

A Comparison of Forecast Performance Between Federal Reserve Staff Forecasts, Simple Reduced-Form Models, and a DSGE Model

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Broader Research Agenda:

To develop an estimated DSGE model that can be used in policy work, such as:

- Alternative forecast generation;
- Interpretation of incoming data; and,
- Analysis of monetary policy questions.
- This model is intended to serve as a compliment to the FRB/US model.

Note: The FRB/US model has a notable influence on the thinking behind the staff's Greenbook projection but does not directly generate the forecast.

This paper:

- Uses a DSGE model that we developed in earlier work (Edge, Kiley, Laforte; 2006) to generate a set of real-time forecasts.
- Compares the forecast generated by our DSGE model to those implied by alternative models and the Greenbook projection since September 1996.

Outline of the Presentation

- Motivate why a central bank may want a DSGE model in its suite of models.
- Sketch-out our multi-sector production and expenditure DSGE model.
 - Emphasize the features of the model that differ from the canonical Christiano-Eichenbaum-Evans/Smets-Wouters models; and,
- Describe the real-time environment, the Greenbook and the competing models;
- Comparison of the models' forecasts since 1996;
- Sum up.

- Why use a DSGE model in the forecast and policy process?
- Storytelling content is important in a policy context:

“A model-based forecast ends with a story... My experience as a commercial forecaster taught me that clients did not want to be buried in computer output. They demanded a coherent story that tied the forecast together. A model-based forecast has the ability to essentially explain itself.” Laurence H. Meyer (1997)

“As a policymaker, I am less interested in a statement like “GDP will grow by 3-1/4 percent,” than I am in answering the question “Why will GDP grow by 3-1/4 percent?” I find a great value in the story behind a forecast, even if I suspect that unforeseen events could prove the forecast wrong.” Sandra Pianalto (2006)

Model Overview

The model is more disaggregated than most closed economy models.

- The model has two business and institutions production sectors:
 - A slow-growing “consumption” goods producing sector, X^{cbi} ;
and,
 - A fast-growing “capital” goods producing sector, X^{kb} .
- The model has three expenditure aggregates:
 - Expenditures on consumer non-durable goods and services, E^{cnn} ;
 - Expenditures on consumer durable goods, E^{cd} ;
 - Expenditures on non-residential capital, E^{nr} .

Model Overview: Why do we disaggregate the production sector?

- U.S. NIPA data are *not* consistent with a one-sector Solow-Ramsey model. There are:
 - Sizable differences in long-run average real growth rates across expenditure categories; and,
 - Large trends in relative prices (as well different cyclical properties).
- U.S. NIPA data are better approximated by a two-sector model with a steady-state balanced *nominal* growth path.
 - Nominal growth rates are broadly similar across expenditure categories.

Average Growth and Relative Price Changes (1984q1 to 2004q4)

	Avg. Real Growth	Avg. Nom. Growth	Avg. Price Change
Cons. non-durables & services, E^{cnn}	$3\frac{1}{4}$ percent	$6\frac{1}{4}$ percent	n.a.
Cons. durables, E^{cd}	$6\frac{3}{4}$ percent	$6\frac{1}{2}$ percent	-3 percent
Non-res. investment, E^{nr}	$6\frac{1}{4}$ percent	$6\frac{1}{4}$ percent	$-2\frac{3}{4}$ percent

- E^{cnn} is purchased from the slow-growing sector X^{cbi} .
- E^{cd} and E^{nr} are purchased from the fast-growing sector X^{kb} .

Model Overview: Why do we further disaggregate expenditures?

- Different expenditure categories have different cyclical properties.
 - Consumer durables tend to lead business cycles, while *fixed* investment tends to lag.
 - Consumer durables may be more responsive to monetary policy.
- Policy-makers are often concerned with movements in spending detailed aggregates (see Kohn, 2003).
- Growth accounting requires that the (latent) capital stock series used in the model's production functions correspond to conventional definitions of productive capital.

Model Overview

Nominal rigidities:

- Sticky prices and sticky wages, where lagged inflation also determines adjustment costs.

Real rigidities:

- Habit-formation in consumption;
- Adjustment costs to investment; and,
- Adjustment costs to cross-sectoral factor movements; and,
- Variable utilization of non-residential capital.

The model has 14 structural shocks; 9 display persistence.

Balanced Nominal Growth and Production

The intermediate goods sectors' production functions are:

$$X_t^{cbi} = (K_{t-1}^{cbi})^\alpha (Z_t^m L_t^{cbi})^{1-\alpha} \quad \& \quad X_t^{kb} = (K_{t-1}^{kb})^\alpha (Z_t^m Z_t^{kb} L_t^{kb})^{1-\alpha}$$

The technology variables in the intermediate-goods sectors follow

$$\ln(Z_t^s / Z_{t-1}^s) = \ln \Gamma_t^{z,s} = \ln \Gamma_*^{z,s} + \gamma_t^{z,s} \quad \text{where} \quad \gamma_t^{z,s} = \rho^{z,s} \gamma_{t-1}^{z,s} + \epsilon_t^{z,s}, \quad s = m, k.$$

Sector	Real Gr. ($\Gamma_*^{x,s}$)	Inflation ($\Pi_*^{p,s}$)	Nom. Gr. ($\Gamma_*^{x,s} \Pi_*^{p,s}$)
Slow	$\Gamma_*^{z,m} (\Gamma_*^{z,kb})^\alpha$	$\Pi_*^{p,cbi}$	$\Pi_*^{p,cbi} \Gamma_*^{z,m} (\Gamma_*^{z,kb})^\alpha$
Fast	$\Gamma_*^{z,m} \Gamma_*^{z,kb}$	$\Pi_*^{p,cbi} (\Gamma_*^{z,kb})^{\alpha-1}$	$\Pi_*^{p,cbi} \Gamma_*^{z,m} (\Gamma_*^{z,kb})^\alpha$

Household Preferences

- Utility is defined over leisure and two types of goods:
 - Consumer non-durable goods and services, E_t^{cnn} ;
 - Consumer durable capital stock, K_t^{cd} , and
- Within-period utility is:

$$\varsigma^{cnn} \Xi_t^{cnn} \ln \left(E_t^{cnn}(i) - h^{cnn} E_{t-1}^{cnn}(i) \right) + \varsigma^{cd} \Xi_t^{cd} \ln \left(K_t^{cd}(i) - h^{cd} K_{t-1}^{cd}(i) \right) - \varsigma^l \Xi_t^l \frac{\left(L_t^{cbi}(i) + L_t^{kb}(i) \right)^{1+\nu}}{1+\nu}.$$

- Ξ_t^{cnn} , Ξ_t^{cd} and Ξ_t^l , are persistent preference shocks.

Household's Labor Supply Decision

The household's labor supply decision is affected by two types of adjustment costs. These stem from:

- Deviations of the nominal wage from a (geometric) weighted average of its own lag and its steady-state value; and,
- Deviations of the cross-sector allocation of labor from a (geometric) weighted average of its own lag and its steady-state value.

Capital Evolution Processes

- The economy possesses two capital stocks:
 - Non-residential capital, K_t^{nr} ;
 - Consumer durable capital stock, K_t^{cd} .
- Investment incurs adjustment costs; e.g., non-res. capital evolves:

$$K_{t+1}^{nr}(k) = (1 - \delta^{nr})K_t^{nr}(k) + A_t^{nr} E_t^{nr}(k) - \frac{100 \cdot \chi^{nr}}{2} \left(\frac{E_t^{nr}(k) - \eta^{nr} E_{t-1}^{nr}(k) \Gamma_t^{y, kb} - (1 - \eta^{nr}) \tilde{E}_*^{nr} Z_t^m Z_t^{kb}}{K_t^{nr}} \right)^2 K_t^{nr}$$

- A_t^{nr} is a transitory, but persistent, capital “efficiency” shock.
- Consumer durables capital evolves similarly.

Nominal Rigidities

- **Intermediate goods producing firms and households** face convex adjustment costs in altering their prices and nominal wages.
- The log-linearized **price Phillips curves** are:

$$\pi_t^{p,s} = \frac{\eta^{p,s}}{1 + \beta\eta^{p,s}} \cdot \pi_{t-1}^{p,s} + \frac{\beta}{1 + \beta\eta^{p,s}} \cdot E_t \pi_{t+1}^{p,s} - \frac{1}{1 + \beta\eta^{p,s}} \cdot \frac{1}{100 \cdot \chi^{p,s} (\Pi_*^{p,s})^2} ((\Theta_*^{y,s} - 1) mc_t^s - \theta_t^{y,s}).$$

- In this paper, we assume that price adjustment costs are the same in both sectors, *i.e.* $\chi^{p,cbi} = \chi^{p,kb}$.
- The log-linearized **wage Phillips curves** take a similar form.

Monetary Policy

- The log-linearized **monetary policy rule** is:

$$r_t = \phi^r \cdot r_{t-1} + (1 - \phi^r) \cdot \bar{r}_t + \epsilon_t^r$$

where

$$\begin{aligned} \bar{r}_t = & \phi^{\pi, gdp} \cdot \pi_t^{p, gdp} + \phi^{\Delta\pi, gdp} \cdot \Delta\pi_t^{p, gdp} \\ & + \phi^{h, gdp} \cdot h_t^{gdp} + \phi^{\Delta h, gdp} \cdot \Delta h_t^{gdp}. \end{aligned}$$

$\pi_t^{p, gdp}$ = GDP Price Inflation

h_t^{gdp} = Real GDP Growth

Real GDP Growth

- Real GDP growth, H_t^{gdp} , is a Tornquist index.
- Defined as a weighted average of the real growth rates in the economy's three final outputs:
 - X_t^{cbi} : produced in the “slow” sector, purchased for E_t^{cnn} ;
 - X_t^{kb} : produced in the “fast” sector, purchased for E_t^{cd} and E_t^{nr} ;
 - X_t^{gf} : exogenous production, which meets government and foreign demand (and reflects the “production” of housing services).
- These weights are an average of each outputs' share of total nominal output in the current and previous period.
- *Normalized* exogenous production follows the process:

$$\ln \tilde{X}_t^{gf} - \ln \tilde{X}_*^{gf} = \rho^{x,gf} \left(\ln \tilde{X}_t^{gf} - \ln \tilde{X}_*^{gf} \right) + \epsilon^{x,gf}.$$

Estimation: Real-Time Data and the Greenbook I

- At each FOMC meeting (which occurs 8 times a year), the staff produces a detailed forecast of the economic outlook. The projection horizon varies from six to ten quarters.
- Since March 1996 the staff have stored both the GB projection and the historical data of the series with the forecast.
- All the models' forecasts are produced in real-time, i.e. for any given forecast period, set by the date of the FOMC meeting, the estimation and projection of the models are performed using the relevant data series as they were known at the time of the meeting.

Estimation: Real-Time Data and the Greenbook II

- All the atheoretical models are reestimated every projection period. The DSGE model is reestimated once year using the data available at the time of the most recent August meeting. By that time, the annual rebenchmarking had become available. Some the model's coefficients are recalibrated at the time of the reestimation. These coefficients are selected by an automatic procedure that minimizes the distance between the growth rates of key observed aggregates and their theoretical counterparts.
- The latest release of the series by the BEA is considered as their most accurate measure and used to assess the accuracy of the forecasts.

Data

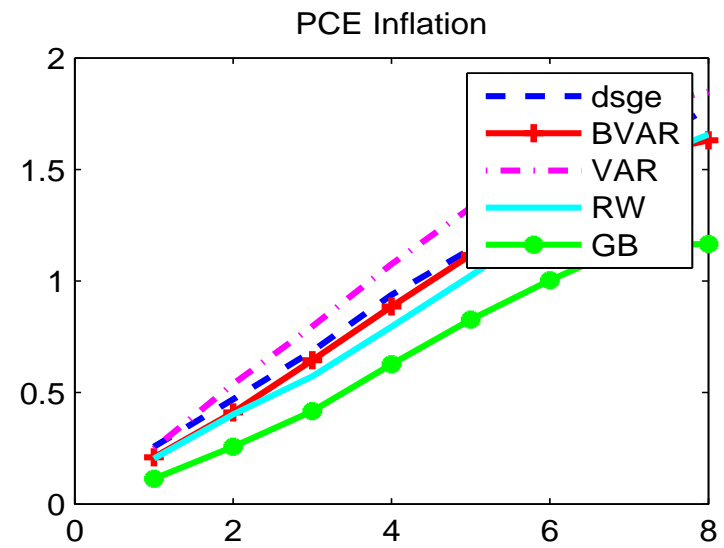
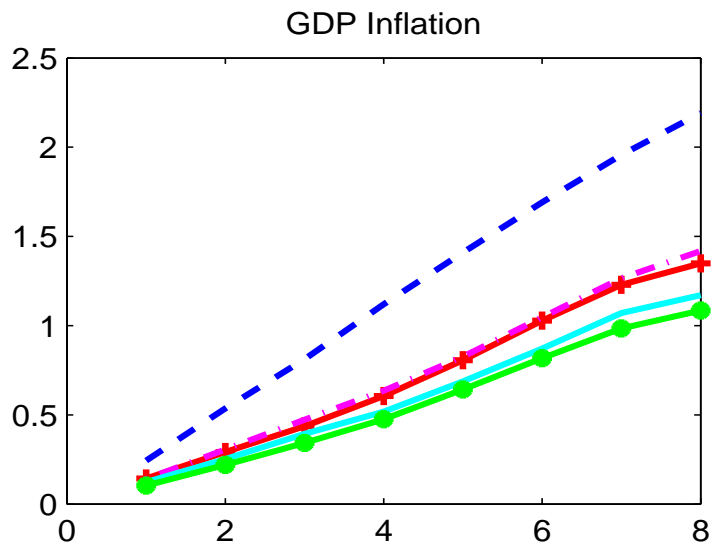
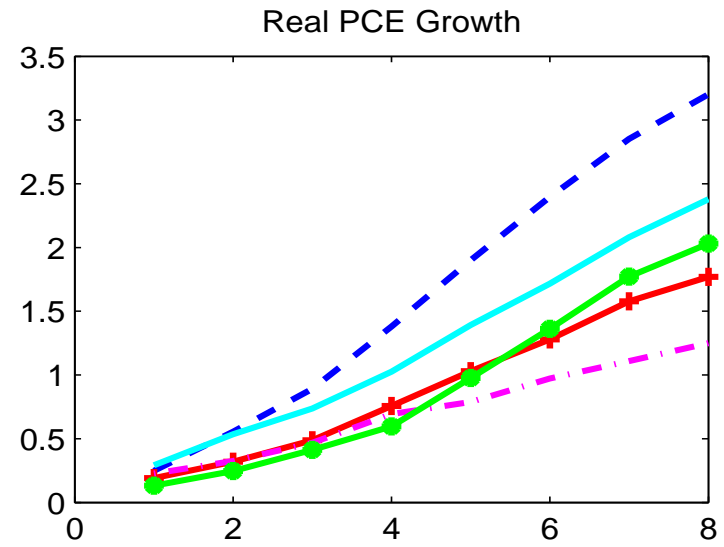
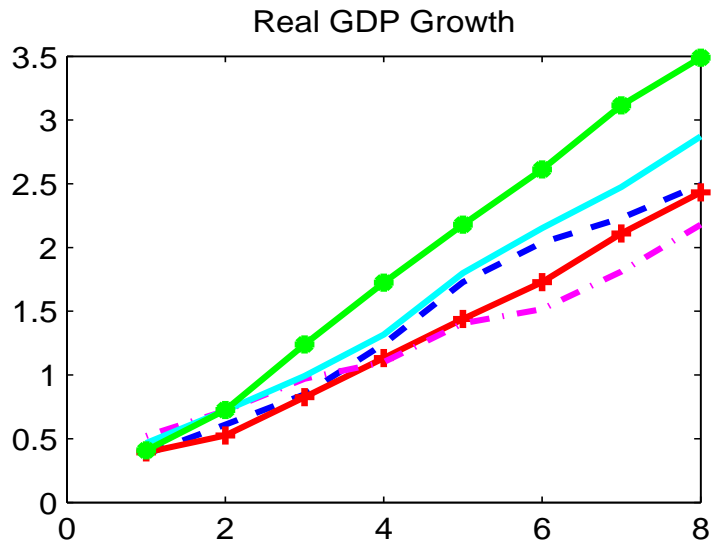
The DSGE model is estimated on the following 11 series:

- Nominal gross domestic product;
- Nominal cons. expenditure on non-durables & services;
- Nominal consumption expenditure on durables;
- Nominal business investment expenditure;
- **Three** series of inflation: GDP price inflation, inflation for consumer nondurables and services and inflation for non-residential investment;
- Hours (labor input);
- Wage inflation (compensation per hour); and,
- The federal funds rate.

Alternative Forecasts

- Greenbook;
- Random Walk;
- VAR (Real GDP growth, Real Cons. Growth, GDP price inflation, Cons. price inflation and the nominal interest rate.);
- Bayesian VAR (Same variables as for the VAR, with a modified Litterman prior).

Figure 1: Mean Absolute Errors (Sept 1996 - May 2000)



Mean Absolute Errors (Sept 1996 - March 2000)

- The mid's-1990s to early 2001 were a period of rapid growth, some of it widely unanticipated.
- The Greenbook poor performance relative to GDP growth over that period is well documented (Tulip (2005), Tetlow and Ironside (2005)).
- The DSGE model performs well at predicting the future GDP growth rate. On the other hand, its performance relative to consumption is not as good relative to the other models.
- The Greenbook outperforms any other model in predicting prices.

Figure 2: Fraction of forecast errors greater than zero (Sept 1996 - March 2000).

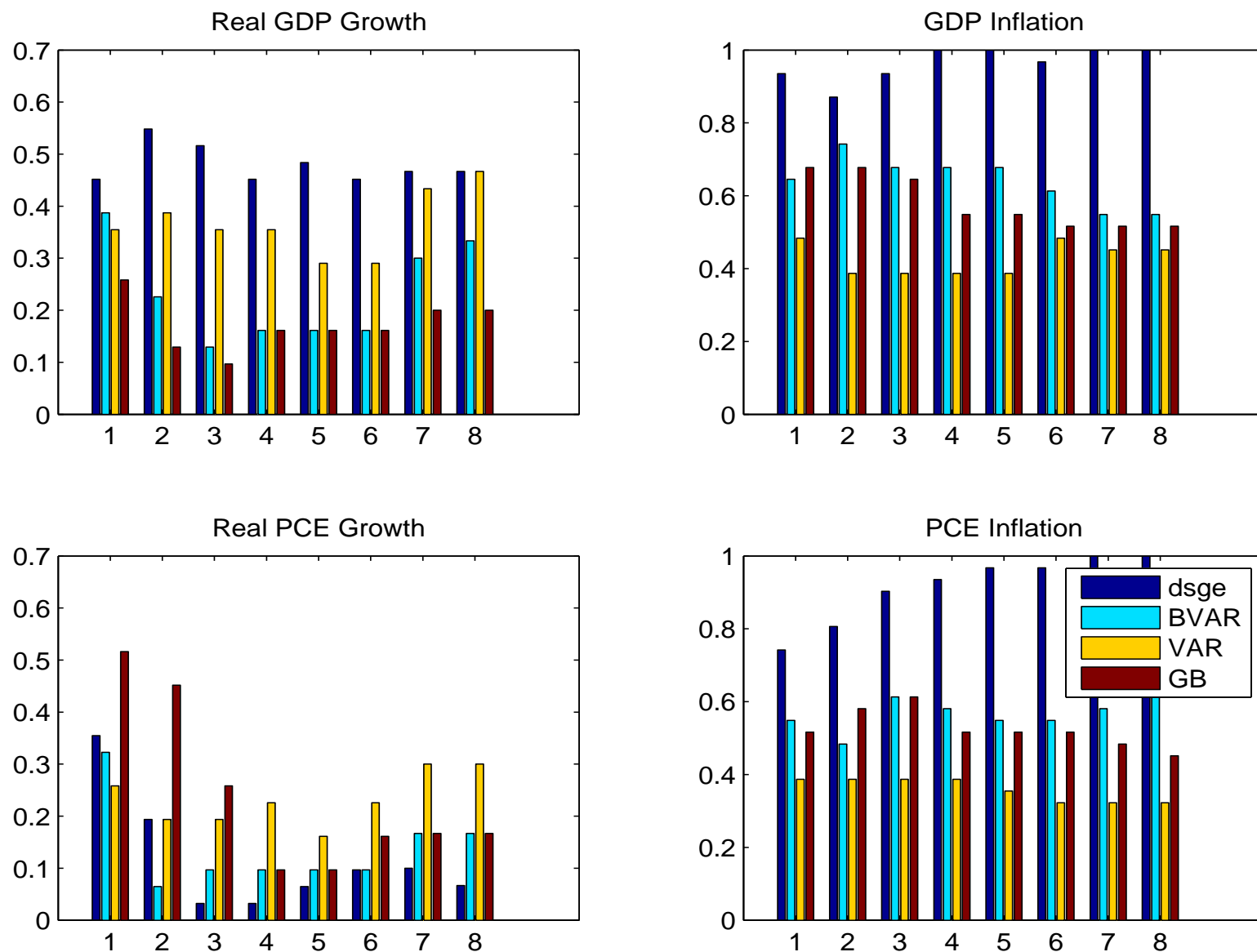
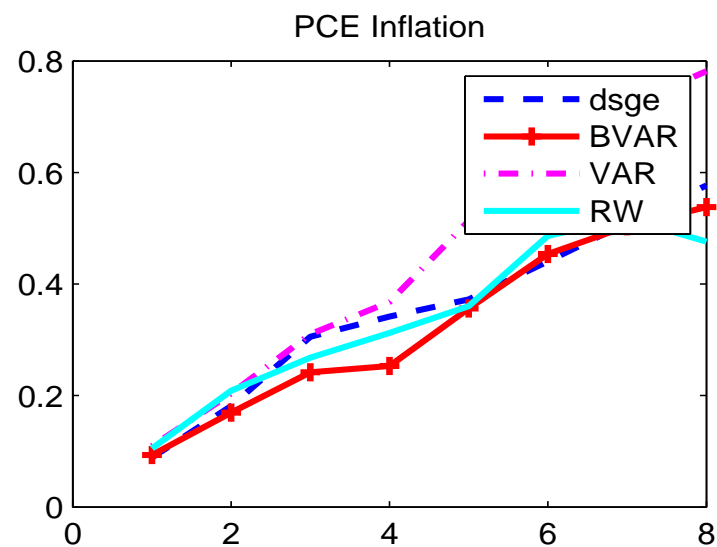
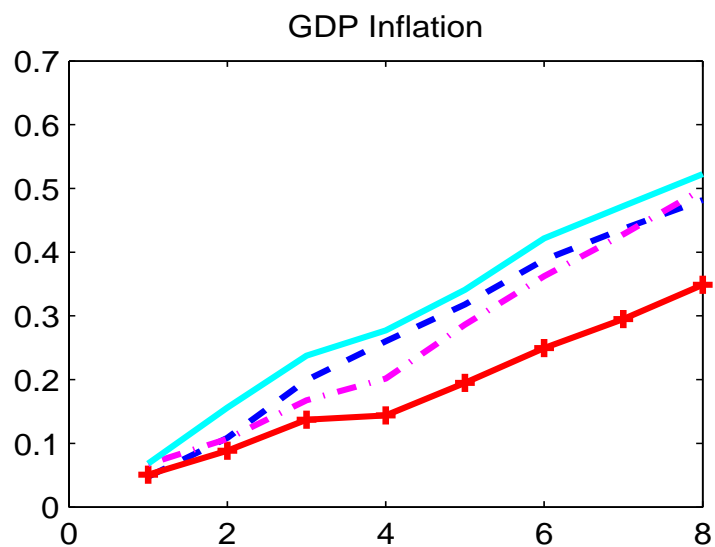
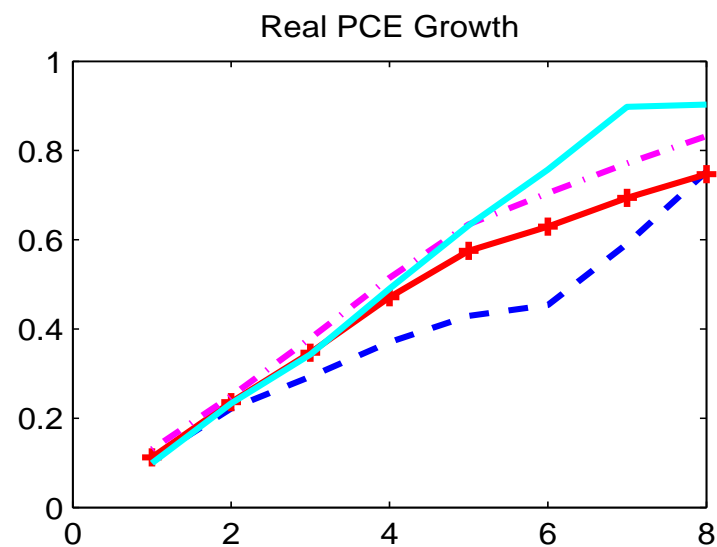
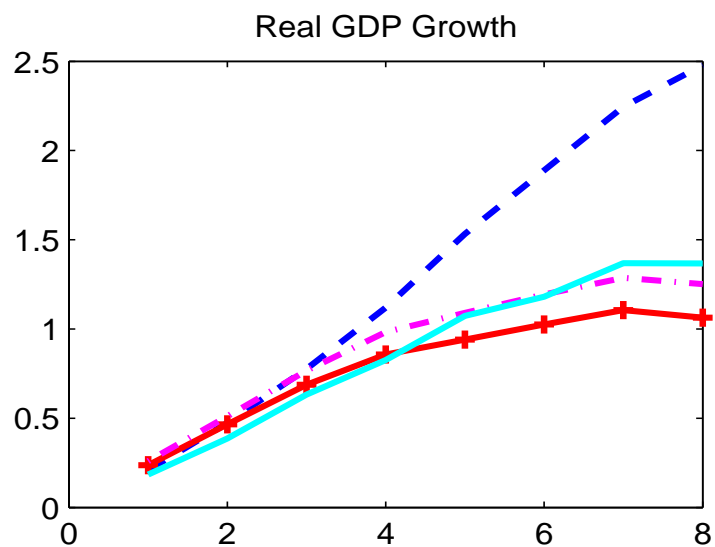


Figure 3: Mean Absolute Errors (May 2000 - Jun 2003)

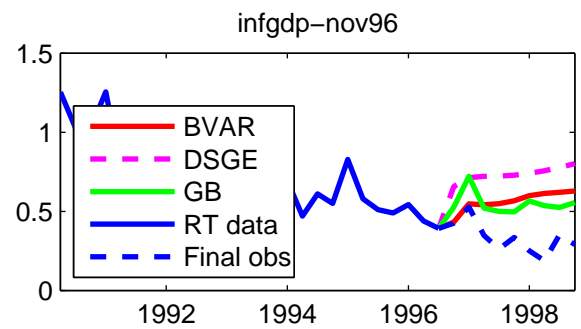
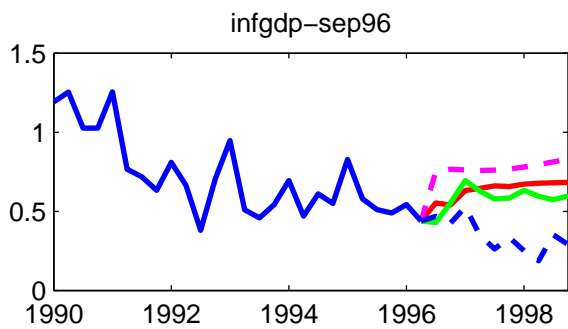
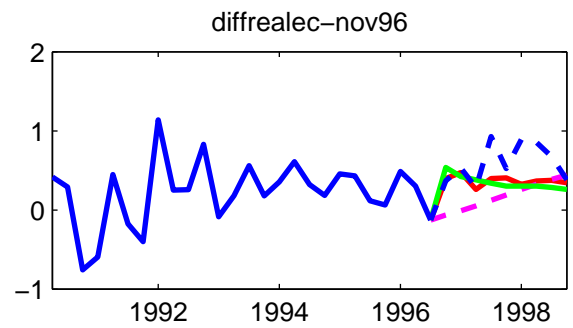
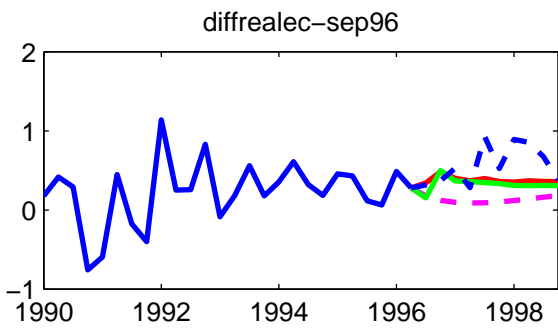
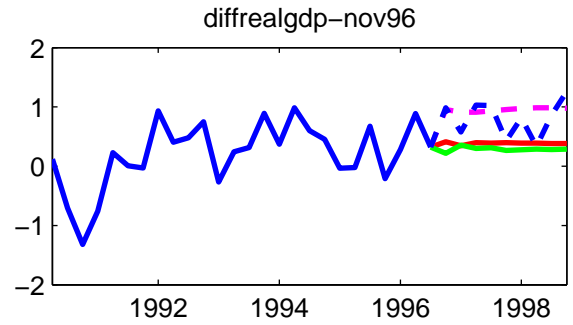
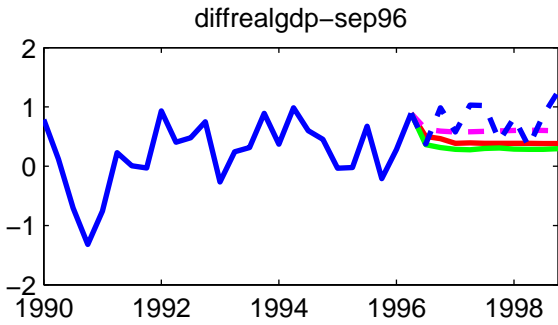


Conclusions I

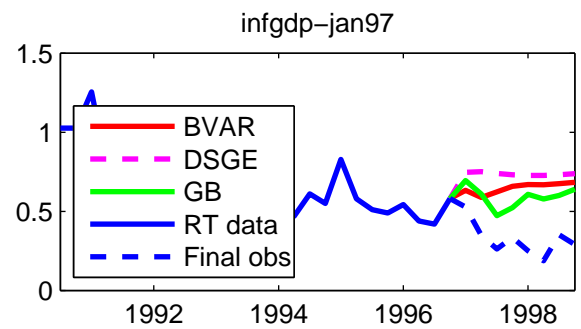
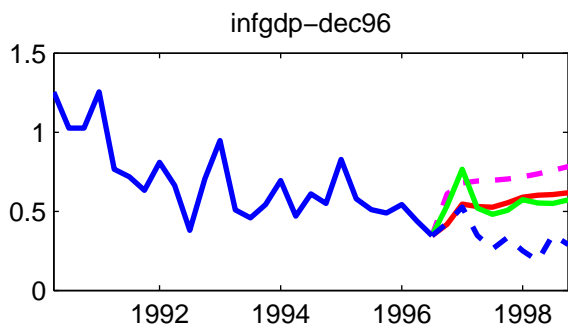
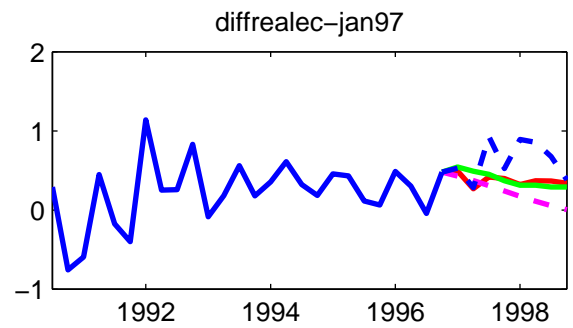
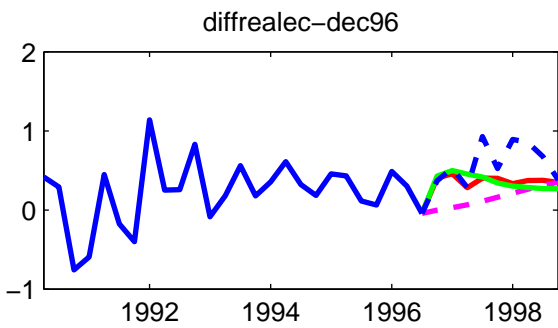
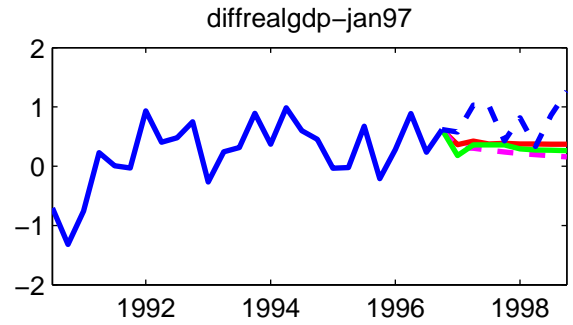
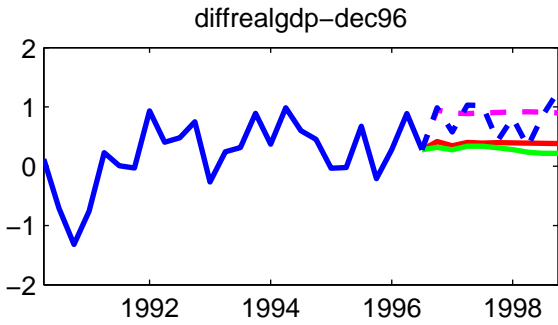
- The current version of our DSGE model provides forecasts that compete in terms of accuracy with popular alternative models.
- Arguments for including estimated DSGE models in the suite of models available to the central banks. Strong storytelling content **and** good forecasting performance.
- Our results indicate that the model can be improved along some dimensions from a forecasting point of view; possible extensions are the inclusion of rule of thumb spenders and financial accelerator.

Conclusions II

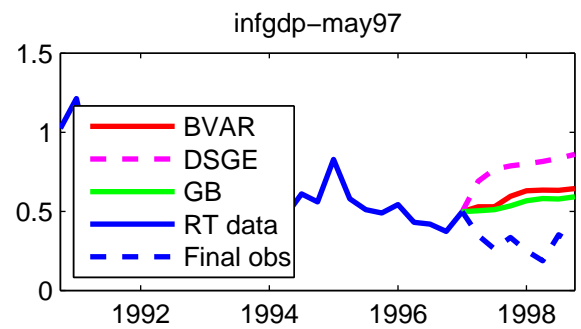
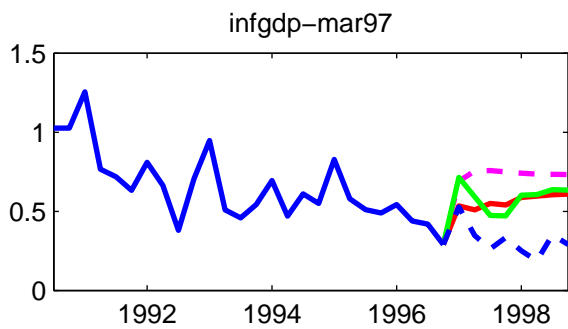
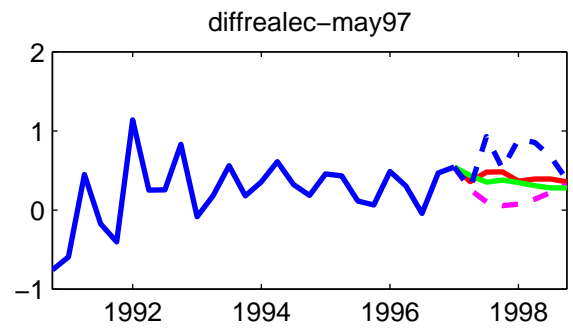
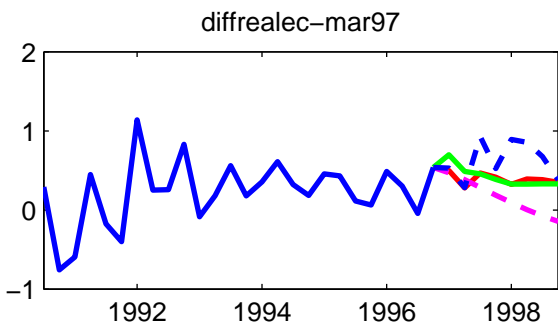
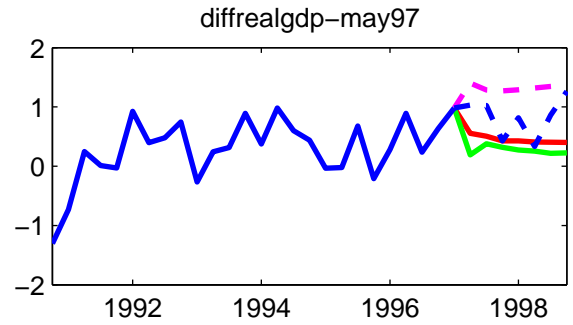
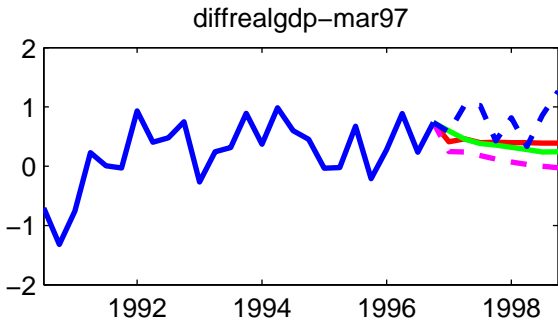
- I am currently working on looking at the real-time performance of an one-sector model since 1979 using archived versions of the Board's MPS model.
- Other considerations include conditional forecasting and hybrid forecast.



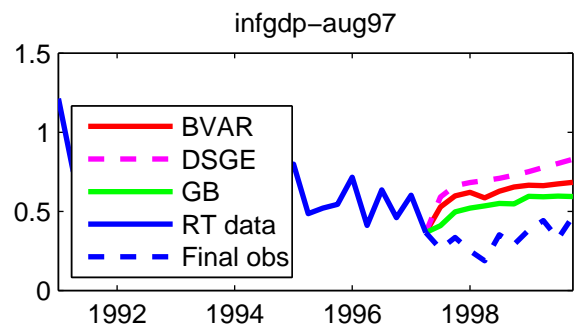
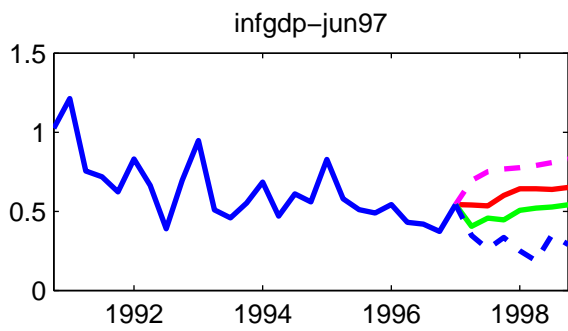
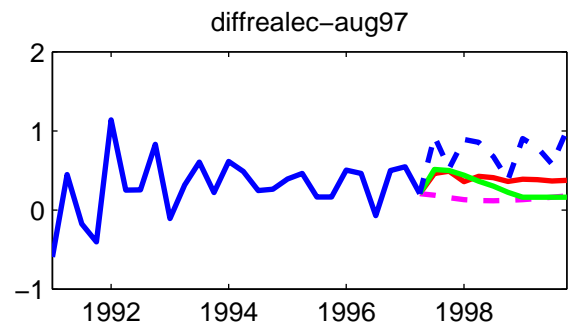
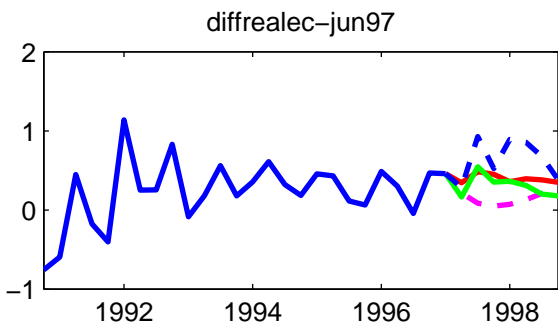
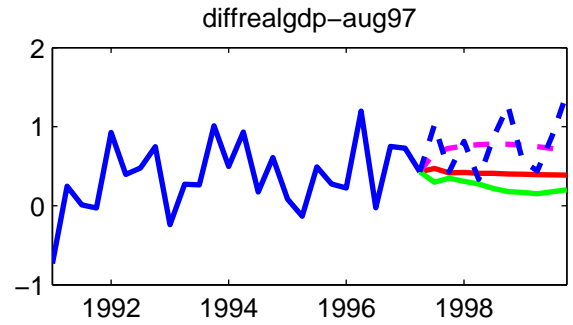
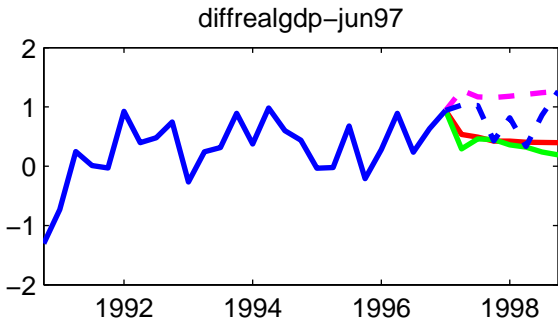
- BVAR
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- GB
- RT data
- - - Final obs

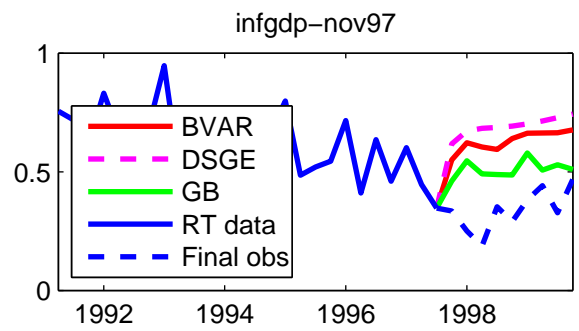
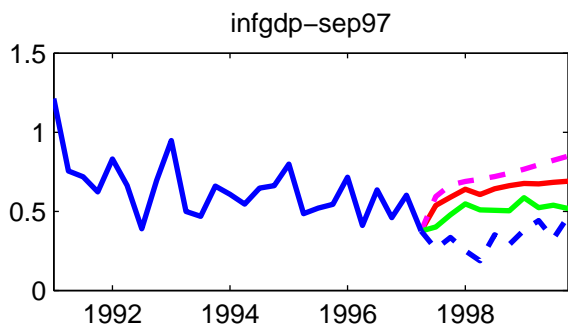
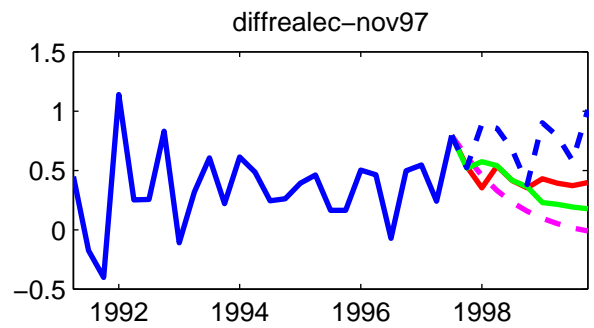
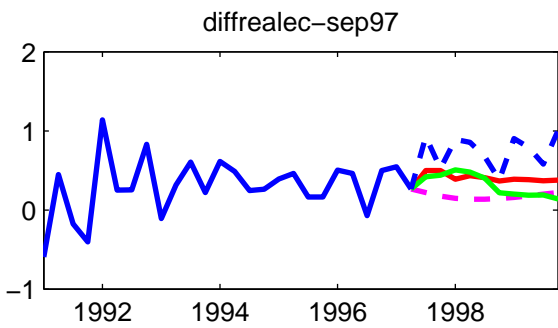
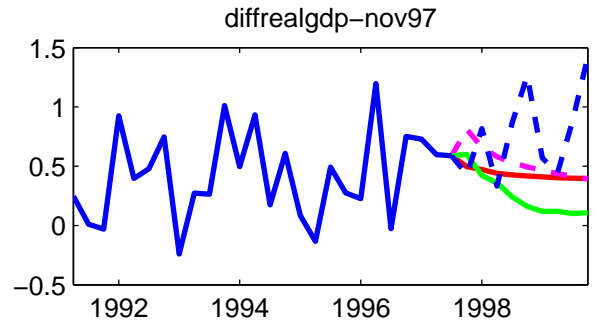
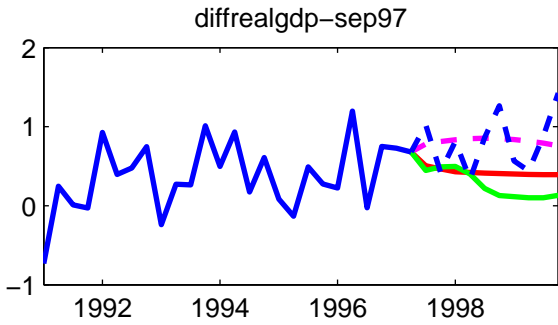


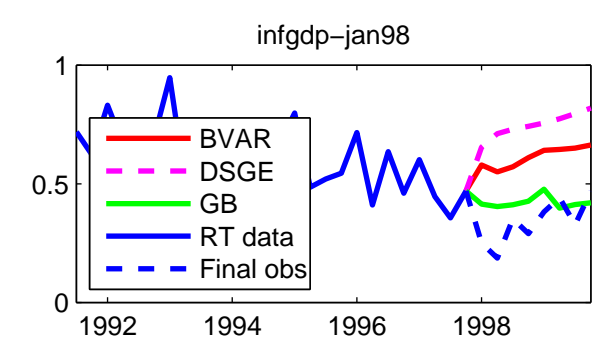
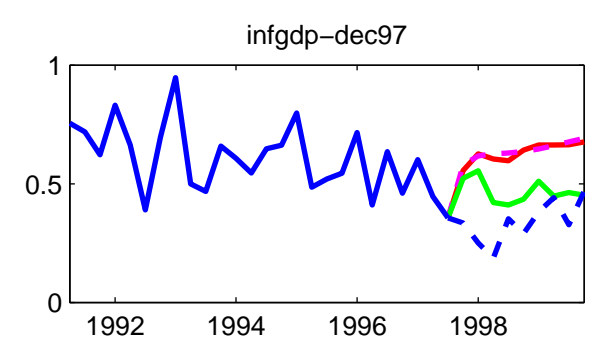
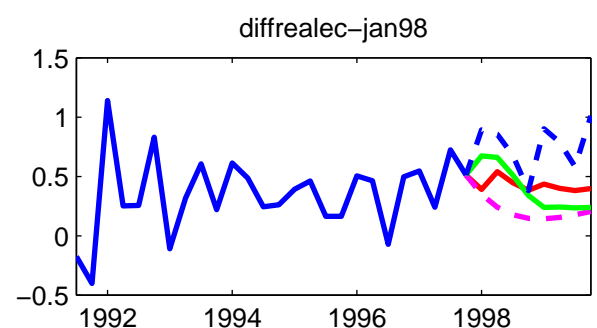
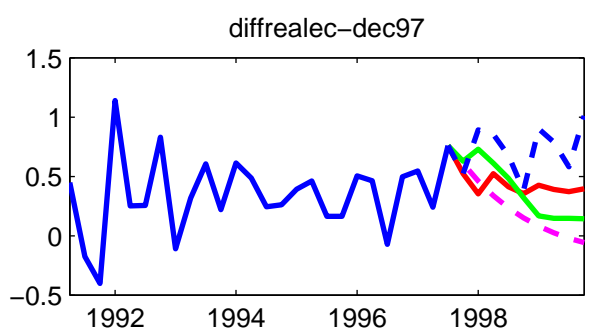
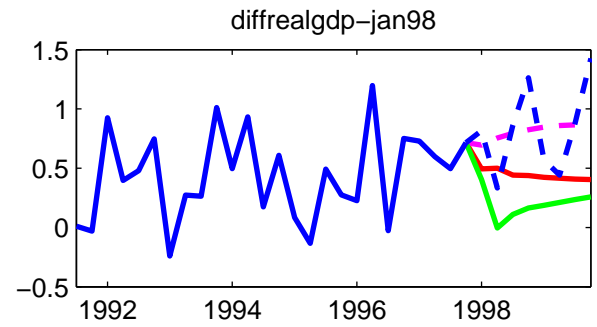
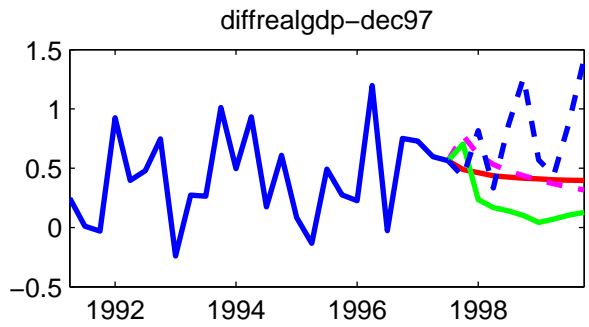
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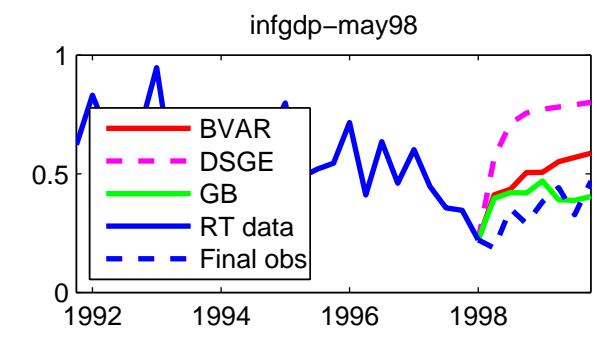
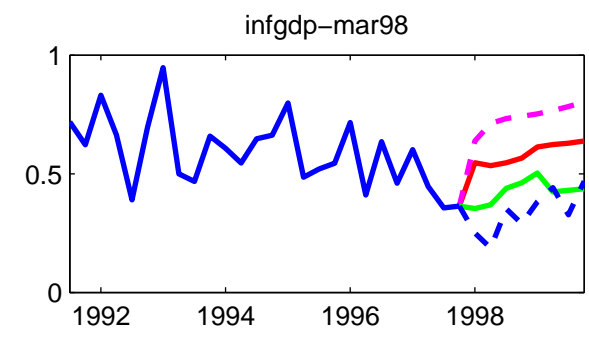
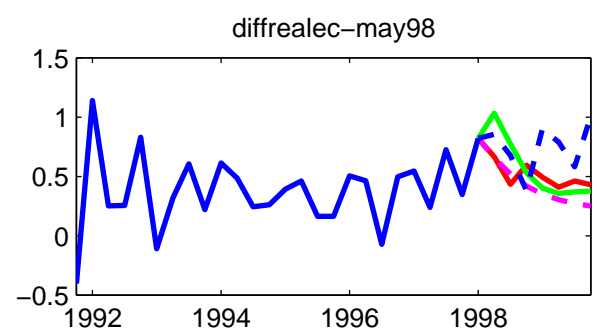
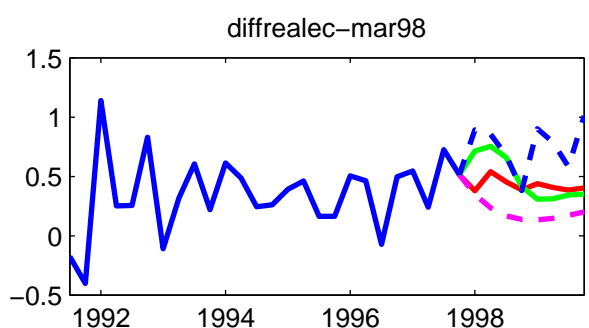
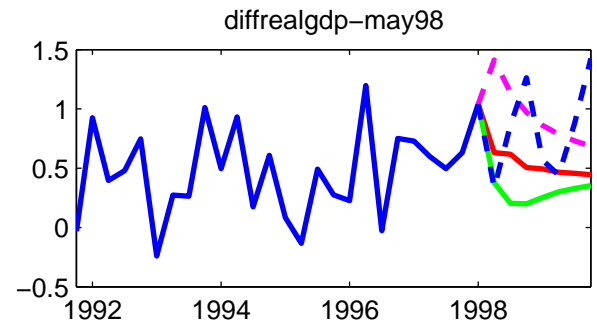
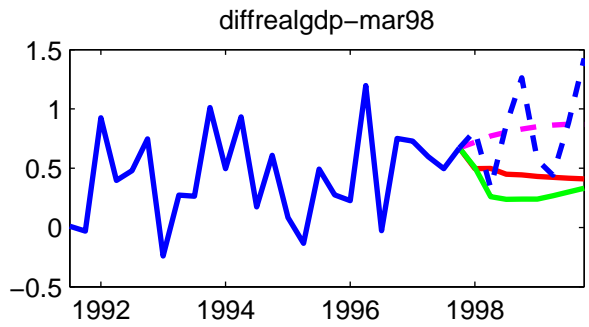
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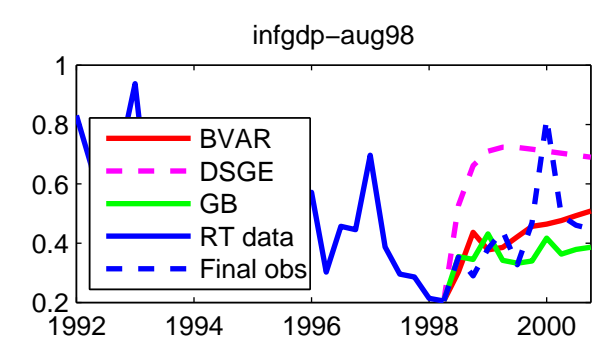
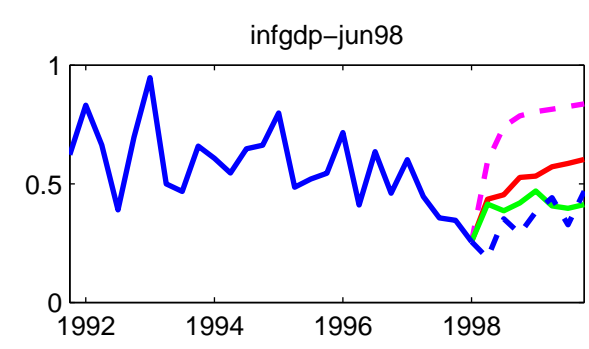
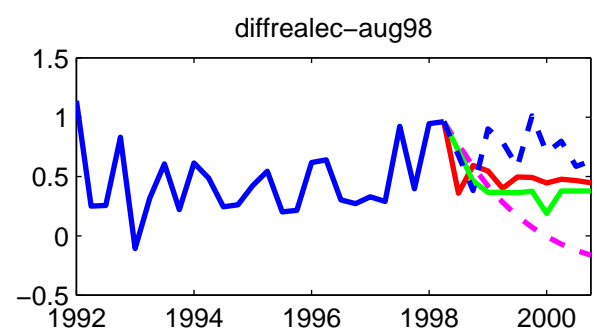
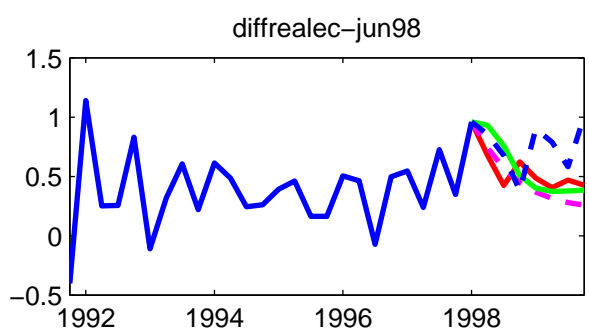
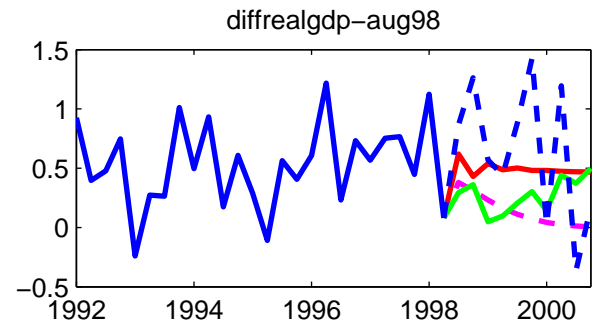
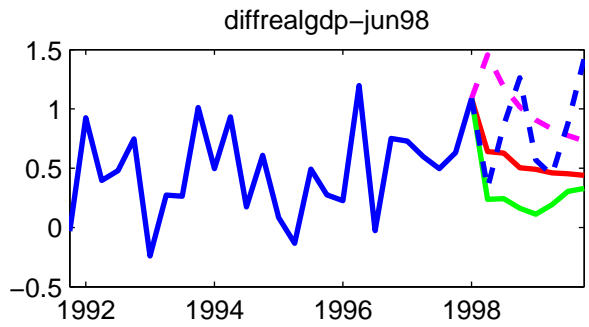


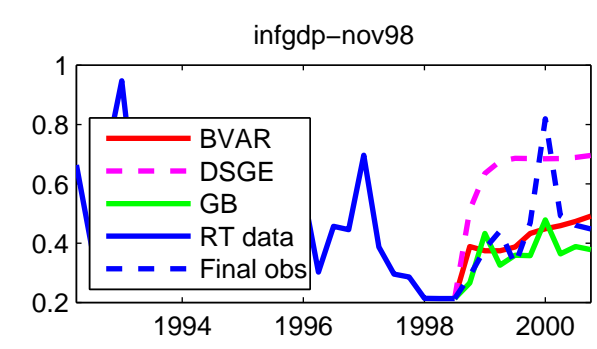
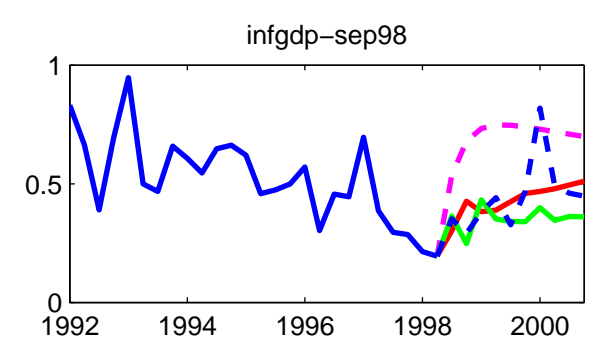
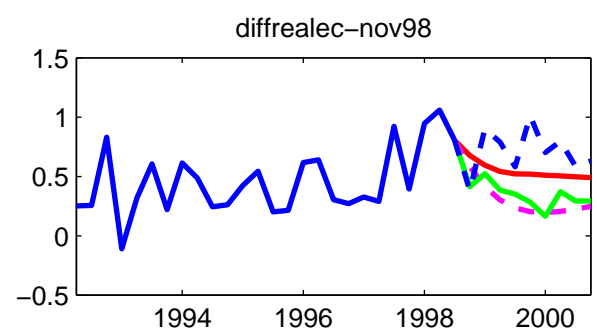
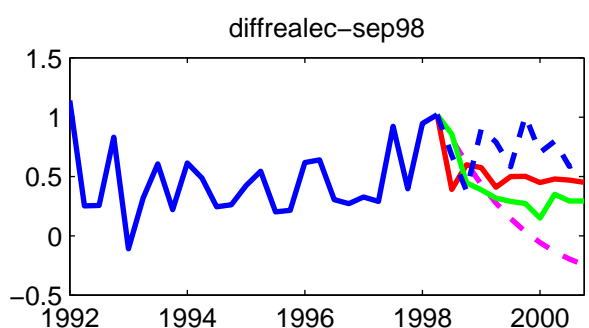
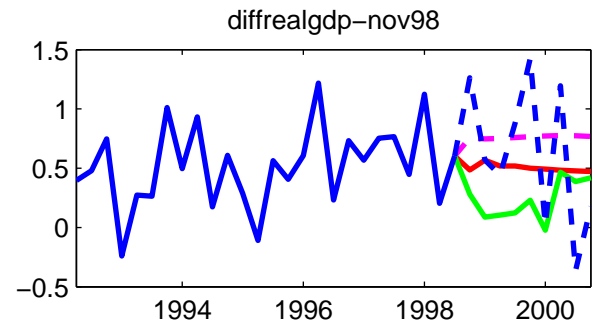
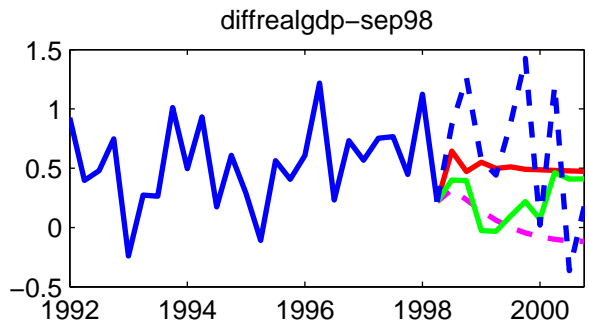


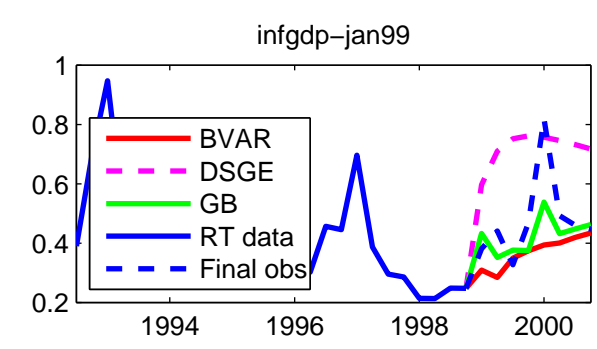
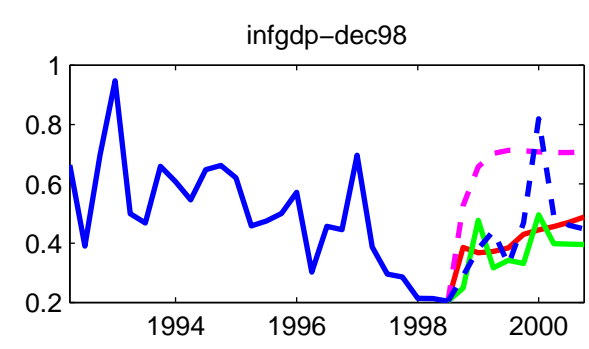
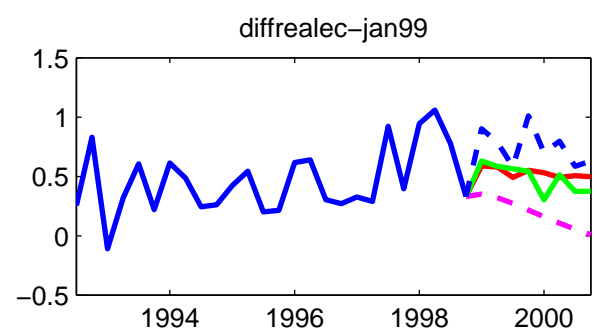
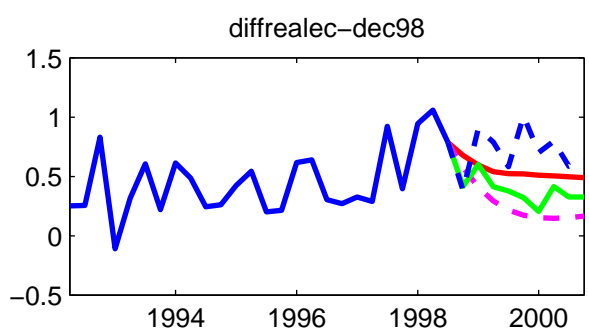
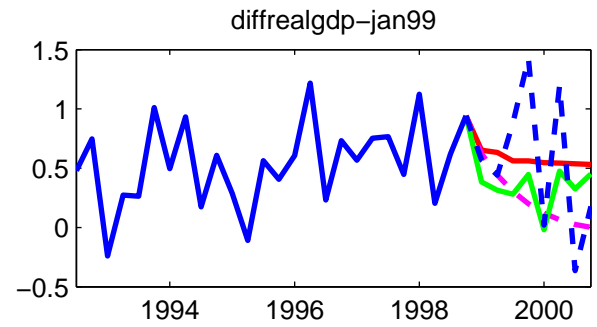
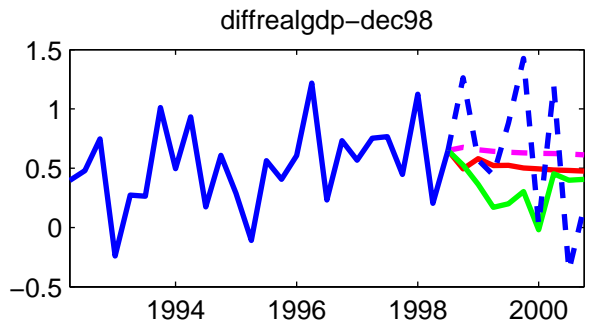


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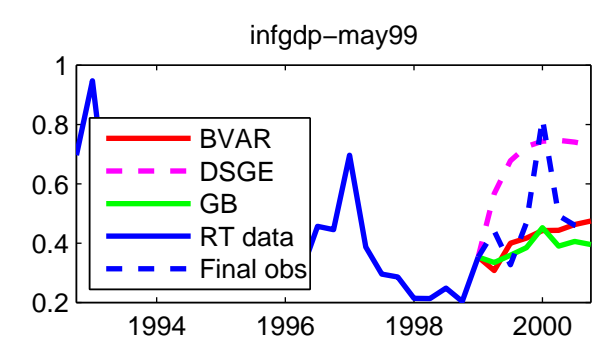
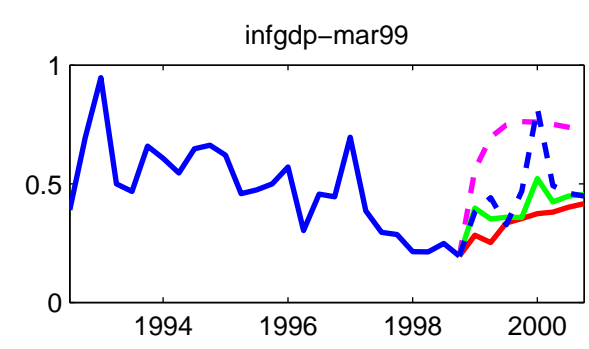
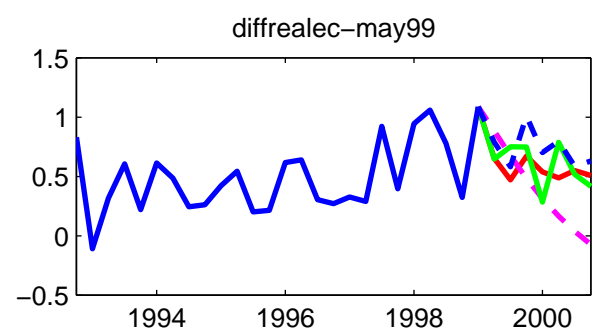
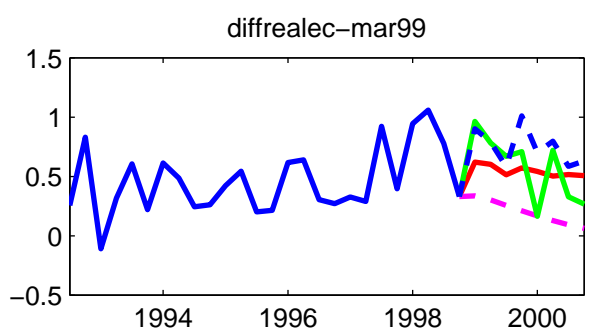
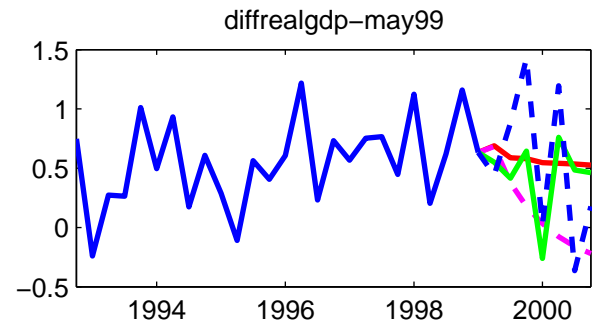
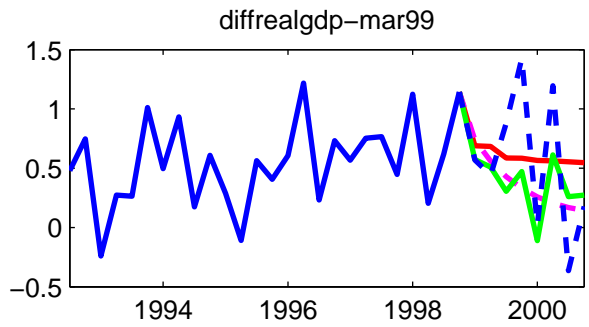


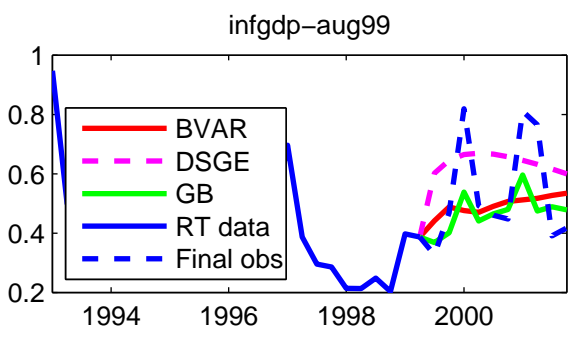
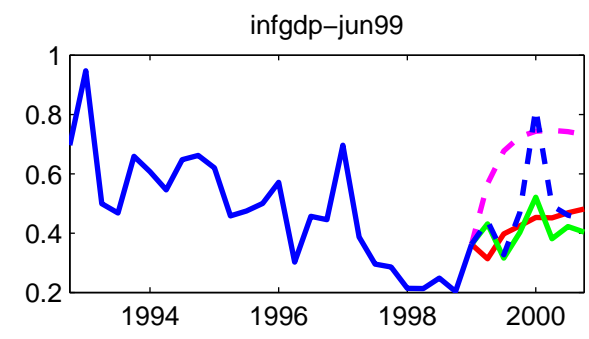
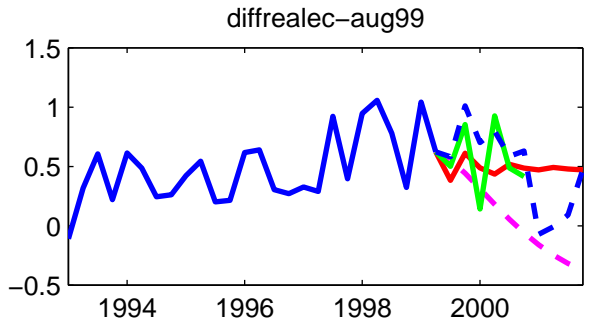
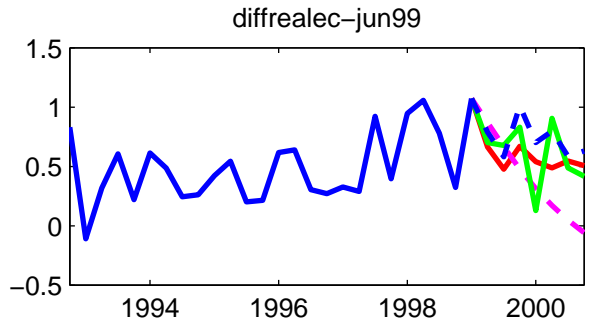
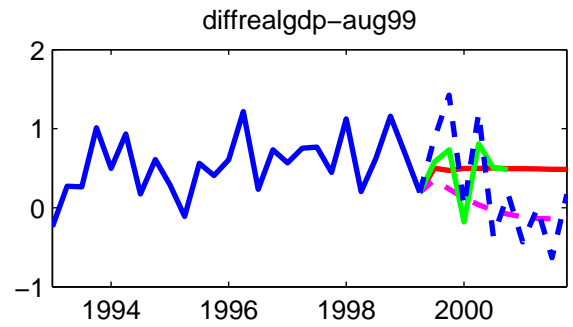
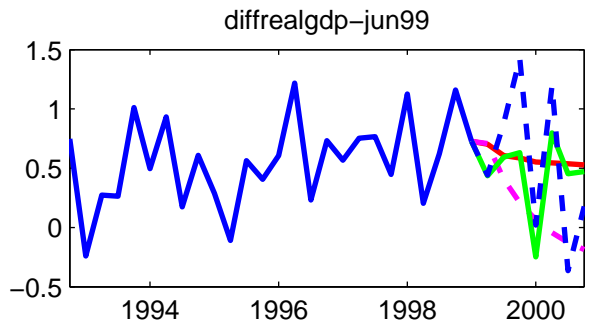


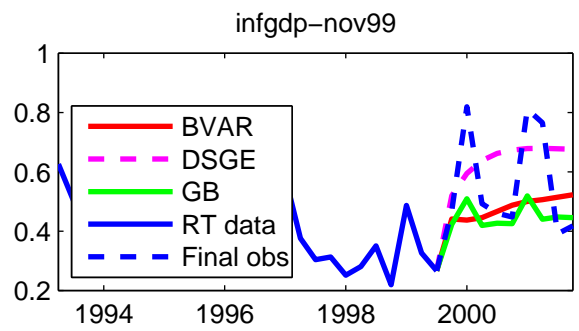
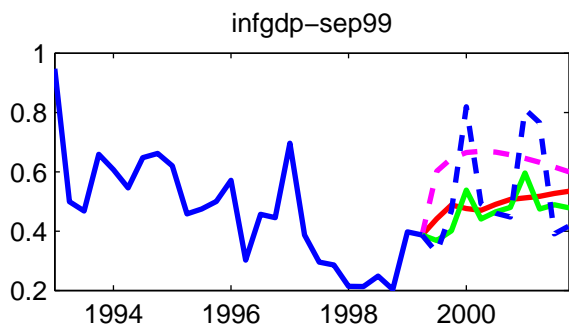
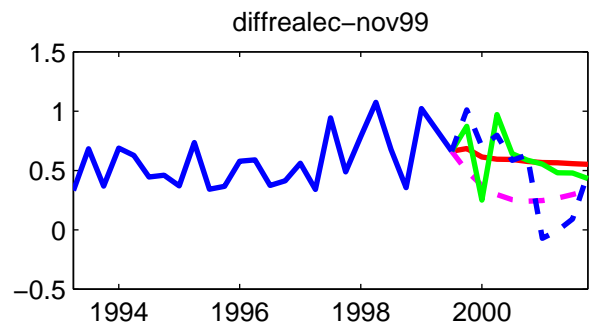
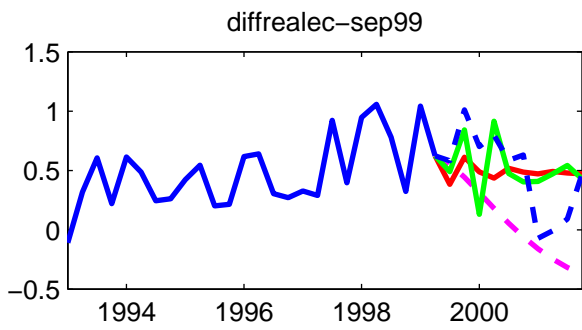
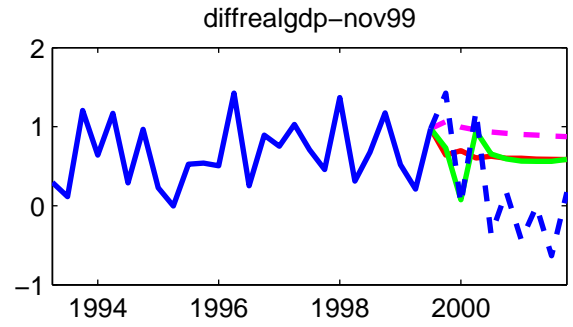
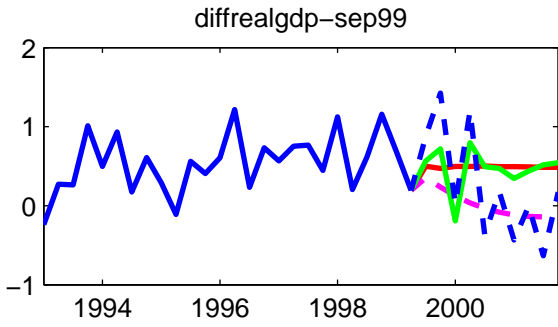




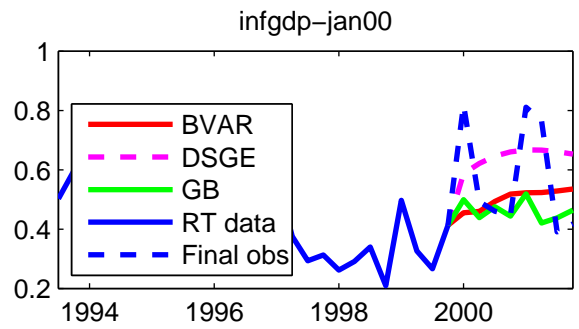
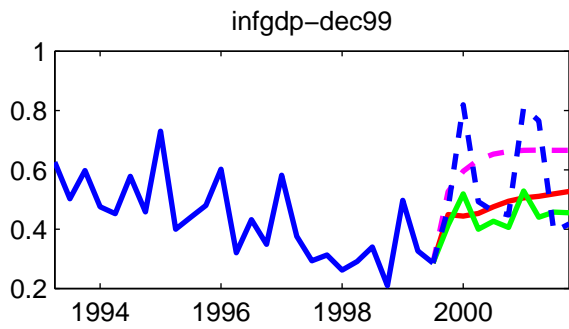
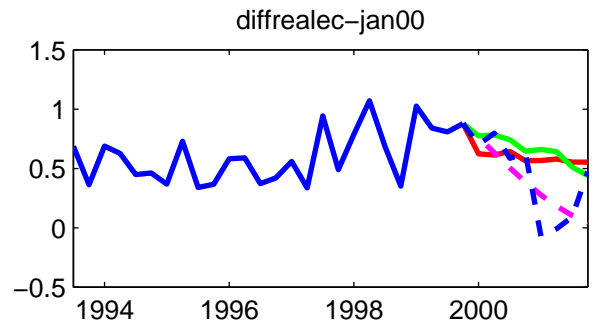
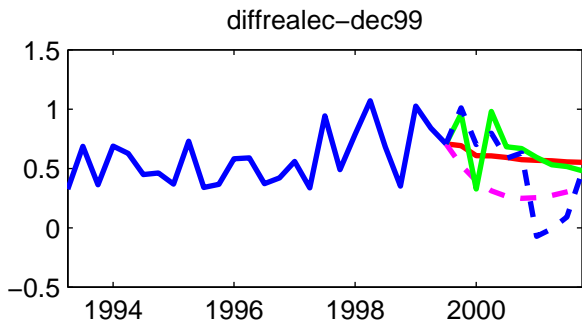
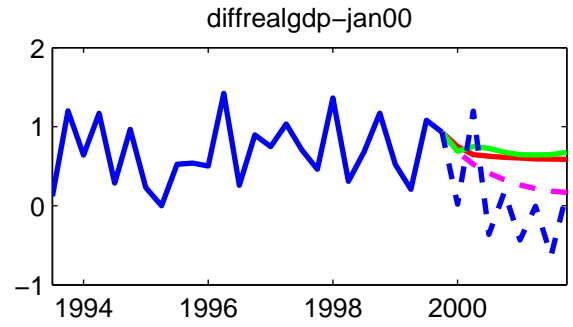
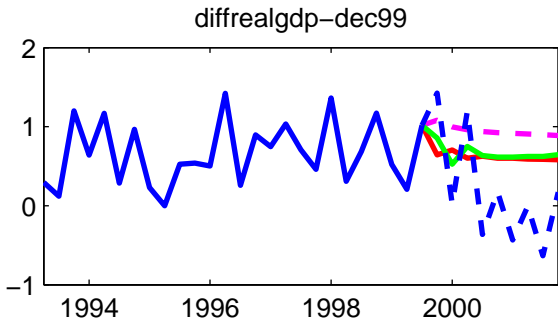
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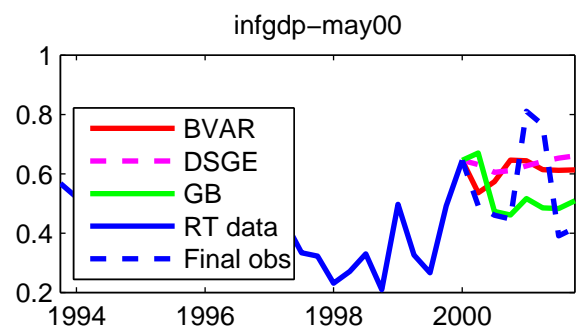
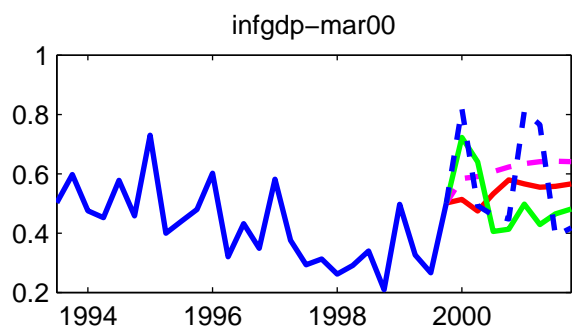
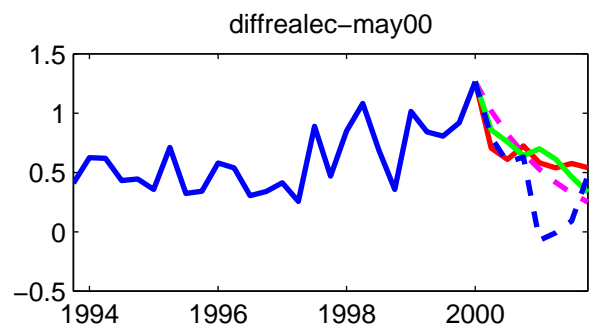
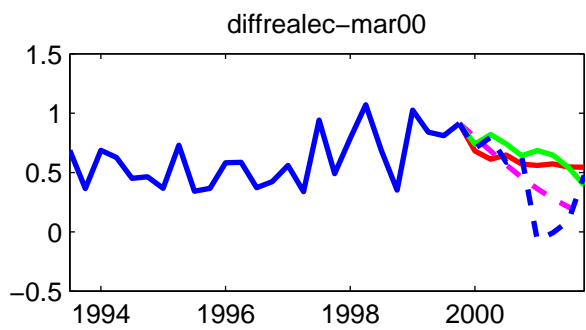
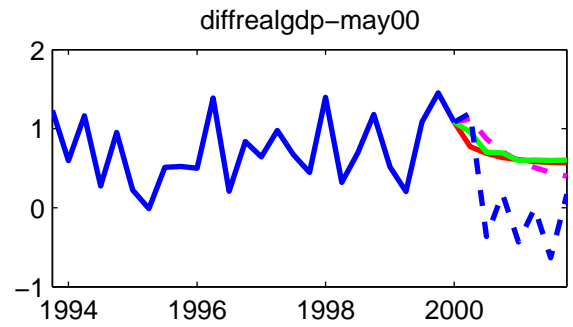
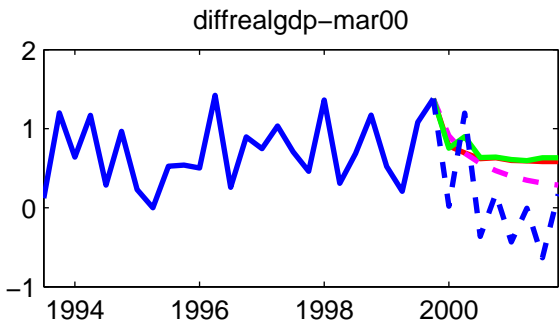


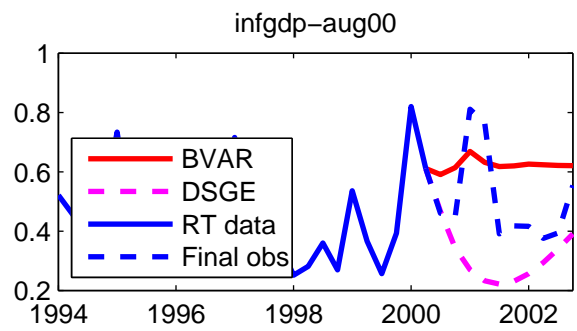
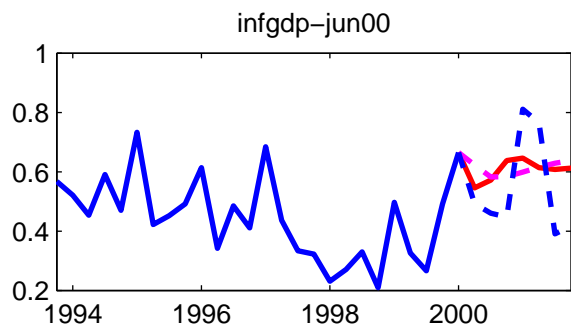
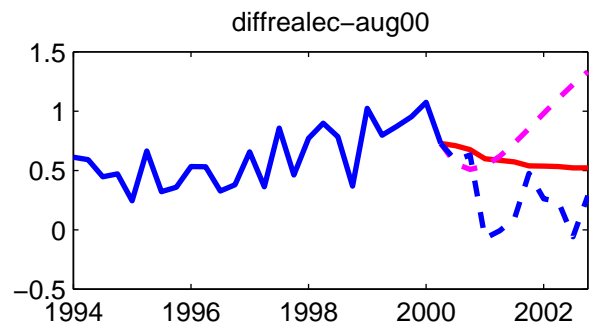
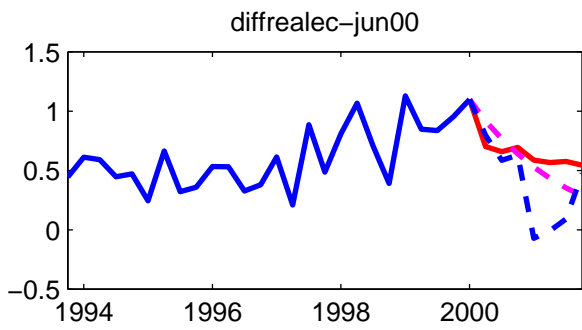
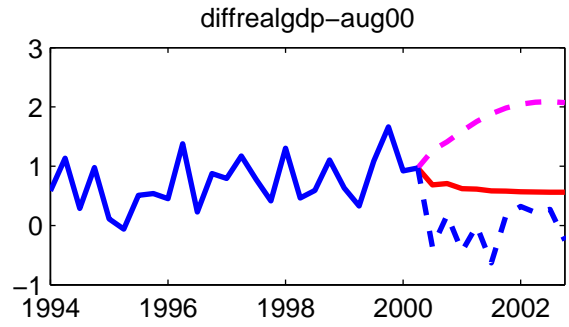
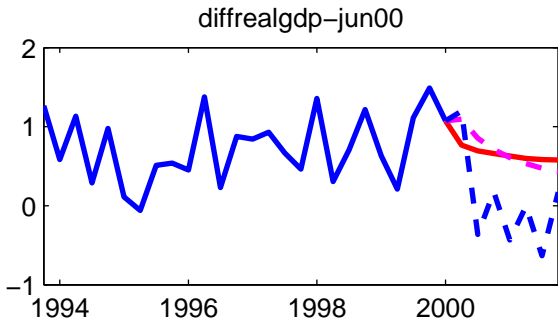


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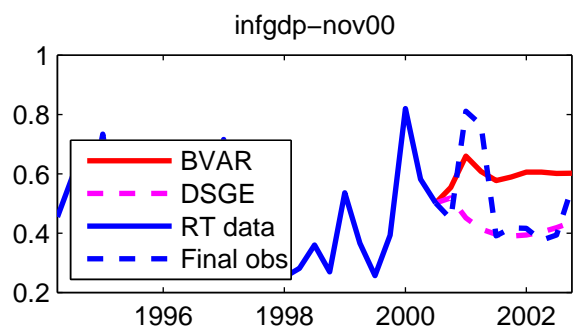
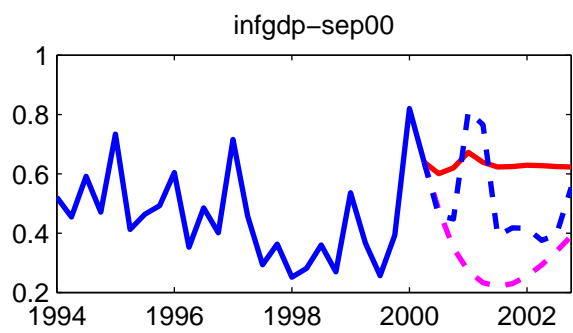
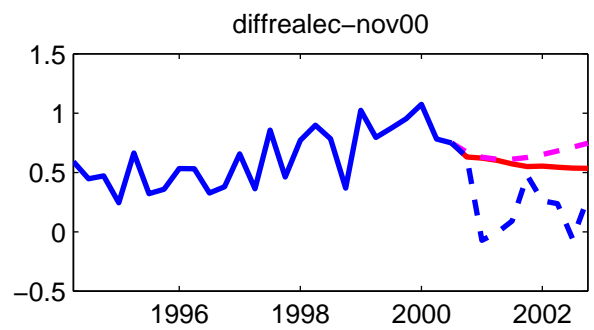
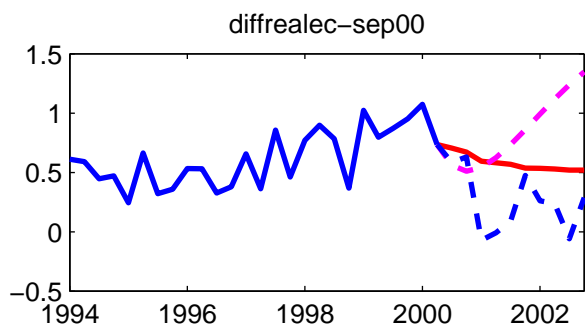
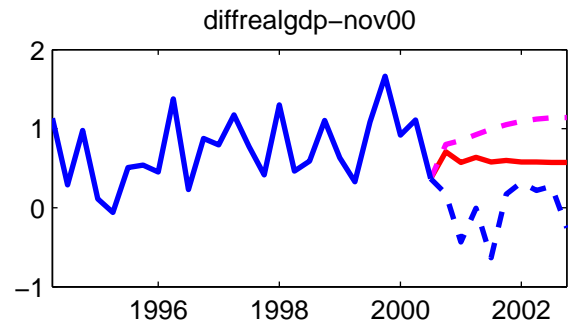
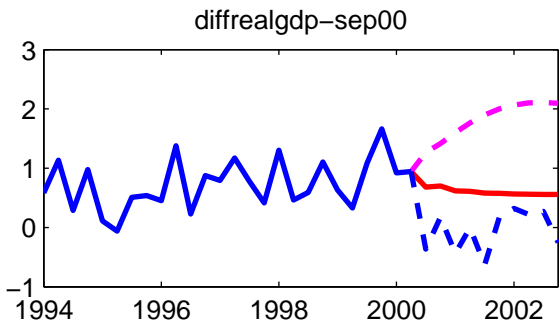


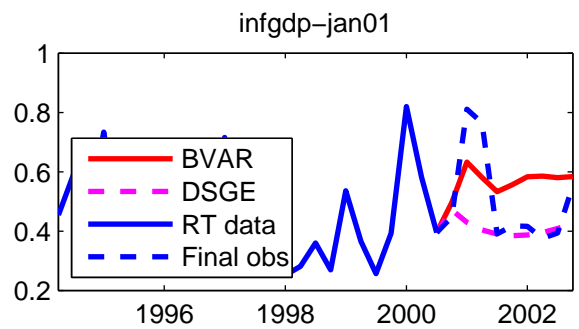
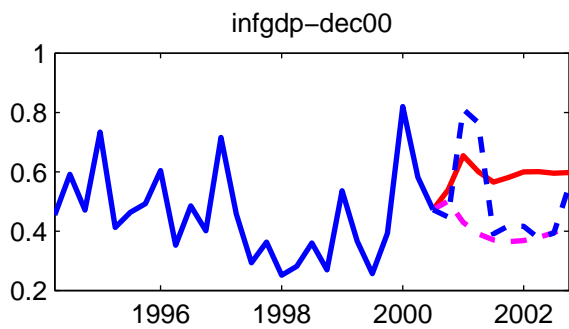
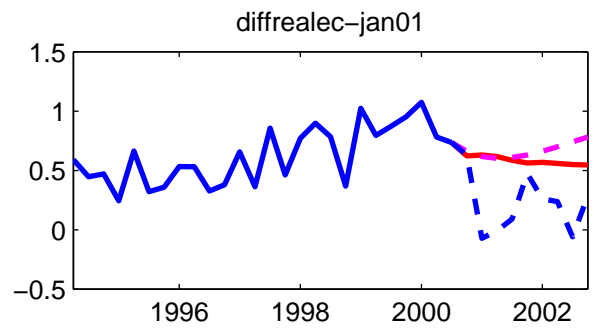
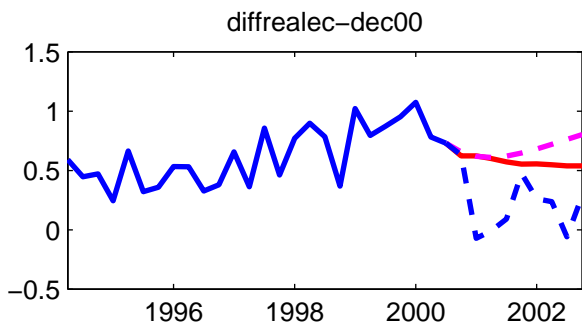
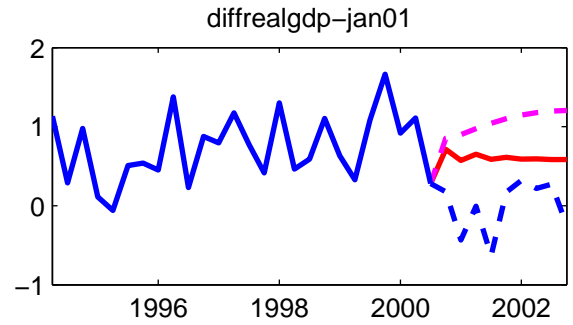
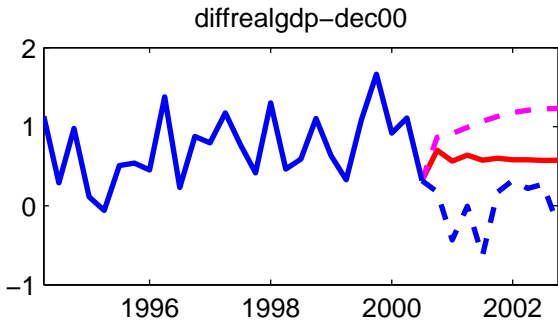
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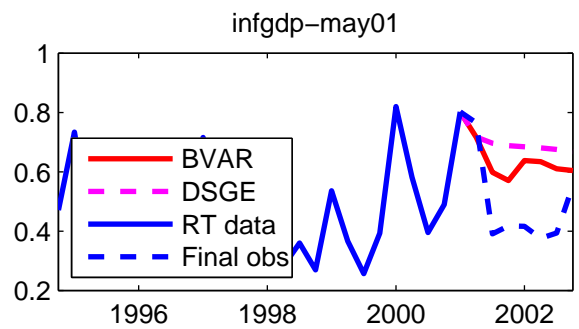
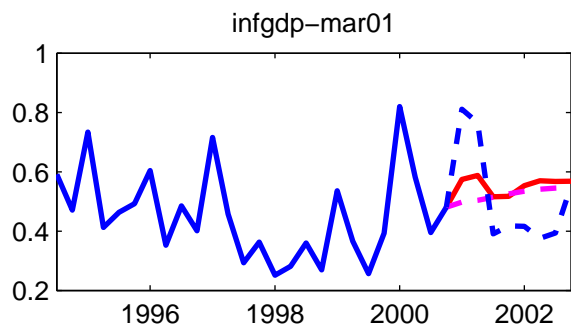
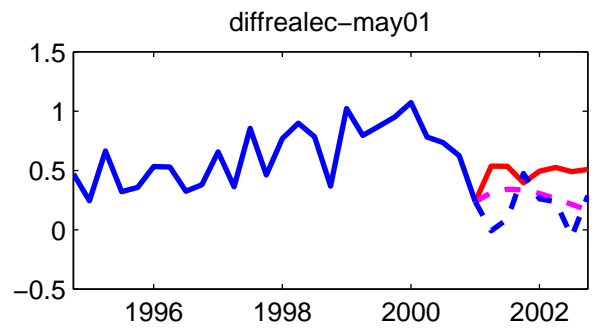
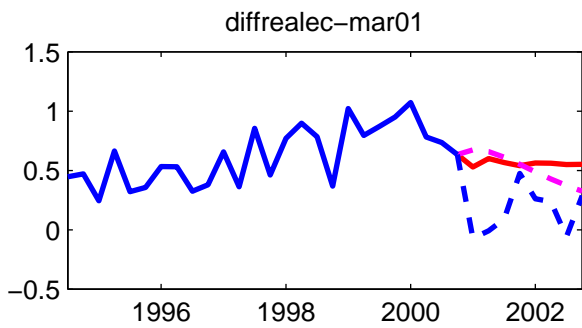
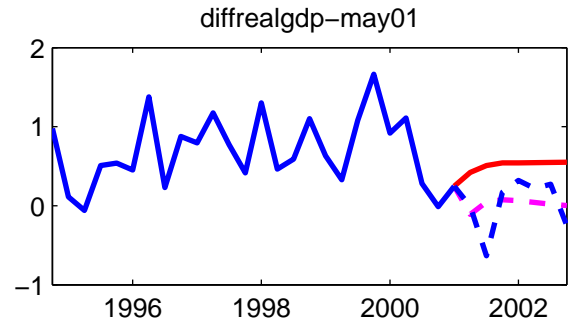
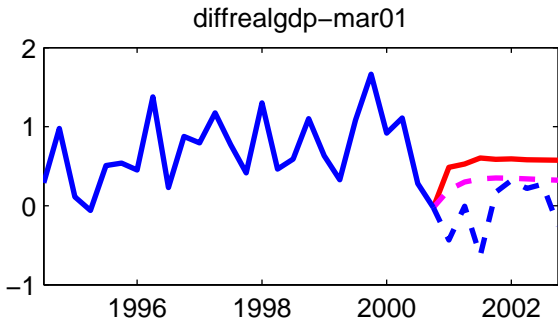


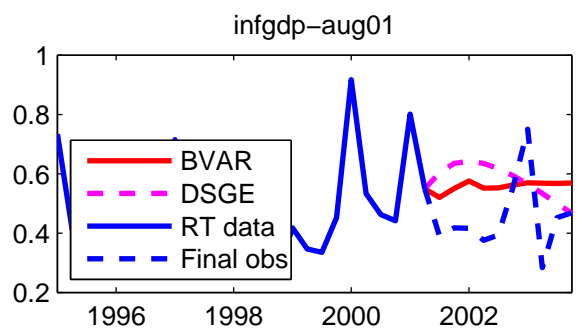
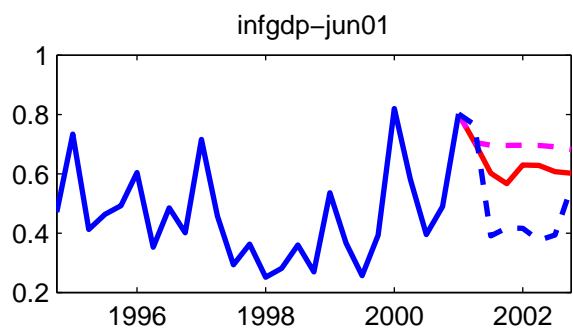
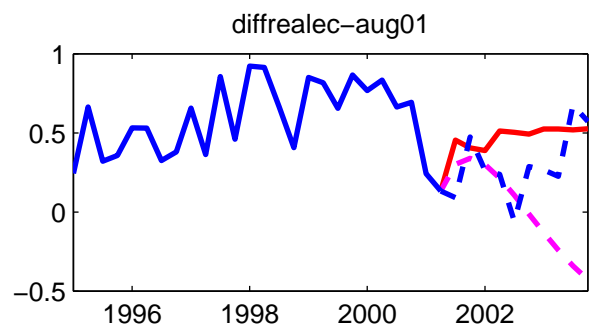
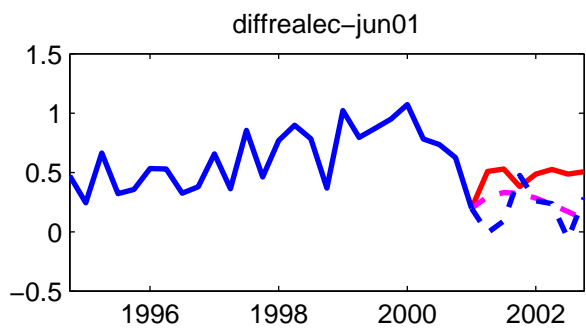
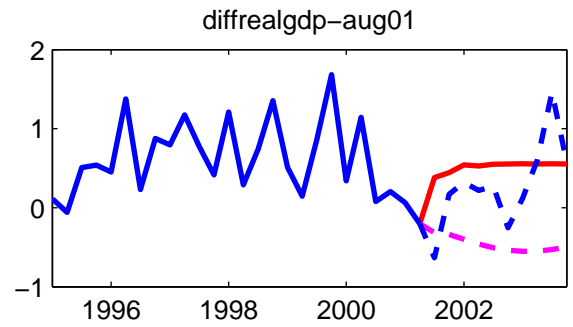
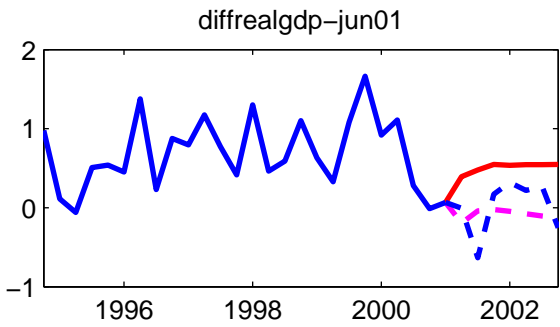
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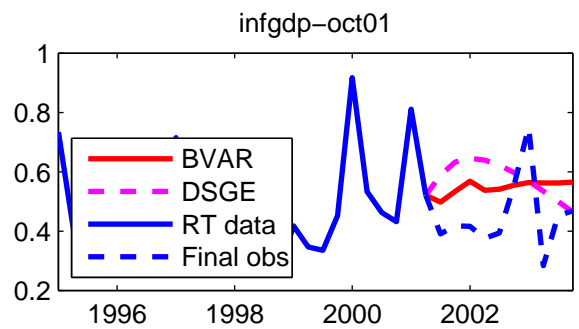
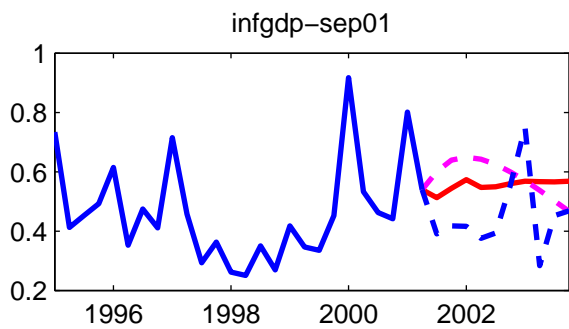
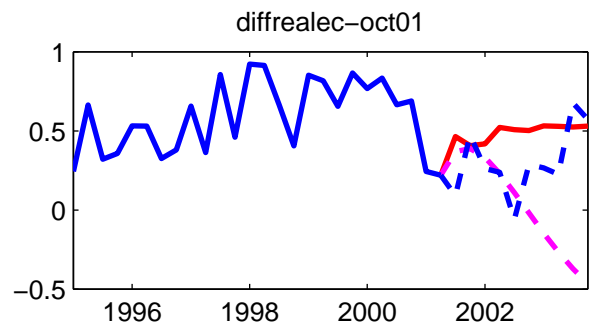
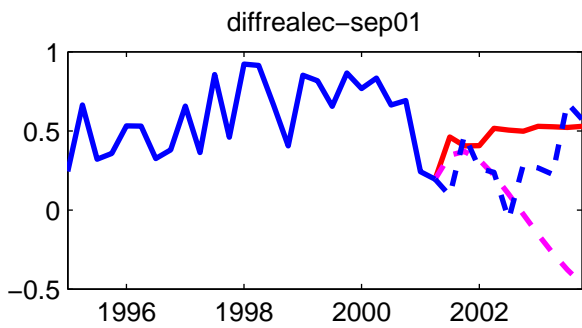
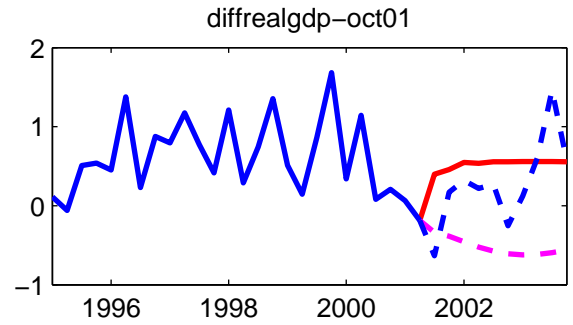
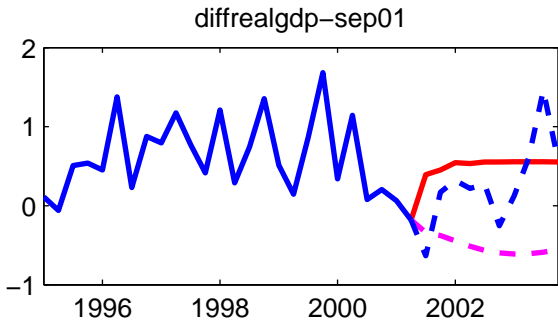


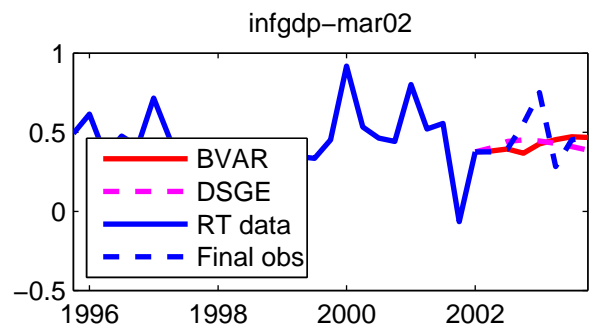
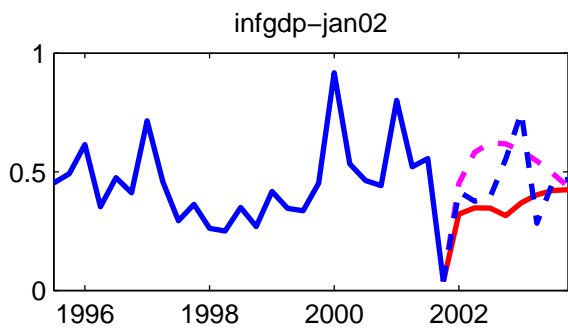
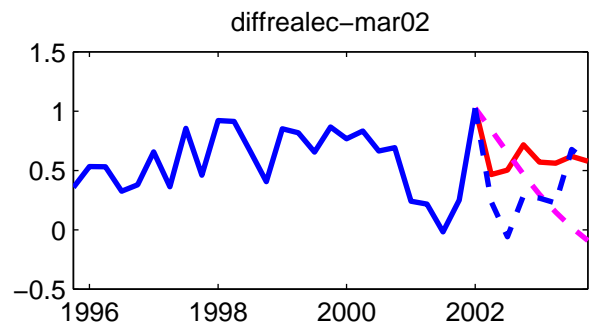
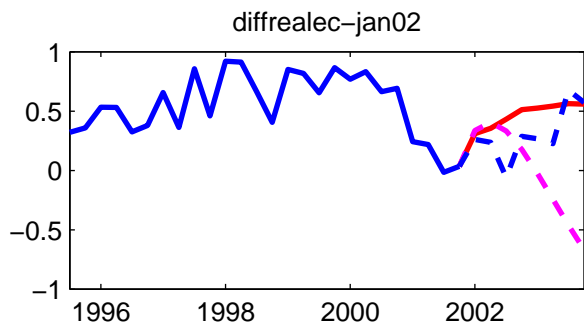
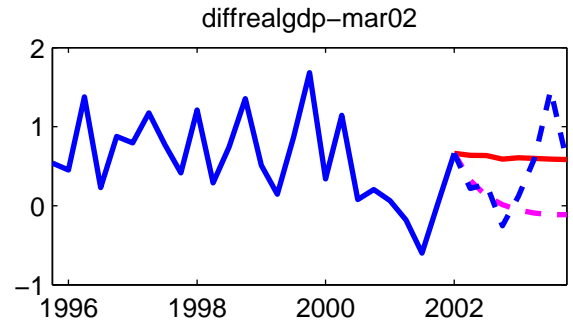
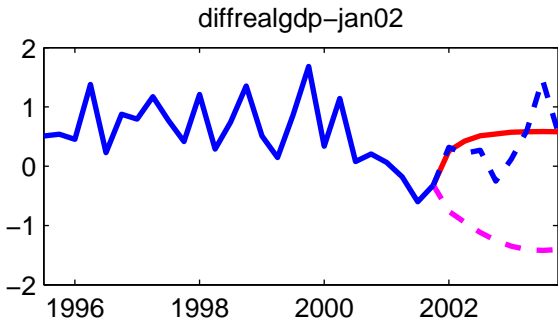


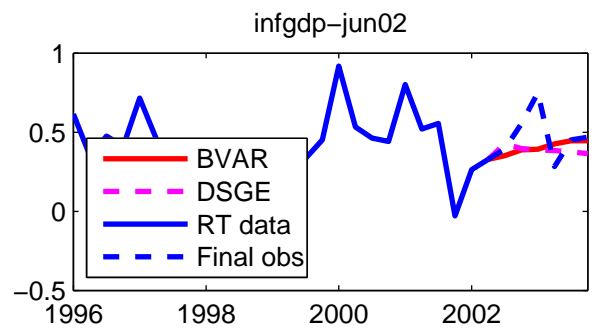
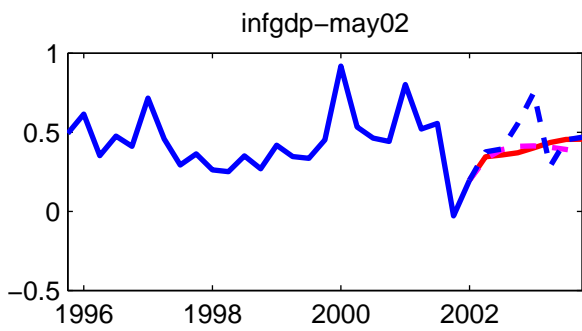
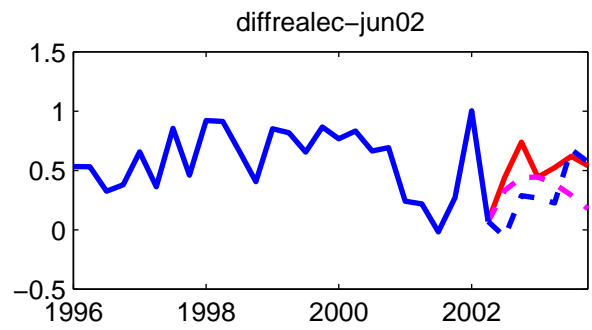
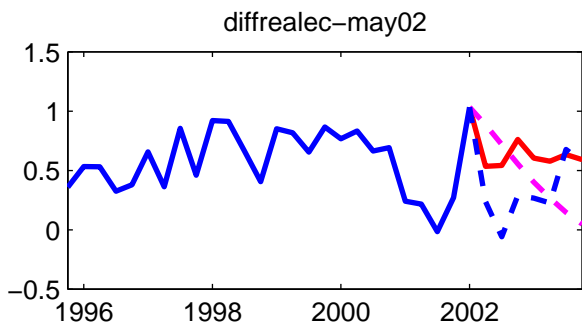
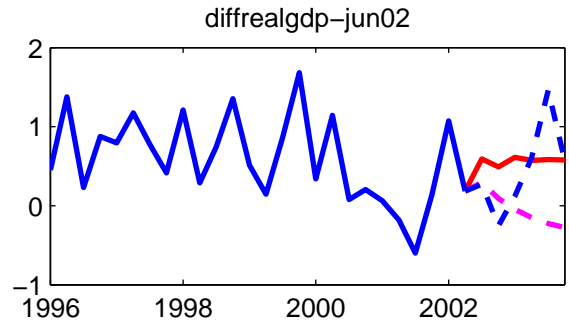
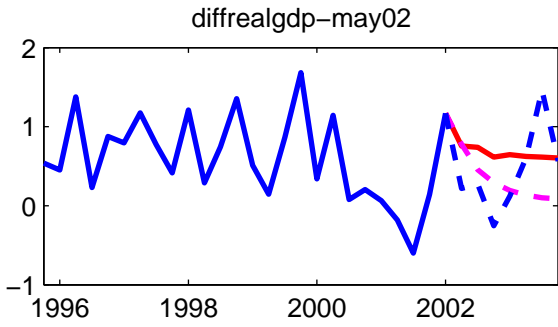
- BVAR
- - - DSGE
- RT data
- - - Final obs



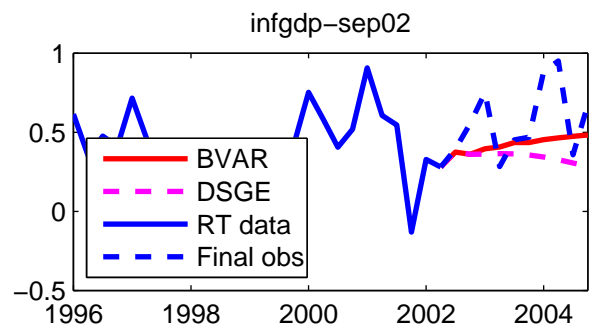
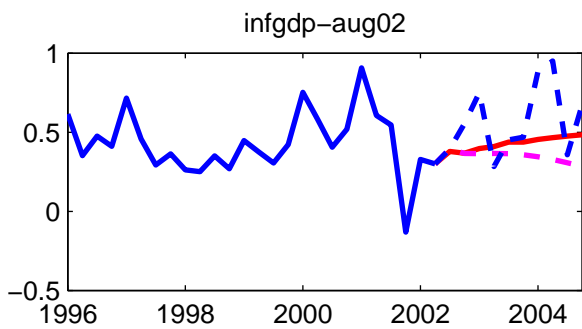
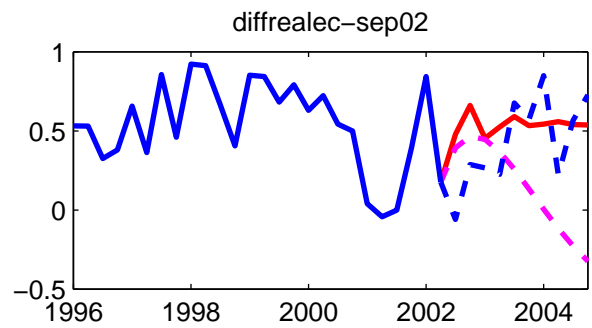
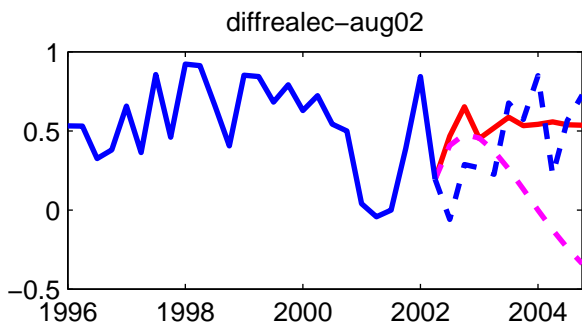
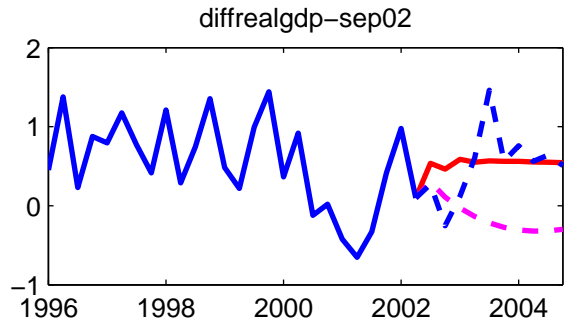
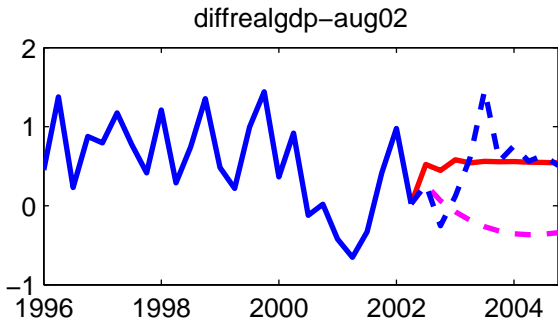


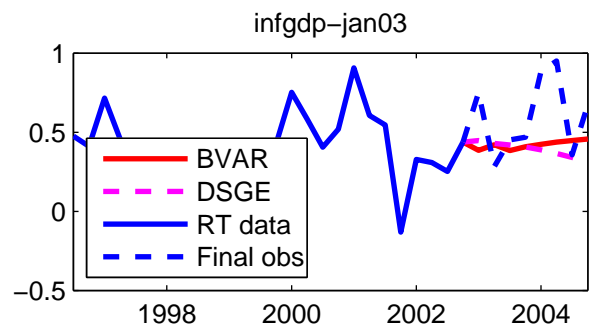
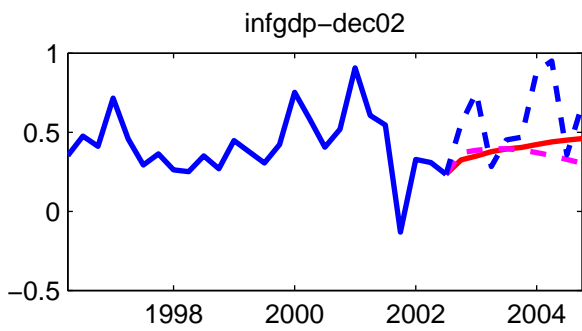
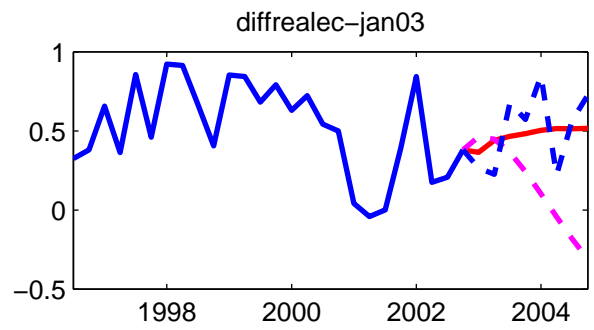
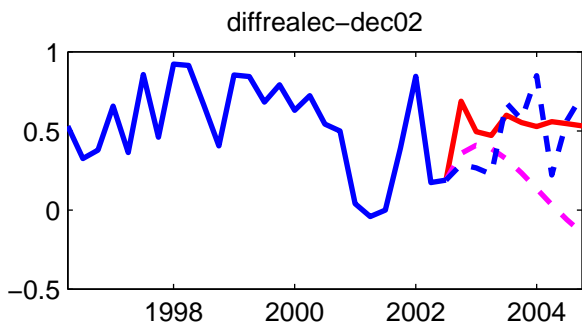
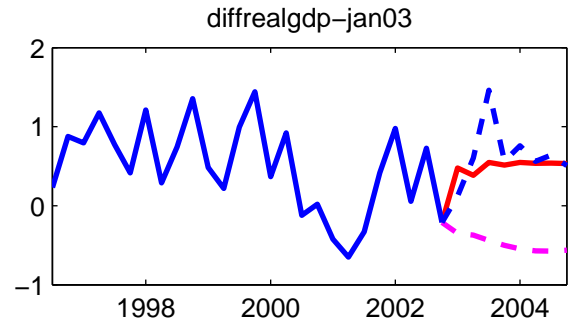
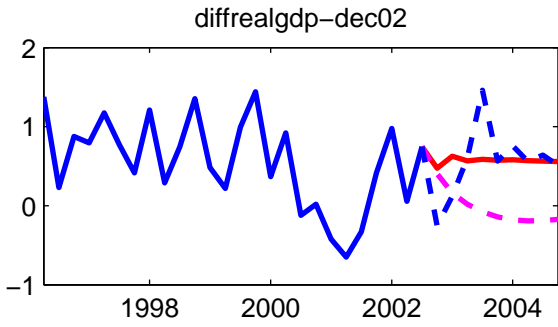


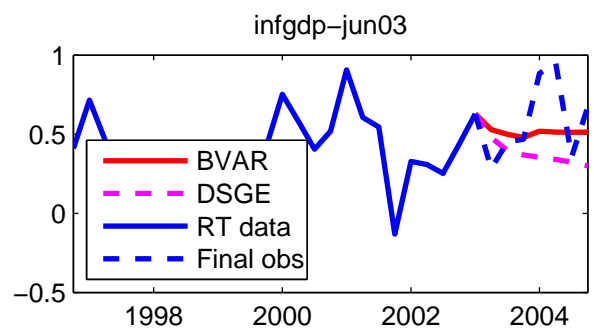
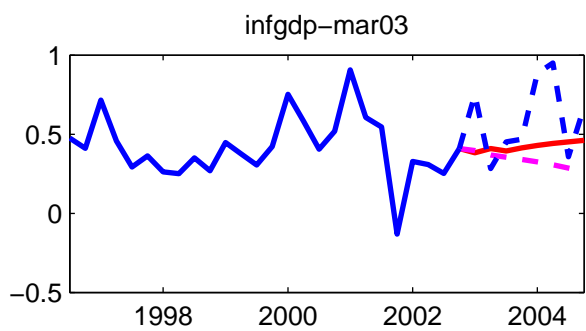
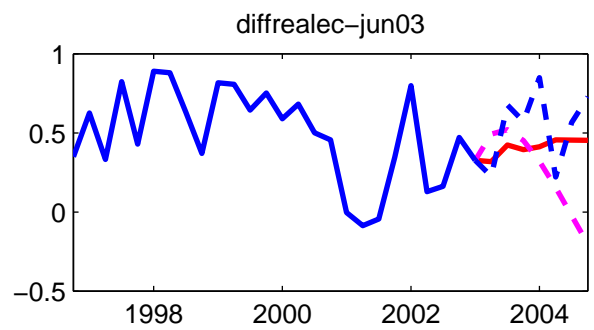
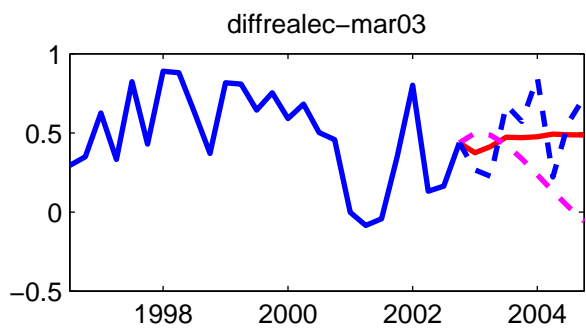
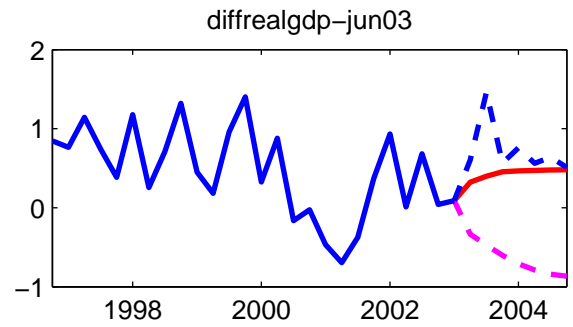
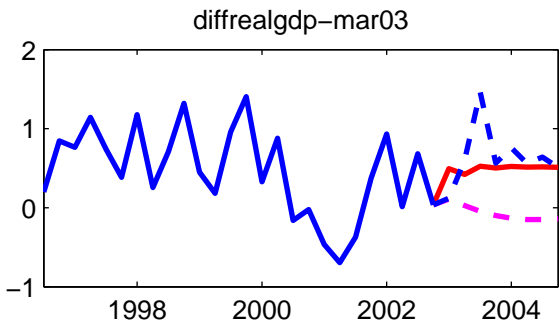




— BVAR
 - - DSGE
 — RT data
 - - Final obs







— BVAR
- - DSGE
— RT data
- - Final obs