Eurasian Economic Review (2023) 13:535–574
https://doi.org/10.1007/s40822-023-00237-9

ORIGINAL PAPER

Impact of uncertainty on inflation forecast errors in Central and Eastern European countries

Agata Kliber[1] · Magdalena Szyszko[2] · Mariusz Próchniak[3] · Aleksandra Rutkowska[1]

Received: 5 May 2023 / Revised: 17 August 2023 / Accepted: 20 August 2023 /
Published online: 11 November 2023

Abstract
The question underlying the research problem addressed by this study concerns various factors, including uncertainty, that could affect forecast errors. Previous works, focusing mainly on world-leading economies, are inconclusive on how economic agents form inflation forecasts or why forecast errors occur. There is a gap in the empirical literature that needs to be filled. The analysis covers the 2016–2020 period and seven economies: Albania, Czechia, Hungary, Poland, Romania, Serbia, and Turkey. We verify whether forecast errors are driven by production, inflation, exchange rates, interest rates, oil prices, changes in the tone of the central bank's releases and their uncertainty. We assess whether economic agents can process available information to present accurate inflation forecasts. The results suggest that neither consumers nor professionals do—they present inaccurate forecasts regularly. The results suggest that exchange rate volatility is the most important variable that positively affects forecast errors, followed by inflation and its volatility. This confirms (in most cases) a theoretical assumption that a stable environment is better for long-term development as lower inflation forecast errors allow for the optimization of economic decisions. The study implies that mechanisms supporting forecasting during turbulent times must be strengthened. It presents the set of variables that should be analyzed more carefully by consumers and professionals. In addition, central banks could provide more precise communication regarding the evolution of error drivers. Our results build on existing literature by explicitly linking macroeconomic uncertainty with forecast errors including for small open economies from Eurasia.

Keywords Inflation expectations · Forecast errors · Economic uncertainty · Central banks' communication tone

Extended author information available on the last page of the article

JEL Classification D84 · D83 · E58

1 Introduction

Our aim in this study is to investigate the relationships between inflation forecast errors and economic uncertainty arising from global and local factors. The research problem of the relationship between expectations and uncertainty is studied in the comparative context of professionals and consumers operating in small open economies. We also address a research question on the similarities of the expectation errors between professionals and consumers in a volatile environment. In addition, we address the issue of forecast accuracy as driven by domestic factors and global factors.

More generally, this study's research problem concerns the identification of the most important determinants of inflation forecast errors. Forecasting inflation, or broadly speaking, forecasting economic perspectives, is crucial for all economic agents: households, companies and policy-makers such as governments and central banks. If forecasts are error free, economic decisions, including price setting, wage negotiations, consumption and investment decisions, made by economic agents could translate into better economic outcomes. It applies primarily to inflation expectations, which are within the scope of this study, as they are the most powerful drivers of inflation and output. This is why the research problem of this examination also matters for central banks—successful guidance of inflation expectations facilitates achieving the inflation target. Identifying the determinants of inflation forecast errors is the first step toward their management by an individual economic agent and policy-makers.

Our motivation for addressing this issue is twofold. First, it is about the importance of expectations for monetary policy conduct. The pivotal role of expectations in monetary policy conduct as presented by Woodford (2003) is not questioned. Inflation targeting central banks (CBs), including those from our sample, closely monitor the evolution of inflation expectations to follow the theoretical premises that background their monetary framework. Models rooted in new neoclassical synthesis perceive inflation expectations as the critical drivers of inflation directly and through output Gali (2008). Thus, central banks attempt to steer inflation expectations. In conditions of increased volatility, it might not be possible to anchor them to the inflation target. Nevertheless, keeping expectations forward-looking—not linked to the past evolution of the economy, namely inflation and production, facilitates expectations' response to policy measures. Recognizing the patterns of expectation formation, including drivers of their errors, enables CBs to actively create communication and other policy tools to affect expectations and smooth monetary transmission. The importance of expectations appears clear in all inflation targeting economies, including small open economies from our sample. These countries are subject to multiple shocks arising from the local and global economies, and thus the ability not to transform shocks into expectations formation is important.

Second, despite the voluminous literature comprising both theoretical and empirical work on expectations, how inflation expectations are formed is not fully recognized. From a theoretical perspective, various hypotheses explaining expectation formation exist, including rational, adaptive (error-learning), adaptive learning, and bounded- and near-rationality hypotheses. Theoretical considerations are complemented by empirical tests of formation patterns, disagreement, heterogeneity, (de)anchoring or forecast errors. Studies on expectations formation return to the centre of economic discussion when uncertainty increases. This is why we are particularly interested in investigating expectation error drivers among the volatility of economic outcomes.

This paper investigates inflation expectations of professionals and consumers in seven post-transition European economies: Albania, Czechia, Hungary, Poland, Romania, Serbia, and Turkey. The common denominator of our sample is the monetary policy strategy implemented by the studied central banks, namely inflation targeting (IT). The sample spans from 2016 to 2020. After running preliminary verification, we noticed that up to 2016, the forecasts were much less accurate than afterward. The end of the research period was set at 2020, as with the end of that year the pandemic effects became reflected in macro data.

This study focuses on inflation expectation errors[1]. Before discussing forecast errors, we test the rational expectations hypothesis. Non-rationality of expectations allows the possibility of studying errors multi-dimensionally: comparing them between professionals and consumers, discussing drivers of forecast errors among the uncertainty of macro variables, including how central banks communicate and the political uncertainty occurring in European economies.

We consider inflation forecasts presented by professionals (Consensus Economics Consensus Forecast) and consumers (Business and Consumers Survey). Both series need to be processed: we derived fixed-horizon forecasts (12 M) for professionals and quantified consumer expectations with a probabilistic method. After pre-processing the data, we tested the forecasts' unbiasedness and macroeconomic efficiency. These standard tests are run to reject the rationality of expectations and, as far as macroeconomic efficiency is considered, to determine the starting point set of forecast error drivers.

To verify the drivers of forecast errors, we estimate panel models where inflation forecast errors are regressed against several potential determinants, including uncertainty (or volatility) in /a/ observed inflation, /b/ industrial production, /c/ exchange rates, /d/ interest rates, and /e/ oil prices. The macroeconomic variables encompass the domestic drivers of inflation expectations and global factors (oil prices). In addition, we test the dependence of forecast errors and the central bank tone estimated by applying the dictionary method. A recent strand of work investigates relationships between expectations and central bank tone, as presented by Baranowski et al. (2021) and Szyszko et al. (2022), and confirms that communication nuances add value to the expectation formation process.

In the study, we measure uncertainty as the standard deviation of a given variable (e.g. inflation rate, industrial production growth rate, or interest rate). Such an approach is not the only option to define uncertainty, but it is well-embodied in the

[1] In this article, we use the terms *forecast* and *expectations* interchangeably.

theory of economics (see, e.g., Wander and D'Vari (2003)). In the basic setup of our models, we approximate uncertainty by the standard deviation of observed values in the past 12 months. As a robustness check, we apply this proxy for 6 months. Economic agents, mainly consumers, could focus on the most recent events when forming their expectations. Regarding the monetary policy tone variable, we estimate tone uncertainty as the difference between two subsequent releases made by central banks and published with their decisions on policy settings. We thus assume that the more volatile the path of the economy follows, as reflected by higher fluctuations, the more uncertain the future will be, making it more challenging to formulate accurate forecasts. We hypothesise that the stable past evolution of economic indicators translates into more accurate inflation forecasts. There are several papers suggesting that uncertainty matters for forecast accuracy. Most past studies discuss the accuracy of micro-data forecasts during increased volatility. They suggest that the accuracy of analyst forecasts of earnings is compromised at times of increased economic policy uncertainty when market volatility and information opacity are high (Chahine et al., 2021). Findings reveal that when uncertainty is high, analysts' earning forecasts are more timely but less accurate (Amiram et al., 2018). Economic policy uncertainty also positively affects analyst forecast errors (Biswas, 2019 and Chourou et al., 2021). Regarding essential macroeconomic time series, Reif (2021) found for the US data that information on macroeconomic uncertainty improves forecast accuracy.

We apply fixed-effect panel models to study the vulnerability of the inflation forecast error to economic uncertainty. Models are estimated separately for professionals and consumers and for the absolute value of the nominal and relative forecast error. Panels are run for the full sample, EU member states, non-EU economies and the full sample excluding Turkey. Our results indicate that consumers rely more on basic economic variables (captured by our models) when forecasting inflation than professionals. Inflation forecast errors are explained by the level of economic variables and, to a lesser extent, by their volatility.

Our contribution to the literature is as follows. First, although numerous studies investigate inflation forecast errors, we attribute them to the uncertainty of macroeconomic variables. There are some previous papers discussing uncertainty effects on expectations such as Coibion et al. (2022). However, they focus primarily on the world-leading central banks. Our sample of post-transformation economies, not being at the centre of the research discussion, constitute the value added of this study. Conducting economic studies of local economies matters by providing implications for local policymakers. Moreover, it could be constrained due to limited data availability. We show that the role of the risk associated with the macro variables is unambiguous—it can contribute to the growth or decline of the error, which is not in line with most papers regarding forecast accuracy as presented above. The direction of the reaction is counterintuitive for most of the variables—when their volatility increases, economic agents can provide more accurate forecasts. We discuss these findings and their rationale in Sect. 5.2. Eventually, we test the role of policy communication tone and its effect on expectation errors augmenting the existing literature investigating the tone effect for expectations as presented by Baranowski et al. (2021) and Szyszko et al. (2022).

The paper is structured as follows. The literature review (Sect. 2) appears after this introduction. Section 3 presents the data used. The methodology is described in Sect. 4. Section 4 presents, interprets and discusses the outcomes of our models. In the last section, we discuss the results and formulate conclusions.

2 Literature review

Since the neoclassical revolution in macroeconomics, monetary transmission models based on New Keynesian frameworks have assumed the rationality of inflation expectations. A voluminous empirical literature rejects the rational expectations hypothesis (REH) as presented for European economies by Łyziak and Mackiewicz-Łyziak (2014). Moreover, theoretical extensions of the baseline model that account for non-rational expectations exist (Woodford, 2013). Nonetheless, the question of expectations properties remains open and—when expectations are studied—the investigation starts with testing the unbiasedness and efficiency of forecasts, as discussed in the seminal paper by Holden and Peel (1990). An empirical rejection of the REH creates the possibility to investigate forecast errors, including their drivers. The accuracy of the inflation forecast is not linked to the degree of forward-lookingness of inflation expectations. However, the general conclusion from previous papers suggests that professionals are more forward-looking and more accurate when presenting their forecasts than consumers (Gerberding, 2001; Berge, 2018; Szyszko et al., 2020). Previously identified discrepancies between forecasts by professionals and households motivate us to compare expectations properties, including forecast errors between these two groups of economic agents.

Empirical papers investigating the relationship between economic uncertainty and forecast accuracy suggest that increased volatility induces less accurate forecasts as presented by Amiram et al. (2018) and Chahine et al. (2021). This strand of the literature focuses mostly on microeconomic forecasts as companies' earnings. When macroeconomic forecasts are discussed in terms of uncertainty, Reif (2021) found in US data that including information on macroeconomic uncertainty improves the forecast accuracy. Uncertainty was identified as a relevant factor for forecasting recession, again for US data by Balcilar et al. (2016) and Pierdzioch and Gupta (2017). Uncertainty can also help predict growth in the US (Bekiros and Paccagnini, 2015 and Segnon et al., 2018). None of these contributions considers inflation forecasts as we do in this study. Moreover, note that most of the papers cover the US or other leading central banks. Time series available for the most developed economies linked to, i.a., central bank transparency and the maturity of financial markets are often not available for small open economies.

After devising the setup of this study, we reviewed empirical papers focusing on inflation and forecasting inflation. First, we searched for the possible drivers of expectation errors among standard macroeconomic and financial variables recognized as inflation and inflation expectations drivers. Other authors apply the same approach. Bec and De Gaye (2016) empirically investigate the impact of oil price forecast errors on US, UK, and French inflation forecast errors during the period 1992–2013. The study concludes that there is a significant contribution of oil price forecast errors to explaining inflation forecast errors, whatever the country or period considered. This justifies our approach to include the volatility in oil prices as one of the explanatory variables in the econometric model. Another justification for including oil prices in the model comes from the paper by Castillo et al. (2020), who show that higher oil price volatility induces higher average inflation levels. Glas and Drechsel (2021) analyze the role of ex ante conditioning variables for macroeconomic forecasts, including inflation forecasts. They show that inflation forecasts are closely associated with oil price expectations, while forecast errors are strongly related to assumption errors. Oil price errors and wage growth errors are the most important for inflation. This study also shows the need to include oil prices in our considerations. Kim and Kim (2019) use a Bayesian DSGE approach to analyze the dynamics of inflation forecast errors. They address how actual inflation and inflation forecasts respond to various exogenous economic shocks (including supply, demand, and inflation target shocks). The authors find that supply shocks and measurement errors in inflation are dominant forces driving variations in inflation forecast errors. In contrast, secular shifts in inflation are generated mainly by supply and inflation target shocks. Based on these findings, our model includes the variables related to demand- and supply-side shocks (industrial production, oil prices and interest rates). Apergis (2017) uses a similar set of variables, investigating the impact of both asset and macroeconomic forecast errors on inflation forecast errors in the USA. The set of forecasts of macroeconomic variables used in the study comprises exchange rates, 3-month bill rates, 10-year bond rates, housing prices, the manufacturing index PMI and GDP. The forecasts of asset prices are approximated by S &P 500 forecasts. The author documents a significant impact of both types of forecast errors on the explanation of inflation forecast errors, which was another inspiration for our research.

Second, we introduce two additional perspectives besides the standard drivers of expectation errors. The first regards monetary policy communication tone. There is broad evidence that policy transparency and communication affect expectations in many ways, allowing for their alignment with the inflation target (Geraats, 2014) or greater coordination between central banks' forecasts and private forecasts (Ehrmann et al., 2012; Hubert, 2015). The effect is also found for inflation forecast errors: Gamber et al. (2015) analyze the distribution of inflation forecast errors in the US during the period 1984–2007. According to their findings, since 1994, when the Fed moved toward greater transparency, its forecasting record ceases to be significantly better than the forecasting record composed of randomly assigned forecasts. In this study, we want to verify whether policy communication tone volatility, as detected by the dictionary method, affects inflation expectations. Thus, we diverge from transparency or communication policies understood generally. Instead, we encode policy communication regarding the central bank releases published with the policy setting decision. The tone of communication is detected using the dictionary method as presented by Algaba et al. (2021) and applied by Hansen and McMahon (2016) and Baranowski et al. (2021). Baranowski et al. (2021) and Szyszko et al. (2022) have already found the effect of tone on expectations. This study attempts to identify whether tone volatility affects expectation errors.

Finally, we introduce the economic policy uncertainty index (EPU) into our model—a proxy for policy uncertainty occurring in the European Union. This index was used in a relatively recent paper by Binder et al. (2022) that studied the term structure of uncertainty of (inter alia) inflation forecasts. Uncertainty was measured as a standard deviation of the density of the forecast. The authors reveal a statistically significant relationship between forecast uncertainty and economic policy uncertainty. The latter result justifies our inclusion of this measure in the set of explanatory variables.

As the literature review above indicates, inflation forecast errors are the topic of many empirical studies. However, we have not seen a study that attempts to empirically investigate the determinants of inflation forecast errors in terms of the uncertainty of macroeconomic variables. The current study is likely to build on the existing literature that discusses expectations.

3 Data

We collected monthly data for the 2016–2020 period for Albania, Czechia, Hungary, Poland, Romania, Serbia, and Turkey. The central banks of the economies we discuss implement inflation targeting. Nevertheless, their experience in policy strategy that focuses on expectation formation varies.[2] The common denominator of the countries studied is inflation targeting implementation and their recent transition from centrally planned to market economies. Similar to the experience in implementing IT frameworks, the economies we discuss have different levels of market orientation. Most studies focus on world-leading central banks–this study coverage builds on the literature on expectations formation under IT regimes in less apparent economies.

The study focuses on expectation formation and errors. Except for the expectations of professionals and consumers (described in Sect. 3.1)—our dependent variables— we collect and process monthly data on macroeconomic indicators that could explain expectation errors, monetary policy communication tone and an economic policy uncertainty index (see Sect. 3.2). Table 1 presents details regarding the data sources.

3.1 Dependent variable

This study examines and compares the dependent variable, inflation expectations, for consumers and professionals. Consumer data are derived from Business and Consumer Surveys. The survey question on the expected inflation rate is qualitative[3]. Expectations are quantified by the canonical probabilistic method of Carlson and Parkin (1975) adjusted for the polychotomous (five question) survey as

[2] IT was implemented in our countries of focus as follows: Albania in 2008, Czechia in 1998, Hungary in 2001, Poland in 1999, Romania in 2005, Serbia in 2009 and Turkey in 2006.

[3] ‘When compared to the past 12 months, how do you expect consumer prices to develop in the next 12 months?’ The answers to choose from included: ‘They will... increase more rapidly, increase at the same rate, increase at a slower rate, stay about the same, fall, don’t know’ (Commission, 2016).

Table 1 Data sources and processing

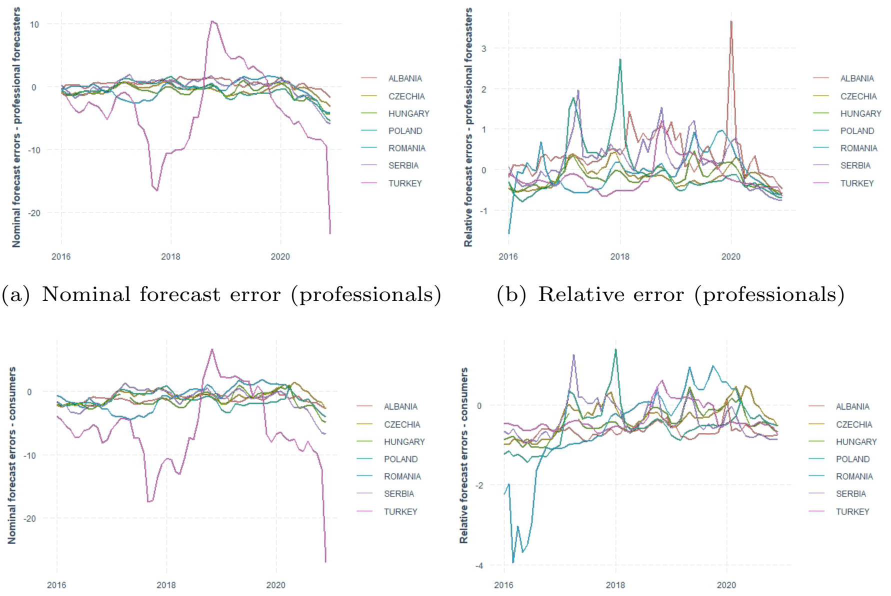
Variable	Source	Description
Professional expectations	Consensus Economics	Consensus Forecast—mean inflation forecast in % for the end of ongoing and subsequent year
Consumer expectations	Business and Consumer Survey	Percents of responses to the qualitative survey question about the price evolution within forthcoming 12 M, quantified with probabilistic method
Inflation	National Statistical Offices	CPI (official inflation measure in the CB of interest), % change compared to corresponding month of the previous year
Industrial production	Eurostat	IPI, Production in the industry—monthly data; Volume index of production; % change compared to corresponding month of the previous year
Interest rates	Eurostat	IR, Money market interest rates: monthly data: monthly data, day-to-day rate, % per annum
Exchange rates	Eurostat	ER, Euro/ECU exchange rates—monthly data; National currency per 1 EUR, value
Oil prices	CEIC	Brent crude oil price; USD/Barrel
Monetary policy tone	CBs websites	Tone, index obtained after dictionary method application
Policy uncertainty	Economic Policy Uncertainty	EPU, European_News_Index; Economic Policy Uncertainty

presented by Batchelor and Orr (1988). According to a comprehensive survey conducted for European economies by Szyszko et al. (2020), probabilistic methods outperform alternative specifications for expectation quantification. We avoid its detailed presentation here because the method and procedure are commonly acknowledged.

Professional expectations are derived from Consensus Economics Consensus Forecast data. As the Consensus Economics forecasts are fixed-event, we apply the approach of (Dovern et al., 2012) to transform them into fixed-horizon (12 M) forecasts. The professionals present their inflation expectations at the end of the current and the next calendar year. Dovern et al. (2012) approximate fixed-horizon forecasts as a weighted average of fixed-event forecasts. Let us denote by $F^e_{y_0,m,y_1}(x)$ the fixed-event forecast of variable x for year y_1 formulated in month m of the previous year, $y_0 = y_1 - 1$. Let us then denote by $F^h_{y_0,m,12}(x)$ the fixed-horizon, twelve-month-ahead forecast made at the same time. The fixed-horizon forecast for the next 12 months is approximated as an average of the forecasts for the current and next calendar year weighted by their share in the forecasting horizon:

$$F^h_{y_0,m,12}(x) = \frac{12 - m + 1}{12} \cdot F^e_{y_0,m,y_0}(x) + \frac{m - 1}{12} \cdot F^e_{y_0,m,y_1}(x) \tag{1}$$

Primary time series with consumer and professional expectations were used to test the rationality of private inflation forecasts and then discuss their errors. There is no consensus in the literature on how to calculate forecast errors. For instance, Nolte et al. (2019) calculate inflation forecast errors as the deviation from rational expectations, as opposed to the deviation from realized inflation. Yet another approach is to calculate the error as the difference between the yearly forecast and the annualized inflation rate – see, e.g., Berge (2018). This study analyses two kinds of forecast errors – nominal and relative. Including different variants of errors, both nominal and relative, is a commonly applied procedure when errors are discussed as presented for inflation forecasts by Łyziak and Mackiewicz-Łyziak (2014) and Dellas et al. (2018). The errors are included in two variants in the final estimations of the econometric model. The first variant represents the inflation forecast error calculated in percentage terms, i.e., the absolute value of the error divided by the observed inflation rate. It is called a relative or percentage error. Such an approach results from the fact that an error of 1 p.p. is serious when inflation stands at, e.g., a 2% level but is negligible if the inflation rate exceeds, e.g., 20%. However, this approach also has a serious shortcoming. Suppose that realized inflation is close to 0%. In that case, the relative error may be excessively high (for example, if we divide the error of 3 p.p. by the observed inflation rate of 0.1%, we obtain the value of the relative error equal to 30; moreover, in the case of stable prices, any error turns out to be infinitely high). That is why we also include the second variant of the dependent variable in the calculations. This variant represents the absolute value of the forecast error (without dividing it by the observed inflation rate). It is called a nominal error.



(a) Nominal forecast error (professionals) (b) Relative error (professionals)

(c) Nominal forecast error (households) (d) Relative error (households)

Fig. 1 Inflation forecast errors formulated by professionals (**a**, **b**) and consumers (**c**, **d**)

Let us denote by $e^n_{y_0,m}(x)$ the forecast error of the prediction formulated in month m of year y_0 and by $x_{y_1,m}$ the realized value of variable x in month m of year y_1. The error is calculated as:

$$e^n_{y_0,m}(x) = x_{y_1,m} - F^h_{y_0,m,12}(x) \tag{2}$$

The relative forecast error $e^r_{y_0,m}(x)$ of the prediction formulated in month m of year y_0 is the nominal error divided by the realized value of variable x:

$$e^r_{y_0,m}(x) = \frac{e^n_{y_0,m}(x)}{x_{y_1,m}} \tag{3}$$

As Fig. 1 presents, the error values vary across countries. We present the nominal errors on the left-hand side, while the right-hand side reports relative errors. The highest nominal errors (in absolute terms) were recorded for Turkey. However, the difference is negligible when relative errors are discussed.

The analysis of Fig. 1 leads to two conclusions. First, high forecast errors for Turkey result from the fact that it is an unstable emerging economy undergoing various economic and political shocks. The environment is characterized by high uncertainty. Unplanned actions by the government and the president reinforce this. The external environment is also unstable: turbulent relations with Greece, the closed border with Armenia, and military operations on the border of Turkey, Syria and Iraq (in the area of the so-called Kurdistan). This is strengthened by the high inflation observed in recent years. The above factors make it much more difficult to formulate accurate inflation forecasts. Second, all other countries in Fig. 1 are post-socialist countries. At the turn of the 1980s and 1990s, they transformed from centrally planned to market economies. They also took the same path of structural and institutional reforms, although they were launched at different times. Most of them belong to the European Union. As a result, these countries are subject to similar demand and supply shocks, both internal and external. Hence, these countries exhibit a relatively high degree of cyclical convergence, and as a result, inflation forecast errors show similar fluctuations.

Tables 27 and 28 present statistical proprieties of forecast errors for our sample. Note that forecasts by Albanian professionals are the only case where, on average, expected inflation is undershot. Statistics for Turkey (nominal errors) confirm higher levels and volatility of inflation expectations as presented in Fig. 1. As Table 26 reports, forecast errors are, on average, different for consumers and professionals in most cases, regardless of the error. Albania, Poland and Serbia exhibit no difference in relative errors.

3.2 Explanatory variables

Inflation forecasts are affected by both nominal and real macroeconomic variables reflecting current and past macroeconomic performance. As a result, we have decided to choose the following variables that should impact inflation expectations: inflation itself, industrial production, the exchange rate, the interest rate, and oil prices (see Table 1 for details). We assume that uncertainty regarding these variables may cause the inflation forecast error. Therefore, in the econometric models, we regress the inflation forecast error against the volatility of these variables. The volatility is approximated by the standard deviation of the respective variables' observations taken from the last 12 months:

$$\sigma_{X,k} = \sqrt{\frac{1}{12} \sum_{i=(k-13)}^{k-1} (X - \bar{X}^2)} \tag{4}$$

where $\sigma_{X,k}$ is the standard deviation of variable X in the k-th month. There are numerous studies in the literature where uncertainty (or risk) is defined in this way (see, e.g., Wander and D'Vari (2003), Minot (2014), Mital et al. (2015) and Gülşen and Kara (2019)).

Beyond standard macroeconomic variables, we seek to test whether forecast errors are linked to monetary policy tone. The tone was derived from monetary policy releases published together with the immediate decision explanation (decision rationale, governor's statement, minutes, press releases). Each central bank designs such documents. However, to a large extent, these releases exhibit a similar structure and content. A dictionary method we apply allows for tone classification, ordering, and quantification. This method has found broad application in previous studies to detect the tone as presented by Hansen and McMahon (2016), Bennani

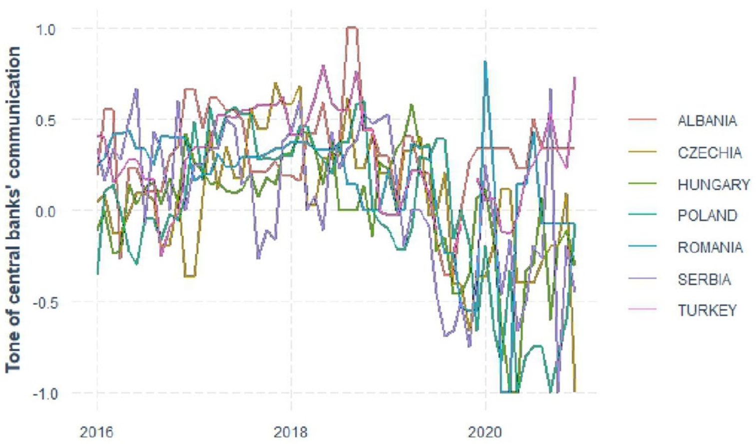


Fig. 2 Tone of central banks' communication over 2016–2020

and Neuenkirch (2017), Picault and Renault (2017), Baranowski et al. (2021, 2021) and Szyszko et al. (2022). The presented papers applied different lexicons to detect tone to discuss monetary-policy relevant issues. Our dictionary choice is to apply that proposed by Apel and Grimaldi (2014) because it is tailored to monetary policy analysis and is based on bigrams that make accurate classification possible for the phrases such as *increasing unemployment*. In this case, the *increase* does not denote better economic conditions that could suggest future policy tightening. The phrase is dovish, not hawkish.

We calculate the tone using the following equation:

$$TONE_{t,i} = \frac{PositiveWords_{t,i} - NegativeWords_{t,i}}{PositiveWords_{t,i} + NegativeWords_{t,i}} \quad (5)$$

where $TONE_{t,i}$ is the tone of the policy releases in period t for the i-th central bank; $PositiveWords_{t,i}$ is the number of expressions indicating strong economic conditions, and $NegativeWords_{t,i}$ is the number of expressions indicating weak economic conditions. The procedure returns a continuous variable $TONE_{t,i}$ for each set of press releases, the value of which varies from -1 (all words are dovish) to 1 (all words are hawkish). Tone estimations at the individual country level are presented in Fig. 2. Tone uncertainty is approximated by the change in the tone of the respective central bank's communication between two announcements: $\Delta Tone_{m-1} = Tone_{m-2} - Tone_{m-1}$.

We approximate the uncertainty regarding the macroeconomic situation in the region with the European policy-related economic uncertainty index taken from the Economic Policy Uncertainty (EPU) organization (see Baker et al. 2016; Index 2023

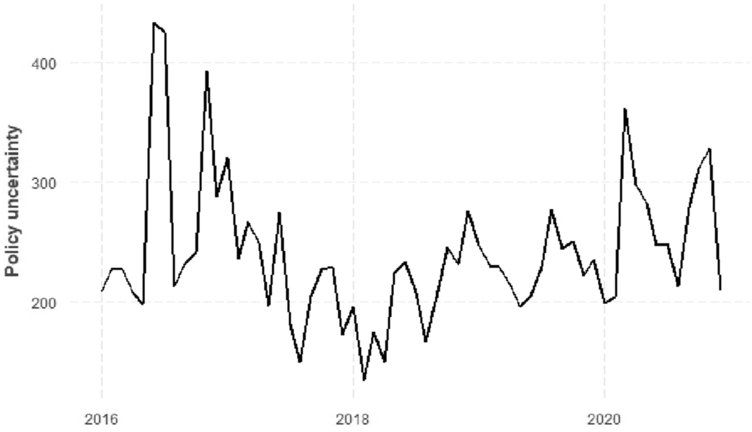


Fig. 3 Economic Policy Uncertainty over the period 2016–2020

for details). The index is based on newspaper articles regarding policy uncertainty in Europe. Two newspapers per country are incorporated into the index: *Le Monde* and *Le Figaro* for France, *Handelsblatt* and *Frankfurter Allgemeine Zeitung* for Germany, *Corriere Della Sera* and *La Stampa* for Italy, *El Mundo* and *El Pais* for Spain, and *The Times of London* and *Financial Times* for the United Kingdom. The number of newspaper articles containing the terms *uncertain* or *uncertainty*, *economic* or *economy* and one or more policy-relevant terms is considered. All searches were conducted in the native language of the newspaper in question. Next, the raw EPU count is scaled by a measure of the number of articles in the same newspaper and month (see European Uncertainty Index, (2023) for more information). The index represents economic uncertainty in Europe (the whole region), although it does not include all European countries. From the perspective of our sample, the index represents an external variable that could affect the domestic situation due to obvious linkages between European economies. We decided to introduce the index of economic policy uncertainty as the additional explanatory variable for European Union member states only. Economic and political ties between EU economies are much closer than those between all countries covered by this study. It could be observed, inter alia, that the extraordinary policy measures by the European Central Bank strongly influenced the financial markets of Czechia, Hungary and Poland (Grabowski and Stawasz-Grabowska, 2021).

The values of the EPU index are displayed in Fig. 3. The evolution of the index over time suggests volatility of economic uncertainty, with higher intensity at the beginning of this study research period.

4 Methodology

The research procedure of this study covers:

- testing rationality of inflation expectations with unbiasedness and macroeconomic efficiency tests,
- testing the impact of uncertainty on inflation forecast accuracy.

4.1 Rationality of inflation expectations

To test the rationality of inflation forecasts, we only refer to two principal conditions that need to be met to confirm REH: unbiasedness and macroeconomic efficiency following the approach by Gerberding (2001) and Łyziak (2013). The applied specifications are theory related. Unbiasedness is tested with Eq. 6, where $CPI_{y_1,m}$ represents inflation observed in the m-th month of year y_1 and $F^h_{y_0,m,12}(CPI)$ denotes the inflation forecast made 1 year ago for the 12 M horizon (formulated in month m of the previous year y_0):

$$CPI_{y_1,m} = \alpha_0 + \beta F^h_{y_0,m,12}(CPI) + \varepsilon_t \tag{6}$$

The expectations can be considered unbiassed when α_0 is insignificantly different from 0 and β equals 1.

We also test the efficiency of forecasts. This condition is met if economic agents efficiently process available information while forming their expectations, meaning that forecast errors are orthogonal to the available information. The results of efficiency tests allow us to present the variables that could affect the forecast errors. Macroeconomic efficiency is described with the following equations:

$$e^Z_{y_0,m}(x) = \alpha_0 + \alpha\Omega_{y_0,(m-2)} + \varepsilon_m, \tag{7}$$

where Ω is a set encompassing macroeconomic variables. In our case these are the logarithms of oil prices, logarithms of exchange rates, interest rates, IPI, CPI and central banks' communication tone. All variables are included in the equation with lag 1 or 2. Due to the correlation between variables, we run macroeconomic efficiency tests on each of them separately, which repeats the standard procedure (see Łyziak and Mackiewicz-Łyziak, 2014).

The second equation describing the efficiency of the forecasts takes the following form:

$$e^Z_{y_0,m}(x) = \alpha_0 + \alpha\Omega_{y_0,(m-2)} + \beta e^Z_{y_0,(m-1)}(x) + \varepsilon_m, \tag{8}$$

where the current value of the error also depends on the error of the forecast formulated in the previous month. In Eqs. (7) and (8), $\Omega_{y_0,m-i}$ denotes the set of economic

Table 2 Unbiasedness tests results—professionals

	Estimate	Std. Error	t-value	Pr (> |t|)
α_0	0.196	0.204	0.959	0.338
β	0.997	0.043	23.004	< 0.001

Note R^2 of the regression is 0.57

Table 3 Unbiasedness tests results—consumers

	Estimate	Std. Error	t-value	Pr(> |t|)
α_0	1.306	0.203	6.425	< 0.001
β	1.010	0.054	18.546	< 0.001

Note R^2 of the regression is 0.47

variables observed i months before formulating the forecast, while $Z \in \{n, r\}$, where n is the nominal error, while r-the relative error. For both specifications, we assume an information lag of 2 M to ensure that economic agents, especially non-professionals, have access to relevant macro news. Macroeconomic efficiency does not occur when α is significantly different from zero.

4.2 Forecast error uncertainty

Eventually, we applied the classical approach and estimate the fixed effect model for the nominal and relative forecast error. The specification has been chosen based on the outcomes of the Hausmann test.

We estimate the model in the following form:

$$e^Z_{y_0,m}(x) = \alpha_{0,i} + \alpha\Omega_{y_0,(m-2)} + \beta\Sigma_{y_0,m} + u_{i,t}, \tag{9}$$

where $\Sigma_{y_0,m}$ encompasses standard deviations (calculated according to Eq. (4)) of log oil prices, log exchange rates, CPI, IPI, IR, and the change in the tone of the respective central bank's communication, lagged by one period: $\Delta Tone_{m-1} = Tone_{m-2} - Tone_{m-1}$

The effect of each i-th explanatory variable on the forecast error does not vary over time. The $u_{i,t}$s are random error terms that are specific to each time point. We assume that they are independent of the regressors. Finally, $\alpha_{0,i}$ is an unobserved variable that represents the combined effects on the dependent variable of all variables specific to the given country but that does not change over time. In the fixed effect model, they

Table 4 Efficiency tests results—professionals

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	0.089	0.041	2.169	0.031
$ln(OIL)_{m-2}$	0.068	0.009	7.223	< 0.001
IR_{m-2}	0.704	0.051	13.703	< 0.001
ER_{m-2}	0.011	0.021	0.541	0.589
IPI_{m-2}	– 0.141	0.023	– 6.259	< 0.001
CPI_{m-2}	0.823	0.061	13.534	< 0.001

Table 5 Efficiency test results—consumers

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	0.158	0.039	4.048	0.000
$ln(OIL)_{m-2}$	0.065	0.009	6.851	0.000
IR_{m-2}	0.684	0.050	13.612	0.000
ER_{m-2}	0.022	0.021	1.083	0.280
IPI_{m-2}	– 0.168	0.022	– 7.537	0.000
CPI_{m-2}	0.903	0.054	16.701	0.000

are treated as constants. m denotes the month of the year. The analogous model is estimated for the relative forecast error.

For the EU economies, we also include in the set Σ the logarithmic values of the policy uncertainty index, lagged by two months. We include it only in the subset of the EU countries because the policy uncertainty index is based on press releases in Western European economies. We expect that its impact on the inflation forecast error may be visible only in EU countries.

All the calculations have been performed in R, using packages panelr (Long, 2020) and plm (Croissant and Millo, 2008).

5 Results

5.1 Rationality of inflation expectations

In Table 2, we present the results of unbiasedness tests for professionals (Eq. 6) and in Table 3, we do so for consumers. The model was estimated for all the countries in the sample as a pooling regression. We observe that the coefficient α is insignificant for professionals and significantly greater than 0 for consumers, suggesting that consumer expectations are not free from systematic errors. The coefficient β equals 0.997 for professional forecasters, with a 95% confidence interval of (0.91; 1.08). The respective interval obtained for consumers is (0.90; 1.12), confirming that in both cases, the value of β is equal to 1. The results of unbiasedness tests are surprising because they suggest that professional forecasters present forecasts as being equal to actual future inflation on average (considered a random forecast error period

Table 6 Efficiency test results (past errors augmented specification)—professionals

	Estimate	Std. Error	z-stat.	Pr(> |t|)
$Tone_{t-2}$	– 0.049	0.037	– 1.340	0.180
$ln(OIL_{m-2})$	– 0.047	0.029	– 1.638	0.101
IR_{m-2}	– 0.045	0.020	– 2.257	0.024
ER_{m-2}	– 0.0004	0.000	– 1.638	0.101
IPI_{m-2}	– 0.0171	0.010	– 1.637	0.102
CPI_{m-2}	– 0.046	0.022	– 2.062	0.039

The dynamic panel was estimated in GRETL, using the one-step system GMM approach. However, the p value of Sargant's overidentification test was always ≤ 0.001, which means that the instruments were invalid

Table 7 Efficiency test results (past errors augmented specification)—consumers

	Estimate	Std. Error	z-stat.	Pr(> |t|)
$Tone_{t-2}$	– 0.012	0.006	– 1.947	0.052
$ln(OIL)_{m-2}$	– 0.009	0.005	– 1.620	0.105
ER_{m-2}	$-9.4 \cdot 10^{-5}$	0.000	– 1.801	0.072
IR_{m-2}	– 0.020	0.001	– 14.23	< 0.001
IPI_{m-2}	0.003	0.005	0.607	0.544
CPI_{m-2}	– 0.018	0.002	– 9.242	< 0.001

The dynamic panel was estimated in GRETL, using the one-step system GMM approach. However, the p value of Sargant's overidentification test was always ≤ 0.001, which means that the instruments were invalid

by period). They are free from systematic errors. However, the unbiasedness condition does not correspond fully to the rationality of expectations. The macroeconomic efficiency tests add the other picture to our story.

In Tables 4 and 5, we present the estimates of the test for the efficiency of the forecasts, according to specification (7). The estimates were run one by one for each regressor. Each time, we estimated the fixed effects model (we also tested the pooling regression specification, but the fixed effects model was preferred according to the F test).

The macroeconomic efficiency condition is not met for professionals or consumers. Information regarding some variables, such as inflation, oil prices, interest rates, industrial production or inflation, is not processed efficiently for either consumers or professionals. The only variable that is processed efficiently by economic agents is the exchange rate. Its importance seems justified in small open economies implementing the IT regime.

In Tables 6 and 7, we present the estimates of the second specification of the test for the efficiency of forecasts. As the lagged dependent variable is on the right-hand side of the equation, we used the dynamic-panel specification. If we assume a 5% significance level—forecasters efficiently process information from

Table 8 Impact of uncertainty on nominal forecast error—professional forecasters

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.089	0.036	– 2.472	0.014
$ln(OIL)_{m-2}$	1.045	0.605	1.728	0.085
IR_{m-2}	0.274	0.078	3.498	0.001
IPI_{m-2}	– 0.081	0.015	– 5.372	0.000
CPI_{m-2}	0.146	0.093	1.570	0.117
$\Delta Tone_{m-1}$	0.036	0.076	0.473	0.636
$\sigma_{ln(OIL)}$	– 3.010	1.727	– 1.743	0.082
σ_{IR}	– 0.584	0.252	– 2.315	0.021
$\sigma_{ln(ER)}$	22.782	7.280	3.129	0.002
σ_{IPI}	– 0.271	0.048	– 5.605	0.000
σ_{CPI}	1.704	0.328	5.199	0.000
R^2=0.55				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report the uncertainty related to macro variables. The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

the oil market, exchange rates and industrial production, and the tone of the central banks' communication. At a 10% significance level, the set reduces for households to oil and industrial production. However, Sargant's test of overrestrictions suggests that the instruments used are invalid. Therefore, in a further step of the research, we return to the static panel specifications.

The results of rationality tests confirm past studies' findings as presented by Łyziak and Mackiewicz-Łyziak (2014) and Szyszko et al. (2020) for small open economies from the European region. Non-rationality of expectations not only allows for further examination but also provides implications for central banks. If economic agents are not rational, central bank macro models should not consider the standard assumption of the new neoclassical synthesis about rationality.

5.2 Forecast error uncertainty

The most important part of this study is verifying the possible relationships between uncertainty connected with selected macroeconomic variables that are used to drive inflation and inflation expectations and, thus, could influence inflation forecast errors.

We estimated simple fixed effects models for the whole sample and the whole period, taking into account the forecasts formulated by professionals (Tables 8 and 10) and consumers (Tables 9 and 11), as well as the nominal (Tables 8 and 9) and relative forecast errors (Tables 10 and 11).

Table 9 Impact of uncertainty on nominal forecast error—consumers

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.092	0.034	– 2.723	0.007
$ln(OIL)_{m-2}$	0.016	0.011	1.503	0.134
IR_{m-2}	0.101	0.073	1.380	0.169
IPI_{m-2}	– 0.082	0.014	– 5.756	0.000
CPI_{m-2}	0.627	0.088	7.154	0.000
$\Delta Tone_{m-1}$	0.029	0.071	0.405	0.686
$\sigma_{ln(OIL)}$	– 0.600	1.590	– 0.377	0.706
σ_{IR}	– 0.580	0.237	– 2.446	0.015
$\sigma_{ln(ER)}$	– 1.341	6.771	– 0.198	0.843
σ_{IPI}	– 0.274	0.047	– 5.845	0.000
σ_{CPI}	1.155	0.306	3.775	0.000
$R^2 = 0.58$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report uncertainty related to macro variables. The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 10 Impact of uncertainty on relative forecast error—professional forecasters

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.019	0.008	– 2.483	0.013
$ln(OIL)_{m-2}$	0.268	0.131	2.052	0.041
IR_{m-2}	– 0.017	0.017	– 0.981	0.327
IPI_{m-2}	– 0.009	0.003	– 2.741	0.006
CPI_{m-2}	0.084	0.020	4.165	0.000
$\Delta Tone_{m-1}$	– 0.020	0.016	– 1.234	0.218
$\sigma_{ln(OIL)}$	– 1.583	0.373	– 4.246	0.000
σ_{IR}	0.019	0.054	0.343	0.732
$\sigma_{ln(ER)}$	2.915	1.571	1.856	0.064
σ_{IPI}	– 0.028	0.010	– 2.686	0.008
σ_{CPI}	– 0.015	0.071	– 0.206	0.837
$R^2 = 0.33$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel we report the uncertainty related to macro variables. The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 11 Uncertainty and relative forecast error—consumers

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.006	0.007	– 0.850	0.396
$ln(OIL)_{m-2}$	0.162	0.111	1.452	0.147
IR_{m-2}	– 0.101	0.014	– 7.111	0.000
IPI_{m-2}	– 0.013	0.003	– 4.517	0.000
CPI_{m-2}	0.305	0.017	17.984	0.000
$\Delta Tone_{m-1}$	– 0.003	0.014	– 0.232	0.817
$\sigma_{ln(OIL)}$	– 1.136	0.316	– 3.596	0.000
σ_{IR}	– 0.035	0.046	– 0.760	0.448
$\sigma_{ln(ER)}$	– 7.992	1.319	– 6.062	0.000
σ_{IPI}	– 0.013	0.009	– 1.469	0.143
σ_{CPI}	– 0.197	0.059	– 3.323	0.001
$R^2 = 0.60$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report the uncertainty related to macro variables. The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 12 Uncertainty and nominal forecast error—professional forecasters, EU

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.121	0.021	– 5.639	0.000
$ln(OIL)_{m-2}$	– 0.365	0.389	– 0.938	0.349
IR_{m-2}	0.426	0.101	4.223	0.000
IPI_{m-2}	– 0.059	0.011	– 5.312	0.000
CPI_{m-2}	0.222	0.057	3.915	0.000
$ln(POLUNC)_{m-2}$	– 0.239	0.273	– 0.876	0.382
$\Delta Tone_{m-1}$	– 0.003	0.044	– 0.063	0.950
$\sigma_{ln(OIL)}$	– 4.695	1.102	– 4.261	0.000
σ_{IR}	– 0.132	0.340	– 0.389	0.698
$\sigma_{ln(ER)}$	41.996	10.562	3.976	0.000
σ_{IPI}	– 0.312	0.037	– 8.420	0.000
σ_{CPI}	0.195	0.253	0.770	0.442
$R^2 = 0.61$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report the uncertainty related to macro variables. The values of oil prices, policy uncertainty (POLUNC) and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 13 Uncertainty and nominal forecast error—consumers, EU

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.128	0.022	– 5.912	0.000
$ln(OIL)_{m-2}$	– 0.753	0.404	– 1.866	0.064
IR_{m-2}	0.463	0.105	4.422	0.000
IPI_{m-2}	– 0.047	0.012	– 3.864	0.000
CPI_{m-2}	0.641	0.058	11.127	0.000
$ln(POLUNC)_{m-2}$	– 0.157	0.275	– 0.570	0.570
$\Delta Tone_{m-1}$	– 0.005	0.045	– 0.120	0.905
$\sigma_{ln(OIL)}$	– 0.978	1.125	– 0.869	0.386
σ_{IR}	0.506	0.380	1.332	0.184
$\sigma_{ln(ER)}$	57.440	11.358	5.057	0.000
σ_{IPI}	– 0.396	0.043	– 9.124	0.000
σ_{CPI}	0.032	0.256	0.126	0.900
$R^2 = 0.67$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we repot the uncertainty related to macro variables. The values of oil prices, policy uncertainty (POLUNC) and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 14 Uncertainty and relative forecast error—professional forecasters, EU

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.040	0.010	– 3.918	0.000
$ln(OIL)_{m-2}$	– 0.004	0.183	– 0.023	0.982
IR_{m-2}	0.130	0.047	2.727	0.007
IPI_{m-2}	– 0.008	0.005	– 1.464	0.145
CPI_{m-2}	0.121	0.027	4.522	0.000
$ln(POLUNC)_{m-2}$	0.138	0.129	1.073	0.285
$\Delta Tone_{m-1}$	0.002	0.021	0.087	0.931
$\sigma_{ln(OIL)}$	– 2.121	0.519	– 4.086	0.000
σ_{IR}	– 0.196	0.160	– 1.223	0.223
$\sigma_{ln(ER)}$	13.053	4.976	2.623	0.009
σ_{IPI}	– 0.032	0.017	– 1.832	0.068
σ_{CPI}	0.006	0.119	0.050	0.960
$R^2 = 0.33$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report the uncertainty related to macro variables. The values of oil prices, policy uncertainty (POLUNC) and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 15 Uncertainty and relative forecast error—consumers, EU

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{t-2}$	– 0.039	0.008	– 5.062	0.000
$ln(OIL)_{m-2}$	– 0.202	0.145	– 1.390	0.166
IR_{m-2}	0.151	0.038	4.033	0.000
IPI_{m-2}	– 0.007	0.004	– 1.512	0.132
CPI_{m-2}	0.435	0.021	21.029	0.000
$ln(POLUNC)_{m-2}$	0.112	0.099	1.139	0.256
$\Delta Tone_{m-1}$	0.023	0.016	1.444	0.150
$\sigma_{ln(OIL)}$	– 1.983	0.404	– 4.910	0.000
σ_{IR}	– 0.436	0.136	– 3.200	0.002
$\sigma_{ln(ER)}$	2.755	4.077	0.676	0.500
σ_{IPI}	– 0.008	0.016	– 0.543	0.588
σ_{CPI}	– 0.370	0.092	– 4.025	0.000
$R^2 = 0.80$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report the uncertainty related to macro variables. The values of oil prices, policy uncertainty (POLUNC) and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 16 Uncertainty and nominal forecast error—professional forecasters, non-EU

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.075	0.079	– 0.950	0.344
$ln(OIL)_{m-2}$	2.306	1.280	1.802	0.074
IR_{m-2}	0.075	0.159	0.469	0.640
IPI_{m-2}	– 0.083	0.029	– 2.891	0.004
CPI_{m-2}	0.198	0.211	0.935	0.351
$\Delta Tone_{m-1}$	0.081	0.168	0.485	0.628
$\sigma_{ln(OIL)}$	– 0.017	3.708	– 0.004	0.996
σ_{IR}	– 1.346	0.493	– 2.731	0.007
$\sigma_{ln(ER)}$	19.215	12.624	1.522	0.130
σ_{IPI}	– 0.214	0.092	– 2.311	0.022
σ_{CPI}	2.857	0.679	4.208	0.000
$R^2 = 0.57$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report the uncertainty related to macro variables. The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 17 Uncertainty and nominal forecast error—consumers, non-EU

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{t-2}$	– 0.059	0.071	– 0.833	0.406
$ln(OIL)_{m-2}$	1.665	1.150	1.448	0.150
IR_{m-2}	– 0.143	0.143	– 1.000	0.319
IPI_{m-2}	– 0.088	0.026	– 3.425	0.001
CPI_{m-2}	0.757	0.190	3.976	0.000
$\Delta Tone_{m-1}$	0.050	0.150	0.329	0.742
$\sigma_{ln(OIL)}$	– 0.725	3.319	– 0.218	0.827
σ_{IR}	– 1.158	0.441	– 2.626	0.009
$\sigma_{ln(ER)}$	– 8.524	11.348	– 0.751	0.454
σ_{IPI}	– 0.245	0.083	– 2.953	0.004
σ_{CPI}	2.061	0.608	3.392	0.001
$R^2 = 0.61$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report the uncertainty related to macro variables. The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 18 Uncertainty and relative forecast error—professional forecasts, non-EU

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{t-2}$	– 0.005	0.012	– 0.437	0.663
$ln(OIL)_{m-2}$	0.552	0.200	2.766	0.006
IR_{m-2}	– 0.030	0.025	– 1.221	0.224
IPI_{m-2}	– 0.007	0.004	– 1.591	0.114
CPI_{m-2}	0.072	0.033	2.200	0.029
$\Delta Tone_{m-1}$	– 0.033	0.026	– 1.248	0.214
$\sigma_{ln(OIL)}$	– 1.618	0.578	– 2.799	0.006
σ_{IR}	0.056	0.077	0.734	0.464
$\sigma_{ln(ER)}$	2.312	1.968	1.175	0.242
σ_{IPI}	– 0.030	0.014	– 2.114	0.036
σ_{CPI}	– 0.013	0.106	– 0.119	0.905
$R^2 = 0.43$				

In this table, we present the estimates of the fixed-effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report the uncertainty related to macro variables. The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 19 Uncertainty and relative forecast error—consumers, non-EU

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.002	0.007	– 0.225	0.822
$ln(OIL)_{m-2}$	0.152	0.115	1.326	0.187
IR_{m-2}	– 0.057	0.014	– 4.005	0.000
IPI_{m-2}	– 0.006	0.003	– 2.193	0.030
CPI_{m-2}	0.132	0.019	6.941	0.000
$\Delta Tone_{m-1}$	– 0.003	0.015	– 0.233	0.816
$\sigma_{ln(OIL)}$	– 0.724	0.331	– 2.190	0.030
σ_{IR}	– 0.090	0.044	– 2.055	0.042
$\sigma_{ln(ER)}$	– 1.392	1.130	– 1.231	0.220
σ_{IPI}	– 0.014	0.008	– 1.738	0.084
σ_{CPI}	0.096	0.061	1.587	0.115
$R^2 = 0.55$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report the uncertainty related to macro variables. The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 20 Uncertainty and nominal forecast error—professional forecasters, Turkey excluded

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.091	0.018	– 4.978	0.000
$ln(OIL)_{m-2}$	0.485	0.303	1.600	0.111
IR_{m-2}	0.389	0.081	4.769	0.000
IPI_{m-2}	– 0.039	0.008	– 4.945	0.000
CPI_{m-2}	0.210	0.053	3.957	0.000
$\Delta Tone_{m-1}$	0.022	0.038	0.564	0.573
$\sigma_{ln(OIL)}$	– 5.252	0.884	– 5.941	0.000
σ_{IR}	– 0.917	0.272	– 3.374	0.001
$\sigma_{ln(ER)}$	26.057	8.071	3.229	0.001
σ_{IPI}	– 0.141	0.024	– 5.939	0.000
σ_{CPI}	– 0.239	0.238	– 1.004	0.316
$R^2 = 0.54$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we present the uncertainty related to macro variables. The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 21 Uncertainty and nominal forecast error—consumers, Turkey excluded

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.081	0.019	– 4.313	0.000
$ln(OIL)_{m-2}$	0.353	0.318	1.112	0.267
IR_{m-2}	0.417	0.087	4.798	0.000
IPI_{m-2}	– 0.041	0.008	– 4.895	0.000
CPI_{m-2}	0.614	0.055	11.126	0.000
$\Delta Tone_{m-1}$	0.004	0.040	0.111	0.912
$\sigma_{ln(OIL)}$	– 1.945	0.930	– 2.092	0.037
σ_{IR}	– 0.830	0.293	– 2.830	0.005
$\sigma_{ln(ER)}$	28.981	8.366	3.464	0.001
σ_{IPI}	– 0.165	0.026	– 6.387	0.000
σ_{CPI}	– 0.260	0.246	– 1.059	0.290
$R^2 = 0.57$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report the uncertainty related to macro variables. The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 22 Uncertainty and relative forecast error—professional forecasters, Turkey excluded

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.029	0.009	– 3.404	0.001
$ln(OIL)_{m-2}$	0.206	0.143	1.448	0.148
IR_{m-2}	0.057	0.038	1.484	0.139
IPI_{m-2}	– 0.009	0.004	– 2.327	0.021
CPI_{m-2}	0.125	0.025	4.983	0.000
$\Delta Tone_{m-1}$	– 0.022	0.018	– 1.211	0.227
$\sigma_{ln(OIL)}$	– 1.763	0.416	– 4.236	0.000
σ_{IR}	– 0.388	0.128	– 3.036	0.003
$\sigma_{ln(ER)}$	12.426	3.799	3.271	0.001
σ_{IPI}	– 0.029	0.011	– 2.642	0.009
σ_{CPI}	– 0.156	0.112	– 1.395	0.164
$R^2 = 0.35$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report the uncertainty related to macro variables. The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

Table 23 Uncertainty and relative forecast error—consumers, Turkey excluded

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.026	0.006	– 4.498	0.000
$ln(OIL)_{m-2}$	– 0.098	0.097	– 1.006	0.315
IR_{m-2}	0.062	0.027	2.327	0.021
IPI_{m-2}	– 0.011	0.003	– 4.231	0.000
CPI_{m-2}	0.412	0.017	24.452	0.000
$\Delta Tone_{m-1}$	0.004	0.012	0.331	0.741
$\sigma_{ln(OIL)}$	– 1.185	0.284	– 4.174	0.000
σ_{IR}	– 0.304	0.089	– 3.397	0.001
$\sigma_{ln(ER)}$	– 0.552	2.553	– 0.216	0.829
σ_{IPI}	– 0.027	0.008	– 3.406	0.001
σ_{CPI}	– 0.382	0.075	– 5.086	0.000
$R^2 = 0.77$				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report the uncertainty related to macro variables. The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

We consider full sample estimation as our benchmark model and the remaining specifications as the robustness checks. Additional estimations are run for EU member states, non-EU economies, and all countries except Turkey for nominal and relative errors, consumers and professionals.

In Tables 12, 13, 14 and 15, we present the results of the estimations obtained for the EU economies. Tables 16, 17, 18 and 19 report estimates for non-EU economies. Ultimately, we verified the effect of removing Turkey from the analysis. The results for nominal errors are presented in Tables 20 and 21, the results for relative errors appear in Tables 22 and 23. We decided to run additional estimations with Turkey excluded because the Turkish economy diverged from the rest of our sample regarding inflation rates and nominal errors as presented in Fig. 1.

Finally, as a robustness check, we verify the stability of the results by changing the uncertainty measure in our benchmark model (full sample). Instead of calculating standard deviation based on yearly observations, we use only 6 months' history. We present the results in Tables 24 and 25. We find the shortening of the uncertainty proxy justified for two reasons. First, it is linked to functioning in turbulent times. When volatility increases, economic agents focus more on the most recent information. Second, consumers' ability to keep in mind and process more extended time series is constrained.

When interpreting the results of estimations, we refer to the statistical significance of parameters (p values) and their estimates as presented in all relevant tables. Due to the number of estimations provided, we avoid a detailed description of numbers.

First, we note that results for nominal and relative errors are different but not contradictory. We believe more in the explanatory power and meaningfulness of the

Table 24 Impact of uncertainty measured with 6-month standard deviation on *nominal* forecast error—professional forecasters versus consumers

	Estimate	Std. Error	t-value	Pr(> |t|)
Professional forecasters:				
$Tone_{m-2}$	– 0.120	0.037	– 3.264	0.001
$ln(OIL)_{m-2}$	2.742	0.555	4.942	0.000
IR_{m-2}	0.419	0.082	5.088	0.000
IPI_{m-2}	– 0.059	0.016	– 3.728	0.000
lag(CPI, 2:2)	0.111	0.088	1.255	0.210
$lag(diff(ABG1, 1), 2:2)$	0.027	0.078	0.350	0.726
$\sigma_{ln(OIL)}$	1.284	1.420	0.904	0.367
σ_{IR}	– 0.512	0.298	– 1.720	0.086
$\sigma_{ln(ER)}$	17.103	9.005	1.899	0.058
σ_{IPI}	– 0.100	0.045	– 2.200	0.028
σ_{CPI}	1.700	0.323	5.266	0.000
R2=0.52				
Consumers:				
$Tone_{m-2}$	– 0.103	0.035	– 2.953	0.003
lag(oil, 2:2)	0.048	0.010	4.826	0.000
IR_{m-2}	0.236	0.078	3.008	0.003
IPI_{m-2}	– 0.060	0.015	– 4.014	0.000
lag(cpi, 2:2)	0.472	0.084	5.617	0.000
lag(diff(ABG1, 1), 2:2)	– 0.003	0.074	– 0.044	0.965
$\sigma_{ln(OIL)}$	2.051	1.341	1.530	0.127
σ_{IR}	– 0.631	0.281	– 2.241	0.026
$\sigma_{ln(ER)}$	– 4.475	8.481	– 0.528	0.598
σ_{IPI}	– 0.054	0.045	– 1.199	0.231
σ_{CPI}	1.346	0.305	4.414	0.000
R^2=0.54				

In this table, we present the estimates of the fixed effects panel model. In the upper panel, we include the lagged levels of the macro variables included in the macroeconomic efficiency and unbiasedness tests, and in the lower panel, we report the uncertainty related to macro variables. The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

results for relative forecasts due to their link to actual inflation. The estimated relative errors yielded an interesting conclusion that professionals use different information than consumers, as suggested by the lower R^2 for all panels (all economies, EU member states, non-EU economies, and all economies except Turkey). The difference between coefficients of determination, when a specification is estimated for consumers and professionals, is remarkable. It suggests that consumers rely more on basic economic variables (captured by our models) than professionals. The conclusion arising from this finding is that consumers and professionals need a different set of information or different information strategies for presenting expectations. Note

Table 25 Impact of uncertainty measured with 6-month standard deviation on *relative* forecast error—professional forecasters versus consumers

	Estimate	Std. Error	t-value	Pr(> |t|)
$Tone_{m-2}$	– 0.023	0.008	– 2.865	0.004
$ln(OIL)_{m-2}$	0.672	0.120	5.621	0.000
IR_{m-2}	0.003	0.018	0.156	0.876
IPI_{m-2}	– 0.004	0.003	– 1.160	0.247
lag(cpi, 2:2)	0.053	0.019	2.787	0.006
$Tone_{m-2}$	– 0.031	0.017	– 1.816	0.070
$ln(OIL)_{m-2}$	– 0.118	0.306	– 0.385	0.701
σ_{IR}	– 0.033	0.064	– 0.520	0.604
$\sigma_{ln(ER)}$	3.222	1.941	1.660	0.098
σ_{IPI}	– 0.009	0.010	– 0.894	0.372
σ_{CPI}	0.087	0.070	1.246	0.213
R2=0.27				
Consumers:				
$Tone_{m-2}$	– 0.009	0.007	– 1.246	0.213
$ln(OIL)_{m-2}$	0.540	0.106	5.075	0.000
IR_{m-2}	– 0.106	0.016	– 6.766	0.000
IPI_{m-2}	– 0.011	0.003	– 3.494	0.001
lag(CPI, 2:2)	0.236	0.017	14.086	0.000
$Tone_{m-2}$	– 0.019	0.015	– 1.248	0.213
$ln(OIL)_{m-2}$	0.177	0.272	0.652	0.515
σ_{IR}	0.145	0.056	2.574	0.010
$\sigma_{ln(ER)}$	– 4.935	1.701	– 2.901	0.004
σ_{IPI}	– 0.015	0.009	– 1.663	0.097
σ_{CPI}	– 0.109	0.061	– 1.775	0.077
R^2=0.53				

In this table, we present the estimates of the fixed effects panel model. In the upper panel we present the results obtained for professional forecasters and in the lower panel, we report those for consumers.The values of oil prices and exchange rates were taken in logarithms to make the magnitudes comparable to the values of the remaining explanatory variables

that despite the non-rationality of both groups of economic agents, as discussed in Sect. 5.1, their errors are significantly different as presented in Table 26.

Second, we note that forecast errors are explained by the level of economic variables and, to a lesser extent, by their volatility. As macroeconomic efficiency tests suggest (specification 7), only the exchange rate data were processed efficiently when presenting an inflation forecast. Naturally, forecast accuracy depends on the set of variables and, additionally, on their variability. This study focuses on the uncertainty effects on forecast accuracy, even if, to maintain econometric soundness, we retain levels in our models. Thus, while interpreting the results, we focus more on uncertainty. Note that from a CB's perspective, communicating the economic

Table 26 Bootstrapped *p* values of the test for the equality of means of the absolute errors

	Nominal	Relative
Albania	< 0.001	0.085
Czechia	< 0.001	< 0.001
Hungary	< 0.001	< 0.001
Poland	0.004	0.055
Romania	< 0.001	< 0.001
Serbia	0.004	0.334
Turkey	0.003	0.016

In this table, we present the bootstrapped p values of the paired t test for equality of absolute values of error means. We do not assume equality of means; hence, the Welch modification to the degrees of freedom is used. A *p* value smaller than 0.05 denotes that we reject the null hypothesis of the equality of means and accept the alternative— that the absolute value of consumers' forecast error is greater than that of professionals

situation (levels) is easier and more meaningful for non-specialists than discussing uncertainty (volatility).

Third, the most surprising result suggested by our analysis is that an increase in economic volatility within a year preceding the forecast translates into more accurate forecasts. The direction of the relationship does not confirm our assumption of greater forecast accuracy in a stable economic environment. It could be noted that in most cases, the estimates of parameters for statistically significant uncertainty proxies are negative; see Tables 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22 and 23. This conclusion holds for most of the studied cases and variables, except the effect of exchange rate uncertainty. Previous studies suggest that as macroeconomic uncertainty complicates forecasting tasks, forecasters devote more time and effort to collecting and processing macro data before the forecast is made (Hope and Tony, 2005). This assumption confirms the standard approach presented by near-rationality theories of expectation formation—economic agents change the effort they devote to forecasting whether inflation is higher and more volatile. As agents face the costs of acquiring, absorbing and processing information, they might rationally choose only sporadically to update their information. Between updating data sets, they remain inattentive (Mankiw and Reis, 2002). Increased volatility could trigger them to update and thus could be reflected in more accurate forecasts. Although greater adaptiveness of professionals—who are more experienced and trained in processing economic news—is not particularly puzzling, the negative relationship between consumer expectations and macroeconomic efficiency is more surprising. However, bounded-rationality theories also explain, in terms of more accurate information processing during turbulent times, consumer behavior (Reis, 2006).

Fourth, the exchange rate is the only exception regarding the negative association between forecast errors and uncertainty. In most cases, when exchange rate variability is statistically significant as the driver of forecast errors, the coefficient is positive. This result is puzzling in the sense that bounded rationality theories allow for more accurate forecasting during more turbulent times. However, if the fact that all studied economies represent small open economies with inflation targeting as a monetary policy regime, we could assume that economic agents update news on exchange rates regularly and consistently use this single variable to forecast inflation. A positive association (a starting point assumption for all variables) holds if this explanation holds. Two factors can support this interpretation. First, it is relatively easy to find exchange rate data. Second, in small open economies, including emerging economies, exchange rate evolution constitutes the important transmission channel for inflation as presented by Ca'Zorzi et al. (2007) and a more recent study by Cheikh and Zaied (2020). Evidence for Czechia suggests pass-through also for inflation expectations (Nasir et al., 2020). The exchange rate effect for inflation is more visible in economies implementing fully fledged inflation targeting when inflation expectations are considered a transition variable (Anderl and Caporale, 2023), which is the case of our sample.

Fifth, in many models, there is a positive relationship between the volatility of inflation rates and inflation expectation errors. In the basic models presented in Tables 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18 and 19, this relationship is positive and statistically significant in as many as six specifications (p values not greater than 0.053 and in many cases equal to 0.000). Only in two models estimated for the relative error does the volatility of inflation rates turn out to be statistically insignificant (in the case of professionals) or statistically significant but negative (for consumers). The relationship between the standard deviation of past inflation rates and inflation expectation errors is also positive in most models estimated in the sensitivity analysis. This result is in line with our initial assumption that the volatility of inflation rates negatively affects the accuracy of forecasts. In countries and periods in which the inflation rate fluctuated substantially in the near past, consumers and professionals found it difficult to make correct forecasts and exhibited greater errors in expectations. This is because when inflation rates fluctuated widely in the past, similar volatility was likely to be seen in many other macroeconomic variables. As a result, the economy did not follow a stable development path, which makes the future very difficult to predict. This is particularly the case for large fluctuations in inflation rates, as they can change substantially in any direction in the future, which increases the potential variance of errors, while in a country where inflation is regularly close to zero, it is rather difficult to expect and forecast its decrease.

Sixth, there is a positive relationship between the level of inflation and forecast errors. In basic models, this relationship is positive and statistically significant with a p value lower than 0.001 in three specifications; in one specification, it is also positive but insignificant (p value equals 0.117). These results are economically justified. A higher inflation rate means a more turbulent economic environment, making predicting inflation more challenging. In the case of nominal errors, a high inflation rate also means high inflation expectations and higher nominal errors. However, this relationship is also statistically significant for relative errors. At first glance, this result may be caused by the unusual behavior of Turkey, in which high errors in expectations resulted, among other things, from the exceptionally high levels of inflation recorded in that country. However, the robustness analysis shows that this relationship is also true for the EU countries. When considering the tables presenting the results of model estimations for EU economies, we find that in all four specifications, the relationship between the lagged level of inflation and the forecast error is positive and statistically significant. That means that it is difficult to predict inflation in countries with a high degree of internal imbalance. This conclusion can be extended to the entire economy. Suppose that macroeconomic performance is weak and a large internal and external disequilibrium characterizes the country. In that case, it is difficult to predict not only inflation rates but also, for example, the economic growth rate, budget deficit or the unemployment rate.

Seventh, excluding Turkey from our sample increases the number of variables whose volatility matters for forecast accuracy. This is because, among other factors, Turkey behaved differently from the other groups of countries in terms of the behavior of inflation forecast errors. In Turkey, they were higher than in other countries. They followed a different path regarding the amplitude of fluctuations and the distribution of peaks and troughs. As a result, the inclusion of Turkey decreased the statistical reliability of the model. Excluding Turkey improved the statistical fit of the estimated models while keeping unchanged, in most cases, the direction of the relationship between the explanatory variables and the dependent variable.

Eighth, in none of our specifications was central bank communication tone change between two periods a statistically significant variable explaining forecast errors, even if the tone expressed in levels was significant for some of the specifications. Tone change is negligible for professionals' and consumers' errors even if there are papers suggesting that there is a relationship between communication tone and expectations (see, e.g., Baranowski et al. (2021) and Szyszko et al. (2022)). However, this does not occur when volatility and errors are considered. This finding could be interpreted in two ways. First, it could suggest that economic agents adequately interpret policy communication change. However, the research period of this study is characterized by relatively stable monetary policy —with inflation kept within the target level and a few interest rate adjustments[4]— and the central bank communication change could not constitute the main driver when presenting expectations. The takeaway for central bankers is that their communication does not contribute to expectation errors.

Ninth, as an additional uncertainty factor, we include the logarithmic values of the policy uncertainty index when models are estimated for EU member states. We observe that the index was insignificant in all specifications, despite that the EPU index was demonstrated to be professional inflation expectations driver by Istrefi and Piloiu (2014) or the driver of forecast errors when professionals forecasted earnings (Chourou et al., 2021). The lack of statistical significance of this indicator results from several reasons. First, and probably most important, this indicator was calculated based on data from only a few Western European countries, which are not covered by this analysis. Including this variable in the regression model, we assumed that the instability in Western European countries is analogous to that observed in the new EU member states. Of course, this assumption need not be accurate. This

[4] This does not hold for Turkey. Nevertheless, in most economies discussed, monetary policy was conducted under standard settings, successfully keeping the inflation target bands.

is perhaps the most important reason for obtaining the insignificance of the EPU variable. Events such as Brexit, riots in France, the migration crisis in Italy and the resulting political disputes do not necessarily mean upheavals on the political scene in countries such as Poland or Hungary. While in economic terms, cyclical convergence occurs, which is confirmed by many empirical studies and could also be explained based on economic theory, this does not have to be the case in politics. At least this is how we interpret it in light of the results obtained. The political situation in Western Europe turned out not to have a substantial impact on inflation forecasts made by professionals and consumers in the countries of Central and Eastern Europe. Another reason for the lack of statistical significance of the EPU variable may be its construction. This indicator is based on searching for specific keywords in the press, which can often lead to an article being identified as about political uncertainty when the article is about something completely different. This can happen because the same words in different contexts can have different meanings. It is also essential to consider that the search is limited to a select few journals, which comprise a small proportion of the press, and that articles may be politically oriented and represent the point of view of the journal's editors or the author of the text.

Tenth, when comparing the results with the shorter proxy for uncertainty considered (6-month standard deviation), we observed only one difference for the volatility effect for nominal error estimations. If only recent uncertainty of industrial production is considered, it does not affect consumer errors. In the case of relative error, more factors lose their statistical significance. The most surprising is the loss of statistical significance of the oil price volatility for both households and professionals.

5.3 Results summary and implications

Ultimately, the results of this study should be discussed in the economic context, providing a general conclusion for consumers and professionals and central banks. Both perspectives are interrelated.

Discussing forecast errors and their drivers when consumers are involved requires reference to their economic (il)literacy. Households are the least qualified group of economic agents. They exhibit limited ability to process economic news and present close to rational or even forward-looking expectations (Gerberding, 2001; Łyziak, 2014). As a recent study conducted on the US suggests, their ability to present consistent (point and density) inflation forecasts is linked with higher levels of income, education, and financial literacy Zhao (2022). We expect that these factors also matter for consumers from our sample. Recent papers suggest that cognitive abilities (arithmetic, verbal, and visuospatial) and psychological characteristics affect perception and forecasting abilities (D'Acunto et al., 2019; Abildgren and Kuchler, 2021). Factors underlying expectation formation are far beyond the control of monetary authorities. Only systemic changes, such as creating an educational system that strengthens economic literacy, could be a long-run remedy.

In the short run, more direct communication with the general public is needed. If central banks apply jargon to non-specialists, the understanding of the evolution of expectation-formation drivers could be limited. Central banks, as senders of complicated economic news, have more room to manoeuvre than the recipients—consumers considered as a group.

Central banks from our sample have constantly been modifying both toward greater transparency and communication directed more toward the general public than professionals. Such strategies could be effective, as presented in previous studies by Binder (2017) and Ehrmann and Wabitsch (2022) even if households are less educated economic agents. Nonetheless, the issue of optimal communication strategy to steer expectations during turbulent times needs further investigation. Modifying communication policies toward consumers is a must because consumer expectations better represent the price-setting patterns for the economy than specialists, as found by Coibion and Gorodnichenko (2015). They also generate demand-driven economic output when deciding about their spending. Professional expectations also constitute a driving force for economic development. Professional forecasters hold managerial positions in many financial institutions and corporations. They co-create financial and pricing decisions of large market players. Inaccurate forecasts of professionals also have implications for economic output. However, note that the study presents a comparative context, and when comparing the power of consumer and professional expectations to affect the aggregate output, household expectations are more powerful.

When the monetary policy perspective is considered, the conclusions and implications for central banks are as follows. The occurrence of systemic expectation errors, as identified by rationality tests, complicate the conduct of monetary policy, question the credibility of the central bank and affect economic output. From the central bank perspective, the most desirable situation concerns inflation expectations anchored to the inflation target, which means that they are not reacting to inflation shocks. We did not discuss expectation anchoring in this study. However, we can directly refer to the desired patterns of expectation formation. If systemic errors occur, managing inflation expectations is constrained. In the case of the economies discussed here, inflation was mostly overshot as presented in Appendix.[5] This situation might create an additional challenge for monetary policy conduct in the era of increasing inflation. Moreover, as presented in recent papers, inflation expectations can translate into higher consumption through household balance sheet channels (Lieb and Schuffels, 2022) even if the distribution of consumption between durable and non-durable goods (not reacting to elevated inflation expectations) is not equal Burke and Ozdagli (2023). As the results of this study suggest, the expectation errors are driven not only by macro variables but also by their volatility. This complicates the issue of steering private forecasts because it adds uncertainty to the set of variables that are beyond the central bank's control. It is much easier to present negative consequences for monetary policy conduct if forecast accuracy is limited and driven by volatility than to present a remedy.

[5] Professional forecasters from Albania were the only group of economic agents that, on average, undershot inflation.

6 Conclusions

In this study, we identified factors affecting inflation forecast error by professionals and consumers from seven economies that adopted the inflation targeting strategy: Albania, Czechia, Hungary, Poland, Romania, Serbia, and Turkey. The period covered includes the period 2016–2020. The analysis has an empirical nature. We verified whether a stable past evolution of an economy facilitated formulating accurate inflation forecasts. Our results can be summarized as follows:

- inflation forecast errors are explained by the level of economic variables and, to a lesser extent, by their volatility;
- the exchange rate was the most important variable, the volatility of which positively affected inflation forecast errors;
- in many cases, there was a positive relationship between the inflation rate and its volatility and inflation expectation errors;
- a central bank communication tone change between two periods was a statistically significant variable explaining forecast errors, even if the tone expressed in levels was significant in some models; and
- the Economic Policy Uncertainty Index was an insignificant determinant of inflation forecast errors.

This study indicates that the room for analyzing determinants of inflation forecast errors remains open. We shed some light on the factors affecting errors made by consumers and professionals in forecasting inflation rates. However, the analysis shows that the variables included only partially explain the behavior of inflation forecast errors. Room for further studies exists.

The novelty of our research is threefold. First, we directly linked inflation forecast errors to the uncertainty of economic variables. Greater economic volatility affects forecast errors. Second, we rejected economic policy uncertainty and communication tone change as drivers of inflation forecast errors. The contribution of this paper consists in the first attempt to incorporate factors beyond the standard macro variables, such as economic policy uncertainty and policy tone, in error analysis. This extension of control variables was in line with the effect of these variables on expectations. However, this effect does not extend to forecast errors. Third, we extended the perspective of studies for post-transition economies instead of focusing on word-leading central banks, opening the discussion on individual country-level dependencies.

The results are significant for decision-makers—here, consumers and professionals. A good understanding of factors affecting their forecasting errors might increase forecast accuracy and thus support decision-making. Expected inflation is a significant factor considered when making saving and investment decisions, for price-setting (as under a market economy, households' own production factors) and wage bargaining.

The relevance of this study for policy-makers involves presenting factors that need to be communicated in a way that enables better processing of economic news.

The perspective of central banks is interlaced with the perspective of individual economic agents. According to theoretical frameworks of monetary policy, expectations are a driving force of inflation and aggregate output. As mentioned above, central banks might optimize their communication tools. However, their ability to steer economic situations, including uncertainty, is limited.

Takeaways from this study can be summarized as follows. First, the existence of systemic errors of expectations driven, i.a., by the volatility of macro variables, in the past is unfavourable for central bankers. It reduces the effectiveness of monetary policy and challenges central banks' communication strategies. Central banks' ability to shape economic conditions is limited, and the transmission of policy measures is lagged. Global shocks, such as oil price shocks, are beyond the central bank's control. Consistent institutional solutions provided by inflation targeting frameworks, including transparency and communication, could be helpful but do not offer the ultimate solution. Second, as consumers' and professionals' decisions are driven by their expectations, inaccurate forecasts could translate into suboptimal economic decisions. Overshooting inflation creates additional inflation pressure because it can translate into higher prices and wages. Third, there is no simple remedy for reducing forecast errors. Each economy provides numerous releases daily. How they are assimilated and processed by different groups of economic agents is not fully recognized.

Appendix A: Statistical properties of forecast errors

See Tables 27 and 28.

Table 27 Statistical properties of nominal forecast errors

	Mean	Std	Min	Max	KPSS p-val	PP p-val
Albania—professionals	0.480	0.629	– 1.725	1.573	0.097	0.728
Albania—consumers	– 1.237	0.546	– 2.785	0.065	0.100	0.614
Czechia—professionals	– 0.617	0.798	– 3.173	0.679	0.100	0.845
Czechia—consumers	– 0.905	1.000	– 2.856	1.329	0.076	0.656
Hungary—professionals	– 0.780	1.098	– 4.450	1.018	0.100	0.791
Hungary—consumers	– 1.482	1.206	– 4.961	0.984	0.100	0.741
Poland—professionals	– 0.742	1.389	– 5.551	1.631	0.010	0.981
Poland—consumers	– 1.437	1.060	– 4.090	0.843	0.100	0.596
Romania—professionals	– 0.460	1.416	– 4.159	1.671	0.100	0.977
Romania—consumers	– 1.020	1.885	– 4.481	1.795	0.010	0.616
Serbia—professionals	– 0.094	1.640	– 5.982	1.967	0.061	0.990
Serbia—consumers	– 1.332	1.693	– 6.797	1.265	0.100	0.990
Turkey—professionals	– 3.602	6.413	– 23.456	10.374	0.100	0.929
Turkey—consumers	– 6.100	5.925	– 26.982	6.583	0.100	0.941

The null hypothesis in the KPSS and PP test is that the time series is stationary

Table 28 Statistical properties of relative forecast errors

	Mean	Std	Min	Max	KPSS p-val	PP p-val
Albania—professionals	0.398	0.583	– 0.464	3.655	0.100	0.010
Albania—consumers	– 0.659	0.177	– 0.958	0.161	0.100	0.010
Czechia—professionals	– 0.178	0.264	– 0.588	0.424	0.100	0.584
Czechia—consumers	– 0.316	0.381	– 0.978	0.492	0.015	0.504
Hungary—professionals	– 0.178	0.247	– 0.601	0.463	0.100	0.417
Hungary—consumers	– 0.437	0.352	– 1.081	0.447	0.010	0.473
Poland—professionals	– 0.049	0.675	– 0.784	2.718	0.100	0.367
Poland—consumers	– 0.521	0.517	– 1.432	1.405	0.097	0.393
Romania—professionals	– 0.053	0.473	– 1.584	0.976	0.080	0.146
Romania—consumers	– 0.601	1.187	– 3.949	0.997	0.010	0.263
Serbia—professionals	0.208	0.558	– 0.757	1.967	0.100	0.256
Serbia—consumers	– 0.371	0.441	– 0.932	1.265	0.100	0.233
Turkey—professionals	– 0.159	0.402	– 0.658	1.206	0.100	0.717
Turkey—consumers	– 0.357	0.330	– 0.747	0.621	0.092	0.776

The null hypothesis in the KPSS and PP test is that the time series is stationary

Acknowledgements The authors would like to thank the participants of the 4th Warsaw Money-Macro-Finance Conference and 43rd EBES Conference, Madrid for the discussion on the early version of this research.

Funding This paper includes the results of the research project funded by the National Science Center, Poland, no. 2018/31/B/HS4/00164.

Data availability The data that support the findings of this study (consumer expectations and tone estimations) are available from the corresponding author, [M.P.], upon reasonable request. Professional expectations data that support the findings of this study are Consensus Economics data. Restrictions apply to the availability of these data, which were used under license for this study. Macrodata used for this study are derrived from publicly available collections of the IMF and Eurostat.

Declarations

Conflict of interest The authors have not disclosed any competing interests.

References

Abildgren, K., & Kuchler, A. (2021). Revisiting the inflation perception conundrum. *Journal of Macroeconomics*. https://doi.org/10.1016/j.jmacro.2020.103264

Algaba, A., Ardia, D., Bluteau, K., Borms, S., & Boudt, K. (2021). Econometrics meets sentiment: An overview of methodology and applications. *Journal of Economic Surveys, 34*(3), 512–547.

Amiram, D., Landsman, W. R., Owens, E. L., & Stubben, S. R. (2018). How are analysts' forecasts affected by high uncertainty? *Journal of Business Finances & Accounting, 45*, 295–318. https://doi.org/10.1111/jbfa.12270

Anderl, C., & Caporale, G. M. (2023). Nonlinearities in the exchange rate pass-through: The role of inflation expectations. *International Economics, 173*, 86–101. https://doi.org/10.1016/j.inteco.2022.10.003

Apel, M., & Grimaldi, M. B. (2014). How informative are central bank minutes? *Review of Economics, 65*(1), 53–76.

Apergis, N. (2017). New evidence on the ability of asset prices and real economic activity forecast errors to predict inflation forecast errors. *Journal of Forecasting, 36*(5), 557–565. https://doi.org/10.1002/for.2453

Baker, S. R., Bloom, N., & Davis, S. J. (2016). Measuring economic policy uncertainty. *The Quarterly Journal of Economics, 131*(4), 1593–1636. https://academic.oup.com/qje/article-pdf/131/4/1593/30636768/qjw024.pdf. https://doi.org/10.1093/qje/qjw024

Balcilar, M., Gupta, R., & Segnon, M. (2016). The role of economic policy uncertainty in predicting us recessions: A mixed-frequency Markov-switching vector autoregressive approach. *Economics, 10*(27), 1–20. https://doi.org/10.5018/economics-ejournal.ja.2016-27

Baranowski, P., Bennani, H., & Doryń, W. (2021). Do the ECB's introductory statements help predict monetary policy? Evidence from a tone analysis. *European Journal of Political Economy, 66*, 101964. https://doi.org/10.1016/j.ejpoleco.2020.101964

Baranowski, P., Doryń, W., Łyziak, T., & Stanisławska, E. (2021). Words and deeds in managing expectations: Empirical evidence on an inflation targeting economy. *Economic Modelling, 95*, 49–67. https://doi.org/10.1016/j.econmod.2020.12.003

Batchelor, R. A., & Orr, A. B. (1988). Inflation expectations revisited. *Economica, 55*(219), 317. https://doi.org/10.2307/2554010

Bec, F., & De Gaye, A. (2016). How do oil price forecast errors impact inflation forecast errors? An empirical analysis from US, French and UK inflation forecasts. *Economic Modelling, 53*, 75–88. https://doi.org/10.1016/j.econmod.2015.11.008

Bekiros, S., & Paccagnini, A. (2015). Estimating point and density forecasts for the us economy with a factor-augmented vector autoregressive dsge model. *Studies in Nonlinear Dynamics & Econometrics, 19*(2), 107–136. https://doi.org/10.1515/snde-2013-0061

Bennani, H., & Neuenkirch, M. (2017). The (home) bias of European central bankers: New evidence based on speeches. *Applied Economics, 49*(11), 1114–1131. https://doi.org/10.1080/00036846.2016.1210782

Berge, T. J. (2018). Understanding survey-based inflation expectations. *International Journal of Forecasting, 34*(4), 788–801. https://doi.org/10.1016/j.ijforecast.2018.07.003

Binder, C. (2017). Fed speak on main street: Central bank communication and household expectations. *Journal of Macroeconomics, 52*, 238–251. https://doi.org/10.1016/j.jmacro.2017.05.003

Binder, C., McElroy, T. S., & Sheng, X. S. (2022). The term structure of uncertainty: New evidence from survey expectations. *Journal of Money, Credit and Banking, 54*(1), 39–71. https://doi.org/10.1111/jmcb.12811

Biswas, R. (2019). Does economic policy uncertainty affect analyst forecast accuracy? *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3407668

Burke, M. A., & Ozdagli, A. (2023). Household inflation expectations and consumer spending: Evidence from panel data. *The Review of Economics and Statistics*. https://doi.org/10.1162/rest_a_01118

Carlson, J. A., & Parkin, M. (1975). Inflation expectations. *Economica, 42*(166), 123–38.

Castillo, P., Montoro, C., & Tuesta, V. (2020). Inflation, oil price volatility and monetary policy. *Journal of Macroeconomics, 66*, 103259. https://doi.org/10.1016/j.jmacro.2020.103259

Ca'Zorzi, M., Hahn, E., S'anchez, M. (2007). Exchange rate pass-through in emerging markets. Working Paper Series 739, European Central Bank. https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp739.pdf

Chahine, S., Daher, M., & Saade, S. (2021). Doing good in periods of high uncertainty: Economic policy uncertainty, corporate social responsibility, and analyst forecast error. *Journal of Financial Stability, 56*, 100919. https://doi.org/10.1016/j.jfs.2021.100919

Cheikh, N. B., & Zaied, Y. B. (2020). Revisiting the pass-through of exchange rate in the transition economies: New evidence from new EU member states. *Journal of International Money and Finance, 100*, 102093. https://doi.org/10.1016/j.jimonfin.2019.102093

Chourou, L., Purda, L., & Saadi, S. (2021). Economic policy uncertainty and analysts' forecast characteristics. *Journal of Accounting and Public Policy, 40*, 106775. https://doi.org/10.1016/j.jaccpubpol.2020.106775

Coibion, O., Gorodnichenko, Y. (2015). Is the Phillips curve alive and well after all? Inflation expectations and the missing disinflation. *American Economic Journal: Macroeconomics, 7*, 197–232. http://www.jstor.org/stable/43189954

Coibion, O., Gorodnichenko, Y., & Weber, M. (2022). Monetary policy communications and their effects on household inflation expectations. *Journal of Political Economy, 130*, 49–67.

Commission, E. (2016). *The Joint Harmonised EU Programme of Business and Consumer Survey. User Guide. Technical Report*. European Commission, Directorate-General for Economic and Financial Affairs.

Croissant, Y., & Millo, G. (2008). Panel data econometrics in R: The plm package. *Journal of Statistical Software, 27*(2), 1–43. https://doi.org/10.18637/jss.v027.i02

D'Acunto, F., Hoang, D., Paloviita, M., Weber, M. (2019). *Cognitive Abilities and Inflation Expectations*. AEA Papers and Proceedings, 562–566. https://doi.org/10.1257/pandp.20191050

Dellas, H., Gibson, H. D., Hall, S. G., & Tavlas, G. S. (2018). The macroeconomic and fiscal implications of inflation forecast errors. *Journal of Economic Dynamics and Control, 93*, 203–217. https://doi.org/10.1016/j.jedc.2018.01.030. Monetary and Fiscal Policy Stabilization amid a Debt Crisis.

Dovern, J., Fritsche, U., & Slacalek, J. (2012). Disagreement among forecasters in G7 countries. *The Review of Economics and Statistics, 94*(4), 1081–1096.

Ehrmann, M., Eijffinger, S., & Fratzscher, M. (2012). The role of central bank transparency for guiding private sector forecasts. *The Scandinavian Journal of Economics*. https://doi.org/10.1111/j.1467-9442.2012.01706.x

Ehrmann, M., & Wabitsch, A. (2022). Central bank communication with non-experts—A road to nowhere? *Journal of Monetary Economics, 127*, 69–85. https://doi.org/10.1016/j.jmoneco.2022.02.003

European Uncertainty Index: Methodology (2023). https://www.policyuncertainty.com/methodology.html

Gali, J. (2008). *Monetary Policy, Inflation, and the Business Cycle, an Introduction to the New Keynesian Framework*. Princeton: Princeton University Press.

Gamber, E. N., Liebner, J. P., & Smith, J. K. (2015). The distribution of inflation forecast errors. *Journal of Policy Modeling, 37*(1), 47–64. https://doi.org/10.1016/j.jpolmod.2015.01.002

Geraats, P.M. (2014). Monetary Policy Transparency. CESifo Working Paper Series **4611**

Gerberding, C. (2001). The information content of survey data on expected price development for monetary policy. Deutsche Bundesbank Discussion Paper **9**

Glas, A., & Drechsel, K. (2021). Conditional macroeconomic forecasts: Disagreement, revisions and forecast errors. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3861829

Grabowski, W., & Stawasz-Grabowska, E. (2021). How have the European central bank's monetary policies been affecting financial markets in CEE-3 countries? *Eurasian Economic Review, 11*, 43–83. https://doi.org/10.1007/s40822-020-00160-3

Gülşen, E., & Kara, H. (2019). Measuring inflation uncertainty in turkey. *Central Bank Review, 19*(2), 33–43. https://doi.org/10.1016/j.cbrev.2019.06.003

Hansen, S., & McMahon, M. (2016). Shocking language: Understanding the macroeconomic effects of central bank communication. *Journal of International Economics, 99*, 114–133. https://doi.org/10.1016/j.jinteco.2015.12.008

Holden, K., & Peel, D. A. (1990). On testing for unbiasedness and efficiency of forecasts. *The Manchester School, 58*(2), 120–127. https://doi.org/10.1111/j.1467-9957.1990.tb00413.x

Hope, O.-H., & Tony, K. (2005). The association between macroeconomic uncertainty and analysts' forecast accuracy. *Journal of International Accounting Research, 4*, 23–38. https://doi.org/10.2308/jiar.2005.4.1.23
Hubert, P. (2015). Do central bank forecasts influence private agents forecasting performance vs. signals? *Journal of Money, Credit and Banking, 4*(47), 771–789. https://doi.org/10.1111/jmcb.12227
Hubert, P. (2015). The influence and policy signaling role of FOMC forecasts. *Oxford Bulletin of Economics and Statistics, 5*(75), 655–680. https://doi.org/10.1111/obes.12093
Index, E.U. (2023). Europe Monthly Index. https://www.policyuncertainty.com/europe_monthly.html
Istrefi, K., & Piloiu, A. (2014). Economic policy uncertainty and inflation expectations. Banque de France Document de Travail
Kim, I., & Kim, Y. S. (2019). Inattentive agents and inflation forecast error dynamics: A Bayesian DSGE approach. *Journal of Macroeconomics, 62*, 103139. https://doi.org/10.1016/j.jmacro.2019.103139
Lieb, L., & Schuffels, J. (2022). Inflation expectations and consumer spending: The role of household balance sheets. *Empirical Economics, 63*, 2479–2512. https://doi.org/10.1162/rest_a_01118
Long, J.A. (2020). Panelr: Regression Models and Utilities for Repeated Measures and Panel Data. R package version 0.7.3. https://cran.r-project.org/package=panelr
Łyziak, T. (2014). Inflation expectations in Poland, 2001–2013. Measurement and macroeconomic testing. *NBP Working Paper, 178*, 1–36. https://doi.org/10.2139/ssrn.2646519
Łyziak, T. (2013). Formation of inflation expectations by different economic agents. *Eastern European Economics, 51*, 5–33. https://doi.org/10.2753/EEE0012-8775510601
Łyziak, T., & Mackiewicz-Łyziak, J. (2014). Do consumers in Europe anticipate future inflation? Has it changed since the beginning of the financial crisis. *Eastern European Economics, 52*, 5–32. https://doi.org/10.2753/EEE0012-8775520301
Mankiw, N. G., & Reis, R. (2002). Sticky information versus sticky prices: A proposal to replace the New Keynesian Phillips Curve. *The Quarterly Journal of Economics, 17*, 1295–1328. https://doi.org/10.1162/003355302320935034
Minot, N. (2014). Food price volatility in sub-Saharan Africa: Has it really increased? *Food Policy, 45*, 45–56. https://doi.org/10.1016/j.foodpol.2013.12.008
Mital, P., Goetschalckx, M., & Huang, E. (2015). Robust material handling system design with standard deviation, variance and downside risk as risk measures. *International Journal of Production Economics, 170*, 815–824. https://doi.org/10.1016/j.ijpe.2015.02.003
Nasir, M. A., Huynh, T. L. D., & Vo, X. V. (2020). Exchange rate pass-through & management of inflation expectations in a small open inflation targeting economy. *International Review of Economics & Finance, 69*, 178–188. https://doi.org/10.1016/j.iref.2020.04.010
Nolte, I., Nolte, S., & Pohlmeier, W. (2019). What determines forecasters' forecasting errors? *International Journal of Forecasting, 35*(1), 11–24. https://doi.org/10.1016/j.ijforecast.2018.07.007. Special Section: Supply Chain Forecasting.
Picault, M., & Renault, T. (2017). Words are not all created equal: A new measure of ECB communication. *Journal of International Money and Finance, 79*, 136–156. https://doi.org/10.1016/j.jimonfin.2017.09.005
Pierdzioch, C., Gupta, R. (2017). Uncertainty and forecasts of U.S. recessions. Working Papers, University of Pretoria, Department of Economics. https://doi.org/10.5018/economics-ejournal.ja.2016-27.
Reif, M. (2021). Macroeconomic uncertainty and forecasting macroeconomic aggregates. *Studies in Nonlinear Dynamics & Econometrics Journal of Business & Economic Statistics, 25*(2), 20190073. https://doi.org/10.1515/snde-2019-0073
Reis, R. (2006). Inattentive consumers. *Journal of Monetary Economics, 56*, 1295–1328. https://doi.org/10.1016/j.jmoneco.2006.03.001
Segnon, M., Gupta, R., Bekiros, S., & Wohar, M.E. (2018). Forecasting US GNP growth: The role of uncertainty. *Journal of Forecasting, 37*(5), 541–559. https://doi.org/10.1002/for.2517
Szyszko, M., Rutkowska, A., & Kliber, A. (2020). Inflation expectations after financial crisis: Are consumers more forward-looking? *Economic Research-Ekonomska Istraživanja, 33*, 1052–1072. https://doi.org/10.1080/1331677X.2019.1595083
Szyszko, M., Rutkowska, A., & Kliber, A. (2022). Do words affect expectations? The effect of central banks communication on consumer inflation expectations. *Quarterly Review of Economics and Finance, 86*, 221–229. https://doi.org/10.1016/j.qref.2022.07.009
Szyszko, M., Rutkowska, A., & Pietrzak, M. (2020). When all we have is not enough: A search for the optimal method of quantifying inflation expectations. *Economic Research-Ekonomska Istraživanja, 36*(1), 977–996. https://doi.org/10.1080/1331677X.2022.2081231

Wander, B. H., & D'Vari, R. (2003). The limitations of standard deviation as a measure of bond portfolio risk. *The Journal of Wealth Management, 6*(3), 35–38. https://doi.org/10.3905/jwm.2003.320488

Woodford, M. (2003). *Interest and Prices. Foundations of a Theory of Monetary Policy*. Princeton University Press.

Woodford, M. (2013). Macroeconomic analysis without the rational expectations hypothesis. *Annual Review of Economics, 5*(1), 303–346. https://doi.org/10.1146/annurev-economics-080511-110857

Zhao, Y. (2022). Internal consistency of household inflation expectations: Point forecasts vs. density forecasts. *International Journal of Forecasting*. https://doi.org/10.1016/j.ijforecast.2022.08.008

Authors and Affiliations

Agata Kliber[1] · Magdalena Szyszko[2] · Mariusz Próchniak[3] · Aleksandra Rutkowska[1]

✉ Mariusz Próchniak
mproch@sgh.waw.pl

Agata Kliber
agata.kliber@ue.poznan.pl

Magdalena Szyszko
magdalena.szyszko@poznan.merito.pl

Aleksandra Rutkowska
aleksandra.rutkowska@ue.poznan.pl

1 Poznan University of Economics and Business, Al. Niepodleglosci 10, 61-875 Poznan, Poland

2 WSB Merito University Poznan, Powstancow Wielkopolskich 5, 61-895 Poznan, Poland

3 SGH Warsaw School of Economics, Al. Niepodległosci 162, 02-554 Warsaw, Poland