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2020

BANCO DE ESPAÑA
Eurosistema

Documentos Ocasionales
N.º 2018

Luis J. Álvarez and Mónica Correa-López

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Luis J. Álvarez and Mónica Correa-López (**)

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(*) The authors would like to thank seminar participants at the European Central Bank's Working Group of Forecasting for their comments and suggestions. The views expressed in this paper do not necessarily represent those of Banco de España or the Eurosystem. All errors remain our own.
(**) E-mail addresses: ljalv@bde.es (L. J. Álvarez), monica.correa@bde.es (M. Correa-López).

Documentos Ocasionales. N.º 2018

2020

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ISSN: 1696-2230 (on-line edition)

Abstract

We analyze the information content of alternative inflation expectations measures, including those from consumers, firms, experts and financial markets, in the context of open economy Phillips curves. We adopt a thick modeling approach with rolling regressions and we assess the results of an out-of sample conditional forecasting exercise by means of meta regressions. The information content varies substantially across inflation expectations measures. In particular, we find that those from consumers and firms are better at predicting inflation if compared to those from experts and, especially, those from financial markets.

Keywords: inflation dynamics, inflation expectations, Phillips curve, euro area, thick modeling, meta regressions.

JEL classification: E31, E37, E52.

Resumen

Este documento analiza la información contenida en medidas alternativas de expectativas de inflación —incluidas las obtenidas a partir de consumidores, empresas, expertos y mercados financieros—, en el contexto de curvas de Phillips de economía abierta. Adoptando una aproximación metodológica denominada *thick modeling*, se evalúan los resultados de un ejercicio de predicción condicionada fuera de muestra por medio de metarregresiones. La información contenida en las medidas alternativas de expectativas varía sustancialmente. En particular, las medidas de expectativas derivadas de datos de consumidores y empresas predicen mejor la inflación que las derivadas de datos de expertos y, especialmente, de mercados financieros.

Palabras clave: dinámica de la inflación, expectativas de inflación, curva de Phillips, área del euro, *thick modeling,* metarregresión.

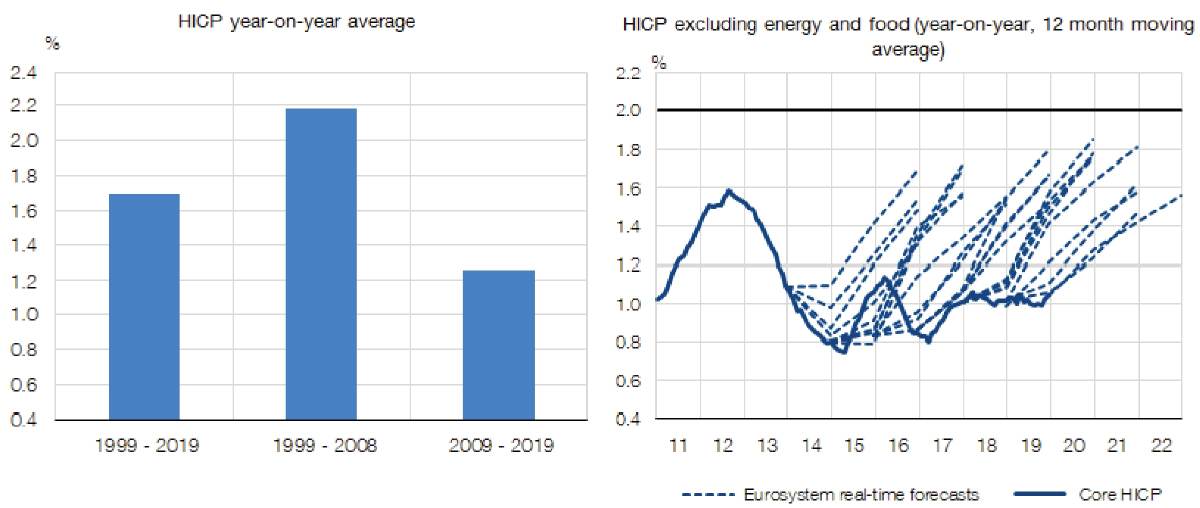
Códigos JEL: E31, E37, E52.

Contents

1 Introduction

In the decade since the onset of the global financial crisis, advanced economies have navigated through the missing disinflation episode and then into the era of low inflation at the zero lower bound for nominal interest rates. During this period, inflation has been particularly hard to forecast. As shown in Figure 1 for the euro area, this is evidenced by the systematic over-prediction of core inflation rates in Eurosystem Macroeconomic Projection Exercises, amid an unprecedented effort by monetary authorities to raise them (Eser et al. (2020)). For the conduct of monetary policy, identifying the factors that determine inflation dynamics thus remains a pressing task.

Figure 1: Euro area inflation rates



To model inflation, a growing body of evidence shows the empirical limitations of the Phillips curve when combined with the full information rational expectations assumption.[1] Among them, the low predictive power of out-of-sample inflation forecasts, the sensitivity to the economic slack variable used, the absence of inflation persistence, or the missing disinflation puzzle are well-documented (see, e.g., Stock and Watson (2007, 2010), King and Watson (2012), Mavroeidis et al. (2014), Coibion et al. (2018), Bobeica and Sokol (2019)). The use of survey expectations appears to alleviate many of these shortcomings (e.g., Brissimis and Magginas (2008), Adam and Padula (2011), Fuhrer et al. (2012), Fuhrer (2017), Coibion and Gorodnichenko (2015)).[2] For the US, Coibion

[1] Essentially, this is the New Keynesian Phillips curve (NKPC) as in Clarida et al. (1999) and Woodford (2003).

[2] Adam and Padula (2011) illustrate the validity of Phillips curves when direct, survey-based measures of expectations are used, provided that economic agents satisfy the law of iterated expectations by, for example, being rational but not sufficiently informed.

et al. (2018) find that household expectations make the Phillips curve more stable and with more predictive power than other real-time expectations, such as those derived from financial markets and expert surveys.[3]

The main aim of this paper is to identify the type of economic agents whose expectations have the most predictive power for inflation in the euro area. To do so, we comprehensively compare several inflation expectations measures from four types of agents: consumers, firms, experts, and financial markets. Some of these measures are derived from surveys while others are extracted from market data. We also consider the long-term inflation forecast estimated from an unobserved components model with stochastic volatility in Correa-López et al. (2019). Furthermore, we add a synthetic indicator to the battery of inflation expectations proxies by extracting a common inflation expectations measure by means of principal component analysis. Methodologically, we carry out thick modeling estimation of open economy Phillips curves using a wide set of real-time expectations data that reflect economic agents' beliefs about inflation in the short-, medium- and long-term. We perform (pseudo) out-of-sample conditional forecasts by estimating rolling windows of each specification, producing inflation forecasts at different horizons. We then carry out a meta regression analysis on the resulting root mean square errors, so that we are able to test which type of variables and features of the models help forecast inflation. To the best of our knowledge, this kind of methodology has not been previously used in the literature on Phillips curves. There are two advantages of working with euro area data to address this question. First, an ample set of measures of inflation expectations are available mostly since the euro area inception. Second, the euro area is a representative example of an advanced economy that experienced the twin puzzles of missing disinflation and missing inflation after the global financial crisis, which led to systematic errors in inflation forecasts. Understanding what lies beneath such errors will also contribute to our knowledge on the nature of the inflation process.

Albeit there is a growing literature exploring euro area inflation dynamics after the global financial crisis, most of the work has focused on the existence of the Phillips curve and its main determinants (e.g., Ciccarelli and Osbat (2017), Bobeica and Sokol (2019), Eser et al. (2020)). Several authors have addressed the forecast performance of

[3]Ideally though, any empirical evaluation of Phillips curve models should control for firm managers expectations, since the counterpart term in the theoretical NKPC represents the price-setters beliefs about the future trajectory of inflation. However, long historical series of firm inflation expectations are unavailable in most countries, including the US (Coibion et al. (2019)).

euro area Phillips curves with an emphasis on the role of global factors (Béreau et al. (2018)), the probability of inflation convergence to its long-term mean (e.g., Moretti et al. (2019)), or the predictive power of survey- and market-based inflation expectations (Grothe and Meyler (2018), Kulikov and Reigl (2019)). Although our paper is closer to the latter in the reliance on a battery of specifications to forecast inflation and in the role ascribed to inflation expectations, we evaluate a much wider set of expectations measures at short-, medium-, and long-term forecasting horizons, including those of euro area firms, and summarize results by means of meta regressions. Only putting to the test a comprehensive list of inflation expectations measures would let us discern whose agents' beliefs make inflation more predictable, if any.

2 Econometric strategy

Empirical models of euro area inflation are estimated using two alternative inflation measures, namely, inflation derived from the harmonized consumer price index (HICP or headline inflation) and from the HICP excluding food and energy (core inflation). We compute seasonally adjusted, annualized quarterly inflation rates from price data as: $\pi_t = 100 * ((p_t/p_{t-1})^4 - 1)$, where subscript t stands for the quarter. Data for headline inflation spans from 1995:Q1 until 2019:Q4 while data for core inflation runs from 1997:Q2 to 2019:Q4, albeit the estimation period is set by the availability of the corresponding inflation expectations series.

The inflation process is modeled by means of reduced-form specifications in which inflation is typically influenced by a direct measure of inflation expectations, a macroeconomic indicator of the economy's cyclical position, and empirical proxies for unanticipated cost-push shocks. Theories underpinning such a structure are found in extended price-setting and wage-setting rules of the standard Phillips curve tradition (e.g. Gordon (2011)) or within the NKPC framework when the full information rational expectations assumption is relaxed (e.g., Paloviita (2006), Adam and Padula (2011), Coibion et al. (2018)).

We apply a thick modeling approach (Granger and Jeon (2004)) by estimating many alternative inflation specifications that take the general form:

$$\pi_t = c + \alpha\pi_{t-l} + \beta E_t\left(\pi_{t+j}\right) + \gamma s_{t-l} + \delta p_{t-l}^{input} + \epsilon_t, (1)$$

where subscript $l : l \in \{0, ..., 4\}$ refers to the lag structure of the corresponding variable, $E_t\left(\pi_{t+j}\right)$ denotes expected inflation conditional on information available in quarter t, s_{t-l} is a macroeconomic measure of excess demand, p_{t-l}^{input} is a vector of regressors capturing the evolution of input costs, both domestic and imported, and ϵ_t is an idiosyncratic disturbance.

The variables that may influence inflation dynamics are broadly classified as follows[4]:

1. Inflation expectations derived from

    - Consumers: *European Commission (EC) consumer-based survey qualitative response on inflation over the next 12 months*; *EC consumer-based survey expected value of inflation over the next 12 months*; *EC imputed consumers' expectations.*
    - Producers: *Output prices from the composite Purchasing Managers' Index (PMI)*; *EC expected prices in services.*
    - Financial markets: *1-year in 1-year swap*; *2-year in 2-year swap*; *5-year in 5-year swap.*
    - Experts: *1-year Consensus forecasts*; *1-year fixed horizon Consensus forecasts*; *1-year Survey of Professional Forecasters (SPF)*; *1-year fixed horizon SPF*; *5-year SPF.*
    - Long-term inflation forecast: *Long-horizon forecast of inflation extracted from an unobserved components model with stochastic volatility (see Correa-López et al. (2019)).*
    - Synthetic indicators: *Principal component analysis of the above measures.*

2. Economic slack: *Output gap*; *unemployment gap*; *GDP growth*; *unemployment rate.*

3. Labor costs: *Unit labor costs.*

4. External price developments: *Import prices (adjusted by openness)*; *nominal effective exchange rate.*

For each inflation measure, we estimate two variants of Eq. (1), in particular, *extended PC models* denotes the specifications that include all regressors, while *PC models* denotes

[4]See the Appendix for a detailed definition of the variables and the data sources used for their construction.

the specifications that exclude unit labor costs and the nominal effective exchange rate from the extended ones. Furthermore, we allow for three different structures regarding how inflation expectations are formed: backward-looking (when $\beta = 0$), forward-looking (when $\alpha = 0$), and hybrid (when $\alpha \neq 0$ and $\beta \neq 0$). In practice, we estimate a battery of reduced-form models that, for each variant and structure, considers all combinations of slack and inflation expectations measures, when relevant. To arrive at specifications of similar quality (Granger and Jeon (2004)), we first explore the lag structure of the explanatory variables by including up to four lags of the relevant regressors. We find that either contemporaneous specifications or those including up to one lag, i.e. $l \in \{0, 1\}$, seem to capture fairly well the results of more complex lag structures, thus we achieve a reduction from many-to-fewer models by keeping those.

Next, we perform (pseudo) out-of-sample conditional forecasts by estimating rolling windows of each specification, with the first end-date set at 2011:Q4, a window shift of one quarter at a time, and a final end-date in 2019:Q3. For each rolling estimation, we obtain inflation forecasts at different horizons: 1-quarter ahead, 2, 4, 8, 12 and 16-quarters ahead, and we compute root mean squared errors (RMSEs) from each specification at each forecast horizon.

Finally, we synthesize and evaluate the information contained in the RMSEs by means of meta-regression analysis (Stanley (2001)). Thus, for each inflation measure, we estimate a model of the form:

$$RMSE_j^h = \phi_0 structure_j + \phi_1 expectations_j + \phi_2 slack_j + \phi_3 h + \eta_j^h, \tag{2}$$

where subscript j refers to the inflation specification and h denotes the horizon at which the corresponding RMSE is computed. In Eq. (2), the RMSE is a summary statistic that collects information about forecast quality, while the independent regressors gather characteristics that represent differences in econometric model and variables used. Hence, $\{structure, expectations, slack\}$ refer to, respectively, the structure of inflation expectations formation, the variable that measures expected inflation, and the variable that captures economic slack. These regressors enter Eq. (2) as $(0, 1)$ dummy variables, with the excluded categories being the backward structure, the EC consumer-based survey qualitative response on inflation over the next 12 months, and the output gap, respectively. Finally, η_j^h is the error term. For each inflation measure, we carry out the meta-regression exercise for the variants of *PC models* and *extended PC models*.

3 Results

Table 1 presents the results of estimating Eq. (2) for both headline and core inflation rates. First, among the fifteen measures of inflation expectations reported in Table 1, there is no evidence of improved forecasting performance if compared to the excluded category (i.e., the EC consumer-based survey of inflation over the next 12 months). Furthermore, most expectations measures tend to underperform, in a statistically significant way, the EC consumer-based survey of inflation over the next 12 months, especially in models of headline inflation. There are, however, two exceptions to this result. On the one hand, producers PMI-based prices generate forecasts that are statistically as good as those from the excluded category, for both headline and core inflation. On the other hand, specifications that incorporate experts' Consensus or SPFs at 1 year time-frames produce core inflation forecasts of similar quality to that of the excluded category. The results in Table 1 also suggest that the information content from a long-term inflation forecast worsens forecast accuracy if compared to the excluded category, especially for headline inflation. The synthetic indicators, on the other hand, tend to be as good in terms of forecasting performance as the EC consumer-based survey.

The result that consumers expectations have the same predictive power as those from firms fit well with the argument that, if compared to other sources of expectations, household inflation expectations may be a good historical proxy for price-setters beliefs about the inflation path (see the discussion in, e.g., Coibion et al. (2018)). In other words, it supports the view that managers are very similar to households in the process of forming and using inflation expectations, which would include how they deviate from full information rational expectations behavior.[5]

With regard to activity measures, the results suggest that the forecasting ability of inflation specifications that include either the output gap or the unemployment gap is statistically similar. Conversely, it appears that specifications using either GDP growth or, especially, the unemployment rate as a proxy for slack produce inflation forecasts of lower quality, as evidenced by higher RMSEs, on average.

Finally, we find that, across variants, there is no statistically significant difference between the forecasting performance of forward-looking, hybrid and backward-looking structures of expectations formation. All seem to perform equally well in predicting

[5] For example, by how similarly they face information rigidities.

Table 1: RMSEs meta-regressions for euro area inflation

	Headline		Core	
	PC	Extended PC	PC	Extended PC
Expectations:				
EC expected inflation value (12 M)	0.670***	0.672***	0.222***	0.228***
	(0.0803)	(0.0789)	(0.0611)	(0.0607)
EC imputed expectations (12 M)	0.441***	0.449***	0.222***	0.228***
	(0.0921)	(0.0874)	(0.0611)	(0.0607)
PMI	0.0189	0.00952	0.00168	0.00174
	(0.0861)	(0.0849)	(0.0578)	(0.0573)
EC expected services prices (3 M)	0.397***	0.367***	0.213***	0.212***
	(0.0994)	(0.0937)	(0.0611)	(0.0607)
1 year in 1 year swap	0.759***	0.791***	0.244***	0.249***
	(0.0802)	(0.0796)	(0.0611)	(0.0607)
2 year in 2 year swap	0.348***	0.367***	0.134**	0.130**
	(0.0833)	(0.0826)	(0.0578)	(0.0573)
5 year in 5 year swap	0.577***	0.584***	0.223***	0.218***
	(0.086)	(0.0865)	(0.0578)	(0.0573)
Consensus 1 year	0.537***	0.598***	0.0314	0.0447
	(0.0901)	(0.0888)	(0.0578)	(0.0573)
Consensus 1 year (fixed horizon)	0.350***	0.414***	−0.0231	−0.00905
	(0.0896)	(0.0888)	(0.0578)	(0.0573)
SPF 1 year	0.320***	0.368***	0.0176	0.0337
	(0.0829)	(0.0823)	(0.0578)	(0.0573)
SPF 1 year (fixed horizon)	0.265***	0.319***	−0.0300	−0.0177
	(0.085)	(0.0845)	(0.0578)	(0.0573)
SPF 5 years	5.105***	5.010***	2.403***	2.381***
	(0.0997)	(0.102)	(0.0578)	(0.0573)
Long-term inflation forecast	0.725***	0.774***	0.243***	0.273***
	(0.114)	(0.112)	(0.0578)	(0.0573)
Principal component (1999)	0.0764	0.0628	0.0968*	0.0949*
	(0.0971)	(0.096)	(0.0578)	(0.0573)
Principal component (2004)	0.0327	0.0193	0.0501	0.0494
	(0.0952)	(0.094)	(0.0578)	(0.0573)
Slack:				
Unemployment gap	−0.00666	−0.0162	0.0159	0.0147
	(0.0252)	(0.0278)	(0.0327)	(0.0324)
GDP growth	0.138***	0.142***	0.0330	0.0374
	(0.0315)	(0.0336)	(0.0327)	(0.0324)
Unemployment rate	1.081***	0.882***	0.879***	0.862***
	(0.0687)	(0.0675)	(0.0327)	(0.0324)
Structure:				
Forward-looking	−0.0407	−0.0375	0.0791	0.0621
	(0.105)	(0.103)	(0.0715)	(0.071)
Hybrid	−0.00853	0.000957	0.0661	0.0634
	(0.104)	(0.103)	(0.0715)	(0.071)
R-squared	0.925	0.931	0.902	0.902

Notes: Robust standard errors in parentheses. P-values: *** p<0.01, ** p<0.05, * p<0.1. Excluded categories are the qualitative response of the EC consumer-based survey, the output gap, and the backward structure. PC stands for Phillips curves and M stands for month. For further details, see the main text and the Appendix.

headline and core inflation rates. This is in contrast to the finding in Kulikov and Reigl (2019) whose estimated models that do not contain forward-looking terms almost always produce worse conditional inflation projections than Phillips curve models that include forward-looking behavior. However, Béreau et al. (2018) show that a hybrid Phillips curve specification does not outperform the standard backward-looking Phillips specification. Thus, our results from meta-regressions are more in line with those in Béreau et al. (2018).

All in all, the meta-regressions in Table 1 suggest that either inflation models that accommodate a forward-looking process using a direct inflation expectations measure based on qualitative survey data from consumers or firms, or inflation models that include purely backward-looking inflation expectations, are the most suitable to forecast euro area inflation rates. Expert sources of survey-based information on inflation expectations may also produce similarly accurate forecasts, but only in specifications of core inflation. Finally, the output gap and the unemployment gap appear as equally relevant forcing variables in this forecasting exercise.

4 Conclusion

Using a comprehensive set of inflation expectations measures in a thick-modeling Phillips curve conditional forecasting exercise allows us to identify the economic agents whose beliefs about inflation have the most predictive power. Our findings suggest that the information content in surveys of households and managers improves our ability to forecast inflation dynamics if compared to real-time measures of expectations from experts and financial markets. In the study of how expectations are formed and used, information derived from these sources may be particularly relevant to understand the nature of deviations from the full information rational expectations hypothesis.

A Data definitions and sources

Inflation measures are computed from the Harmonized Index of Consumer Prices (Headline) and the HICP excluding food and energy (Core). The inflation rate is calculated as the annualized quarter-on-quarter growth rate of the respective index, in percentages. Inflation series are seasonally adjusted. Data source: Eurostat.

Inflation expectations based on data from:

Consumers. EC consumer-based survey data that capture the price trends over the next 12 months. The qualitative responses are standardized and the quantitative responses are expected inflation values. Imputed consumers' expectations are derived from the quantitative responses on past and expected price changes. In particular, we use the modification in Buchmann (2009) of the Carlson and Parkin (1975) method to derive quantitative estimates of perceived and expected inflation. For further details, see Álvarez et al. (2019). Data source: European Commission.

Producers. Output price of the composite Purchasing Managers' Index (PMI). Data source: Markit. EC expected prices in services over the next 3 months. Data source: European Commission.

Financial markets. Constructed from data on inflation-linked swaps at horizons 1-year, 2-year, and 5-year. Data source: Reuters.

Experts. Constructed from data on inflation expectations in 1-year, 2-years, and 5-years. 1-year fixed horizon series are derived as in Dovern et al. (2012). Data sources: Consensus Forecast and ECB (SPF).

Long-term inflation forecast. Long-horizon forecast of inflation extracted from an unobserved components model with stochastic volatility. Source: Correa-López et al. (2019).

Synthetic indicators. Principal component analysis of the above measures for two periods, 1999-2019 and 2004-2019. For the period 1999-2019, principal components include all measures except those from financial markets, producers and the consumers' quantitative responses, since these start at a later date. For the period 2004-2019, principal components include all measures.

Economic slack measures. GDP growth is computed as the annualized quarter-on-quarter growth rate. The unemployment gap is the percentage difference between the unemployment rate and the NAIRU. Data sources: Eurostat and ECB.

Import price inflation is computed from the import price deflator index, adjusted by openness (the sum of exports and imports divided by GDP, all nominal). The variable is expressed as annualized quarter-on-quarter growth rates, in percentages. Source: Eurostat, ECB.

Unit labor costs data are expressed as annualized quarter-on-quarter growth rates, in percentages. Sources: Eurostat.

Nominal effective exchange rate of the euro against a currency basket of the euro area's 38 main trading partners. The variable is expressed as quarter-on-quarter growth rates, in percentages. Source: ECB.

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Unidad de Servicios Generales I
Alcalá, 48 - 28014 Madrid
E-mail: publicaciones@bde.es
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