The Bias of the ECB Inflation Projections: a State Dependent Analysis

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- Accuracy of published forecasts deteriorated during the financial crisis (NY FED: Potter 2012, ECB and NY FED: Alessi, Ghysel Onorante Peach and Potter 2014, MPC BoE: Stockton 2012, BoE DSGE: Fawcett, Koerber Masolo and Waldron 2015)
- Following the 2007-2008 financial crisis many monetary authorities consistently overestimated inflation (Riksbank: Iversen Laseen Lundvall and Soderstrom 2016, ECB: Kontogeorgos and Lambrias 2019)
- Repeated large and systematic projection errors may:
  - increase the risk of deanchoring of inflation expectations
  - deteriorate the credibility of the monetary authority

ECB Projections Under Scrutiny

ECB Forecasting Is A Joke

Jan. 21, 2019 6:48 AM ET | FXE, VGK, EUO

Bruegel: ECB's huge forecasting errors undermine credibility of current forecasts

In the past five years ECB forecasts have proven to be systematically incorrect. Such forecast errors raise serious doubts about the reliability of the ECB's current forecast. By Konstantinos Efstathiou and Francesco Papadia

12 December 2018

ECB Projections 1999Q1-2021Q4

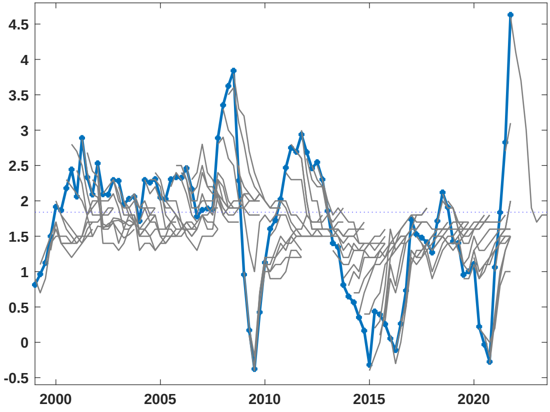

Figure: Actual year-over -year Harmonized Index of Consumer Prices Inflation (HICP), solid blue line with marker, and ECB Quarterly Projections for 1999Q1-2021Q4, grey lines. Projections are produced for the current and following two calendar years, i.e. up to eleven quarters ahead in Q1 and for at most eight quarters ahead in Q4. latest

ECB Inflation Projections

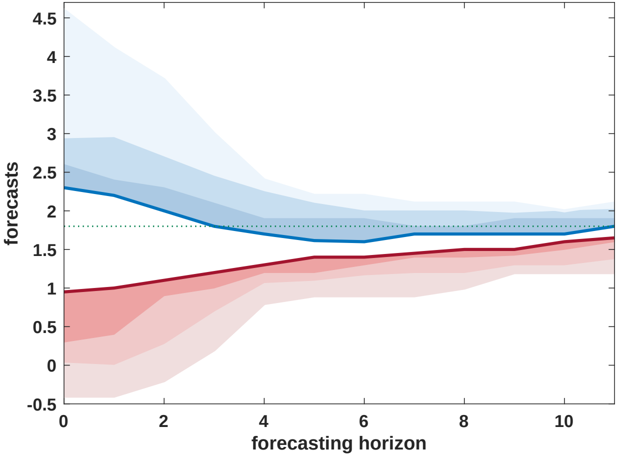

Figure: ECB Projections for HICP Inflation 1999Q1-2021Q4. Shaded areas mark the maximum (blue) and minimum (red) projections, 10^{th} and 25^{th} (75^{th} and 90^{th}) percentiles and the medians (solid lines) conditional on whether inflation was above or below 1.8% (green dotted line) during each projection exercise.

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Testing for State Dependent Forecast Performance

- Test of state dependent forecast performance by Odendahl et al. (2022)

$$Loss_{t,h} = X_t'\mu_h + X_t'\theta_h G\left(S_t; \gamma_h\right) + u_{t+h|t} \tag{1}$$

  with X_t a $(k_1 \times 1)$ vector of explanatory variables, S_t observable variable introducing state dependence, γ_h a parameter, $G(\cdot)$ a nonlinear function.

- Null hypothesis of unbiasedness:

$$E\left(Loss_{t,h}\right) = 0 \tag{2}$$

- Alternative

$$E\left(Loss_{t,h}\right) = X_t'\mu_h + X_t'\theta_h G\left(S_t; \gamma_h\right) \tag{3}$$

$$H_0 : \mu_h = \theta_h = 0 \qquad H_A : \mu_h \neq 0, \theta_h \neq 0 \tag{4}$$

- Advantages
  - Other tests lack power against the alternative of parametric state dependence (Giacomini and Rossi, 2010; Amisano and Giacomini, 2007)
- Inference:
  - Problem of a nuisance parameter (threshold) that is present only under the alternative, which makes standard asymptotic inference invalid
  - Critical values cannot be tabulated, need to simulate them

Testing for Bias

- Loss function:

$$Loss_{t,h} = y_{t+h} - y_{t+h|t} = \epsilon_{t,h} \tag{5}$$

- Linear Model (Holden and Peel, 1990):

$$\epsilon_{t,h} = \mu_h + u_{t+h|t} \tag{6}$$

  with X_t set to 1. Then, the null of unbiasedness is simply $\mu_h = 0$.
- Overall, does the ECB systematically under(over) predict inflation?

- State Dependent Model

$$\epsilon_{t,h} = \mu_h + \theta_h G\left(S_t; \gamma_h\right) + u_{t+h|t} \tag{7}$$

- We assume $G\left(S_t; \gamma_h\right)$ is a threshold regression model:

$$G\left(S_t; \gamma_h\right) = \mathbb{1}\left(S_t \geq \gamma_h\right). \tag{8}$$

  i.e. expected value of $\epsilon_{t,h}$ might differ according on whether S_t is above or below the unknown threshold γ_h
- Given the functional form assumed for $G\left(\cdot\right)$, the state dependent model leads to:

$$E\left(\epsilon_{t,h}\right) = \begin{cases} \mu_h & \text{if } S_t < \gamma_h \\ \mu_h + \theta_h & \text{if } S_t \geq \gamma_h \end{cases}$$

- Does ECB under(over) predict inflation when inflation is above/below a certain value?

Testing for State Dependent Bias: Previous Studies

- Same null hypothesis of unbiasedness:

$$E\left(\epsilon_{t,h}\right) = 0 \tag{9}$$

- Alternative

$$E\left(\epsilon_{t,h}\right) = \mu_h + \theta_h G\left(S_{t+h};\gamma^*\right) \tag{10}$$

- Differences with our approach
  - S_{t+h}, variable that defines the state observed when target variable is *realized*
  - S_{t+h} usually *output*
  - $G\left(S_{t+h};\gamma^*\right)$ is a dummy variable that takes value one if $S_{t+h} \geq \gamma^*$ with γ^* *chosen* by the researcher

- Questions:
  - previous studies: did the FED under/over predict inflation in its projections made in 2008Q1 for 2009Q1, given that we observe a negative output gap in 2009Q1?
  - our study: will the ECB under/over predict inflation for 2009Q1 in its projections made in 2008Q1, given that in 2008Q1 the ECB observes that inflation is high?

Implementation

- Dataset: Quarterly Eurosystem/ECB staff projections for yoy overall HICP inflation over 1999Q1-2021Q4 from nowcasting till 8 quarters ahead
  - 92 (84) observations for nowcasting (eight quarters ahead)
  - ECB staff (March and September), ECB staff + experts in national central banks (June and December)
  - monthly inflation projections are provided by national central bank experts for up to 11 months (NIPE).
  - external assumptions, combination of models, expert knowledge, judgement
  - forecasts evaluated against latest available vintage (2022Q1) as revisions for inflation series negligible

- State variable S_t:
  - approximate the information set available to the staff at the time of forecasting
  - cutoff dates approximately between week 6 and 8 of the quarter
  - ECB observes: previous quarter yoy inflation rate $\left(\pi_{t-1}^{Q}\right)$, first month yoy inflation of current quarter $\left(\pi_t^{M1}\right)$
  - $S_t = \left(\pi_{t-1}^{Q} + \pi_t^{M1}\right)/2$

Results: Bias

$$\epsilon_{t,h} = y_{t+h} - y_{t+h|t} = \mu_h + \theta_h G\left(S_t;\gamma_h\right) + u_{t+h|t} \quad (11)$$

	Forecast Horizon							
	Single						**Pooled**	
$h =$	0	1	2	3	4	5	$0-5$	$0-8$
	Panel A: Linear Model							
μ_h	-0.02	0.04	0.09	0.14	0.16	0.18	0.10**	0.09*
	(0.01)	(0.04)	(0.07)	(0.10)	(0.13)	(0.14)	(0.05)	(0.05)
R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Panel B: State Dependent Model							
μ_h	0.01	-0.03	-0.07	-0.07	-0.09	-0.07	-0.05	-0.03
	(0.04)	(0.05)	(0.10)	(0.14)	(0.17)	(0.18)	(0.05)	(0.06)
θ_h	-0.08*	0.14*	0.29**	0.39**	0.46*	0.45	0.28***	0.22***
	(0.04)	(0.08)	(0.14)	(0.19)	(0.26)	(0.29)	(0.08)	(0.08)
γ_h	2.27	1.80	1.80	1.80	1.80	1.80	1.80	1.80
$p-val$	0.14	0.16	0.06	0.06	0.16	0.14	0.05	0.06
R^2	0.07	0.02	0.06	0.07	0.06	0.05	0.05	0.02

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level.

Bias Results: Discussion

- No bias in the linear model
- Evidence of bias in the state dependent model:
  - ECB systematically overpredicts (underpredicts) inflation when inflation is below (above) the target
  - negative and positive errors cancel out so no bias on average
- Bias is larger in absolute value when inflation is above target
  - μ average of -0.05 when $S_t < \gamma$
  - $\mu + \theta$ average of 0.23 when $S_t \geq \gamma$
- Evidence of bias stronger at the medium horizon
  - bias is larger for intermediate horizons 3, 4, 5
  - $\mu + \theta$ average of 0.36 over $h = 3, 4, 5$ latest surveys
- Threshold value γ consistent with ECB implicit target estimated by Hartmann and Smets (2018), Rostagno et al. (2019) threshold

Bias in the Literature

- No Bias: Greenbook (Clements et al. 2007); FOMC 2009-2015 (Arai 2016); Greenbook over 1986-2006 (El Shagi et al. 2016); Greenbook overall and conditioning on recession (Messina et al. 2015), Kontogeorgeos and Lambrias (2019)
- Bias: Greenbook, underprediction till 1975, overprediction after 1979 (Capistran 2008); Greenbook over recessions and/or inflation cycles Sinclair et al. (2010); Greenbook over rolling samples El Shagi et al. (2016); positive bias of BMPE forecasts (Fisher et al. 2009); six small open economies 2000-2013 (Gomez-Barrero and Parra-Polania 2014); 12-24 months forecasts of core from 10 small open economies (Charemza and Ladley 2016); Kontogeorgeos and Lambrias (2019) for intermediate horizons under prediction in early part of the sample, over-prediction during 2010-2013
- Biased forecast not necessarily irrational. Theoretical models attribute empirical bias to:
  - asymmetric loss function: Capistran (2008)
  - strategic communication: Gomez-Barrero and Parra-Polania (2014)
  - heterogeneous agents beliefs: Herbert (2020)
  - distortion from MPC voting system: Charemza and Ladley (2016)

ECB External Assumptions

- ECB/Eurosystem projections rely on set of assumptions on international environment: can the errors in these exogenous variables drive the errors in inflation forecasts?
- External assumptions:
  - short term interest rates (3month Euribor): constant through the forecast horizons till 2006Q1, afterwards market expectations derived from futures rates
  - exchange rates (EUR/USD): random walk, average over previous two weeks
  - oil prices: average futures price of Brent crude oil over previous two weeks
- Exogenous conditioning assumptions, not affected by ECB inflation projections published in the same quarter
- Dataset:
  - not publicly available at the quarterly frequency
  - sample starts in 2001Q3 for oil prices

Bias: The Role of External Assumptions

- Are the forecast errors in the external assumptions driving the state dependent bias?

- Ideally re-run the models conditioning on realized values for the external assumptions
- But, unable to construct such counterfactual series based on the forecasting models used in real time or to include the ECB expert judgement.

- Feasible alternative: test whether bias still present after controlling for the errors in the external assumptions

$$\epsilon_{t,h} = \mu_{1,h} + \mu_{2,h}\zeta_{t,h} + \theta_h G\left(S_t;\gamma_h\right) + u_{t+h|t} \tag{12}$$

with $\zeta^i_{t,h} = z^i_t - z^i_{t|t-h}$ and z^i_t the realization and $z^i_{t|t-h}$ assumed value

- Rationale: if systematic errors in the external assumptions were driving the forecast errors, then the nonlinear term should not have additional explanatory power. bias in external

Results: Bias and External Assumptions

$$\epsilon_{t,h} = \mu_{1,h} + \mu_{2,h}\zeta_{t,h} + \theta_h G(S_t;\gamma) + u_{t+h|t} \tag{13}$$

$h =$	0	1	2	3	4	5	0 − 5	0 − 8
				Panel A: Interest Rates				
$\mu_{1,h}$	0.00	-0.04	-0.08	-0.09	-0.12	-0.11	-0.07	-0.04
	(0.02)	(0.05)	(0.10)	(0.15)	(0.19)	(0.21)	(0.06)	(0.07)
θ_h	-0.03	0.16***	0.33***	0.45***	0.55***	0.55**	0.32***	0.30***
	(0.03)	(0.07)	(0.14)	(0.20)	(0.25)	(0.27)	(0.09)	(0.09)
$\mu_{2,h}$	-0.11	0.22	0.27*	0.26	0.23	0.15	0.17**	0.19***
	(0.21)	(0.15)	(0.17)	(0.17)	(0.18)	(0.17)	(0.08)	(0.06)
R^2	0.00	0.04	0.11	0.11	0.10	0.08	0.08	0.08
				Panel B: Exchange Rate				
$\mu_{1,h}$	0.00	-0.05	-0.08	-0.10	-0.13	-0.10	-0.07	-0.03
	(0.02)	(0.06)	(0.10)	(0.15)	(0.19)	(0.20)	(0.06)	(0.07)
θ_h	-0.03	0.16***	0.30***	0.42**	0.48*	0.41	0.28***	0.15*
	(0.03)	(0.08)	(0.14)	(0.20)	(0.26)	(0.29)	(0.09)	(0.09)
$\mu_{2,h}$	-0.39	-0.93	0.12	-0.02	-0.50	1.17	0.66	1.72***
	(1.01)	(0.71)	(0.83)	(1.02)	(1.14)	(1.17)	(0.49)	(0.42)
R^2	0.00	0.03	0.06	0.06	0.07	0.09	0.07	0.09
				Panel C: Oil Prices				
$\mu_{1,h}$	0.00	-0.03	-0.10	-0.14	-0.19	-0.21	-0.11*	-0.11
	(0.02)	(0.04)	(0.09)	(0.14)	(0.19)	(0.20)	(0.06)	(0.07)
θ_h	-0.02	0.08	0.26**	0.40**	0.50**	0.56**	0.29***	0.26***
	(0.03)	(0.06)	(0.13)	(0.19)	(0.25)	(0.27)	(0.08)	(0.09)
$\mu_{2,h}$	0.01***	0.01***	0.01***	0.01*	0.01	0.01	0.01***	0.01***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)
R^2	0.07	0.41	0.21	0.14	0.12	0.13	0.15	0.09

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level. The state dependent model assumes that the threshold γ_h is known and fixed at 1.80

Bias and Exogenous Assumptions Results: Discussion

- Evidence of state dependent bias after controlling for the errors in exogenous assumptions:
  - magnitude unaffected
  - significance unaltered
- When conditioning on interest rates:
  - significance of non-linear term for all horizons except nowcast
  - interest rates errors significant only for $h = 2$
- When conditioning on exchange rate:
  - significance of non-linear term at short and intermediate horizons for $h = 1 - 4$ and pooled
  - exchange rates errors significant only when all horizons are pooled
- When conditioning on oil prices:
  - significance of non-linear term from h=2, and pooled
  - errors in oil prices significant in the short horizons $h = 0 - 3$

Robustness Analysis

- Results are robust to:
  - alternative assumptions on the information set available to the ECB at the time of forecasting: ▸ infoset
    - nowcast
    - actual inflation
    - first month only
    - last three months
  - using a known threshold, $\gamma \leq 1.8$ ▸ known gamma
  - conditioning on when inflation is realized ▸ timing dummy
  - exclusion of COVID period ▸ sample

Conclusions

- We document three novel findings regarding the ECB inflation forecasts:
  - a systematic bias towards the target, which implies over (under) prediction when inflation is low (high);
  - a larger bias when inflation is above the target
  - bias larger at medium horizons
- Results robust to:
  - assumption on information set
  - excluding COVID sample
- How can we explain the state dependent bias?
  - external assumptions not enough
- Further Investigation
  - dynamics of forecasting models
  - expert judgement/strategic communication motives

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  - FED produces two sets of forecasts: staff forecasts (Tealbook) confidential for 5 years; FOMC forecasts released same quarter

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Inflation Above Threshold

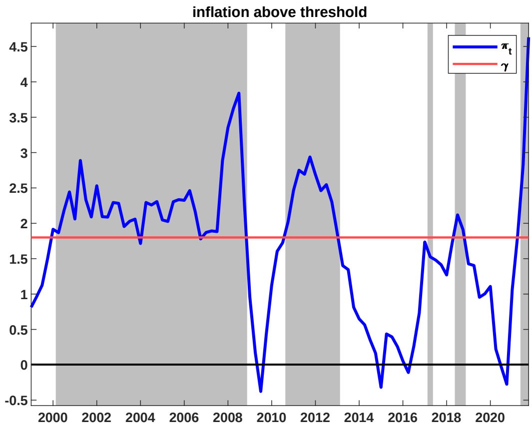

Figure: Actual year-over -year Harmonized Index of Consumer Prices Inflation (HICP), solid blue line, estimated threshold, red solid line, quarters in which observed inflation S_t is above the threshold, grey shaded areas.

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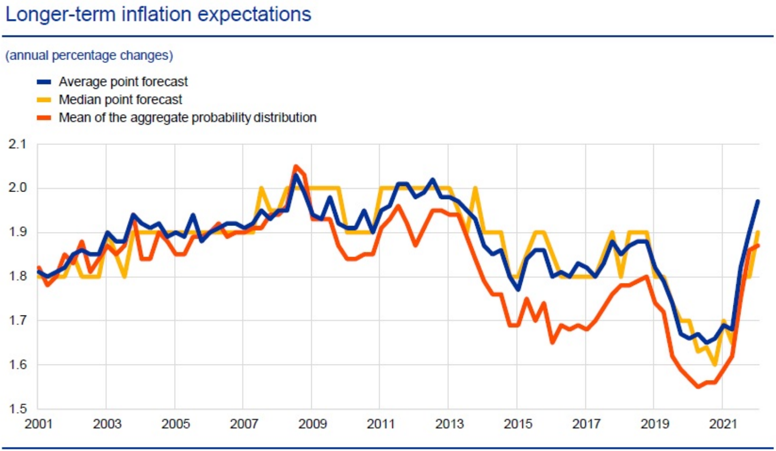
SPF Long Term Inflation Expectations



Outline

- Testing Framework
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Bias Sample 1999Q4-2019Q4

	Forecast Horizon							
	Single						**Pooled**	
$h =$	0	1	2	3	4	5	$0-5$	$0-8$
	Panel A: Linear Model							
μ_h	-0.02	0.05	0.10	0.14	0.16	0.17	0.10**	0.10*
	(0.01)	(0.04)	(0.07)	(0.11)	(0.14)	(0.14)	(0.05)	(0.05)
R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Panel B: State Dependent Model							
μ_h	0.01	0.00	-0.02	-0.06	-0.07	-0.08	-0.04	-0.03
	(0.04)	(0.05)	(0.09)	(0.13)	(0.16)	(0.18)	(0.05)	(0.05)
θ_h	-0.08**	0.10	0.23*	0.38*	0.42	0.46	0.25***	0.19***
	(0.04)	(0.08)	(0.14)	(0.20)	(0.27)	(0.29)	(0.08)	(0.08)
γ_h	2.27	1.81	1.81	1.81	1.81	1.80	1.81	1.81
$p-val$	0.14	0.27	0.10	0.08	0.22	0.14	0.00	0.02
R^2	0.07	0.00	0.03	0.05	0.05	0.02	0.04	0.01

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level.

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Bias: Known Threshold

$$\epsilon_{t,h} = y_{t+h} - y_{t+h|t} = \mu_h + \theta_h d\left(S_t > \gamma^*\right) + u_{t+h|t} \quad (14)$$

	Forecast Horizon							
	Single						Pooled	
$h =$	0	1	2	3	4	5	$0-5$	$0-8$
	Panel A: State Dependent Model: $\gamma = 1.8$							
μ	0.00	-0.03	-0.07	-0.07	-0.09	-0.07	-0.05	-0.03
	(0.02)	(0.05)	(0.10)	(0.14)	(0.18)	(0.20)	(0.06)	(0.07)
θ	-0.03	0.14*	0.29**	0.39**	0.46*	0.45*	0.28***	0.22***
	(0.03)	(0.07)	(0.13)	(0.19)	(0.25)	(0.27)	(0.08)	(0.09)
R^2	0.00	0.02	0.06	0.07	0.06	0.05	0.05	0.02
	Panel B: State Dependent Model: $\gamma = 1.9$							
μ	0.00	0.02	0.04	0.07	0.14	0.15	0.07	0.07
	(0.02)	(0.05)	(0.09)	(0.14)	(0.18)	(0.20)	(0.06)	(0.06)
θ	-0.04	0.05	0.11	0.17	0.06	0.07	0.07	0.05
	(0.03)	(0.07)	(0.14)	(0.21)	(0.27)	(0.29)	(0.09)	(0.10)
R^2	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Panel C: State Dependent Model: $\gamma = 1.7$							
μ	0.00	-0.03	-0.06	-0.08	-0.09	-0.09	-0.06	-0.04
	(0.02)	(0.05)	(0.10)	(0.15)	(0.19)	(0.20)	(0.06)	(0.07)
θ	-0.03	0.13*	0.28**	0.39**	0.45*	0.48*	0.28***	0.24***
	(0.03)	(0.07)	(0.13)	(0.20)	(0.25)	(0.27)	(0.08)	(0.09)
R^2	0.00	0.02	0.06	0.07	0.05	0.06	0.05	0.03

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level.

Results: Bias When Inflation Realized

$$\epsilon_{t,h} = y_{t+h} - y_{t+h|t} = \mu_h + \theta_h G\left(S_{t+h};\gamma\right) + u_{t+h|t} \tag{15}$$

	Forecast Horizon							
	Single						**Pooled**	
$h =$	0	1	2	3	4	5	$0-5$	$0-8$
				Panel A: Linear Model				
μ	-0.02	0.04	0.09	0.14	0.16	0.18	0.10**	0.09*
	(0.01)	(0.04)	(0.07)	(0.10)	(0.13)	(0.14)	(0.05)	(0.05)
R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				Panel B: State Dependent Model				
μ	0.01	-0.06	-0.20	-0.32	-0.44*	-0.51*	-0.28***	-0.44***
	(0.04)	(0.08)	(0.14)	(0.21)	(0.28)	(0.31)	(0.08)	(0.08)
θ	-0.08*	0.24***	0.60***	0.96***	1.28***	1.41***	0.74***	0.99***
	(0.04)	(0.08)	(0.12)	(0.17)	(0.20)	(0.20)	(0.08)	(0.08)
γ	2.27	1.87	1.84	1.89	1.94	1.94	1.84	1.81
$p-val$	0.14	0.03	0.00	0.00	0.00	0.00	0.00	0.00
R^2	0.07	0.07	0.21	0.36	0.45	0.52	0.27	0.37

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level.

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Bias: Alternative Observed Inflation: I

	Single						Pooled	
$h =$	0	1	2	3	4	5	$0-5$	$0-8$
	Panel A: Nowcast							
μ	0.00	-0.02	-0.07	-0.09	-0.09	-0.11	-0.06***	-0.04***
	(0.04)	(0.06)	(0.10)	(0.14)	(0.17)	(0.18)	(0.05)	(0.06)
θ	-0.06	0.11	0.29***	0.42***	0.46*	0.52**	0.29***	0.24***
	(0.04)	(0.08)	(0.13)	(0.18)	(0.24)	(0.26)	(0.07)	(0.08)
γ	2.30	1.80	1.80	1.80	1.80	1.80	1.80	1.80
p_{val}	0.25	0.23	0.05	0.03	0.14	0.10	0.00	0.01
R^2	0.03	0.01	0.07	0.08	0.06	0.08	0.06	0.03
	Panel B: Ex-Post Realized							
μ	0.00	-0.03	-0.06	-0.07	-0.07	-0.05	-0.05	-0.00
	(0.03)	(0.06)	(0.10)	(0.14)	(0.17)	(0.17)	(0.05)	(0.05)
θ	-0.04	0.14*	0.30***	0.43***	0.46*	0.44*	0.28***	0.20***
	(0.03)	(0.08)	(0.13)	(0.18)	(0.24)	(0.25)	(0.07)	(0.08)
γ	1.88	1.87	1.87	1.87	1.87	1.87	1.87	1.92
p_{val}	0.33	0.18	0.05	0.03	0.15	0.14	0.00	0.00
R^2	0.01	0.03	0.07	0.09	0.06	0.05	0.06	0.02

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level. back

Bias: Alternative Observed Inflation: II

	Single						Pooled	
$h =$	0	1	2	3	4	5	$0-5$	$0-8$
	Panel C: First Month of Current Quarter							
μ	0.00	-0.02	-0.05	-0.07	-0.05	-0.05	-0.04	-0.00
	(0.03)	(0.05)	(0.09)	(0.13)	(0.16)	(0.17)	(0.05)	(0.05)
θ	-0.05*	0.12*	0.27***	0.40***	0.39	0.42	0.26***	0.19***
	(0.02)	(0.07)	(0.13)	(0.18)	(0.25)	(0.27)	(0.07)	(0.08)
γ	2.22	1.76	1.76	1.76	1.76	1.71	1.76	1.79
p_{val}	0.28	0.22	0.07	0.04	0.20	0.15	0.00	0.01
R^2	0.01	0.12	0.23	0.38	0.48	0.56	0.28	0.38
	Panel D: Last Three Months							
μ	0.01	-0.03	-0.08	-0.09	-0.07	-0.01	-0.05	-0.03
	(0.04)	(0.05)	(0.10)	(0.14)	(0.18)	(0.19)	(0.05)	(0.06)
θ	-0.08***	0.14*	0.31***	0.43***	0.46*	0.45	0.28***	0.22***
	(0.04)	(0.07)	(0.13)	(0.19)	(0.25)	(0.28)	(0.08)	(0.08)
γ	2.23	1.67	1.67	1.67	1.78	1.78	1.78	1.78
p_{val}	0.11	0.15	0.04	0.04	0.15	0.14	0.00	0.01
R^2	0.01	0.01	0.05	0.07	0.04	0.04	0.04	0.02

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level. back

Bias in Exogenous Assumptions: Short Term Rate

$$\zeta_{t,h} = y_{t+h} - y_{t+h|t} = \mu_h + \theta_h G\left(S_t; \gamma_h\right) + u_{t+h|t} \tag{16}$$

	Forecast Horizon							
	Single						Pooled	
$h =$	0	1	2	3	4	5	$0-5$	$0-8$
	Panel A: Linear Model							
μ_h	-0.01	-0.03	-0.05	-0.10	-0.19	-0.26	-0.11***	-0.24***
	(0.01)	(0.03)	(0.06)	(0.09)	(0.12)	(0.14)	(0.04)	(0.06)
R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Panel B: State Dependent Model, Fixed γ							
μ_h	0.00	0.00	-0.01	-0.03	-0.08	-0.15	-0.04	-0.15*
	(0.01)	(0.05)	(0.10)	(0.14)	(0.18)	(0.21)	(0.06)	(0.09)
θ_h	-0.03	-0.06	-0.07	-0.13	-0.19	-0.19	-0.11	-0.16
	(0.02)	(0.07)	(0.13)	(0.18)	(0.23)	(0.28)	(0.08)	(0.12)
R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Panel C: State Dependent Model, Unknown γ							
μ_h	0.01	0.02	0.02	0.03	0.00	-0.07	0.00	-0.11
	(0.02)	(0.07)	(0.13)	(0.19)	(0.27)	(0.34)	(0.09)	(0.12)
θ_h	-0.03*	-0.12*	-0.20**	-0.36**	-0.53*	-0.55	-0.29***	-0.38***
	(0.01)	(0.08)	(0.14)	(0.18)	(0.24)	(0.29)	(0.08)	(0.10)
γ_h	1.81	2.01	2.10	2.13	2.13	2.13	2.13	2.13
$p-val$	0.47	0.43	0.53	0.30	0.16	0.19	0.01	0.00
R^2	0.03	0.03	0.03	0.07	0.11	0.08	0.07	0.05

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level. ▸ back

Bias in Exogenous Assumptions: Exchange Rate

$$\zeta_{t,h} = y_{t+h} - y_{t+h|t} = \mu_h + \theta_h G\left(S_t; \gamma_h\right) + u_{t+h|t} \quad (17)$$

	Forecast Horizon							
	Single						**Pooled**	
$h =$	0	1	2	3	4	5	$0-5$	$0-8$
	Panel A: Linear Model							
μ_h	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.01
	(0.00)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Panel B: State Dependent Model, Fixed γ							
μ_h	0.00	-0.01	-0.01	-0.03	-0.02	-0.03	-0.02***	-0.03***
	(0.00)	(0.01)	(0.02)	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)
θ_h	0.00	0.02*	0.03	0.07***	0.07**	0.09***	0.05***	0.07***
	(0.00)	(0.01)	(0.02)	(0.03)	(0.03)	(0.03)	(0.01)	(0.01)
R^2	0.00	0.02	0.02	0.08	0.07	0.11	0.07	0.10
	Panel C: State Dependent Model, Unknown γ							
μ_h	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.01	-0.02*
	(0.00)	(0.01)	(0.02)	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)
θ_h	0.01*	0.02*	0.04	0.06**	0.07*	0.09**	0.04***	0.07***
	(0.00)	(0.01)	(0.02)	(0.03)	(0.04)	(0.04)	(0.01)	(0.01)
γ_h	1.83	1.80	1.81	1.81	1.81	1.81	1.83	1.83
$p-val$	0.30	0.34	0.39	0.20	0.21	0.13	0.00	0.00
R^2	0.02	0.02	0.02	0.06	0.07	0.12	0.05	0.09

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level. back

Bias in Exogenous Assumptions: Oil Prices

$$\zeta_{t,h} = y_{t+h} - y_{t+h|t} = \mu_h + \theta_h G(S_t; \gamma_h) + u_{t+h|t} \quad (18)$$

	Forecast Horizon							
	Single						Pooled	
$h =$	0	1	2	3	4	5	$0-5$	$0-8$
	Panel A: Linear Model							
μ_h	0.50	1.62	1.13	0.99	1.01	0.87	1.01	1.10*
	(0.47)	(1.75)	(2.00)	(1.98)	(2.15)	(2.22)	(0.76)	(0.65)
R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Panel B: State Dependent Model, Fixed γ							
μ_h	0.43	-1.20	-2.10	-2.36	-0.84	-0.12	-1.00	-0.24
	(0.70)	(2.39)	(2.77)	(2.82)	(3.19)	(3.33)	(1.08)	(0.94)
θ_h	0.12	5.22	5.91	5.89	3.35	1.79	3.65***	2.40*
	(0.94)	(3.26)	(3.75)	(3.73)	(4.28)	(4.47)	(1.45)	(1.26)
R^2	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00
	Panel C: State Dependent Model, Unknown γ							
μ_h	1.10	-1.88	-2.10	-1.90	2.46	-1.38	-1.00	-0.33
	(0.00)	(0.01)	(0.02)	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)
θ_h	-1.98	6.34*	5.91	5.34**	-5.35*	4.39**	3.65***	2.85***
	(0.00)	(0.01)	(0.02)	(0.03)	(0.04)	(0.04)	(0.01)	(0.01)
γ_h	2.18	1.71	1.81	1.83	2.20	1.84	1.81	1.84
$p-val$	0.17	0.08	0.39	0.53	0.67	0.42	0.02	0.03
R^2	0.02	0.02	0.00	0.00	0.00	0.00	0.01	0.01

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level.

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Results: Bias and External Assumptions: Unknown Gamma

$h =$	0	1	2	3	4	5	$0-5$	$0-8$
				Panel A: Interest Rates				
μ_1	0.01	-0.06	-0.16	-0.26	-0.39	-0.43	-0.23	-0.34
	(0.15)	(0.59)	(0.72)	(0.88)	(1.17)	(1.24)	(0.31)	(0.31)
θ	-0.07	0.28	0.59	0.93*	1.27**	1.38***	0.73***	0.95***
	(0.12)	(0.46)	(0.55)	(0.53)	(0.61)	(0.61)	(0.18)	(0.15)
μ_2	-0.15***	0.47*	0.46	0.37	0.34	0.28	0.33***	0.24*
	(0.06)	(0.25)	(0.31)	(0.36)	(0.47)	(0.49)	(0.13)	(0.13)
γ	2.101	1.868	1.840	1.895	1.895	1.895	1.840	1.840
R^2	0.04	0.16	0.35	0.47	0.55	0.59	0.36	0.43
				Panel B: Exchange Rate				
μ_1	0.01	-0.07	-0.23	-0.36	-0.48	-0.53	-0.30	-0.42
	(0.40)	(0.23)	(0.54)	(1.47)	(3.18)	(2.53)	(0.82)	(0.70)
θ	-0.08	0.25*	0.63**	1.00	1.33	1.43	0.77	1.00***
	(0.36)	(0.13)	(0.30)	(0.93)	(2.30)	(1.72)	(0.56)	(0.45)
μ_2	-0.36***	-0.03	-0.03	-0.87	-2.27*	-1.60*	-1.15***	-1.10***
	(0.13)	(0.10)	(0.23)	(0.56)	(1.18)	(0.92)	(0.32)	(0.26)
γ	2.268	1.868	1.840	1.895	1.935	1.935	1.840	1.868
R^2	0.07	0.05	0.25	0.39	0.48	0.49	0.29	0.38
				Panel C: Oil Prices				
μ_1	0.00	-0.03	-0.23	-0.36	-0.49	-0.99	-0.31	-0.48
	(0.06)	(0.28)	(0.53)	(0.84)	(1.20)	(1.24)	(0.32)	(0.33)
θ	-0.04	0.29*	0.58*	0.97***	1.32***	1.61*	0.74***	1.01***
	(0.04)	(0.15)	(0.30)	(0.41)	(0.56)	(0.92)	(0.15)	(0.16)
μ_2	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.01
	(0.02)	(0.10)	(0.22)	(0.33)	(0.46)	(0.60)	(0.13)	(0.13)
γ	2.101	2.361	1.840	1.895	1.935	1.304	1.840	1.814
R^2	0.09	0.48	0.31	0.37	0.45	0.57	0.31	0.39

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level.

Bias: Output as State

	Forecast Horizon							
	Single						**Pooled**	
$h =$	0	1	2	3	4	5	$0-5$	$0-8$
				Panel A: Linear Model				
μ	-0.02	0.03	0.07	0.11	0.13	0.14	0.06	0.07
	(0.01)	(0.06)	(0.09)	(0.12)	(0.16)	(0.16)	(0.05)	(0.05)
R^2	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01
				Panel B: State Dependent Model				
μ	0.03	-0.02	-0.01	-0.05	0.01	-0.01	-0.01	-0.03
	(0.02)	(0.19)	(0.30)	(0.22)	(0.42)	(0.47)	(0.14)	(0.12)
θ	-0.05	0.31*	0.46	0.41*	0.63	0.72	0.42***	0.50***
	(0.03)	(0.18)	(0.28)	(0.19)	(0.21)	(0.40)	(0.13)	(0.12)
γ	-0.10	0.60	0.60	0.40	0.60	0.60	0.60	0.60
R^2	0.00	0.08	0.07	0.04	0.05	0.06	0.06	0.06

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level.

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ECB Projections during COVID

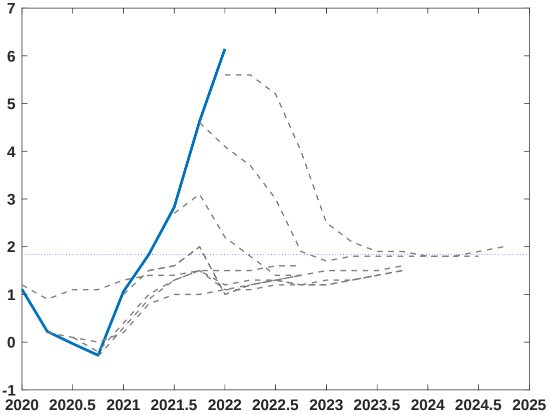

Figure: Actual year-over -year Harmonized Index of Consumer Prices Inflation (HICP), solid blue line with marker, and ECB Quarterly Projections for 2020Q1-2022Q1, grey lines. Projections are produced for the current and following two calendar years, i.e. up to eleven quarters ahead in Q1 and for at most eight quarters ahead in Q4. back

Results: Bias in Survey Data, 4 Quarters Ahead

$$\epsilon_{t,h} = \mu_h + \theta_h G(S_t; \gamma) + u_{t+h|t} \tag{19}$$

Source	ECB		*SPF*	*Consensus*
	Panel A: Linear Model			
μ	0.15		0.11	0.13
	(0.15)		(0.09)	(0.09)
R^2	0.00		0.00	0.00
RMSFE	0.95		0.86	0.86
	Panel B: State Dependent Model			
μ	-0.44	-0.51*	-0.47*	-0.36*
	(0.28)	(0.27)	(0.25)	(0.21)
θ	1.28***	1.30***	1.17***	0.99***
	(0.20)	(0.19)	(0.18)	(0.19)
γ	1.935	1.839	1.839	1.839
R^2	0.20	0.46	0.38	0.52
$\mu + \theta$	0.84	0.79	0.70	0.63

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level. RMSFE of naive 1.8% forecast is 0.99. The SPF survey is usually conducted in the second half of the first month of each quarter. back

Testing for Efficiency

- Was there additional information readily available to the forecasters that could have been used to improve the accuracy of the projections?
- For $h \geq 1$, define forecast revision between t and $t+1$ as: $r_{t,h} = y_{t+h|t+1} - y_{t+h|t}$,
- Linear Model (Nordhaus, 1987, Coibion and Gorodnichenko 2015):

$$\epsilon_{t,h} = \mu_{1,h} + \mu_{2,h} r_{t,h} + u_{t+h|t} \tag{20}$$

- Is the forecast error uncorrelated with the previous forecast revision?
- State Dependent Efficiency Test (Odendhals, Rossi and Sekhposyan 2022):

$$\epsilon_{t,h} = \mu_{1,h} + \mu_{2,h} r_{t,h} + \left(\theta_{1,h} + \theta_{2,h} r_{t,h}\right) G\left(S_t; \gamma\right) + u_{t+h|t} \tag{21}$$

where $X_t' = [1, r_{t,h}]$

- non-linear term: allows for the possibility that ECB revises forecasts differently during high vs low inflation episodes.

Results: Efficiency

$$\epsilon_{t,h} = \mu_{1,h} + \mu_{2,h} r_{t,h} + \left(\theta_{1,h} + \theta_{2,h} r_{t,h}\right) G\left(S_t; \gamma\right) + u_{t+h|t} \quad (22)$$

$h =$	0	1	2	3	4	5	$0-4$	$0-7$
Panel A: Linear Model								
μ_1	0.04	0.21*	0.22	0.37	0.04	0.15	0.19	0.13
	(0.04)	(0.11)	(0.21)	(0.30)	(0.78)	(0.95)	(0.14)	(0.17)
μ_2	-0.02	0.05	0.09	0.11	0.13	0.13	0.07	0.08
	(0.01)	(0.05)	(0.09)	(0.12)	(0.16)	(0.17)	(0.05)	(0.05)
R^2	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Panel B: State Dependent Model								
μ_1	0.01	0.06	0.14	0.21	0.26	0.13	0.14*	0.17*
	(0.04)	(0.09)	(0.16)	(0.15)	(0.27)	(0.21)	(0.09)	(0.08)
μ_2	0.02	0.09	028	0.45***	0.54	1.23	0.25**	0.24**
	(0.06)	(0.32)	(0.25)	(0.18)	(0.93)	(1.05)	(0.13)	(0.13)
θ_1	-0.09***	-0.09	-0.14	-0.22	-0.27	0.11	-0.15	-0.19**
	(0.04)	(0.11)	(0.19)	(0.25)	(0.35)	(0.39)	(0.11)	(0.10)
θ_2	0.09	0.34	-0.03	-0.08	-1.36	-2.66	-0.08	-0.18
	(0.08)	(0.40)	(0.28)	(0.32)	(0.94)	(1.61)	(0.16)	(0.16)
γ	2.101	1.971	2.061	2.101	2.131	1.804	2.101	2.131
R^2	0.12	0.07	0.03	0.04	0.04	0.07	0.03	0.02

Table: Note: R^2 is the adjusted R^2. Newey-West standard errors are in parenthesis. Stars denote the 10% (*), 5% (**) and 1% (***) significance level.

Efficiency Results: Discussion

- No evidence of inefficiency or information rigidities in the linear model
- Some evidence of inefficiency in the state dependent model:
  - $\mu_2 > 0$, $\theta_2 < 0$, but $\mu_2 + \theta_2 > 0$
  - evidence of underreaction to news
- Smoothing
  - reputational concerns: avoid large and frequent revisions (Scotese (1994), Tillman (2011))
  - when inflation is volatile staff may only partially revise its previous forecast in order to avoid having to reverse the changes incorporated into the new forecast, if subsequent data reverse the earlier movements.
- Information rigidities
  - consistent with models of information rigidities, e.g. noisy information model (Coibion and Gorodnichenko (2015)
  - forecasts are weighted average of new information (weight $= W$) and previous forecasts
  - pooled h, $W = 1/(1 + \mu_2) = 0.80$
  - in these models $W = 1$: signal perfectly revealing of state