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ARTICLE

Are the Forecasts of Professionals Compatible with the Taylor Rule? Evidence from the Euro Area

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Abstract

This article examines if professional forecasters form their expectations regarding the policy rate of the European Central Bank (ECB) consistent with the Taylor rule. In doing so, we assess micro-level data including individual forecasts for the ECB main refinancing operations rate as well as inflation and gross domestic product (GDP) growth for the Euro Area. Our results indicate that professionals indeed form their expectations in line with the Taylor rule. However, this connection has diminished over time, especially after the policy rate hit the zero lower bound. In addition, we also find a relationship between forecasters' disagreement regarding the policy rate of the ECB and disagreement on future GDP growth, which disappears when controlling for monetary policy shocks proxied by changes in the policy rate in the quarter the forecasts are made.

Keywords: Disagreement; expectations; forecast; monetary policy

JEL Classification: D84; E43; E52

1. Introduction

The increasing availability and popularity of survey data enable us to verify if professionals believe in simple models often used as crucial building blocks for larger economic models. One prominent example is the so-called Taylor (1993) rule and the ideal case to study the expectation formation mechanism in the context of the Taylor rule is provided by the European Central Bank (ECB) and the professionals monitoring and forecasting its policy. In this vein, the ECB Survey of Professional Forecasters (SPF) directly asks participants to reveal their view about the future development of the policy rate in contrast to other surveys providing forecasts for market interest rates. Therefore, in this article, we study whether professional forecasters form their expectations regarding the policy rate of the ECB consistent with the Taylor rule and whether the expectation building mechanism has changed over the recent two decades.

Following the original version of the Taylor (1993) rule, the nominal policy rate i_t should be set in reaction to deviations of the inflation rate π_t from its target π_t^* and of GDP y_t from its potential $\bar{y}_t$

$$i_t = \pi_t + r_t^* + \phi_1 \left(\pi_t - \pi_t^*\right) + \phi_2 \left(y_t - \bar{y}_t\right). \tag{1}$$

r_t^* denotes the equilibrium real interest rate consistent with an output gap $y_t - \bar{y}_t$ equal to zero and $\phi_1 > 0$ as well as $\phi_2 > 0$. Taylor (1993) proposes $\phi_1 = \phi_2 = 0.5$ and the rationale is to tighten monetary policy by increasing the policy rate when inflation is above its target and/or output is above its potential. In the opposite situation, the rule recommends a decrease of the policy rate to stimulate economic activity. Subsequent studies have shown that estimations of policy reaction functions in the sense of equation (1) based on ex post revised data are not reliable (Orphanides, 2001) and emphasize the importance of forward-looking versions of equation (1) by replacing the actual inflation rate by an expected value (Clarida et al., 1998, 1999, 2000; Orphanides, 2003). Malmendier et al. (2021) also follow this notion but additionally introduce heterogeneity in inflation expectations across individuals. In this study, we proceed in the same direction and replace all components by expectations of professionals and also allow for heterogeneity across professional forecasters. In addition, we further exploit the cross-sectional variation inherent in our survey data set and also test whether the Taylor rule relationship provided in equation (1) translates into a connection between forecasters' disagreement regarding the policy rate, inflation, and GDP growth.

This article also relates to studies by Fendel et al. (2011) and Pierdzioch et al. (2012), who use survey data to estimate monetary policy reaction functions for G7 economies and for the United States (US) based on data from Consensus Economics and the Livingston survey, respectively.[1] Gorter et al. (2008) also rely on data from Consensus Economics to estimate a Taylor rule for the ECB but they do not study expectation formation as they use realized interest rates on the left-hand side of their Taylor rule and solely rely on mean forecasts across individual forecasters for inflation and GDP growth. They do not exploit the heterogeneity in individual forecasts. In addition, their sample period ends in December 2006 and therefore also does not cover the turbulent times of ECB policy since the global financial crisis. The only other study also using the ECB SPF data set for the estimation of the Taylor rule is provided by Frenkel et al. (2011). We extend their study into several directions: first, we exploit the cross-sectional variation by estimating a dynamic fixed-effects model while also accounting for a potential Nickell (1981) bias and by relying on individual reaction functions. Second, we also study changes over time by adding nearly 10 years of most recent data, which includes the crisis period and the zero lower bound period. Third, we also assess whether the Taylor rule might provide the foundation for the co-movement in disagreement among forecasters regarding the three variables of interest. Therefore, we extend the existing literature by the estimation of Taylor rule-type reaction functions based on individual expectations included in survey data for the Euro Area and provide important insights into the expectations formation mechanism of professionals. A clear benefit of the ECB SPF data set is the fact that it includes forecasts for the ECB policy rate in contrast to other sources such as Consensus Economics, which solely include forecasts for money market rates (e.g. 3-month interest rates) that can only serve as a proxy for the policy rate. This offers the possibility to examine directly whether professionals believe in the concept of the Taylor rule when forming their expectations.

The remainder of the article is organized as follows. Section 2 describes our data set. Section 3 presents our empirical framework and our main findings while Section 4 concludes.

2. Data

Our empirical study is based on micro-level data from the ECB SPF spanning a quarterly sample period from 2002Q1 to 2020Q2. The ECB initiated this SPF together with the introduction of the euro in 1999 and started asking all participants to provide fixed-event as well as fixed-horizon forecasts regarding inflation, real GDP growth, and unemployment for the Euro Area (EA) at the beginning of each quarter. In 2002Q1, the SPF has been extended to also cover forecasts regarding the policy rate of the ECB, that is, the rate of main refinancing operations (MRO), as part of the assumptions upon which forecasters base their inflation and GDP growth forecasts. Therefore, the start of our sample period is restricted by the availability of MRO rate forecasts in the ECB SPF. In this study, we rely on forecasts for the MRO rate, inflation, and real GDP growth as proxies for expectations of professionals to examine if they form their expectations in line with the concept of the Taylor rule.

More precisely, we use so-called rolling horizon forecasts for the month (quarter) 1-year ahead of the latest available observation at the time the survey is conducted for inflation (real GDP growth). This means that, for example, for inflation forecasts made in Q1, the latest available observation is from December of the previous year and therefore the forecast is made for December 1-year ahead. In case of real GDP growth forecasts made in Q1, the latest available observation is from Q3 of the previous year. Therefore, in this case, the forecast is made for Q3 1-year ahead. This means that although the period being forecasted is not identical for inflation and GDP growth, we use in both cases 1-year ahead forecasts made at the same time using the latest available information. Fixed-horizon forecasts for consecutive quarters are not provided within the survey for inflation and GDP growth. These 1-year ahead forecasts correspond to the forecast horizon of $h = 4$ quarters. To match this horizon, we have also selected the four quarters ahead forecasts for the MRO rate. In contrast to inflation and GDP growth forecasts, participants are asked to provide forecasts for four consecutive quarters starting with the quarter when the survey is conducted for the MRO rate.

This data set has often been considered in previous studies concerning the evaluation of forecasts and the expectation building mechanism regarding inflation, GDP growth, unemployment, or the crude oil price (see e.g. Reitz et al., 2012; Andrade and Le Bihan, 2013; Dovern, 2015; Abel et al., 2016). We add to this strand of the literature by using this data set to assess whether professional expectations are formed consistent with the Taylor rule. Professional forecasters participating in the ECB SPF include forecast units of several different institutions within the EA such as banks or research institutes. These professionals can be considered as most informed economic agents, which are mostly familiar with the general concept of the Taylor rule and/or the reasoning behind it. The number of participating forecasters varies over time, ranges between 41 and 61 within the sample period and totals 103 different institutions.

Panel (a) in Figure 1 displays individual quarterly four quarters ahead MRO rate point forecasts (black points) together with the corresponding mean forecasts across individual forecasters (red line) for the period from 2002Q1 to 2020Q2. The points around the red line illustrate the disagreement across forecasters regarding the future monetary policy rate of the ECB. It becomes evident that the disagreement among forecasters clearly decreased in the latest period characterized by a policy rate of (nearly) zero but it has not disappeared completely. This indicates that several forecasters have also expected changes in the stance of monetary policy within this period. Panel (b) compares mean forecasts for the policy rate across forecasters over four different forecast horizons with the actual realization of the MRO rate at the time forecasts are made, which exactly matches the dates at which forecasters had to submit their forecasts. This graph illustrates that mean forecasts are closely attached to the current policy rate but also shows forecasters' expectations about a potential change in the policy rate. Figure 2 also visualizes individual and mean forecasts for inflation and GDP growth and explicitly shows a stronger disagreement among forecasters and a substantial downturn of real GDP growth in the latest period (i.e. 2020Q2) due to the impact of the COVID-19 pandemic.

The data set includes variation across forecasters ($j = 1, \ldots, n$) and over time ($t = 1, \ldots, T$). $T = 74$ while n varies between 41 and 61. As both dimensions (i.e. cross-section and time) are of medium size, our estimations benefit from the panel dimension in terms of efficiency by exploiting variation across forecasters and over time. However, in further robustness checks, we also switch to the time series perspective relying on the mean across forecasters and also on individual estimates.

3. Empirical framework and findings

Our empirical implementation of equation (1) consists of a fixed-effects model exploiting the heterogeneity across forecasters and the variation over time

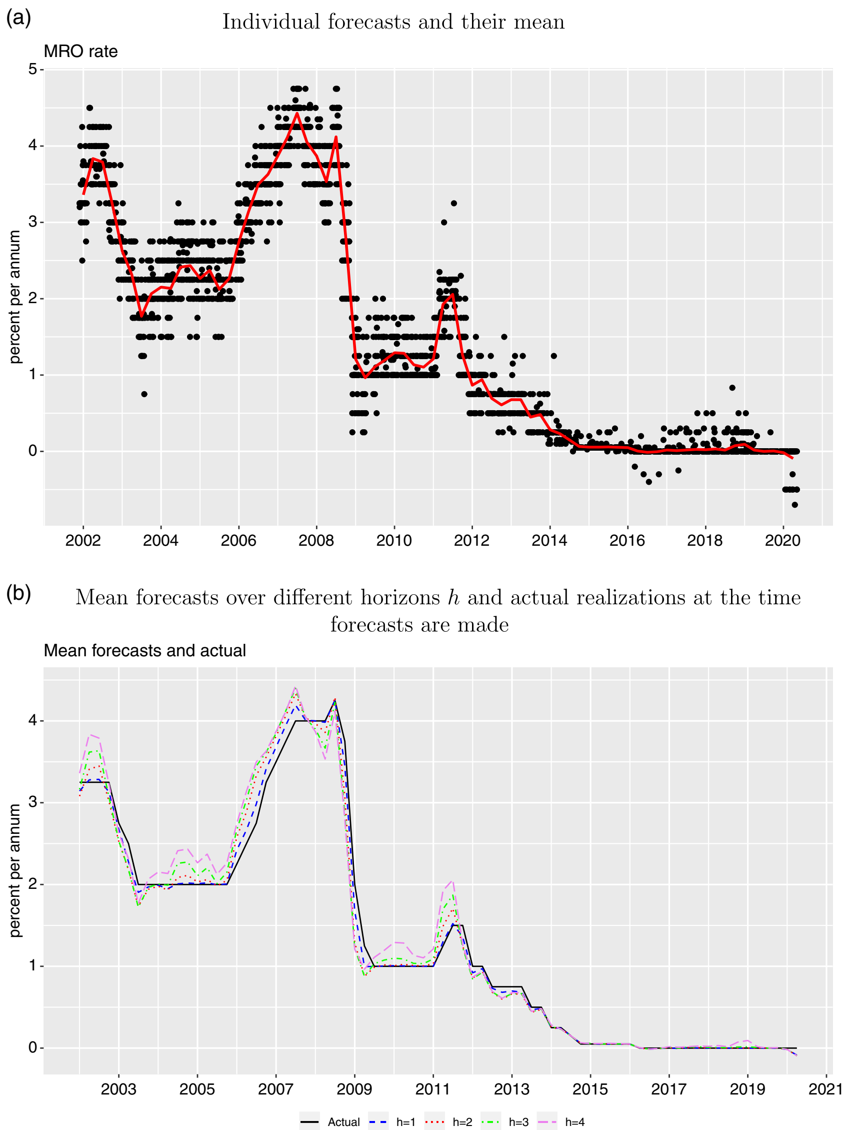

Figure 1. Individual and mean forecasts for the ECB policy rate.
The plots show quarterly time series of the ECB rate for main refinancing operations (MRO) forecasts (in percent per annum) across individual forecasters (black points) together with mean forecasts across individuals (red line) for the period from 2002Q1 to 2020Q2 and for the forecast horizon of four-quarters-ahead. The data has been taken from the ECB Survey of Professional Forecasters (SPF).

$$E_{j,t}\left(i_{t+h}\right) = \phi_1\left[E_{j,t}(\pi_{t+h}) - \pi^*\right] + \phi_2\left[E_{j,t}\left(\Delta y_{t+h}\right) - \overline{E}_t^*\left(\Delta y_{t+h}\right)\right] + \phi_3 E_{j,t-1}\left(i_{t+h}\right)$$
$$+ \mu_j + \lambda_t + \varepsilon_{j,t+h}, \tag{2}$$

where $E_{j,t}(.)$ denotes the forecast for the period $t+h$ made in t by forecaster j, i_t stands for the ECB policy rate, π_t represents EA inflation and Δy_t denotes EA real GDP growth. π^* stands for the inflation target rate of the ECB and equals 2% and $\overline{E}_t^*(\Delta y_{t+h})$ represents EA potential GDP growth measured by Hodrick–Prescott-filtered GDP growth mean forecasts across forecasters with a smoothing parameter $\lambda = 1600$.[2] In addition, it is common practice in the Taylor rule

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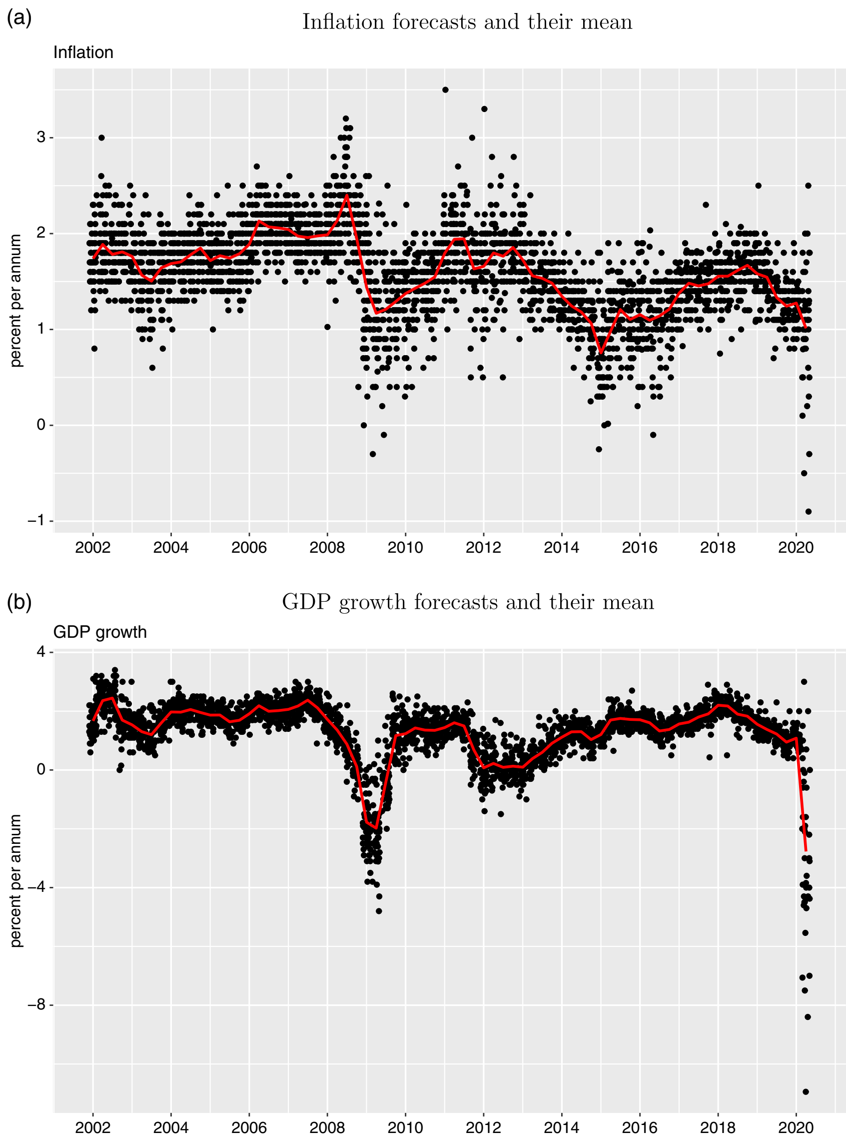

Figure 2. Individual and mean forecasts for inflation and GDP growth.
The plots show quarterly time series of Euro Area inflation and real GDP growth forecasts (in percent per annum) across individual forecasters (black points) together with mean forecasts across individuals (red line) for the period from 2002Q1 to 2020Q2 and for the forecast horizon of four-quarters-ahead. The data has been taken from the ECB Survey of Professional Forecasters (SPF).

literature to account for interest rate smoothing by including the one-period-lagged policy rate due to the tendency of central banks to change its policy rate gradually. In contrast, we include the previous periods' expectations about the future policy rate $E_{j,t-1}(i_{t+h})$ due to the fact that this article focuses on the expectations building process and previous studies have also provided evidence for the sluggishness of economic forecasts due to the presence of information rigidities (Coibion and Gorodnichenko, 2015).[3] Individual fixed and time fixed effects μ_j and λ_t allow for a potential heterogeneity in the estimation of the equilibrium real interest rate across individuals and over time.[4]

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3.1 Fixed-effects model

Panel (a) in Table 1 reports estimation results for equation (2) with and without the lagged policy rate forecast for the full sample period from 2002Q1 to 2020Q2 (Full) as well as three sub-sample periods: 2002Q1 to 2008Q3 (I), 2008Q4 to 2016Q1 (II), and 2016Q2 to 2020Q2 (III). The first sub-sample period is considered as the pre-crisis period and the collapse of Lehman Brothers in September 15, 2008 is chosen as the start of the crisis. The second sub-sample period is roughly defined as crisis period, which includes the global financial crisis and also the following European debt crisis. Finally, the third sample period is simply classified as the zero lower bound (ZLB) period and includes the time frame with a MRO rate of zero. The main findings are as follows. First, except for the ZLB period professional forecasters seem to follow the Taylor rule as their policy rate expectations are positively affected by their expectations regarding both deviations of inflation from its target and of GDP growth from its potential and both coefficients (i.e. ϕ_1 and ϕ_2) are significantly different from zero. In the latest period, this connection unsurprisingly disappears due to the zero interest rate policy of the ECB supported by announcements within its forward guidance strategy. Therefore, during the ZLB period, the ECB has not changed their policy rate due to variations in inflation and/or output gap and professionals have expected this policy rate path. Therefore, both coefficients are not significantly different from zero in the latest period. Second, the connection of policy rate expectations of professionals to their expectations regarding inflation and output gap has lowered over time, which is indicated by the magnitude of the coefficients and by the R^2. Third, the one-quarter lagged policy rate forecast also turns out to be (highly) significant and confirms an interest rate smoothing in the expectation building mechanism.

As a robustness check, Panel (b) in Table 1 also reports coefficient estimates for the means across individual forecasters solely focusing on the variation over time. These results generally confirm our previous findings but show much larger coefficient estimates due to aggregation across forecasters. We also find that average policy rate expectations can significantly be explained by inflation expectations and that this association decreases over time. Output gap expectations are especially significant within the crisis period, for which professionals expected the ECB to lower its policy rate to stimulate economic activity and to fight against the recession. To check for robustness, Table 2 provides additional estimation results including several types of location shifts, which account for quarterly periodicity in the forecasts, for decisions of the ECB to change the policy rate and for further location shifts endogenously determined by the split-sample algorithm approach outlined by Castle and Hendry (2019), which basically selects all possible location shift dates that turn out to be significant at the 5% level. Overall, the estimates of the coefficients for the expected inflation and output gap do not differ considerably compared to the initial findings reported in Panel (b) in Table 1. Therefore, our main findings seem not to be sensitive to the inclusion of different types of location shifts.[5]

As an additional robustness check for the fixed-effect model estimation results reported in Panel (a) in Table 1, Table 3 provides random effects estimation results.[6] The coefficients are all very close to the fixed-effects estimates reported in Panel (a) in Table 1. Solely the coefficient estimate of the lagged MRO rate forecast is remarkably higher compared to the fixed-effects model. The significance of the coefficients is diminished, especially for the full sample period specifications. However, the expected inflation gap turns out to be significant even in the zero lower bound period in contrast to the fixed-effects estimates. The next section provides an additional robustness check.

3.2 Bias correction

Dynamic fixed-effects models as given by equation (2) are well-known to be subject to the so-called Nickell (1981) bias. In order to cope with that we also rely on the Bayesian orthogonal reparameterization approach proposed by Lancaster (2002). This approach has several benefits compared to other frameworks that are able to eliminate the Nickell (1981) bias in dynamic

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Table 1. Panel Taylor rule estimations

	ϕ_1	$SE(\phi_1)$	$p(\phi_1)$	ϕ_2	$SE(\phi_2)$	$p(\phi_2)$	ϕ_0	$SE(\phi_0)$	$p(\phi_0)$	ϕ_3	$SE(\phi_3)$	$p(\phi_3)$	R^2	N	$p(F)$
(a) $E_{j,t}(i_{t+h}) = \phi_1[E_{j,t}(\pi_{t+h}) - \pi^*] + \phi_2[E_{j,t}(\Delta y_{t+h}) - \bar{E}_t^*(\Delta y_{t+h})] + \phi_3 E_{j,t-1}(i_{t+h}) + \mu_j + \lambda_t + \varepsilon_{j,t+h}$															
Full	0.1106	(0.0206)	[0.0000]	0.0588	(0.0122)	[0.0000]							0.0450	3158	[0.0000]
I	0.2081	(0.0456)	[0.0000]	0.1995	(0.0345)	[0.0000]							0.0995	1197	[0.0000]
II	0.1158	(0.0299)	[0.0001]	0.0774	(0.0173)	[0.0000]							0.0697	1255	[0.0000]
III	0.0217	(0.0180)	[0.2287]	0.0025	(0.0070)	[0.7188]							0.0062	706	[0.0000]
Full	0.0704	(0.0145)	[0.0000]	0.0358	(0.0105)	[0.0006]				0.4207	(0.0245)	[0.0000]	0.2198	2607	[0.0000]
I	0.1258	(0.0358)	[0.0005]	0.1409	(0.0313)	[0.0000]				0.3835	(0.0338)	[0.0000]	0.2420	970	[0.0000]
II	0.0821	(0.0236)	[0.0005]	0.0686	(0.0210)	[0.0012]				0.2910	(0.0456)	[0.0000]	0.1650	997	[0.0000]
III	0.0207	(0.0203)	[0.3085]	0.0023	(0.0079)	[0.7703]				0.2037	(0.1217)	[0.0949]	0.0356	568	[0.0000]
(b) $\bar{E}_t(i_{t+h}) = \phi_0 + \phi_1[\bar{E}_t(\pi_{t+h}) - \pi^*] + \phi_2[\bar{E}_t(\Delta y_{t+h}) - \bar{E}_t^*(\Delta y_{t+h})] + \phi_3 \bar{E}_{t-1}(i_{t+h}) + \varepsilon_{t+h}$															
Full	3.4657	(0.5575)	[0.0000]	–0.3549	(0.2116)	[0.0979]	2.8737	(0.4291)	[0.0000]				0.6338	74	
I	3.0284	(0.4786)	[0.0000]	0.4345	(0.8331)	[0.6068]	3.4508	(0.1672)	[0.0000]				0.5597	27	
II	1.4267	(0.2604)	[0.0000]	0.6551	(0.2319)	[0.0088]	1.6108	(0.3137)	[0.0000]				0.5020	30	
III	0.1508	(0.0433)	[0.0037]	0.0152	(0.0157)	[0.3499]	0.1042	(0.0238)	[0.0006]				0.6249	17	
Full	0.6119	(0.2814)	[0.0331]	0.3017	(0.2693)	[0.2665]	0.4172	(0.2109)	[0.0519]	0.8556	(0.0795)	[0.0000]	0.9501	73	
I	1.2640	(0.2633)	[0.0001]	1.9231	(0.5217)	[0.0013]	0.9389	(0.1848)	[0.0000]	0.7481	(0.0628)	[0.0000]	0.9323	26	
II	0.4451	(0.2406)	[0.0762]	1.0447	(0.4422)	[0.0262]	0.4674	(0.2228)	[0.0462]	0.6516	(0.1252)	[0.0000]	0.8035	29	
III	0.1644	(0.0411)	[0.0018]	0.0106	(0.0172)	[0.5497]	0.1083	(0.0240)	[0.0007]	0.0874	(0.1813)	[0.6385]	0.6942	16	

Note: The table reports panel data estimation results for the regression models given above for a horizon of $h = 4$ quarters-ahead for the period from 2002Q1 to 2020Q2 (Full) as well as three sub-sample periods: 2002Q1 to 2008Q3 (I), 2008Q4 to 2016Q1 (II) and 2016Q2 to 2020Q2 (III). Panel (a) reports fixed-effects regression results exploiting the cross-sectional variation across individual forecasters and Panel (b) provides time series estimation results for the means across individual forecasters. $E_{j,t}(.)$ denotes the forecast for the period $t+h$ made in t by forecaster j and $\bar{E}_t(.)$ gives its mean across forecasters, i_t stands for the ECB policy rate, π_t represents Euro Area (EA) inflation and Δy_t denotes EA GDP growth. π^* stands for the inflation target rate of the ECB and equals 2% and $\bar{E}_t^*(\Delta y_{t+h})$ represents EA potential GDP growth measured by Hodrick-Prescott-filtered GDP growth mean forecasts across forecasters. $SE(.)$ denotes heteroskedasticity and autocorrelation consistent (HAC) standard errors following Andrews (1991) and $p(.)$ gives the corresponding p-values. N reports the sample size and $p(F)$ stands for the p-value for the F-statistic testing the significance of individual and time fixed effects μ_j and λ_t. The R^2 for the panel models reported in Panel (a) gives the incremental R^2 excluding the fraction attributed to individual and time fixed effects μ_j and λ_t, which explain most of the variation in $E_{j,t}(i_{t+h})$.

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Table 2. Robustness of mean Taylor rule estimations

$\overline{E}_t(i_{t+h}) = \phi_1[\overline{E}_t(\pi_{t+h}) - \pi^*] + \phi_2[\overline{E}_t(\Delta y_{t+h}) - \overline{E}^*_t(\Delta y_{t+h})] + \phi_3\overline{E}_{t-1}(i_{t+h}) + \sum_{k=1}^{4} \gamma_k \mathrm{Q}k_t + \sum_{k=1}^{5} \delta_k \mathrm{I}k_t + \omega \mathrm{Decision}_t + \varepsilon_{t+h}$

	Full	I	II	III	Full	I	II	III	Full	Full	Full	Full	Full	Full
ϕ_1	3.4668	3.0365	1.4277	0.1448	0.5935	1.2599	0.4249	0.1418	0.4920	0.4685	3.3110	0.6112	0.4982	0.4666
$SE(\phi_1)$	(0.5695)	(0.6527)	(0.2784)	(0.0464)	(0.2697)	(0.2857)	(0.2323)	(0.0424)	(0.2426)	(0.2260)	(0.4782)	(0.2830)	(0.2353)	(0.2138)
$p(\phi_1)$	[0.0000]	[0.0001]	[0.0000]	[0.0097]	[0.0313]	[0.0003]	[0.0810]	[0.0086]	[0.0466]	[0.0422]	[0.0000]	[0.0343]	[0.0382]	[0.0330]
ϕ_2	-0.3471	0.4106	0.6776	0.0051	0.3295	1.9104	1.0984	−0.0075	0.0428	0.1076	−0.2271	0.2984	0.0567	0.1197
$SE(\phi_2)$	(0.2257)	(1.1836)	(0.2245)	(0.0323)	(0.2464)	(0.6186)	(0.4071)	(0.0262)	(0.1911)	(0.2285)	(0.2446)	(0.2703)	(0.2007)	(0.2357)
$p(\phi_2)$	[0.1287]	[0.7321]	[0.0059]	[0.8773]	[0.1857]	[0.0061]	[0.0131]	[0.7822]	[0.8234]	[0.6393]	[0.3564]	[0.2734]	[0.7784]	[0.6133]
ϕ_3					0.8595	0.7474	0.6627	0.3226		0.2609		0.8578		0.2621
$SE(\phi_3)$					(0.0770)	(0.0672)	(0.1245)	(0.3130)		(0.1658)		(0.0757)		(0.1634)
$p(\phi_3)$					[0.0000]	[0.0000]	[0.0000]	[0.3296]		[0.1205]		[0.0000]		[0.1140]
γ_1	2.8880	3.5004	1.6124	0.1078	0.3410	0.9123	0.4265	0.1007					3.6700	2.7532
$SE(\gamma_1)$	(0.4505)	(0.1870)	(0.3024)	(0.0358)	(0.1835)	(0.2148)	(0.2010)	(0.0326)					(0.0681)	(0.6554)
$p(\gamma_1)$	[0.0000]	[0.0000]	[0.0000]	[0.0118]	[0.0676]	[0.0004]	[0.0454]	[0.0130]					[0.0000]	[0.0001]
γ_2	2.9048	3.4139	1.6648	0.0901	0.4973	0.9331	0.5832	0.0663					3.6694	2.7831
$SE(\gamma_2)$	(0.4273)	(0.2306)	(0.3507)	(0.0156)	(0.2204)	(0.1986)	(0.2647)	(0.0348)					(0.0711)	(0.6483)
$p(\gamma_2)$	[0.0000]	[0.0000]	[0.0001]	[0.0001]	[0.0274]	[0.0002]	[0.0383]	[0.0891]					[0.0000]	[0.0001]
γ_3	2.8763	3.4841	1.5337	0.0948	0.4521	0.9679	0.4173	0.0872					3.6710	2.7734
$SE(\gamma_3)$	(0.4525)	(0.2641)	(0.3190)	(0.0260)	(0.2404)	(0.2165)	(0.2199)	(0.0325)					(0.0846)	(0.6597)
$p(\gamma_3)$	[0.0000]	[0.0000]	[0.0001]	[0.0039]	[0.0645]	[0.0003]	[0.0709]	[0.0251]					[0.0000]	[0.0001]
γ_4	2.8250	3.4020	1.6314	0.1121	0.3200	0.9466	0.3642	0.1078					3.5590	2.6514
$SE(\gamma_4)$	(0.4260)	(0.2363)	(0.3626)	(0.0290)	(0.1890)	(0.2390)	(0.2236)	(0.0276)					(0.0429)	(0.6106)
$p(\gamma_4)$	[0.0000]	[0.0000]	[0.0001]	[0.0026]	[0.0952]	[0.0008]	[0.1176]	[0.0036]					[0.0000]	[0.0001]
δ_1									-1.2317	-0.9337			-1.2355	-0.9434
$SE(\delta_1)$									(0.0272)	(0.2584)			(0.0433)	(0.2584)
$p(\delta_1)$									[0.0000]	[0.0006]			[0.0000]	[0.0005]

Table 2. Continued

	Full	I	II	III	Full	I	II	III	Full	Full	Full	Full	Full	Full
δ_2									1.2804	0.9187			1.2660	0.9107
$SE(\delta_2)$									(0.1120)	(0.1954)			(0.2499)	(0.2158)
$p(\delta_2)$									[0.0000]	[0.0000]			[0.0000]	[0.0001]
δ_3									-2.1509	−1.5629			−2.1372	−1.5552
$SE(\delta_3)$									(0.1759)	(0.3227)			(0.2848)	(0.3432)
$p(\delta_3)$									[0.0000]	[0.0000]			[0.0000]	[0.0000]
δ_4									-0.7379	−0.5535			−0.7429	−0.5546
$SE(\delta_4)$									(0.0431)	(0.1125)			(0.0730)	(0.1259)
$p(\delta_4)$									[0.0000]	[0.0000]			[0.0000]	[0.0000]
δ_5									-0.4257	-0.2551			-0.4092	-0.2486
$SE(\delta_5)$									(0.1134)	(0.1130)			(0.1098)	(0.1189)
$p(\delta_5)$									[0.0004]	[0.0275]			[0.0004]	[0.0407]
ω											0.4266	−0.0185	0.0389	0.0206
$SE(\omega)$											(0.2416)	(0.1007)	(0.0835)	(0.0787)
$p(\omega)$											[0.0818]	[0.8544]	[0.6430]	[0.7947]
$\bar{R}^2$	0.8079	0.9642	0.7632	0.5503	0.9746	0.9939	0.9197	0.7282	0.9673	0.9703	0.6384	0.9472	0.9838	0.9852

Note: The table reports time series estimation results for the means across individual forecasters using the regression model given above for a horizon of $h = 4$ quarters-ahead for the period from 2002Q1 to 2020Q2 (Full) as well as three sub-sample periods: 2002Q1 to 2008Q3 (I), 2008Q4 to 2016Q1 (II) and 2016Q2 to 2020Q2 (III). $\bar{E}_t(.)$ denotes the mean forecast across forecasters for the period $t + h$ made in t, i_t stands for the ECB policy rate, π_t represents Euro Area (EA) inflation and Δy_t denotes EA GDP growth. π^* stands for the inflation target rate of the ECB and equals 2% and $\bar{E}^*_t(\Delta y_{t+h})$ represents EA potential GDP growth measured by Hodrick-Prescott-filtered GDP growth mean forecasts across forecasters. Qk_t with $k = 1, 2, 3, 4$ stands for quarterly dummy variables taking a value of 1 in quarter k, and 0 otherwise. Ik_t with $k = 1, \ldots, 5$ represent location shifts $I(t \leq s) = 1$ for all quarters up to s, and 0 otherwise, for the quarters s: 2003Q1, 2006Q2, 2009Q1, 2012Q1 and 2014Q2. Decision$_t$ defines a binary variable equal to 1, if the Governing Council of the ECB made the decision to change its policy rate i_t in the quarter prior to the forecast made in t but after the last forecast in $t - 1$, and 0 otherwise. $SE(.)$ denotes heteroskedasticity and autocorrelation consistent (HAC) standard errors following Andrews (1991) and $p(.)$ gives the corresponding p-values. $\bar{R}^2$ provides the adjusted R^2.

Table 3. Random effects Taylor rule estimations

	ϕ_1	$SE(\phi_1)$	$p(\phi_1)$	ϕ_2	$SE(\phi_2)$	$p(\phi_2)$	ϕ_0	$SE(\phi_0)$	$p(\phi_0)$	ϕ_3	$SE(\phi_3)$	$p(\phi_3)$	R^2	N
(c) $E_{j,t}(i_{t+h}) = \phi_0 + \phi_1[E_{j,t}(\pi_{t+h}) - \pi^*] + \phi_2[E_{j,t}(\Delta y_{t+h}) - \bar{E}_t^*(\Delta y_{t+h})] + \phi_3 E_{j,t-1}(i_{t+h}) + \nu_{j,t+h}$														
Full	0.1172	(0.2326)	[0.6146]	0.0585	(0.0549)	[0.2866]	1.5055	(0.1142)	[0.0000]				0.2586	3158
I	0.2184	(0.1633)	[0.1812]	0.1957	(0.0868)	[0.0243]	3.0847	(0.0297)	[0.0000]				0.1936	1197
II	0.1196	(0.0936)	[0.2016]	0.0774	(0.0376)	[0.0399]	0.8996	(0.0567)	[0.0000]				0.1946	1255
III	0.0367	(0.0198)	[0.0641]	0.0033	(0.0066)	[0.6141]	0.0284	(0.0152)	[0.0618]				0.0530	706
Full	0.0788	(0.0484)	[0.1037]	0.0284	(0.0250)	[0.2562]	0.5805	(0.0604)	[0.0000]	0.5958	(0.0411)	[0.0000]	0.9229	2607
I	0.1384	(0.0779)	[0.0759]	0.1002	(0.0586)	[0.0874]	1.4221	(0.1198)	[0.0000]	0.5434	(0.0411)	[0.0000]	0.7966	970
II	0.0858	(0.0492)	[0.0818]	0.0595	(0.0295)	[0.0439]	0.4802	(0.0445)	[0.0000]	0.3888	(0.0400)	[0.0000]	0.6553	997
III	0.0429	(0.0200)	[0.0327]	0.0005	(0.0065)	[0.9373]	0.0285	(0.0122)	[0.0200]	0.4242	(0.1336)	[0.0016]	0.2310	568

Note: The table reports panel data estimation results for the regression models given above for a horizon of $h = 4$ quarters-ahead for the period from 2002Q1 to 2020Q2 (Full) as well as three sub-sample periods: 2002Q1 to 2008Q3 (I), 2008Q4 to 2016Q1 (II) and 2016Q2 to 2020Q2 (III). It accompanies Table 1 and adds Panel (c), which reports random effects regression results. $E_{j,t}(.)$ denotes the forecast for the period $t+h$ made in t by forecaster j and $\bar{E}_t(.)$ gives its mean across forecasters, i_t stands for the ECB policy rate, π_t represents Euro Area (EA) inflation and Δy_t denotes EA GDP growth. π^* stands for the inflation target rate of the ECB and equals 2% and $\bar{E}_t^*(\Delta y_{t+h})$ represents EA potential GDP growth measured by Hodrick-Prescott-filtered GDP growth mean forecasts across forecasters. $SE(.)$ denotes heteroskedasticity and autocorrelation consistent (HAC) standard errors following Andrews (1991) and $p(.)$ gives the corresponding p-values. N reports the sample size.

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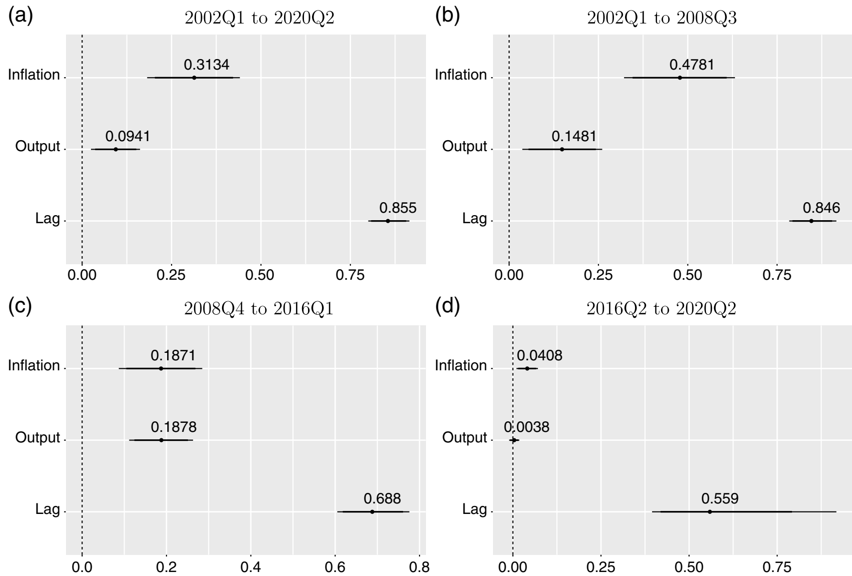

Figure 3. Coefficient estimates and credible intervals.

The plots show parameter estimates and credible intervals based on the dynamic panel model with fixed effects provided in equation (2) using the orthogonal reparameterization approach proposed by Lancaster (2002) to eliminate the Nickell (1981) bias for the full sample period and three sub-sample periods. The parameter estimates are given by the posterior medians and are shown by the black dots. The thin (thick) horizontal lines provide the 95% (90%) credible intervals. The labels Inflation, Output and Lag in the plots refer to estimates of the following coefficients: ϕ_1, ϕ_2, and ϕ_3 provided in equation (2).

fixed-effects models such as, for example, different generalized method of moments (GMM) estimators (Arellano and Bond, 1991; Blundell and Bond, 1998), which often appear to be inefficient and also assume the reliability of lags of the left-hand side as instruments and/or require further instruments. The approach proposed by Lancaster (2002) is a likelihood-based estimator, which relies on a reparameterization of the individual fixed effects such that these are information orthogonal with all other parameters within the model. This basically means that the slope of the log-likelihood with respect to the individual fixed effects is independent of the slope of the log-likelihood with respect to all other parameters within the model. This approach involves a Bayesian estimation strategy, for which we directly refer to Lancaster (2002) and which is carried out with 10,000 Monte Carlo iterations to estimate the posterior distribution. Then parameter estimates are derived as posterior medians and inference is conducted based on credible intervals as quantiles of the posterior.

Figure 3 provides parameter estimates and credible intervals based on the dynamic panel model with fixed effects provided in equation (2) using this orthogonal reparameterization approach for the full sample period and three sub-sample periods. The parameter estimates for ϕ_i for $i = 1, 2, 3$ are shown by the black dots together with the 95% (90%) credible intervals represented by thin (thick) horizontal lines. Overall, the parameter estimates generally confirm the finding that professionals seem to follow the Taylor rule when forming their expectations as the coefficients related to inflation and output gap expectations are significantly positive in (nearly) all cases as the credible intervals do not cover zero. Solely for the ZLB period, the parameter estimates are close to zero, although the coefficient for inflation gap expectations is still significantly different from zero. Therefore, generally Figure 3 confirms our findings provided in Table 1 but it also shows that the coefficient estimates are larger compared to the ones reported in Panel (a) of Table 1 in (nearly) all cases. The latter indicates a potential Nickell (1981) bias in the estimates provided in Table 1, Panel (a). However, this bias is clearly negative as it turns out in parameter estimates that are too

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Table 4. Arellano-Bond estimation results

	Full	I	II	III
$E_{j,t}(i_{t+h}) = \phi_1[E_{j,t}(\pi_{t+h}) - \pi^*] + \phi_2[E_{j,t}(\Delta y_{t+h}) - \overline{E}_t^*(\Delta y_{t+h})] + \phi_3 E_{j,t-1}(i_{t+h}) + \mu_j + \lambda_t + \varepsilon_{j,t+h}$				
ϕ_1	0.2392	0.5796	0.3444	0.1727
$SE(\phi_1)$	(0.0246)	(0.0951)	(0.0367)	(0.1374)
$p(\phi_1)$	[0.0000]	[0.0000]	[0.0000]	[0.2084]
ϕ_2	0.1470	0.4184	0.1902	-0.0030
$SE(\phi_2)$	(0.0313)	(0.0533)	(0.0135)	(0.0197)
$p(\phi_2)$	[0.0000]	[0.0000]	[0.0000]	[0.8808]
ϕ_3	0.7508	0.6802	0.5021	–0.0731
$SE(\phi_3)$	(0.0206)	(0.0291)	(0.0324)	(0.2011)
$p(\phi_3)$	[0.0000]	[0.0000]	[0.0000]	[0.7159]

Note: The table reports dynamic panel data Arellano and Bond (1991) GMM estimation results for the regression model given above for a horizon of $h = 4$ quarters-ahead for the period from 2002Q1 to 2020Q2 (Full) as well as three sub-sample periods: 2002Q1 to 2008Q3 (I), 2008Q4 to 2016Q1 (II) and 2016Q2 to 2020Q2 (III). $E_{j,t}(.)$ denotes the forecast for the period $t + h$ made in t by forecaster j, i_t stands for the ECB policy rate, π_t represents Euro Area (EA) inflation and Δy_t denotes EA GDP growth. π^* stands for the inflation target rate of the ECB and equals 2% and $\overline{E}_t^*(\Delta y_{t+h})$ represents EA potential GDP growth measured by Hodrick-Prescott-filtered GDP growth mean forecasts across forecasters. $SE(.)$ denotes heteroskedasticity and autocorrelation consistent (HAC) standard errors following Windmeijer (2005) and $p(.)$ gives the corresponding p-values.

small. This can be seen as evidence for the robustness of the results as the bias-corrected estimates are even more in favor of the finding that professionals believe in the Taylor rule concept.

For comparison, Table 4 also reports results for the Arellano and Bond (1991) estimator. As can be seen, the coefficient estimates are also larger compared to the ones reported in Panel (a) of Table 1 and roughly similar to the ones provided by the Lancaster (2002) approach, which additionally confirms the robustness of our findings. The next section also tests this hypothesis for each individual forecaster and checks the stability of this finding over time.

3.3 Heterogeneity of parameter estimates

Figure 4 also illustrates Taylor rule coefficient estimates for each individual forecaster j and therefore exploits the cross-sectional variation across forecasters in the data.[7] The relationship between MRO rate and inflation expectations becomes at least evident for 35% of the forecasters, for which we find a significantly positive coefficient over the entire sample period as indicated by a red dot in Panel (a) in Figure 4. Most of the individual estimates of $\phi_{j,1}$ range between 0.1 and 0.6 while the fixed-effects regression model estimates range between 0.02 and 0.21 across the different specifications (see Panel (a) in Table 1). First of all, the ranges of coefficient estimates overlap and therefore confirm the robustness of the fixed-effects regression estimates. Second, they tend to be a bit higher on the individual level, which is also supported by the Taylor rule relationship and which also underlines the relevance to account for heterogeneity among forecasters. In line with the Taylor principle, the plot also displays one coefficient estimate larger than unity. Third, the individual coefficient estimates are more in line with the bias corrected dynamic panel model estimates provided in Figure 3 and Table 4.

The association of MRO rate expectations with output gap expectations is less clear but also provides significantly positive coefficients for several forecasters as shown in Panel (b). For $\phi_{j,2}$ individual coefficient estimates mostly range between –0.1 and 0.3 while the corresponding fixed-effects regression model estimates range between 0.02 and 0.12 (see Panel (a) in Table 1), which also supports the robustness of the panel regression results.

To further account for variation over time, Figure 5 also provides cross-sectional Taylor rule regressions for each quarter of our sample period and supports our finding mentioned above that

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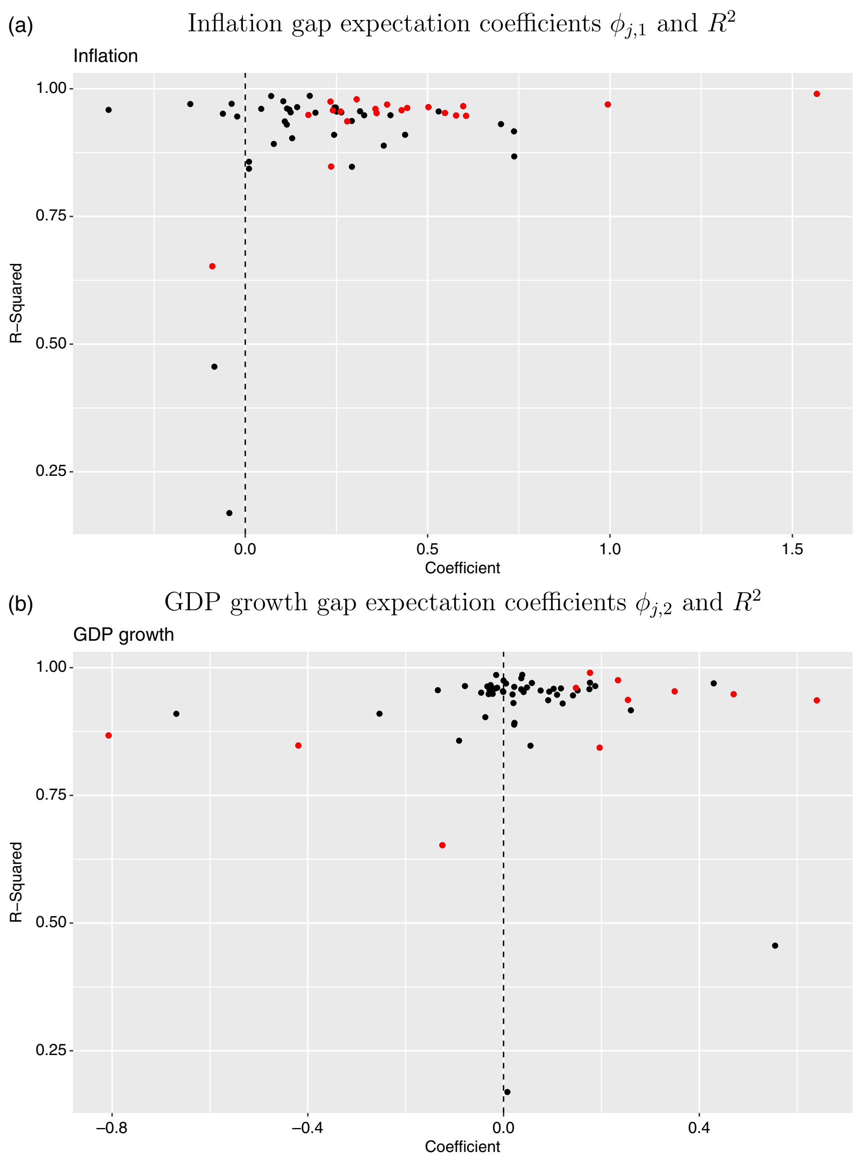

Figure 4. Individual Taylor rule estimations.
The plots show individual ordinary least squares (OLS) estimation results for the following regression model

$$E_{j,t}(i_{t+h}) = \phi_{j,1}[E_{j,t}(\pi_{t+h}) - \pi^*] + \phi_{j,2}[E_{j,t}(\Delta y_{t+h}) - \overline{E}_t^*(\Delta y_{t+h})] + \sum_{k=1}^{4} \gamma_{j,k} Qk_t + \sum_{k=1}^{5} \delta_{j,k} Ik_t + \varepsilon_{j,t+h},$$

where $E_{j,t}(.)$ denotes the forecast for the period $t+h$ made in t by forecaster j, i_t stands for the ECB policy rate, π_t represents Euro Area (EA) inflation and Δy_t denotes EA GDP growth. π^* stands for the inflation target rate of the ECB and equals 2% and $\overline{E}_t^*(\Delta y_{t+h})$ represents EA potential GDP growth measured by Hodrick-Prescott- filtered GDP growth mean forecasts across forecasters. Qk_t represents quarterly dummy variables and Ik_t stands for location shifts both defined in Table 2. Panels (a) and (b) illustrate OLS estimates for $\phi_{j,1}$ and $\phi_{j,2}$, respectively, for individual forecasters and a horizon of $h = 4$ quarters-ahead plotted against the R^2 of the regression. Red dots represent coefficient estimates, which are significantly different from zero at a 5% level.

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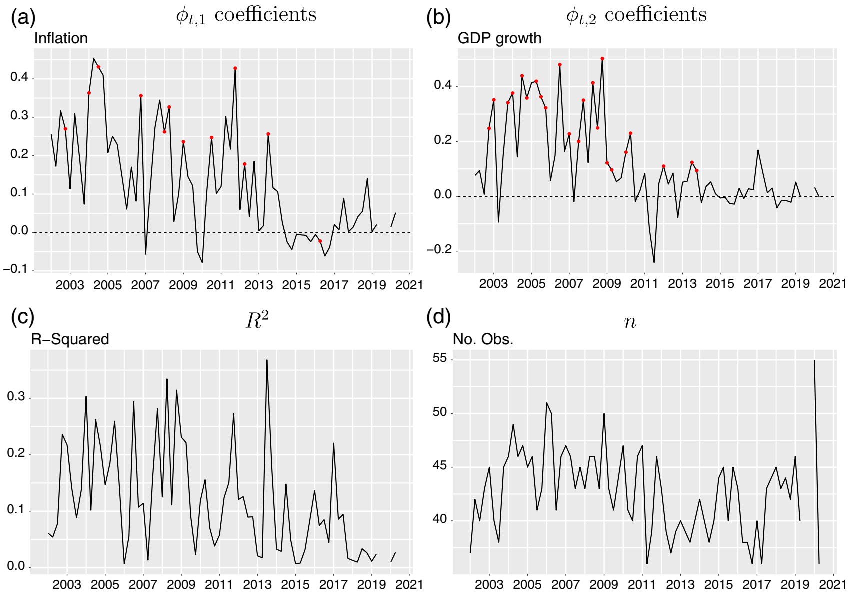

Figure 5. Cross-sectional Taylor rule regressions over time.
The plots show individual ordinary least squares (OLS) estimation results for the following regression model

$$E_{j,t}(i_{t+h}) = \phi_{t,0} + \phi_{t,1}[E_{j,t}(\pi_{t+h}) - \pi^*] + \phi_{t,2}[E_{j,t}(\Delta y_{t+h}) - \overline{E}_t^*(\Delta y_{t+h})] + \varepsilon_{j,t+h},$$

where $E_{j,t}(.)$ denotes the forecast for the period $t+h$ made in t by forecaster j, i_t stands for the ECB policy rate, π_t represents Euro Area (EA) inflation and Δy_t denotes EA GDP growth. π^* stands for the inflation target rate of the ECB and equals 2% and $\overline{E}_t^*(\Delta y_{t+h})$ represents EA potential GDP growth measured by Hodrick-Prescott-filtered GDP growth mean forecasts across forecasters. Panels (a) and (b) illustrate OLS estimates for $\phi_{t,1}$ and $\phi_{t,2}$, respectively, plotted over time and a horizon of $h = 4$ quarters-ahead. Panels (c) and (d) report the R^2 of the regressions and the number of observations (n), respectively. Red dots represent coefficient estimates, which are significantly different from zero at a 5% level. Two values during the ZLB period are missing due to no variation in the left-hand side variable as all forecasters expected a policy rate of zero within these two periods.

professionals made their forecasts roughly in line with the Taylor rule until the start of the ZLB period. This is indicated by (significantly) positive coefficients for inflation and GDP growth gap expectations as shown in Panels (a) and (b), although these also vary over time. The range of coefficient estimates is similar to the one for individual time series and panel fixed effect estimates discussed above.

3.4 Disagreement among forecasters

When assuming that professionals believe (at least to some extent) in the concept of the Taylor rule, then the cross-sectional variation of our data set can be further exploited to study if there is also a relationship in the disagreement among forecasters between the policy rate, inflation, and GDP growth (see also Dräger and Lamla, 2017). The theoretical foundation for this relationship is provided by Bauer and Neuenkirch (2017), who propose a forward-looking Taylor rule augmented by forecasters' disagreement regarding inflation and GDP growth which they interpret as proxies for uncertainty. If professionals believe that the central bank sets its policy rate in response to uncertainty regarding inflation and/or GDP growth and if we consider the disagreement among forecasters as a proxy for uncertainty,[8] then we would also expect to find a relation between forecasters' disagreement regarding the policy rate and both macro variables.

Therefore, as a next step, we have also computed the cross-sectional standard deviation across forecasters for the forecasts regarding all three variables as a measure of disagreement among

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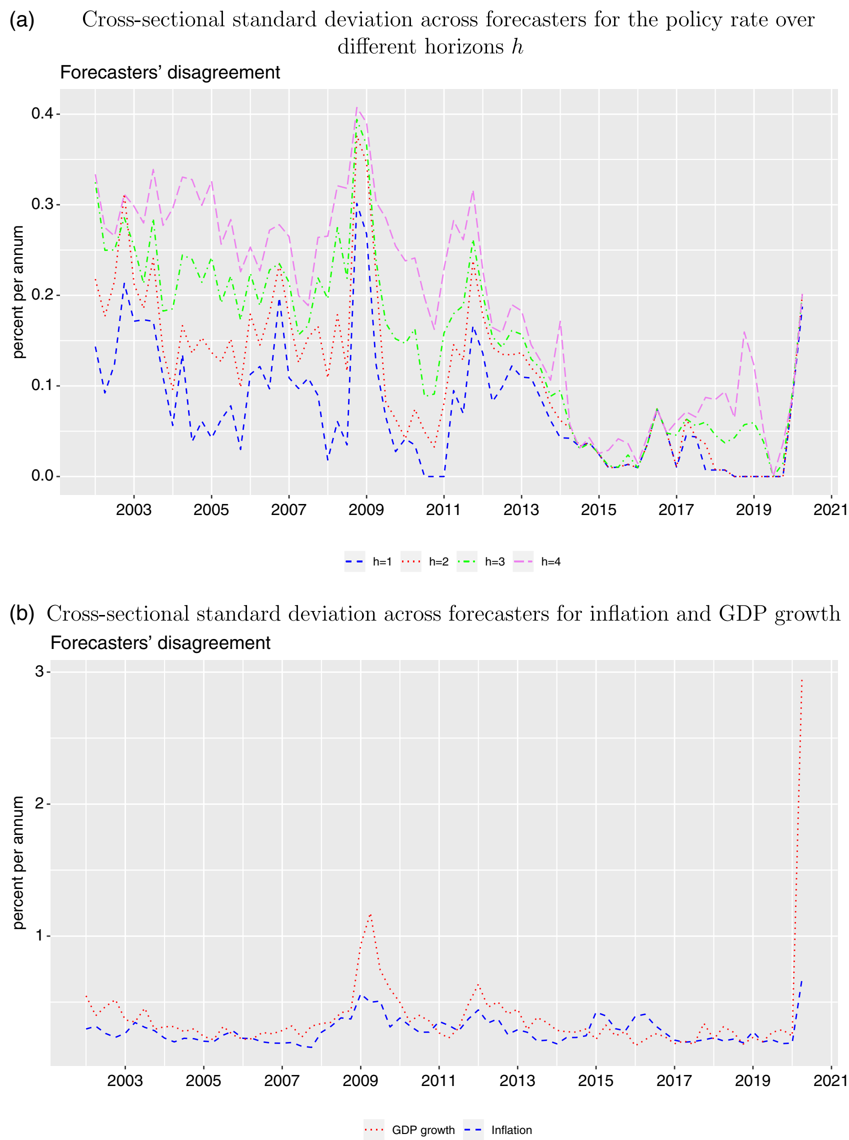

Figure 6. Forecasters' disagreement.
The plot shows quarterly disagreement among forecasters for the ECB policy rate, inflation and GDP growth measured as the cross-sectional standard deviation across forecasters (in percent per annum) for the period from 2002Q1 to 2020Q2 and for the forecast horizon of four-quarters-ahead. The data has been taken from the ECB survey of professional forecasters (SPF).

professional forecasters. Panel (a) in Figure 6 displays this disagreement measure for policy rate forecasts across different forecast horizons h and it becomes clear that disagreement increases with the horizons, peaks around the period of the global financial crisis and has substantially decreased in latest ZLB period. Panel (b) in Figure 6 also provides disagreement among forecasters for 1-year-ahead forecasts for inflation and GDP growth. The general level of disagreement is higher for inflation and GDP growth compared to the policy rate and the most pronounced spikes become evident around the global financial crisis and the corona crisis in the latest period of our sample.

Finally, we estimate the following regression model to examine the Taylor rule-based relationship among the disagreement measures:

$$s_t(i_{t+h}) = \beta_0 + \beta_1 s_t(\pi_{t+h}) + \beta_2 s_t(\Delta y_{t+h}) + \nu_{t+h}, \tag{3}$$

where $s_t(.)$ denotes the cross-sectional standard deviation across forecasters regarding forecasts made in t.[9] Panel (a) in Table 5 reports the corresponding coefficient estimates for the full sample period and the three sub-samples already considered above. Our findings indicate that forecasters' disagreement regarding the policy rate appears not to be attached to disagreement regarding inflation since the corresponding β_1 coefficient is clearly insignificant for all sample periods. This result contrasts the finding of Dräger and Lamla (2017), who find that disagreement regarding the interest rate is dominated by disagreement on future inflation relying on US survey data. However, the disagreement among forecasters regarding the policy rate seems to be an increasing function of the disagreement regarding GDP growth as β_2 is significantly different from zero at least at the 10% level in all four cases. In a final setting we also augment the regression model provided above by a dummy variable, which takes a value of 1, if the Governing Council of the ECB made the decision to change its policy rate i_t in the quarter prior to the forecast made in t but after the last forecast in $t-1$, and 0 otherwise. This dummy variable can be seen as a very simply proxy for a monetary policy shock. When controlling for periods marked by Governing Council decisions to change the policy rate, the significant relation mentioned above disappears completely and shows that forecasts of professionals are mainly attached to the current path of the policy rate. According to our findings, the disagreement regarding the policy rate significantly increases if the policy rate has been changed in the current quarter. This finding either might be explained by forecasters' uncertainty about the future path of monetary policy, which is amplified by the current policy change, or by the presence of information rigidity as outlined by Coibion and Gorodnichenko (2015). Following their arguments, the inattention of some forecasters in combination with forecast revisions of other forecasters allows the disagreement among forecasters increase after a shock such as the change in the policy rate.

As an additional robustness test, Panel (b) in Table 5 also reports coefficient estimates for the regression model provided in equation (3) in natural logarithms to circumvent any problems that might arise from the non-negativity constraint mentioned in Footnote 9. Overall, the estimation results for the log-specification support our main findings for the baseline model that disagreement regarding inflation is insignificant in all specifications and that disagreement regarding GDP growth is significantly positive in all specifications. The only difference is that disagreement regarding GDP growth stays significant at the 5% level even after controlling for a policy change within the last model specification.

4. Conclusion

This study examines if professional forecasters form their expectations regarding the policy rate of the ECB consistent with the Taylor rule. Overall, our findings suggest that this is the case. When considering variation in expectations across forecasters and over time, it becomes evident that professional forecasters explicitly or implicitly take the Taylor rule as a guideline to form their policy rate expectations as we have found a clearly significant relationship between these forecasts and their individual expectations regarding inflation and output gap. This shows that professionals indeed believe that the ECB reacts to deviations in inflation from its target and output from its potential when setting its policy rate. However, we also find that this connection has weakened over the recent decades and has (nearly) disappeared in the latest ZLB period. This is reasonable due to the fact that the policy rate of the ECB is zero for a relatively long period of time and that the ECB has also enhanced communication of their willingness to maintain this policy in the future. Nevertheless, the variation of MRO forecasts in the cross-section and the results for individual forecasters also show that at least some forecasters still believe in a connection of the policy rate with the inflation rate. In addition, we also find a relationship between forecasters' disagreement regarding the policy rate of the ECB and disagreement on future GDP growth, which disappears

Table 5. Forecasters' disagreement regression results

	Full	I	II	III	Binary	Full+Binary
(a) $s_t(i_{t+h}) = \beta_0 + \beta_1 s_t(\pi_{t+h}) + \beta_2 s_t(\Delta y_{t+h}) + \beta_3 \text{Decision}_t + \nu_{t+h}$						
β_1	0.0655	0.1189	0.0971	−0.0545		-0.0071
$SE(\beta_1)$	(0.0914)	(0.1541)	(0.2759)	(0.1180)		(0.3121)
$p(\beta_1)$	[0.4755]	[0.4477]	[0.7275]	[0.6512]		[0.9819]
95% CI	{−0.11,0.24}	{−0.18,0.42}	{−0.44,0.64}	{−0.29,0.18}		{−0.62,0.61}
β_2	0.0593	0.1788	0.2863	0.0557		0.0671
$SE(\beta_2)$	(0.0333)	(0.0732)	(0.1618)	(0.0178)		(0.0878)
$p(\beta_2)$	[0.0795]	[0.0224]	[0.0880]	[0.0073]		[0.4472]
95% CI	{−0.01,0.13}	{0.04,0.32}	{−0.03,0.60}	{0.02,0.09}		{−0.11,0.24}
β_0	0.1515	0.1928	0.0249	0.0717	0.1688	0.1462
$SE(\beta_0)$	(0.0581)	(0.0453)	(0.0331)	(0.0309)	(0.0303)	(0.0750)
$p(\beta_0)$	[0.0112]	[0.0003]	[0.4597]	[0.0360]	[0.0000]	[0.0552]
95% CI	{0.04,0.27}	{0.10,0.28}	{−0.04,0.09}	{0.01,0.13}	{0.11,0.23}	{−0.00,0.29}
β_3					0.0707	0.0676
$SE(\beta_3)$					(0.0318)	(0.0326)
$p(\beta_3)$					[0.0294]	[0.0415]
95% CI					{0.01,0.13}	{0.00,0.13}
R^2	0.0538	0.2636	0.3871	0.4331	0.0956	0.1388
T	74	27	30	17	74	74
(b) $\ln s_t(i_{t+h}) = \beta_0 + \beta_1 \ln s_t(\pi_{t+h}) + \beta_2 \ln s_t(\Delta y_{t+h}) + \beta_3 \text{Decision}_t + \nu_{t+h}$						
β_1	−0.8900	0.1268	−0.5420	−0.1487		-0.9119
$SE(\beta_1)$	(0.7068)	(0.1660)	(0.5463)	(0.4711)		(0.6591)
$p(\beta_1)$	[0.2121]	[0.4526]	[0.3299]	[0.7573]		[0.1710]
β_2	1.1369	0.2275	1.5952	0.4227		1.0852
$SE(\beta_2)$	(0.5412)	(0.0938)	(0.7109)	(0.2133)		(0.5140)
$p(\beta_2)$	[0.0393]	[0.0231]	[0.0332]	[0.0691]		[0.0384]
β_0	−1.7810	−0.8387	−1.1155	−2.2350	−2.0251	−1.9837
$SE(\beta_0)$	(0.5566)	(0.1842)	(0.2365)	(0.3976)	(0.2306)	(0.5083)
$p(\beta_0)$	[0.0021]	[0.0001]	[0.0001]	[0.0001]	[0.0000]	[0.0002]
β_3					0.4406	0.3411
$SE(\beta_3)$					(0.2027)	(0.1905)
$p(\beta_3)$					[0.0330]	[0.0777]
R^2	0.2526	0.2706	0.4591	0.2830	0.0684	0.2924
T	73	27	30	16	73	73

Note: The table reports ordinary least squares (OLS) estimation results for a regression of quarterly time series of disagreement among forecasters as given above for the forecast horizon h of four-quarters-ahead for the period from 2002Q1 to 2020Q2 (Full) as well as three sub-sample periods: 2002Q1 to 2008Q3 (I), 2008Q4 to 2016Q1 (II) and 2016Q2 to 2020Q2 (III). $s_t(.)$ measures forecasters' disagreement as the cross-sectional standard deviation across individual forecasts, i_t stands for the ECB policy rate, π_t represents Euro Area (EA) inflation, Δy_t denotes EA GDP growth and Decision_t defines a binary variable equal to 1, if the Governing Council of the ECB made the decision to change its policy rate i_t in the quarter prior to the forecast made in t but after the last forecast in $t-1$, and 0 otherwise. Panel (a) provides the estimation results for the baseline model and Panel (b) reports the estimation results for the model in natural logarithms. For the latter, we have lost one observation in the zero lower bound period (III) as in one quarter the disagreement among forecasters is zero and therefore $\ln(0) = -\infty$. $SE(.)$ denotes heteroskedasticity and autocorrelation consistent (HAC) standard errors following Andrews (1991), $p(.)$ gives the corresponding p-values, 95% CI represents the corresponding 95% confidence interval and T stands for the number of time series observations used for estimation.

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when controlling for monetary policy shocks proxied by changes in the policy rate in the quarter the forecasts are made. Therefore, this study provides useful insights into the expectation building mechanism of professionals and guidelines for calibrating economic models.

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Notes

1 Fendel et al. (2011) include G7 countries over a period from October 1989 to December 2007 but for France, Germany, and Italy their sample period ends in December 1998 due to the introduction of the euro. See also Mitchell and Pearce (2010), Fendel et al. (2013), Carvalho and Nechio (2014), Carlstrom and Jacobson (2015), and Dräger et al. (2016), who rely on data from the University of Michigan Survey of Consumers, the Wall Street Journal poll or the Survey of Professional Forecasters of the Federal Reserve Bank of Philadelphia and also validate the role of the Taylor rule in forming expectations in the USA.
2 In this case, we deviate from equation (1) as we use expectations about the change in the output gap instead of a forecast of the output gap itself and therefore we follow Walsh (2004) and Gorter et al. (2008), who argue that a Taylor rule in which the level is replaced by its growth rate is credible in the presence of imperfect information about the output gap. This choice is simply due to the fact that survey data including individual output gap forecasts is not available. We refer to Frenkel et al. (2011) for an alternative approach, which also requires the observed GDP level and its trend. In this context, it should also be noted that we explicitly rely on the Hodrick–Prescott (HP) filter to approximate potential GDP growth although we are aware of its drawbacks (Hamilton, 2018). This choice is justified by the fact that the HP filter has been used to construct the output gap in the Taylor rule literature as well as in related cases over the recent decades and is still used (see e.g. Gorter et al., 2008; Belke and Klose, 2020, among others). Therefore, it appears to be the best proxy in the context of expectation formation of professional forecasters.
3 The inclusion of previous periods' expectations about the future policy rate $E_{j,t-1}(i_{t+h})$ can also be seen as a test of interest rate smoothing in the expectation forming process. In addition, it is worth noting that it would also be reasonable to include the latest available realized policy rate at the time the forecasts are made. This would also show how closely the forecasts are attached to the current level of the policy rate. However, the realized policy rate offers no variation across forecasters j and therefore it is accounted for by the time fixed effects λ_t within the fixed-effects model given in equation (2). As you will see below Panel (b) in Table 1 also reports coefficient estimates for the same model as given in equation (2) but uses the means across individual forecasters and therefore solely focuses on the variation over time. As a sensitivity check, we have replaced the previous periods' expectations about the future policy rate by the latest available realized policy rate at the time the forecasts are made. The results turned out to be robust to this variation while the inertia parameter ϕ_3 appeared to be slightly higher compared to the findings provided in Table 1 but still below unity.
4 Our specification does not require many assumptions about the error term $\varepsilon_{j,t+h}$. It solely requires the three standard assumptions: First, the error is conditional mean zero, that is, $E(\varepsilon_{j,t+h}|\xi_{j,1+h}, \xi_{j,2+h}, \ldots, \xi_{j,T+h}, \mu_j, \lambda_1, \ldots, \lambda_T) = 0$, where $\xi_{j,t+h}$ is a vector consisting of the three regressors:

$$\xi_{j,t+h} = \Big([E_{j,t}(\pi_{t+h}) - \pi^*], [E_{j,t}(\Delta y_{t+h}) - \overline{E}^*_t(\Delta y_{t+h})], E_{j,t-1}(i_{t+h}) \Big)'.$$

Second, $\varepsilon_{j,t+h}$ and $\xi_{j,t+h}$ are independently and identically distributed (*iid*) with respect to j (not t). Third, $\varepsilon_{j,t+h}$ has nonzero finite fourth moments, that is, $E(\varepsilon^4_{j,t+h}) < \infty$. We do not assume conditional homoskedasticity or serial uncorrelatedness of $\varepsilon_{j,t+h}$ as we rely on heteroskedasticity and autocorrelation consistent (HAC) standard errors. We also do not assume that regressors are orthogonal to fixed effects, that is, $E(\xi_{j,t+h}\mu_j) = 0$, as in the case of a random effects model specification.
5 Endogenously determined location shifts by the split-sample algorithm mentioned above have been identified at the following dates: 2003Q1, 2006Q2, 2009Q1, 2012Q1, and 2014Q2. These dates are economically plausible. Most obviously, the shift in 2009 clearly accounts for the policy response of the ECB to the global financial crisis and the shift in 2014 indicates the MRO rate (nearly) hitting the zero lower bound. The other three dates also allow for larger changes in the policy rate of the ECB, which attribute to large policy rate cuts in 2003 and 2012 and a large policy rate increase in 2006 as can be seen in the MRO forecasts in Figure 1. The significance of the location shifts (see Table 2), especially the ones around the global financial crises and at the beginning of the zero lower bound period, formally rationalized our attempt to allow for time variation within the expectations-based Taylor rule relationship. To account for the latter, we have used a sub-sample analysis within the present section and have also estimated time-varying coefficients in Figure 5.

6 However, it should also be noted that a random effects specification assumes orthogonality between regressors and fixed effects, which would mean that expectations regarding the inflation and the output gap for forecaster j are uncorrelated with his/her forecaster-specific error μ_j. This assumption is hard to justify. In addition, we have also performed a Hausman test, which does not show a rejection. The standard interpretation would be that the test result is in favor of the random effects model. However, as pointed out by Wooldridge (2019), the Hausman test fails to reject when random and fixed-effects estimates are sufficiently close to each other as in our case.
7 Within the individual regressions, we also account for quarterly periodicity in the forecasts and further endogenously determined location shifts as done in Table 2.
8 It should be noted that there is some controversy in the literature whether or not forecasters' disagreement is a reliable proxy for uncertainty (see Giordani and Söderlind, 2003; Lahiri and Sheng, 2010; Ter Ellen et al., 2019; Glas, 2020, among others).
9 It should be noted that $\sum_{j=0}^{2}\beta_j \geq 0$ as the standard deviation must be non-negative. However, it is not necessary that all coefficients are individually non-negative to make sense as this regression model is based on the Taylor rule relationship, according to which the policy rate is set by the central bank in response to the inflation and the output gap. For example, imagine that there is a high uncertainty surrounding inflation forecasts, which is expressed a priori by a high disagreement among forecasters. In such a situation, forecasters might expect the central bank to leave the policy rate unchanged until the current level of inflation becomes evident and this would decrease the disagreement among forecasters regarding the future policy rate resulting in a negative relationship between $s_t(i_{t+h})$ and $s_t(\pi_{t+h})$ (i.e. $\beta_1 < 0$).

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