

A Comprehensive Empirical Evaluation of Biases in Expectation Formation

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 - The models would not have helped an investor make a profit.
- Return predictability is weak at best.

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 - *Mostly no.* The out-of-sample performance is typically weak.
 - The models would not have helped a forecaster improve their forecasts.
 - *But* there are a number of important exceptions.
- Research should focus on models of biases that are strong and stable.

Related literature

- **Predictability in finance:** Meese and Rogoff (1983), Lettau and van Nieuwerburgh (2007), Welch and Goyal (2008), Campbell and Thompson (2008), Farmer and Timmermann (2023) ...
- **Defenses of rationality:** Andolfatto, Hendry and Moran (2008); Elliott, Komunjer and Timmermann (2008); Farmer, Nakamura and Steinsson (2021); Hajdini and Kurmann (2022), ...
- **IS vs OOS:** Pearce (1987), Bonham and Dacy (1991), Shmueli (2010), Bianchi, Ludvigsson and Ma (2022), Croushore (2023, 2024), ...
- **Forecast comparisons:** Giacomini and White (2006), Giacomini and Rossi (2010), Hendry and Mizon (2014), Rossi and Sekhposyan (2016), ...

Models of expectations

At time t , someone makes a prediction $y_{t+h|t}$ of y_{t+h} .

Their information set is $\mathcal{F}_t$ and their forecast errors are:

$$y_{t+h} - y_{t+h|t} = \beta \mathbf{x}_t + u_{t+h}, \mathbb{E}[u_{t+h} | \mathcal{F}_t] = 0$$

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 Their information set is $\mathcal{F}_t$ and their forecast errors are:

$$y_{t+h} - y_{t+h|t} = \beta \mathbf{x}_t + u_{t+h}, \mathbb{E}[u_{t+h} \mid \mathcal{F}_t] = 0$$

- Rational expectations model: $\beta = 0$ for any $\mathbf{x}_t$ in $\mathcal{F}_t$.
 - Forecast errors are *unpredictable*.
 - Forecasts are *optimal*:
 $\mathbb{E}(y_{t+h} - y_{t+h|t})^2$ is minimal among all forecasts in $\mathcal{F}_t$.
- Behavioral models: $\beta \neq 0$ for some $\mathbf{x}_t$ in $\mathcal{F}_t$.
 - Forecast errors are *predictable*.
 - Forecasts are *suboptimal*:
 $\mathbb{E}(y_{t+h} - [y_{t+h|t} + \beta \mathbf{x}_t])^2 < \mathbb{E}(y_{t+h} - y_{t+h|t})^2$.

Measure of predictive performance

- In-sample (IS) bias-adjusted forecast:

$$y_{t+h|t}^{*IS} = y_{t+h|t} + \hat{\beta}_T x_t$$

- Out-of-sample (OOS) bias-adjusted forecast:

$$y_{t+h|t}^{*OOS} = y_{t+h|t} + \hat{\beta}_t x_t$$

where $\hat{\beta}_t$ is the OLS coefficient estimated with data up to time t .

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$$y_{t+h|t}^{*OOS} = y_{t+h|t} + \hat{\beta}_t x_t$$

where $\hat{\beta}_t$ is the OLS coefficient estimated with data up to time t .

$$\Delta SSE_t = \frac{\sum_{s=T_0}^t \left[(y_{t+h} - y_{t+h|t})^2 - (y_{t+h} - y_{t+h|t}^{*})^2 \right]}{\sum_{s=T_0}^T (y_{t+h} - y_{t+h|t})^2}$$

An increase in ΔSSE_t means the behavioral model performs better.

Test statistics

- We use ΔSSE_T as our preferred test statistic and use a bootstrap to obtain critical values.
- Parametric bootstrap under the null of no predictability

$$H_0 : y_{t+h} - y_{t+h|t} = u_{t+h}$$

Model forecast errors u_t as an $MA(h-1)$ process and regressors x_t as $AR(p)$ or $MA(p)$ processes as appropriate.

- We also report Diebold and Mariano (1998, DM) and Clark and West (2007, CW) statistics with bootstrapped critical values. [▶ test statistics](#)
- For individual-level forecasts, we construct panel analogues of the ΔSSE_T , DM and CW statistics.

Data

1 Professional forecasters

- Macro variables from the Survey of Professional Forecasters (SPF) and interest rates in BlueChip (BC)
- Realizations from the Philadelphia Fed Real-Time Data Set (first releases)
- Data are transformed as in Coibion and Gorodnichenko (2015) and Bordo et al. (2020)
- Sample ends in 2022Q2. Sample start varies by variable.

2 Households

- 12-month ahead forecasts of inflation from the Michigan Surveys of Consumers (Michigan) and the FRBNY Survey of Consumer Expectations (SCE)
- Realizations taken as headline 12-month CPI inflation
- Sample: 1978M1–2022M10 (Michigan), 2013M6–2022M3 (SCE).

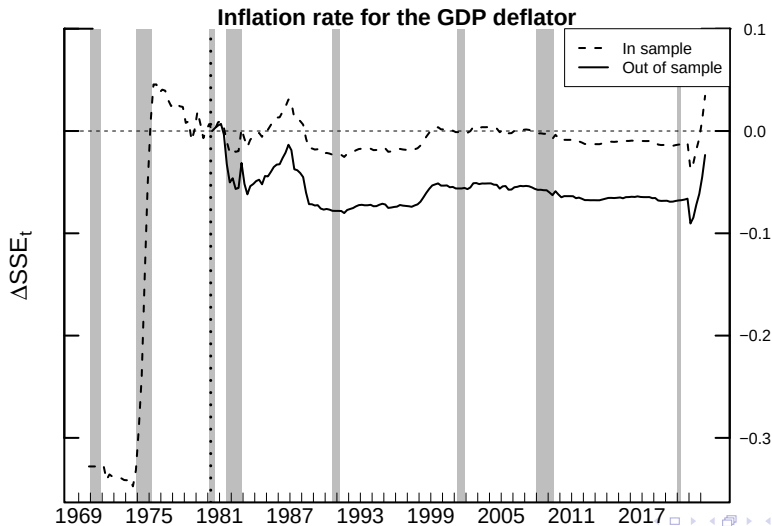
Consensus professional forecasts

- Coibion and Gorodnichenko (2015, “CG”) propose:

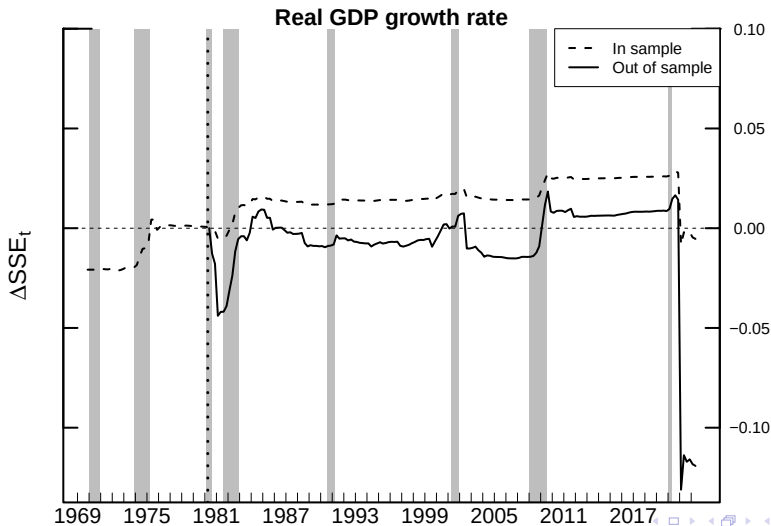
$$y_{t+h} - \bar{y}_{t+h|t} = \beta (\bar{y}_{t+h|t} - \bar{y}_{t+h|t-1}) + u_{t+h}$$

- Evaluation of the model:
 - 3-quarter ahead forecasts ▶ horizons
 - 40-period training period and recursive window estimation ▶ rolling windows
 - Omit an intercept to improve power ▶ intercept
- Other models: Mean bias, autocorrelation, Mincer-Zarnovitz (MZ), Nordhaus

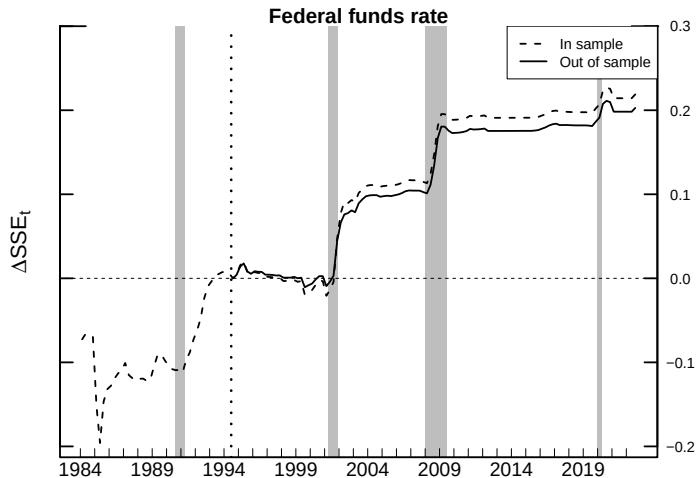
Coibion and Gorodnichenko (2015) model



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Coibion and Gorodnichenko (2015) model



Macro variables: little OOS predictability

ΔSSE_T OOS	(1) CG	(2) Mean bias	(3) Autocorrelation	(4) MZ	(5) Nordhaus
Inflation (deflator)	-0.023	-0.416	0.122**	-0.476	0.066***
Inflation (CPI)	0.015*	-0.073	-0.040	-0.043	0.075***
Real GDP	-0.119	-0.040	0.005	-0.153	-0.074
IP	0.035**	0.007	-0.008	0.008	-0.007
Nominal GDP	-0.101	-0.029	-0.028	-0.052	-0.061
Unemployment rate	-0.251	-0.029	-0.032	-0.041	-0.126
Consumption	-0.031	-0.011	-0.172	0.010	-0.082
Non-residential inv.	-0.061	-0.065	-0.035	-0.112	0.011*
Residential inv.	-0.026	-0.063	-0.007	-0.306	0.098***
Federal govt.	-0.012	-0.062	-0.035	0.027	-0.014
Non-federal govt.	-0.027	-0.105	0.026	-0.103	0.084***
Housing starts	0.047***	-0.043	0.117***	-0.100	0.205***

Interest rates: stable biases

ΔSSE_T OOS	(1) CG	(2) Mean bias	(3) Autocorrelation	(4) Mincer-Zarnowitz	(5) Nordhaus
Federal funds rate	0.203***	0.061*	0.047*	-0.007	0.222***
3-month yield	0.181***	0.129**	0.089**	0.089*	0.217***
6-month yield	0.211***	0.149**	0.129**	0.115*	0.245***
1-year yield	0.196***	0.124*	0.037	0.043	0.227***
2-year yield	0.112***	0.154**	-0.022	0.046*	0.168***
10-year yield	-0.001	0.295***	-0.046	0.054*	0.042**
Aaa yield	0.067**	0.243**	0.016	-0.125	0.093***
Baa yield	0.052*	0.390***	0.108*	0.238**	0.097**
1y-3m spread	-0.009	-0.103	0.011	-0.148	0.017*
10y-2y spread	0.056**	-0.061	-0.022	-0.057	0.090***
Aaa-Baa spread	-0.011	-0.142	0.071	0.036	-0.129

Models for individual forecasts

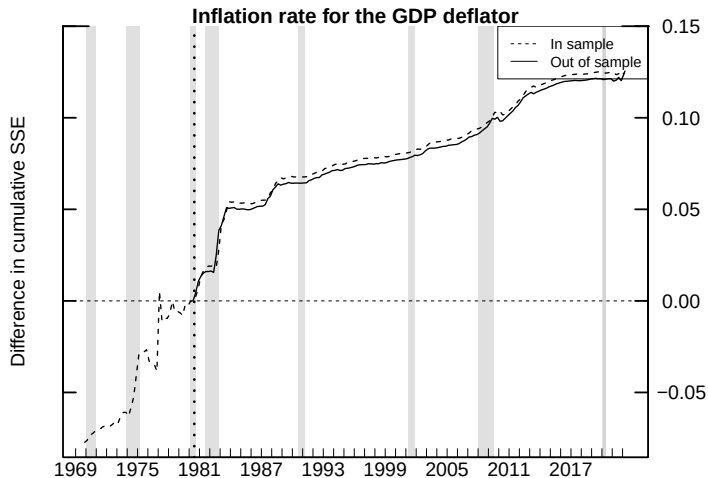
- Forecast errors at the individual level may be more easily predictable.
- Bordalo et al. (2020, BGMS) apply the CG model to individual forecasts:

$$y_{t+h} - y_{t+h|it} = \beta (y_{t+h|it} - y_{t+h|it-1}) + u_{it+h}$$

- Additional models: Autocorrelation, Kohlhas-Walther (2021, KW), Mincer-Zarnovitz, Nordhaus.
- We also propose a feasible model based on forecast combination:

$$y_{t+h} - y_{t+h|it} = \beta (\bar{y}_{t+h-1|t-1} - y_{t+h-1|it-1}) + u_{it+h}$$

Forecast combination model



Forecast combination works best: macro variables ▶ interest rates

ΔSSE_T OOS	(1) BGMS	(2) Autocorr	(3) MZ	(4) Nordhaus	(5) KW	(6) FC
Inflation (deflator)	0.007***	0.114***	-0.513	0.007***	-0.323	0.124***
Inflation (CPI)	-0.003	-0.036	0.043*	-0.009	-0.036	0.032***
Real GDP	0.022***	-0.029	0.042*	0.008***	0.013	0.057***
Industrial Production	-0.010	-0.016	0.036*	-0.008	0.002	0.047***
Nominal GDP	0.011***	-0.060	-0.071	0.005**	-0.061	0.057***
Unemployment rate	-0.114	-0.048	0.010	-0.042	0.024	0.013***
Consumption	0.058***	-0.166	-0.003	0.003**	-0.090	0.035***
Non-residential inv.	-0.018	-0.035	-0.055	-0.004	-0.102	0.060***
Residential inv.	-0.019	0.046**	-0.037	-0.010	-0.092	0.098***
Federal govt.	0.082***	0.063***	-0.009	-0.011	-0.027	0.129***
Non-federal govt.	0.123***	0.039***	0.126***	-0.005	-0.048	0.171***
Housing starts	0.004*	0.208***	-0.099	-0.006	-0.054	0.097***

Household tests: Forecast combination dominates

	(1)	(2)	(3)	(4)	(5)
	Mean bias	CG/BGMS	Autocorrelation	Mincer-Zarnovitz	Forecast combination
Michigan average	0.014*	0.002*	0.063***	0.008*	–
SCE average	-0.110	-0.002	0.032	-1.491	–
Michigan median	-0.243	-0.005	-0.043	-0.252	–
SCE median	-0.568	0.050*	-0.061	-2.139	–
Michigan individual	-0.014	–	–	0.617***	0.889***
SCE individual	-0.113	0.165***	–	0.632***	0.799***

Interpretation

- Our OOS tests raise the bar for claiming biases in expectations.
- Some models of biases clear our bar easily.
- But why do many other models fail to clear the bar?
 - 1 Power of OOS tests could be too low. ▶ power
 - 1 Conditional on IS significance, OOS tests are reasonably powerful.
 - 2 Sampling variation could require shrinkage. ▶ shrinkage
 - 1 No noticeable improvement in OOS performance when adding shrinkage.
 - 3 Biases could be unstable over time. ▶ instability
 - 1 Models do predict well in some periods, but difficult to leverage OOS.

Conclusion

- Many documented biases in macroeconomic expectations do not pass OOS tests.
- The models would not have improved forecasts in real time.
- But some biases hold up *very well* out of sample:
 - Slow adjustment and mean bias in interest rate forecasts
 - Forecast combination bias at the individual level
- These biases merit closer attention in future research.

Thank you!

Power, Shrinkage, and Instability

Power

If the models were true, and there was as much noise as in the data, would the OOS tests reject the null?

- We compute power using a parametric bootstrap under the alternative

$$H_1 : y_{t+h} = y_{t+h|t} + \hat{\beta}_T \mathbf{x}_t + u_{t+h}.$$

- Following Welch and Goyal (2006), we also compute power conditional on rejecting the null IS.

Results:

- Unconditional power is sometimes low, but conditional power is 60% or greater always.
- ΔSSE_T has similar power to DM and CW statistics. [▶ more](#)

Power of OOS tests: CG model

	ΔSSE_T		CW		DM	
	power	cond. power	power	cond. power	power	cond. power
Inflation (deflator)	1.00	1.00	1.00	1.00	1.00	1.00
Inflation (CPI)	0.52	0.77	0.54	0.81	0.44	0.63
Real GDP	0.28	0.70	0.30	0.72	0.25	0.58
Industrial Production	0.93	0.95	0.95	0.97	0.88	0.90
Nominal GDP	0.38	0.73	0.38	0.74	0.33	0.62
Unemployment rate	0.18	0.60	0.15	0.43	0.16	0.47
Consumption	0.20	0.65	0.16	0.51	0.16	0.48
Non-residential inv.	0.33	0.72	0.32	0.67	0.28	0.56
Residential inv.	0.54	0.78	0.55	0.80	0.45	0.64
Federal govt.	0.05	0.62	0.05	0.63	0.05	0.46
Non-federal govt.	0.06	0.62	0.06	0.65	0.06	0.47
Housing starts	1.00	1.00	1.00	1.00	0.99	0.99

Shrinkage

- OOS prediction must rely on less data than IS prediction, so the estimators inevitably have higher variance.
- Reduce the variance of the OOS predictions by shrinking them towards zero:

$$y_{t+h|t}^{*OOS} = y_{t+h|t} + 0.5\hat{\beta}_t x_t$$

- The results are not materially affected by this change. [▶ more](#)

Shrinkage: consensus SPF forecasts

ΔSSE_T , OOS	(1) CG	(2) Mean bias	(3) Autocorr.	(4) MZ	(5) Nordhaus
Inflation (deflator)	0.058***	-0.176	0.084**	-0.191	0.090***
Inflation (CPI)	0.011	-0.023	-0.019	-0.015	0.042**
Real GDP	-0.025	-0.011	0.003	-0.044	-0.006
Industrial Production	0.057***	0.031	-0.003	0.043*	0.052***
Nominal GDP	-0.033	-0.013	-0.01	-0.024	-0.003
Unemployment rate	-0.086	-0.012	-0.014	-0.016	-0.033
Consumption	-0.014	0.005	-0.071	0.021	-0.036
Non-residential inv.	-0.007	-0.014	-0.013	-0.008	0.073***
Residential inv.	0.015*	-0.019	0.005	-0.113	0.101***
Federal govt.	-0.005	-0.029	-0.016	0.032	-0.006
Non-federal govt.	-0.011	-0.036	0.026	-0.030	0.051***
Housing starts	0.100***	-0.014	0.081***	-0.022	0.191***

Instability

- Biases in expectations may exist but could be time-varying
 - Indeed, those biases that survive our OOS tests have the least time variation in estimated parameters.
 - Poor OOS performance is often attributed to structural breaks (e.g. Stock and Watson, 1996; Lettau and van Nieuwerburgh, 2007; Hendry and Mizon, 2014)
- Use “fluctuation tests”. In rolling subsamples,
 - are the estimated parameters $\hat{\beta}_t$ different from zero? (Rossi and Sekhposyan, 2016)
 - is the OOS MSE improvement different from zero? (Giacomini and Rossi, 2010) [▶ more](#)

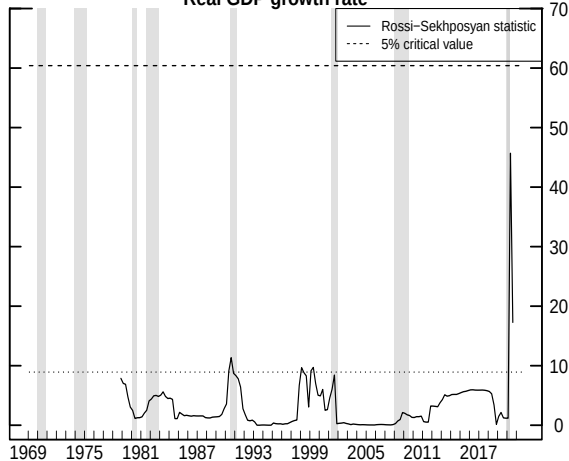
Fluctuating rationality tests: CG model

	ΔSSE_T	Giacomini-Rossi	Rossi-Sekhposyan
Inflation (deflator)	-0.052	1.298	17.71
Inflation (CPI)	-0.028	0.829	9.33
Real GDP	-0.083	1.250	33.19*
Industrial Production	-0.052	2.137	12.25
Nominal GDP	-0.108	1.536	17.44
Unemployment rate	-0.046	3.311**	263.09**
Consumption	-0.019	1.104	839.06***
Non-residential inv.	-0.015	1.963	18.70
Residential inv.	0.042**	1.505	36.79
Federal govt.	-0.063	0.328	15.01
Non-federal govt.	-0.179	1.273	25.79**
Housing starts	0.088***	2.335	95.20***

Instability of parameters means little predictability

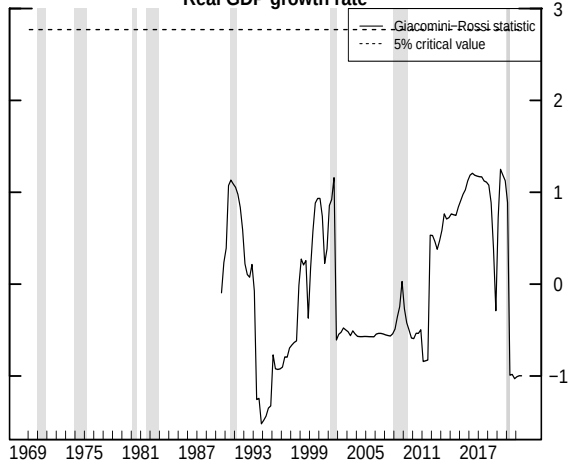
Rossi and Sekhposyan (2016)

Real GDP growth rate



Giacomini and Rossi (2010)

Real GDP growth rate



Additional Results

Comparison of test statistics: CG model

	(1) ΔSSE_T IS	(2) ΔSSE_T OOS	(3) CW	(4) DM
Inflation (deflator)	0.174***	-0.023	3.45***	-0.31
Inflation (CPI)	0.035*	0.015*	1.02	0.52
Real GDP	0.011	-0.119	0.19	-0.77
Industrial Production	0.086***	0.035**	2.37**	0.29
Nominal GDP	0.015	-0.101	-0.37	-0.89
Unemployment rate	0.002	-0.251	-0.52	-0.83
Consumption	0.006	-0.031	-0.56	-0.67
Non-residential inv.	0.017	-0.061	0.28	-0.36
Residential inv.	0.039*	-0.026	0.69	-0.17
Federal govt.	0.000	-0.012	-0.75	-1.02
Non-federal govt.	0.001	-0.027	-0.83	-1.12
Housing starts	0.178***	0.047***	3.60***	0.41

Forecast combination works best: interest rates

ΔSSE_T OOS	(1) BGMS	(2) KW	(3) Autocorr	(4) MZ	(5) Nordhaus	(5) FC
Federal funds rate	0.074***	0.069***	-0.075	0.079***	0.035*	0.034***
3-month yield	0.067***	0.116***	0.024*	0.059***	0.123***	0.042***
6-month yield	0.098***	0.127***	0.083**	0.081***	0.132**	0.030***
1-year yield	0.078***	0.066***	-0.007	0.065***	0.039*	0.039***
2-year yield	0.039***	0.031*	-0.016	0.031***	0.040*	0.042***
10-year yield	-0.003	-0.016	0.008	-0.014	0.099**	0.064***
Aaa yield	0.000	0.005	-0.221	-0.001	-0.16	0.064***
Baa yield	0.001	0.165***	0.011	-0.026	0.248***	0.115***
1y-3m spread	0.077***	-0.025	0.188***	0.098***	-0.233	0.080***
10y-2y spread	-0.002	-0.004	0.028	-0.004	0.002	0.051***
Aaa-Baa spread	0.008	-0.091	0.339***	-0.002	0.066	0.063***

Different horizons: consensus SPF forecasts

	h	(1) CG	(2) Mean bias	(3) Autocorr.	(4) MZ	(5) Nordhaus
Inflation (deflator)	0	0.008*	-0.033	0.040**	-0.039	-0.027
	1	-0.078	-0.130	0.078***	-0.128	0.047***
	2	-0.001	-0.276	0.156***	-0.282	0.066***
Real GDP	0	-0.225	-0.018	-0.028	-0.054	-0.079
	1	-0.195	-0.016	-0.003	-0.094	-0.105
	2	-0.160	-0.033	-0.013	-0.137	-0.074
Unemployment rate	0	-1.622	0.042**	0.110***	0.088***	-0.169
	1	-0.369	-0.003	-0.098	0.002	-0.180
	2	-0.367	-0.014	-0.057	-0.021	-0.126
Housing starts	0	0.090***	-0.009	0.051***	0.013*	0.071***
	1	0.018*	-0.029	-0.005	-0.039	0.147***
	2	0.066***	-0.036	0.059**	-0.066	0.205***

Rolling window regressions: consensus SPF forecasts

ΔSSE_T , OOS	(1) CG	(2) Mean bias	(3) Autocorr.	(4) MZ	(5) Nordhaus
Inflation (deflator)	-0.052	-0.257	0.039*	-0.557	0.051***
Inflation (CPI)	-0.028	-0.102	-0.089	-0.177	0.046**
Real GDP	-0.083	-0.069	-0.146	-0.190	0.083***
Industrial Production	-0.052	-0.019	-0.066	-0.076	-0.056
Nominal GDP	-0.108	-0.073	-0.484	-0.043*	0.028**
Unemployment rate	-0.046	-0.066	-0.156	-0.187	-0.150
Consumption	-0.019	-0.069	-0.075	0.014*	0.069***
Non-residential inv.	-0.015	-0.056	-0.034	-0.069	0.062**
Residential inv.	0.042**	-0.168	0.081**	-0.590	0.167***
Federal govt.	-0.063	-0.201	0.012	-0.019	-0.037
Non-federal govt.	-0.179	-0.055	-0.056	-0.090	0.048**
Housing starts	0.088***	-0.219	0.135***	-0.524	0.223***

Kernel regressions: consensus SPF forecasts

$\Delta SSE_T, \text{ OOS}$	(1) CG	(2) Mean bias	(3) Autocorr.	(4) MZ	(5) Nordhaus
Inflation (deflator)	-0.019	-0.175	0.001	-0.373	0.061***
Inflation (CPI)	-0.033	-0.116	-0.108	-0.197	0.028**
Real GDP	-0.212	-0.060	-0.340	-0.328	0.001*
Industrial Production	-0.189	-0.057	-0.128	-0.174	-0.253
Nominal GDP	-0.231	-0.099	-0.708	-0.095	0.036**
Unemployment rate	-0.228	-0.116	-0.278	-0.265	-1.219
Consumption	-0.046	-0.049	-0.188	-0.298	-0.167
Non-residential inv.	-0.093	-0.085	-0.069	-0.288	0.004*
Residential inv.	0.018*	-0.108	0.056*	-0.522	0.253***
Federal govt.	-0.030	-0.181	-0.010	-0.133	-0.060
Non-federal govt.	-0.062	-0.019	-0.031	-0.040*	0.014*
Housing starts	0.109***	-0.150	0.136***	-0.485	0.228***

Bonferroni-Holm adjusted p-values: consensus SPF forecasts

ΔSSE_T	(1) CG	(2) Mean bias	(3) Autocorr.	(4) MZ	(5) Nordhaus
Inflation (deflator)	1.00	1.00	0.01	1.00	0.00
Inflation (CPI)	0.53	1.00	1.00	1.00	0.00
Real GDP	1.00	1.00	1.00	1.00	1.00
Industrial Production	0.03	1.00	1.00	1.00	1.00
Nominal GDP	1.00	1.00	1.00	1.00	1.00
Unemployment rate	1.00	1.00	1.00	1.00	1.00
Consumption	1.00	1.00	1.00	1.00	1.00
Non-residential inv.	1.00	1.00	1.00	1.00	0.29
Residential inv.	1.00	1.00	1.00	1.00	0.00
Federal govt.	1.00	1.00	1.00	0.97	1.00
Non-federal govt.	1.00	1.00	0.96	1.00	0.00
Housing starts	0.01	1.00	0.01	1.00	0.00

Adding an intercept term: consensus SPF forecasts

$\Delta SSE_T, \text{OOS}$	(1) CG	(2) Autocorrelation	(3) Nordhaus
Inflation (deflator)	-0.143	-0.084	0.001
Inflation (CPI)	-0.053	-0.106	0.005
Real GDP	-0.145	-0.021	-0.029
Industrial Production	0.032*	0.013	0.032***
Nominal GDP	-0.157	-0.070	-0.036
Unemployment rate	-0.274	-0.064	-0.124
Consumption	-0.049	-0.152	-0.076
Non-residential inv.	-0.125	-0.136	0.014*
Residential inv.	-0.088	-0.097	0.111***
Federal govt.	-0.075	-0.091	0.007
Non-federal govt.	-0.134	-0.076	0.089***
Housing starts	0.021*	0.075**	0.206***