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Improving Phillips curve-based inflation forecasts: a monetary approach for the euro area

Abstract

This paper considers if Phillips curve models are preferable in forecasting euro area rate of inflation compared to a simple AR model. In doing so, the author estimates an Autoregressive distributed lag (ARDL) model using monthly data ranging from January 1995 to April 2010 and uses it for forecasting purpose for different horizons. Furthermore, the main objective of this paper is to check if the inclusion of monetary variables such as the price gap could improve the forecast accuracy of the mentioned Phillips curve framework. The findings indicate three main aspects which are as follows. First, Phillips curve forecasts outperform simple autoregressive (AR) forecasts for most of the horizons applied. Second, the forecast accuracy even does not tend to worsen for higher horizons (12 or 24 months). Finally, the inclusion of monetary variables such as the price gap into the ARDL forecast model improves the forecasting performance for every horizon used.

Keywords: euro area, forecast, inflation, Phillips curve, p-star.
JEL Classification: E31, E37, E41.

Introduction

The main objective of the European Central Bank (ECB) is still to ensure a stable price level in the euro area. The current financial and economic crisis that started in 2007 entails forces that threaten that goal and bear inflationary pressure the ECB has to deal with. In the first instance the efforts spent by the ECB to manage the financial crisis by means of lowering its policy rates and conducting unorthodox monetary policies heat the inflation expectations. Furthermore, the financial distress of Greece in 2010 and the fact that the ECB started buying public- and private-sector bonds to regulate the monetary transmission process in reaction to the latter creates the impression that the ECB is dominated by national fiscal policies. Consequently, this effect would put the independence of the ECB into question and force inflation as well. In addition, after the burst of the new economy bubble in 2001 the ECB conducted expansionary monetary policy, but the inflation rate stayed unaffected by that movement. Hence, that could mean that a heavy increase of inflation still impends according to the relationship between the expansion of money supply and inflation. Thus, this development should be observed carefully by the ECB and its policy-makers. In matters of the latter, the estimation of a policy reaction function for the ECB is required under which the ECB's policy rate is set in response to deviations of inflation from target and of output from potential. Thus, forecasts of inflation and output are essential for a forward-looking specifications of the policy reaction function, the so-called Taylor rule (Taylor, 1993). However, a reliable inflation forecast plays a crucial role not only in decision-making of the ECB, but is used by several other economic agents such as the labor unions and the private or the public sector as well. Therefore, we provide additional contribution to the problem of forecasting the inflation rate in the euro area reliably for different horizons and especially in times of the global financial and economic crisis. In doing so, we make use of a real economy-oriented framework, namely the Phillips curve model, for instance, presented by Gali et al. (2001), Gerlach (2004), Neumann and Greiber (2004), Carstensen (2007), Paloviita (2008), Berger and Stavrev (2008), Fanelli (2008), Buchmann (2009) and Lee (2009) in different variants. We evaluate the forecasting performance of our estimated ARDL fra-mework by a comparison to a simple AR model. Furthermore, the main objective of this paper is to check if monetary variables could improve the forecast accuracy of our Phillips curve framework by incorporating the price gap into the inflation forecast model. Thus, our price gap variable is derived from the well-known p-star (P*) approach which conceives of inflation primarily as a monetary phenomenon and has already been applied to explain inflation dynamics in the euro area recently by various authors (Gottschalk and Broeck, 2000; Scheide and Trabandt, 2000; Nicoletti-Altimari, 2001; Scharnagl, 2002; Toedter, 2002; Trecroci and Vega, 2002; Gerlach and Svensson, 2003; Reimers, 2003; Jansen, 2004; and Czudaj, 2011).

The remainder of the paper is organized as follows. Section 1 presents the underlying theory of the Phillips curve and the price gap or the P* approach, respectively, which shows up in the used empirical inflation forecast model. The main part of our study, the econometric analysis, is presented in Section 2, where we discuss the data used, estimate our model and use it for forecasting purpose. The final section concludes and gives an outlook on further research.

1. Inflation forecasting model

1.1. Phillips curve approach. In general, the Phillips curve is first introduced by Phillips (1958) and describes the relation between inflation and unemployment by the following equation:

$$\pi_t = \pi_t^e + \mu - \alpha u_t + \beta z_t, \tag{1}$$

where π_t and π_t^e denote the rate of inflation and the expected rate of inflation, respectively, u_t represents the rate of unemployment, μ stands for a constant term and z_t displays several other factors affecting inflation. Expected inflation is often modelled as backward-looking by setting:

$$\pi_t^e = \theta \pi_{t-1}. \tag{2}$$

Thus, assuming $\theta = 1$ and substituting π_t^e in equation (1) by equation (2) yields the so-called modified Phillips curve or expectations-augmented Phillips curve:

$$\pi_t - \pi_{t-1} = \mu - \alpha u_t + \beta z_t, \tag{3}$$

where u_t and z_t now affect the change of inflation[1]. Equation (3) is the basis for the following h-period ahead Phillips curve forecast model used by Stock and Watson (2009):

$$\begin{aligned}\pi_{t+h}^h - \pi_t = \mu^h + \alpha^h(L)u_t + \beta^h(L)z_t + \\ + \gamma^h(L)\Delta\pi_t + \upsilon_{t+h}^h,\end{aligned} \tag{4}$$

where $\alpha^h(L), \beta^h(L)$ and $\gamma^h(L)$ are lag polynomials in nonnegative powers of L; $\Delta\pi_t$ denotes the change of inflation and υ_{t+h}^h represents the h-step ahead i.i.d. error term.

1.2. P* approach and price gap. In the following we present two versions of the price gap and P* model, respectively, corresponding to Belke, Czudaj (2011) and Polleit (2006) who used the latter in the case of Sweden. Both are incorporated into our inflation forecasting model (4) separately to check the improvement of the forecasting performance of monetary variables. The traditional quantity equation:

$$M \times V = P \times Y \tag{5}$$

forms the starting point of the P^* concept developed by Hallman et al. (1991), where M represents the stock of money, V denotes the income velocity of money, P stands for the price level and Y displays the real output. Rearranging this identity equation with respect to P, representing it in natural logarithms denoted by lower case letters and adding the index t, leads to the short-run price level:

$$p_t = m_t + \upsilon_t - y_t. \tag{6}$$

Given the assumption that υ_t and y_t follow an equilibrium path and that both rapidly arrive on that path after a shock, the long-run price level and the so-called P^* equation, respectively, has the below stated form:

$$p_t^* = m_t + \upsilon_t^* - y_t^*, \tag{7}$$

where equilibrium terms are denoted by an asterisk. The difference between equilibrium and current price level represents the price gap:

$$\left(p_t^* - p_t\right) = \left(\upsilon_t^* - \upsilon_t\right) + \left(y_t - y_t^*\right). \tag{8}$$

Hence, the price gap consists of the liquidity gap $\upsilon_t^* - \upsilon_t$ and the output gap $y_t - y_t^*$. In addition, one can expect the inflation to increase (decrease), if the current price level resides below (above) its equilibrium value, since one can expect p_t to converge towards p_t^*. At first glance, one would assume referring to equation (8) the price gap to increase after a raise of the output y_t above its equilibrium value y_t^*, but that would not be the case resulting from the relationship between income and velocity $\left(\upsilon_t = y_t + p_t - m_t\right)$ mentioned in equation (6). Hence, a raise of y_t leads to an increase of υ_t of the same amount and, therefore, to a complete compensation in equation (8). This makes clear that inflation must be determined by the stock of money and that *inflation is always and everywhere a monetary phenomenon*, respectively[2]. Rearranging equation (6) to

$$-\upsilon_t = m_t - p_t - y_t, \tag{9}$$

and substituting it in equation (8) leads to

$$\left(p_t^* - p_t\right) = \left(m_t + \upsilon_t^* - p_t\right) - y_t^*, \tag{10}$$

and shows that the price gap can be described by the difference between the real stock of money adjusted by the equilibrium velocity and the potential output. Equation (10) will later be inserted into our empirical inflation forecasting model to reassess an improvement of forecast accuracy.

It is also possible to derive the price gap from the money demand. The basis for that is a traditional demand for money function of the following form:

[1] See Blanchard (2009) for further details with regard to the Phillips curve and Buchmann (2009) for a summary of different specifications of the latter.

[2] Milton Friedman, Wincott Memorial Lecture, London, September 16, 1970.

$$m_t - p_t = \beta_c + \beta_y y_t - \beta_i i_t, \tag{11}$$

where i_t represents the interest rate as a proxy of the opportunity costs of money holding. Rearranging the equation with respect to the short-run price level p_t produces the below stated representation:

$$p_t = m_t - \beta_c - \beta_y y_t + \beta_i i_t. \tag{12}$$

Thus, in the long run the following equation holds:

$$p_t^* = m_t - \beta_c - \beta_y y_t^* + \beta_i i_t^*. \tag{13}$$

According to that, the undermentioned price gap corresponds to the difference between equation (13) and (12)

$$\left(p_t^* - p_t\right) = \beta_y\left(y_t - y_t^*\right) + \beta_i\left(i_t^* - i_t\right) \tag{14}$$

and now consists of the output gap $y_t - y_t^*$ and the interest rate gap $i_t^* - i_t$. β_y is expected to be positive as well as to be equal unity corresponding to the quantity theory, whereas β_i is expected to be negative[1]. Both coefficients β_y and β_i will be estimated within the money demand and the resulting price gap (14) will be inserted into our empirical inflation forecasting model as well to check the robustness of our findings in Section 2.4.

2. Empirical analysis

2.1. The data. In our study we use monthly data ranging from January 1995 to April 2010. The underlying time series are taken from the ECB Statistical Data Warehouse. Our inflation variable is constructed by the annualized monthly changes in the price level measured by the Harmonised Index of Consumer Prices (HICP) according to the ECB (ECB, 2004). Furthermore, as exogenous variables we apply standardised unemployment level and world oil price as our supply shock variable z_t.

For the construction of the price gap we take the gross domestic product (GDP) as a proxy of output and as our measure of the money aggregate, we apply the month-end stocks of M3. In addition, for our second price gap variable which is used to check for robustness we need to compute euro area demand for money. Therefore, the nominal three-month Euribor money market rate measures the short-term interest rate and the nominal 10-year treasury bond yield characterizes the long-term interest rate. The difference between long- and short-run interest is taken as our opportunity cost variable.

All series are seasonally adjusted and are taken in logs except for both interest rates. Since GDP is not available in monthly frequency, we use the cubic spline interpolation to convert the series into monthly data following Siklos (2008). The application of that procedure reduces our sample that now ranges from March 1995 to December 2009, but still provides a sufficient number of observations for estimation purpose. Our choice of the use of ex-post data in contrast to real-time data is motivated by the argument following Orphanides and van Norden (2002) and Carstensen (2007) that only the GDP series is heavily revised over time and thus this should not be a major drawback of our forecasts.

2.2. Unit root tests. Before estimation we check the integration order of the relevant series to avoid spurious regression. Hence, as commonly done, we conduct the Dickey-Fuller-GLS (DF-GLS) test and the Elliott-Rothenberg-Stock point optimal (ERS) test to test the null of a unit root in the time series and present our results in Table 1 (see Appendix A)[2]. Besides the inflation rate only the price gap derived from money demand could be seen doubtless to be stationary, i.e., $I(0)$ whereas the other price gap and the exogenous variables show some indication of being an $I(0)$ series as well. Hence, following Stock and Watson (2009) we feel legitimized to include all variables as levels into our empirical model except for the change of the inflation rate.

2.3. Inflation forecast. First, as a benchmark we estimate the following pure autoregressive (AR) model:

$$\pi_{t+h}^h - \pi_t = \mu^h + \gamma^h(L)\Delta\pi_t + \upsilon_{t+h}^h, \tag{15}$$

to compare the results of our different specifications. In doing so, we run an AR regression that regresses $\Delta_h\pi_t$ on the past values of $\Delta\pi_t$ by means of the OLS method. Then the lag length of the lag polynomial $\gamma^h(L)$ is determined by the Akaike information criterion (AIC) up to a maximum lag length of 12.

Second, we compute our autoregressive distributed lag (ARDL) Phillips curve forecast model (4) applying a stepwise procedure similar to the one suggested by Hsiao (1981). In the first step, we run a second regression applying the above used AR specification with the fixed selected lag length of $\gamma^h(L)$ and adding the current and lagged values up to a maximum lag length of 12 of the second regressor u_t into the equation. By doing that we deter-

[1] See Belke and Czudaj (2010) for details with regard to theory of money demand and a summary of recent empirical studies for the euro area.

[2] Both tests are more powerful than, for instance, the augmented Dickey-Fuller (ADF) test which is conducted as well. However, the results are nearly the same as the ones mentioned and are available upon request.

mine the optimal lag order of the lag polynomial $\alpha^h(L)$ with AIC again. In the second step, we run the same regression with fixed lag lengths of $\Delta\pi_t$ and u_t by incorporating the current and past values of the last regressor z_t and selecting the optimal number of lags of $\beta^h(L)$ with AIC.

Finally, we augment our ARDL forecast model by the above mentioned price gap and select the lag length in the same way again. We conduct the whole procedure for forecast horizons of h = 1, 2, 3, 6, 12 and 24 and present some measures of fitment for our different specifications in Table 2 (See Appendix A). For every horizon the Phillips curve forecasts show an adjusted R^2 above 0.4 which indicates a good performance of our model particularly compared to the pure AR model and the inclusion of the price gap yields an even higher adjusted R^2 as well as an even lower AIC which is a first indication that monetary variables indeed help to explain future inflation. Finally, the conducted Ramsey's RESET test does not indicate any specification error of our models.

As Staehr (2010), we have also tested the models for the presence of multicollinearity computing partial correlation coefficients between all exogenous variables and centered variance inflation factors (VIF)[1]. Unsurprisingly, the analysis reveals that one can assume the existence of multicollinearity of a minor degree, but the predominant majority of the centered VIFs turned out to be considerably below the boundary value of 5 and furthermore multicollinearity is not necessarily a problem with regard to the forecasting performance.

As a next step, the forecasting ability of the estimated models should be checked. In this context, in-sample as well as out-of-sample forecasts have been produced. The first case allows to review the forecasting performance of our models which are estimated based on data for the whole available sample period following Inoue and Kilian (2002), who showed that in-sample forecasts are at least as credible in respect of predictability as out-of-sample forecasts. The latter case shall provide insights as to whether actual inflation stuck to the forecasted inflation, which was estimated for a sub-sample period, throughout the whole period under investigation. To achieve a suitable sub-sample we exclude the period which is clouded by the current financial and economic crisis and let our estimation sample period end in April 2007. Hence, May 2007 is the starting point of our forecast. Resulting of the fact that the sample needs to be diminished to conduct out-of-sample forecasts the number of observations becomes relatively small and thus, inference should be drawn with adequate caution.

Overall, the in-sample forecasts of the Phillips curve framework displayed in Figures 1 and 2 (see Appendix B) show for every forecast horizon that our forecasted rate of inflation fits to actual HICP inflation very well and even better if the price gap is included into the model. The out-of-sample forecasts presented in Figures 3 and 4 tell nearly the same story. In addition, Table 3 (see Appendix A) reports some forecast error statistics for both forecasts and affirms according to the root-mean-square error (RMSE) and the mean absolute error (MAE) both the finding of a good forecasting ability of the Phillips curve approach compared to a simple AR process as well as an improvement of the forecast accuracy by the inclusion of the price gap for every horizon since most of the forecast error statistics have decreased in line (2) compared to line (1) of Table 3. Although the forecast error statistics of the out-of-sample forecasts are not for every horizon that unambiguous as the ones of the in-sample forecasts they still support our findings. The current financial and economic crisis which lies in the forecast period does not seem to worsen the forecasting performance. The Theil inequality coefficient confirms our results and lies around 0.4 as well as 0.5 for the in-sample and the out-of-sample forecasts, respectively, where zero indicates a perfect fit.

2.4. Robustness check. To check for robustness of our finding that the inclusion of the price gap into the equation helps to improve the forecasting ability of the Phillips curve we apply a second price gap variable according to Section 1.2. Hence, we have to estimate the money demand and in this regard we make use of Johansen's cointegrated VAR framework (Johansen, 1988; and Johansen, 1991). Consequently, we apply four lags recommend by Schwarz criterion (SC) and Hannan-Quinn (HQ) information criterion and we specify the levels having linear deterministic trends, but the cointegrating equation only an unrestricted intercept according to Coenen and Vega (2001). This yields one cointegrating vector given by the following equation (standard errors in parentheses)[2]:

$$(m-p)_t = \underset{(0.06)}{1.27}\, y_t - \underset{(0.01)}{0.06}\left(i^l - i^s\right)_t . \tag{16}$$

The coefficients have the expected signs and magnitudes and the money demand equation is robust against variations of the lag length and the trend assumption. As expected, the estimated error-correction

[1] To save space the results of both are not listed, but are available upon request.

[2] Both the trace test as well as the maximum eigenvalue test indicate the existence of one cointegrating vector as stated in Table 4 (see Appendix A).

parameter of the demand for money $-0.03_{(0.01)}$ shows that the speed of adjustment to long-run equilibrium seems to be very low. At this point commonly accepted stability tests could be applied to check for a possible shift in money demand during the recent years. Along with others, Beyer (2009) and Belke and Czudaj (2010) recently showed that euro area money demand can be regarded as stable over time, which is required for application of P^*, we do not see any indication which prompts us to deviate from that result and assume the demand for money to be stable.

Finally, after the price gap is computed according to equation (14) the procedure described in Section 2.3 is conducted and the results are presented in Tables 2 and 3 (see Appendix A). It is easy to see that these support the findings derived from the first price gap variable used and provide an even better forecasting performance according to the forecast error statistics of the out-of-sample forecasts displayed in Table 3.

Conclusion

We have shown that Phillips curve forecasts (still) seems to be a good and useful alternative with regard to the objective of predicting the rate of inflation for the euro area. The main findings of our study are as follows. First, our Phillips curve forecasts outperform simple AR forecasts for most of the horizons applied. Second, the forecast accuracy even does not tend to worsen for higher horizons (12 or 24 months). Finally, the inclusion of monetary variables such as the price gap into our ARDL forecast model improves the forecasting performance for every horizon used. Our results indicate that according to Gali (2010) the monetary pillar of the ECB's two-pillar approach becomes more relevant again in the euro area. We have also shown the robustness of our specifications in respect of variations of the price gap variable. Altogether, our concept could be one framework which helps the ECB to manage the expected forthcoming problems regarding increasing consumer price inflation and emphasizes the required focusing on monetary indicators in the future. Thus, the outcome supports the claim provided by Scharnagl (2002) of adopting the price gap into a monetary policy rule.

In addition, the forecasting ability of the price gap could be compared with other (non-monetary) indicators as well. That and further modifications are left for future research.

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Appendix A

Table 1. Unit root tests

Test	Variable	Level			Δ		
		Lags	Exog.	t-stat./P-stat.	Lags	Exog.	t-stat./P-stat.
DF-GLS	π_t	1	c	-5.67***	0	c	-20.75***
		0	t	-9.65***	0	t	-20.91***
	u_t	2	c	-1.36	1	c	-3.08***
		4	t	-2.88*	1	t	-3.38**
	z_t	1	c	-0.11	0	c	-10.59***
		1	t	-3.00**	0	t	-10.56***
	$\left(p_t^* - p_t\right)$	0	c	-1.83*	0	c	-11.97***
		0	t	-2.02	0	t	-12.43***
	$\left(p_t^* - p_t\right)^{md}$	1	c	-3.77***	0	c	-7.16***
		1	t	-3.78***	0	t	-7.56***

Table 1 (cont.). Unit root tests

Test	Variable	Level			Δ		
		Lags	Exog.	t-stat./P-stat.	Lags	Exog.	t-stat./P-stat.
ERS	π_t	0	c	0.40***	2	c	0.01***
		0	t	1.20***	2	t	0.03***
	u_t	4	c	3.48*	1	c	1.57***
		4	t	1.69***	1	t	4.50**
	z_t	1	c	22.72	0	c	0.31***
		1	t	5.09**	0	t	1.09***
	$\left(p_t^* - p_t\right)$	0	c	4.36	0	c	0.35***
		0	t	10.12	0	t	1.20***
	$\left(p_t^* - p_t\right)^{md}$	1	c	0.97***	0	c	0.47***
		1	t	3.24***	0	t	1.42***

Notes: * Statistical significance at the 10% level, ** at the 5% level, *** at the 1% level. For both tests the series contain a unit root under the null. The test equation is estimated including an intercept (c) or a trend and an intercept (t). For the DF-GLS test critical values are taken from MacKinnon (1996): (c) 10% -1.61, 5% -1.94, 1% -2.57 and from Elliott et al. (1996): (t) 10% -2.66, 5% -2.95, 1% -3.48, respectively. For the ERS test critical values are taken from Elliott et al. (1996): (c) 10% 4.30, 5% 3.15, 1% 1.91 and (t) 10% 6.84, 5% 5.65, 1% 4.08. The lag length is chosen by using the SC. Maximum lag number for the used samples is 13. For the ERS test residual spectrum at frequency zero is estimated by using spectral OLS autoregression.

Table 2. Fitment measures of our different specifications

Forcast horizon	(a) $h = 1$	(b) $h = 2$	(c) $h = 3$	(d) $h = 6$	(e) $h = 12$	(f) $h = 24$
AR model						
Adj. R^2	0.31	0.34	0.41	0.41	0.44	0.34
AIC	-5.06	-4.96	-4.90	-4.86	-4.76	-4.93
Ramsey	3.29 (0.07)	2.07 (0.15)	5.21 (0.02)	0.82 (0.37)	7.92 (0.01)	0.36 (0.55)
ARDL model (without price gap)						
Adj. R^2	0.45	0.40	0.47	0.41	0.53	0.42
AIC	-5.24	-4.99	-4.91	-4.86	-4.91	-5.00
Ramsey	0.24 (0.63)	0.52 (0.47)	0.76 (0.38)	0.24 (0.62)	1.09 (0.30)	0.06 (0.81)
ARDL model (with first price gap)						
Adj. R^2	0.50	0.46	0.50	0.42	0.56	0.44
AIC	-5.28	-5.06	-4.94	-4.86	-4.95	-5.00
Ramsey	0.79 (0.37)	0.34 (0.56)	0.00 (0.99)	1.23 (0.27)	1.44 (0.23)	0.16 (0.69)
ARDL model (with second price gap)						
Adj. R^2	0.47	0.44	0.52	0.48	0.60	0.42
AIC	-5.27	-5.05	-4.99	-4.97	-5.00	-5.00
Ramsey	0.04 (0.84)	0.00 (0.95)	0.00 (0.95)	0.97 (0.32)	0.01 (0.92)	0.09 (0.77)

Note: Ramsey's RESET test is applied using squared residuals. *p*-values are in parentheses.

Table 3. Forecast evaluation

Model	Forecast	Criterion	(a) $h = 1$	(b) $h = 2$	(c) $h = 3$	(d) $h = 6$	(e) $h = 12$	(f) $h = 24$
(1)	In-sample	RMSE	0.87	0.92	0.91	0.99	0.90	0.92
		MAE	0.89	0.95	0.97	1.01	0.91	0.93
		Theil	0.41	0.43	0.39	0.46	0.36	0.44
		Obs.	176	172	169	172	158	154
	Out-of-sample	RMSE	0.86	0.99	1.09	1.00	0.97	0.97
		MAE	0.88	0.93	1.06	1.01	0.96	0.95
		Theil	0.45	0.58	0.51	0.51	0.48	0.56
		Obs.	36	36	36	36	36	36
(2)	In-sample	RMSE	0.80	0.85	0.87	0.97	0.86	0.88
		MAE	0.82	0.88	0.92	1.00	0.87	0.90
		Theil	0.37	0.38	0.36	0.44	0.34	0.41
		Obs.	170	170	168	172	158	153
		RMSE	0.90	0.98	1.08	1.00	0.96	1.04

Table 3 (cont.). Forecast evaluation

Model	Forecast	Criterion	(a) h = 1	(b) h = 2	(c) h = 3	(d) h = 6	(e) h = 12	(f) h = 24
	Out-of-sample	MAE	0.91	0.89	1.05	1.01	0.98	1.09
		Theil	0.42	0.56	0.51	0.50	0.48	0.63
		Obs.	33	34	35	36	36	36
(3)	In-sample	RMSE	0.85	0.89	0.87	0.93	0.79	0.91
		MAE	0.87	0.93	0.93	0.97	0.79	0.92
		Theil	0.40	0.41	0.37	0.42	0.31	0.43
		Obs.	173	170	168	172	158	154
	Out-of-sample	RMSE	0.83	0.98	1.05	0.96	0.84	0.96
		MAE	0.86	0.92	1.02	0.96	0.88	0.94
		Theil	0.44	0.56	0.50	0.50	0.41	0.55
		Obs.	33	34	35	36	36	36

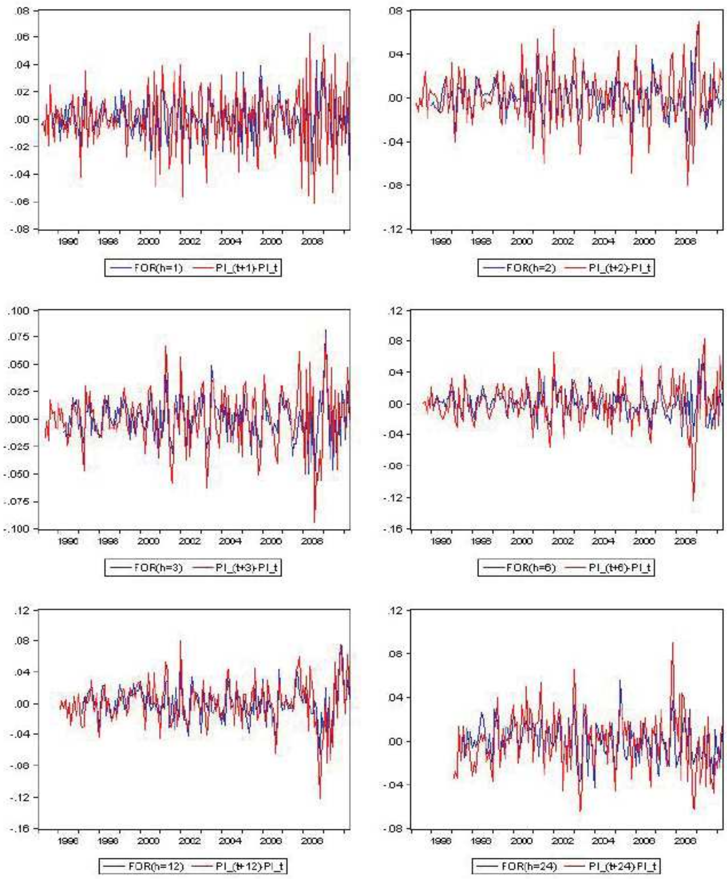
Notes: Root-mean-squared error (RMSE) and mean absolute error (MAE) are given as ratio to the RMSE and MAE values of the AR model. (1), (2) and (3) characterize the ARDL model without price gap, the ARDL model with the first price gap and the ARDL model with the second price gap, respectively.

Table 4. Unrestricted cointegration rank test

Hypothesis	Eigenvalues	Trace-stat.	95% crit. v.	p-value
$r = 0$	0.15	36.98	29.80	0.01**
$r \leq 1$	0.03	9.02	15.50	0.36
$r \leq 2$	0.02	3.19	3.84	0.07
Hypothesis	Eigenvalues	Max-Eigen-stat.	95% crit. v.	p-value
$r = 0$	0.15	27.96	21.13	0.01**
$r \leq 1$	0.03	5.83	14.27	0.64
$r \leq 2$	0.02	3.19	3.84	0.07

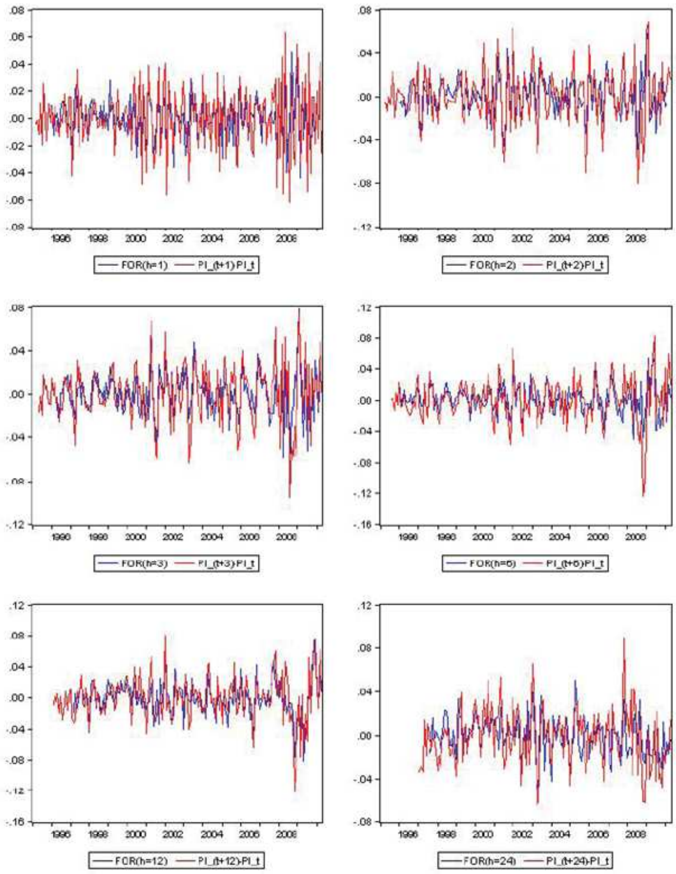
Notes: **denotes rejection of the hypothesis at the 0.05 level. The test is applied using p-values taken from MacKinnon et al. (1999).

Appendix B



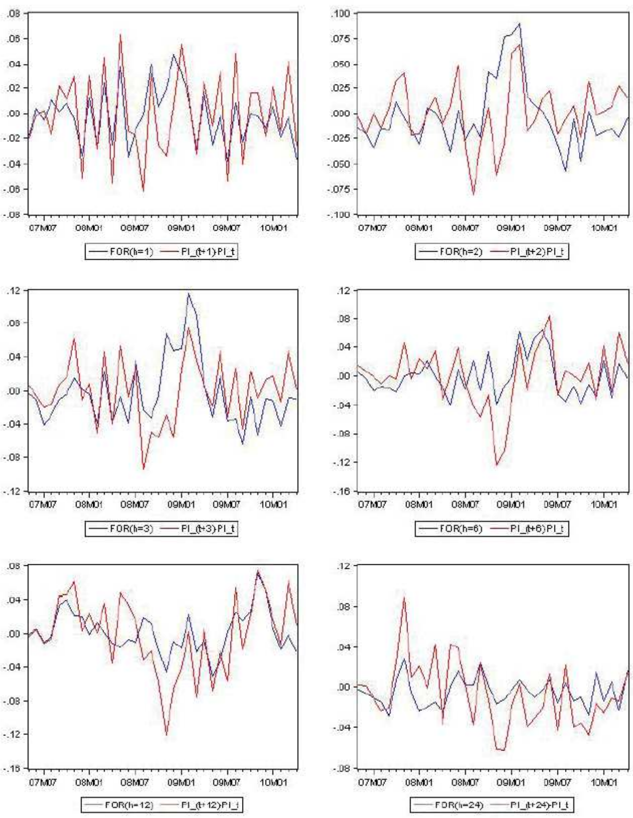
Notes: The figure shows the actual change of the rate of HICP inflation compared to the in-sample forecasts of the estimated ARDL specifications without the price gap for h = 1, 2, 3, 6, 12 and 24.

Fig. 1. Actual change of inflation and in-sample forecasts



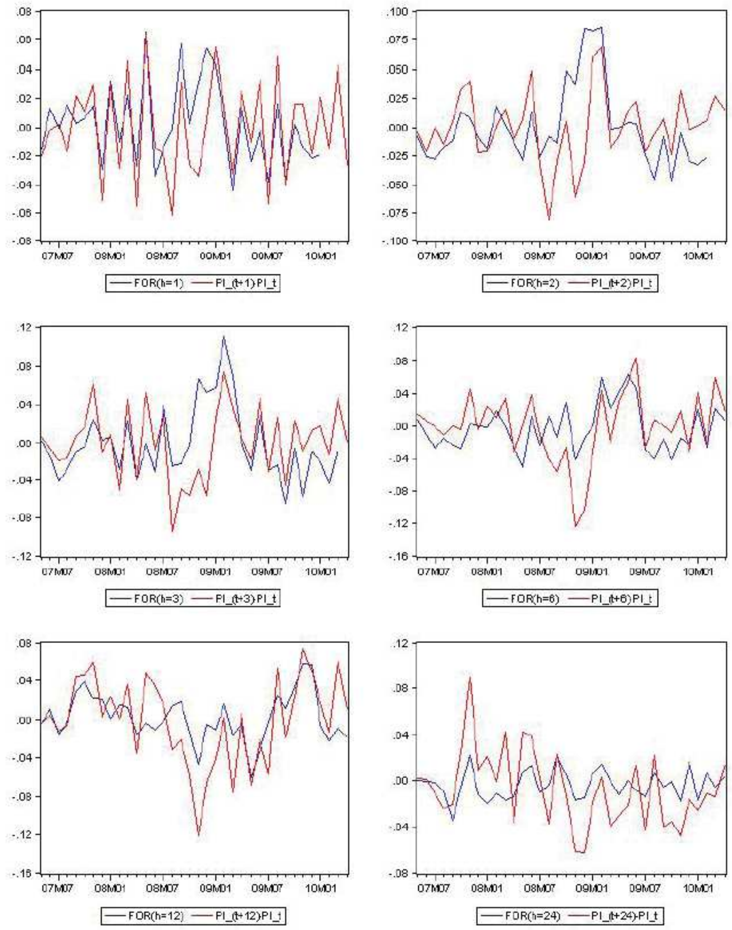
Notes: The figure shows the actual change of the rate of HICP inflation compared to the in-sample forecasts of the estimated ARDL specifications with the first price gap for h = 1, 2, 3, 6, 12 and 24.

Fig. 2. Actual change of inflation and in-sample forecasts



Notes: The figure shows the actual change of the rate of HICP inflation compared to the out-of-sample forecasts of the estimated ARDL specifications without the price gap for h = 1, 2, 3, 6, 12 and 24 and the forecast period of May 2007-April 2010.

Fig. 3. Actual change of inflation and out-of-sample forecasts



Notes: The figure shows the actual change of the rate of HICP inflation compared to the out-of-sample forecasts of the estimated ARDL specifications with the first price gap for h = 1, 2, 3, 6, 12 and 24 and the forecast period of May 2007-April 2010.

Fig. 4. Actual change of inflation and out-of-sample forecasts