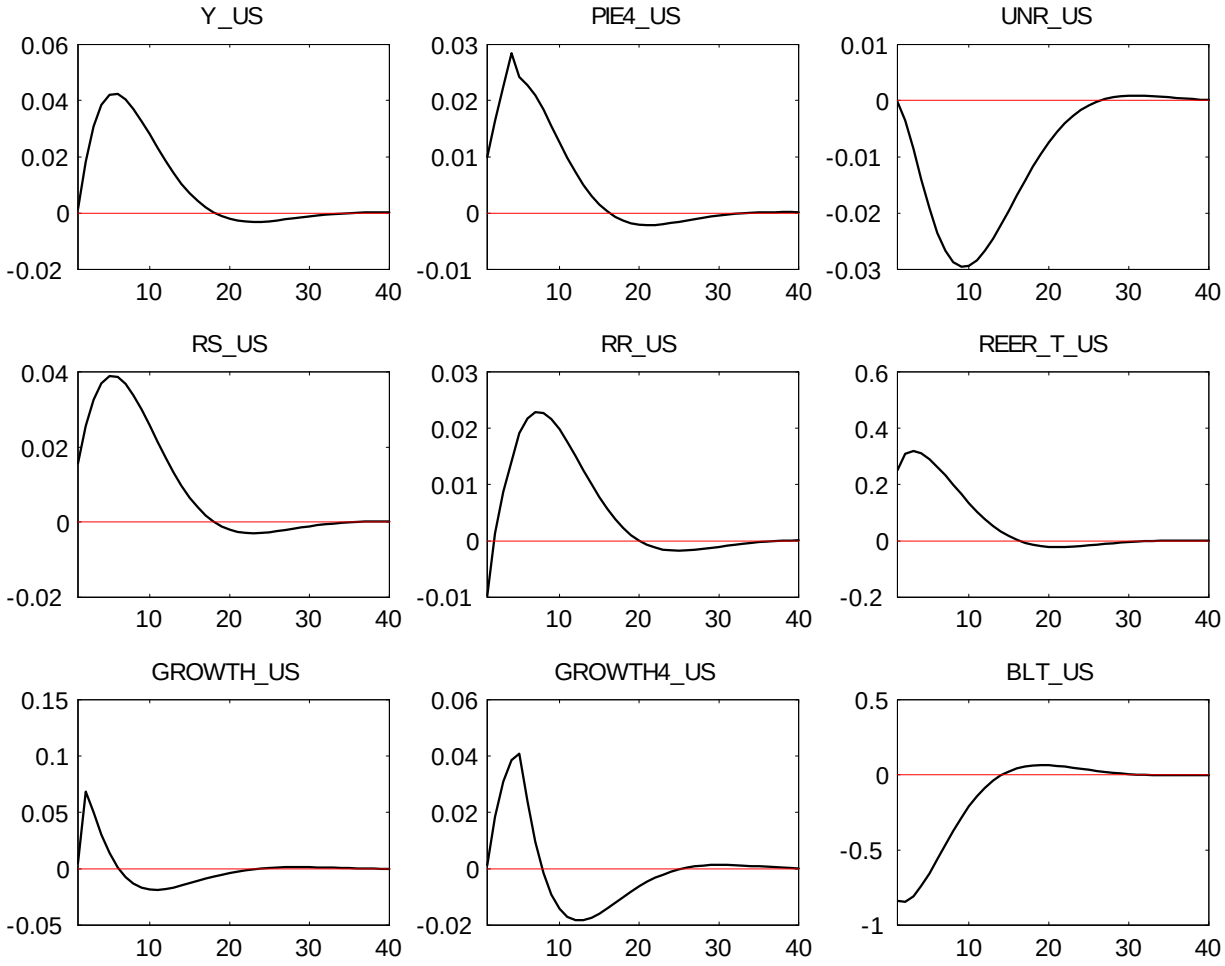


Figure 12: Demand shock in Japan (2)

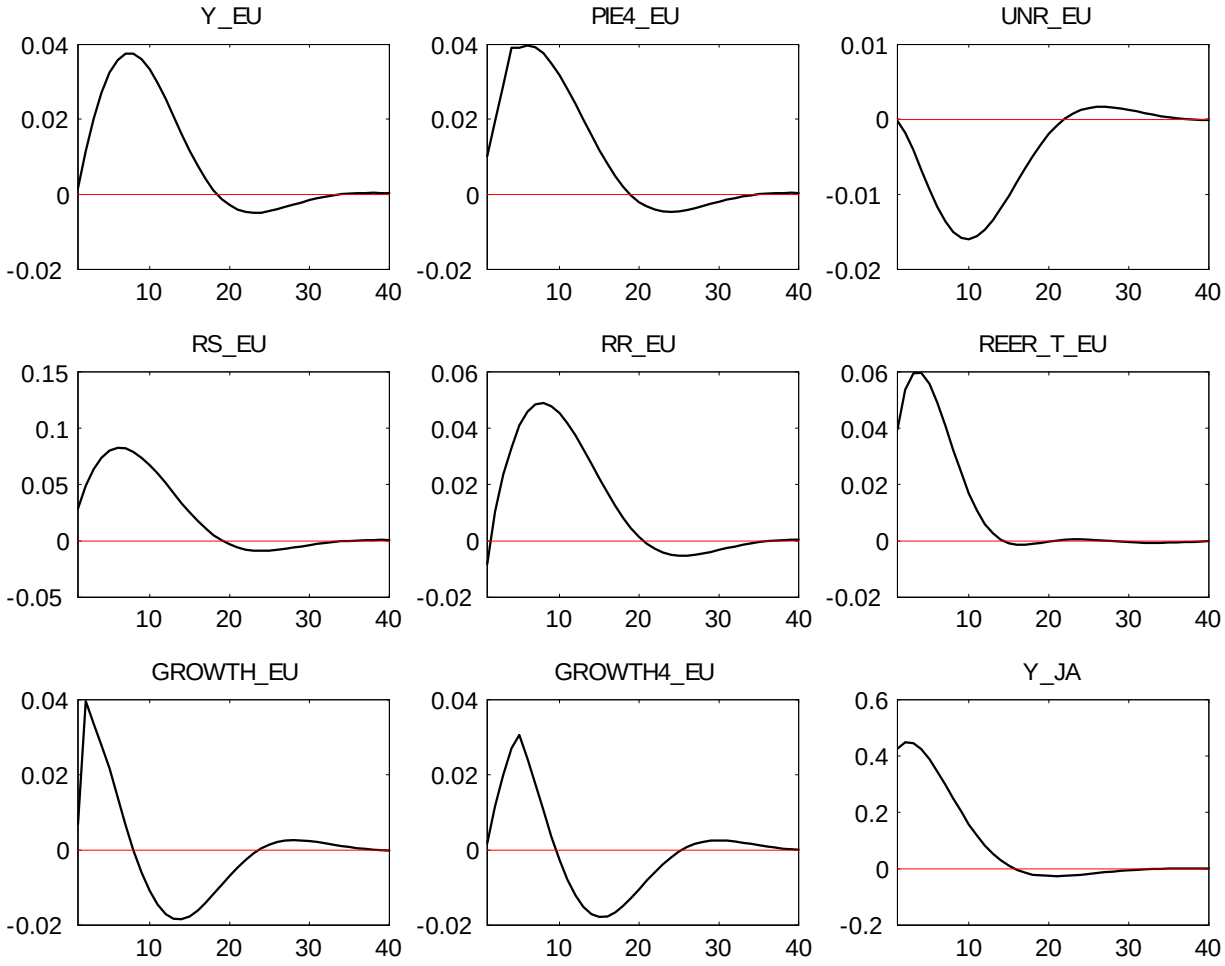


Figure 13: Demand shock in Japan (3)

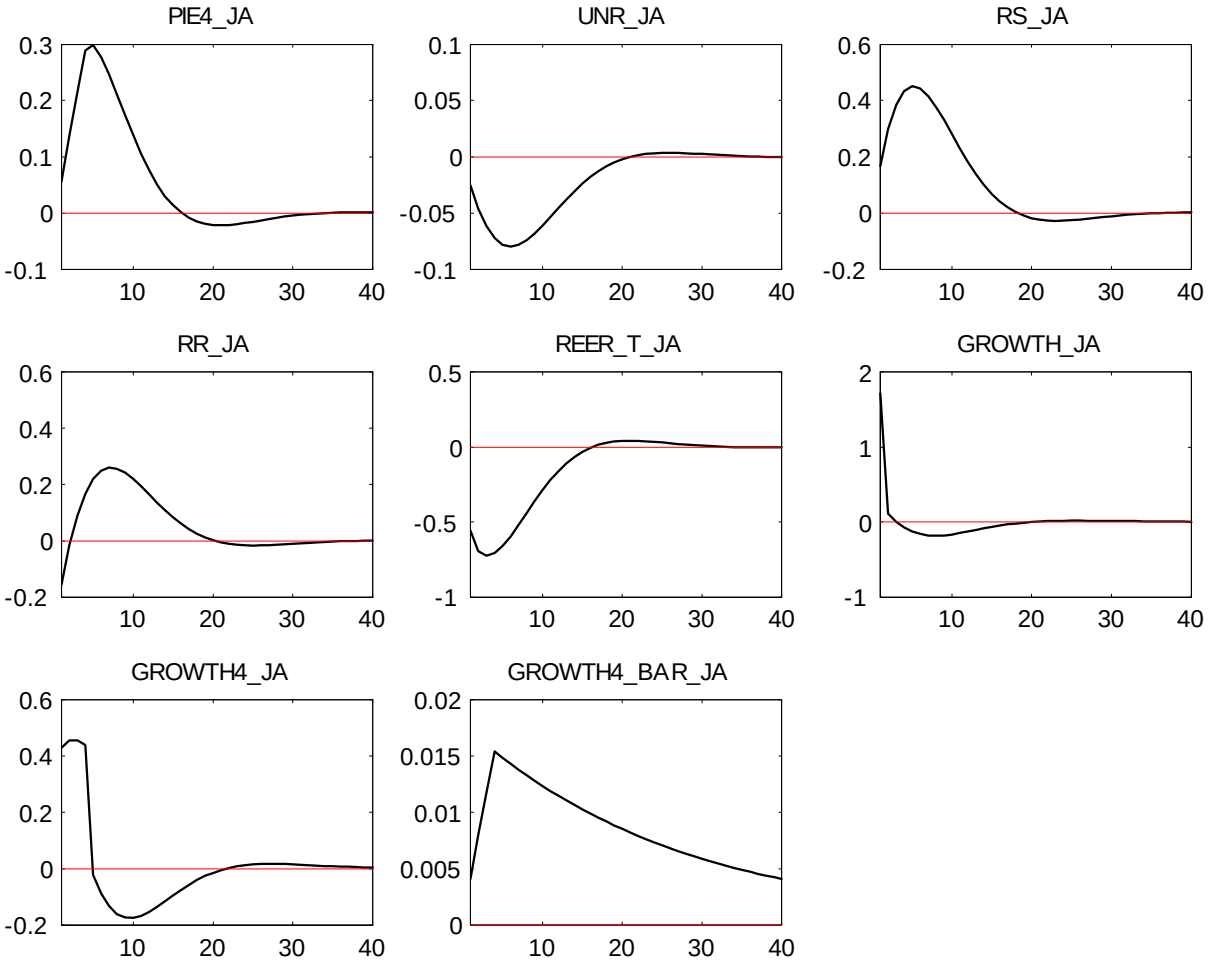


Figure 14: Financial (BLT) shock in the US (1)

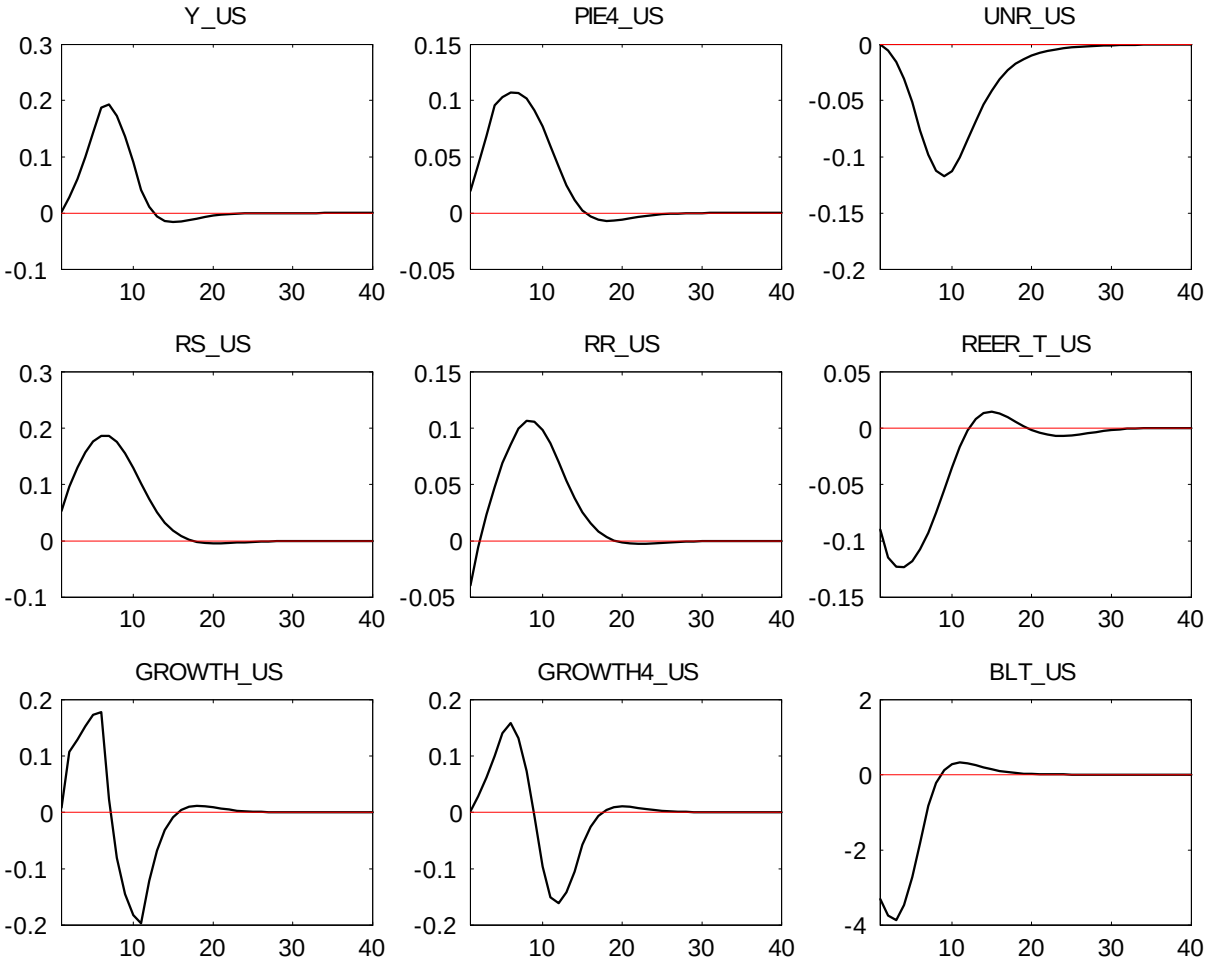


Figure 15: Financial (BLT) shock in the US (2)

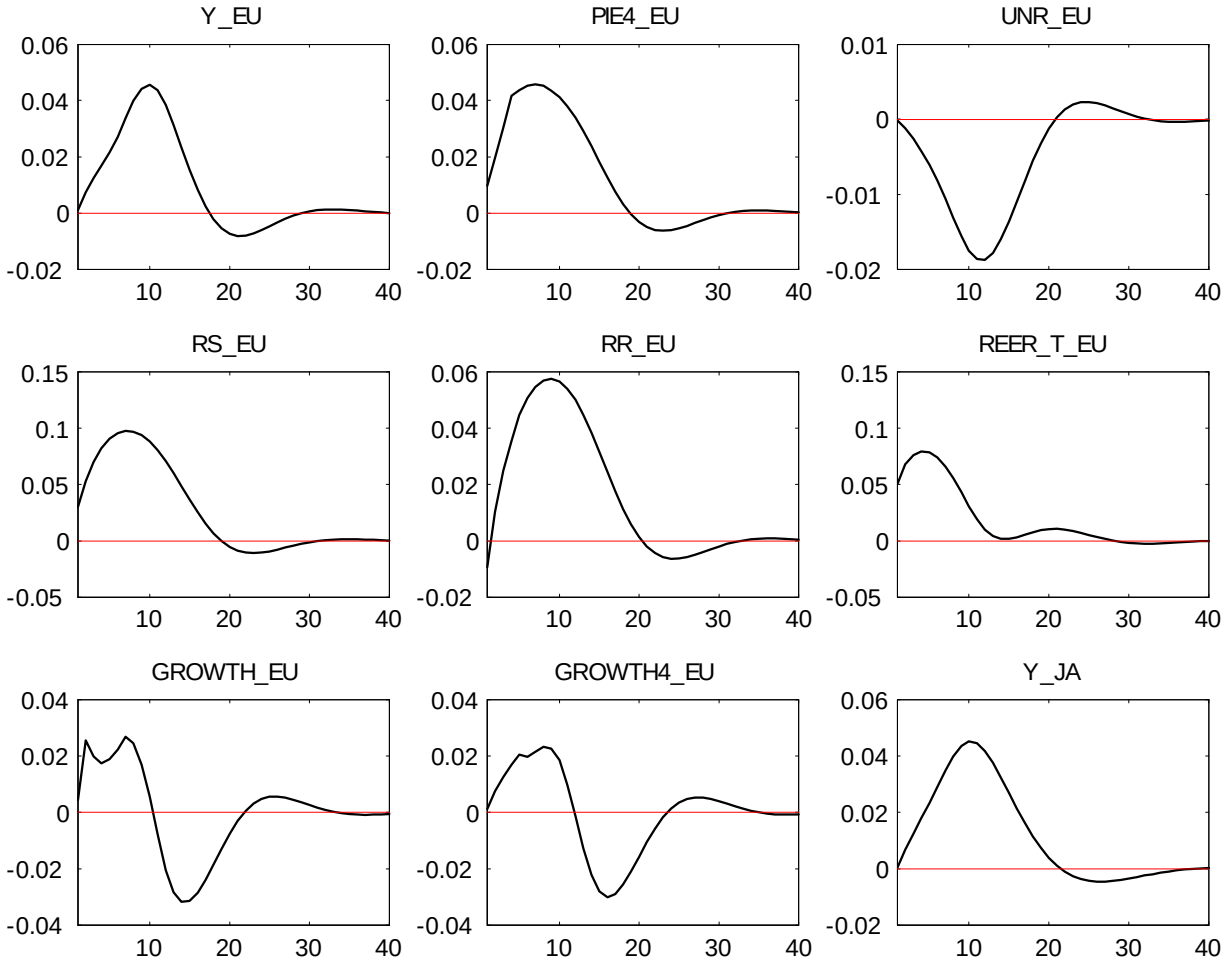


Figure 16: Financial (BLT) shock in the US (3)