# MASTER

MONETARY AND FINANCIAL ECONOMICS

# MASTER´S FINAL WORK

DISSERTATION

CENTRAL BANKS FORECASTING ERRORS

GONÇALO ANTÓNIO FERNANDES CUSTÓDIO

JULY - 2025

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**SUPERVISION:**

**PROF. ANDRÉ MANUEL VENTURA SOARES TEIXEIRA**

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## Glossary

BCI – Composite Business Confidence Index

BoE – Bank of England

CCI – Composite Consumer Confidence Index

CPI – Consumer Price Index

EA – Euro Area

ECB – European Central Bank

FED – Federal Reserve Bank

FOMC – Federal Open Market Committee

FRED – Federal Reserve Bank of St. Louis Economic Data

GDP – Gross Domestic Product

HICP – Harmonized Index of Consumer Prices

IMF – International Monetary Fund

PCE – Personal Consumption Expenditure

OECD – Organisation for Economic Co-operation and Development

VIX – Chicago Board Options Exchange Volatility Index

VSTOXX – EURO STOXX 50 Volatility Index

US – United States of America

UK – United Kingdom

YOY – Year-on-Year

**AI Disclaimer**

This dissertation was developed with strict adherence to the academic integrity policies and guidelines set forth by ISEG, Universidade de Lisboa. The work presented herein is the result of my own research, analysis, and writing, unless otherwise cited. In the interest of transparency, I provide the following disclosure regarding the use of artificial intelligence (AI) tools in the creation of this dissertation:

I disclose that AI tools were employed during the development of this thesis as follows:

AI-based research tools were used to assist in the literature review and data collection.

AI-powered software was utilized for data analysis and visualization.

Generative AI tools were consulted for brainstorming and outlining purposes. However, all final writing, synthesis, and critical analysis are my own work. Instances where AI contributions were significant are clearly cited and acknowledged.

Nonetheless, I have ensured that the use of AI tools did not compromise the originality and integrity of my work. All sources of information, whether traditional or AI-assisted, have been appropriately cited in accordance with academic standards. The ethical use of AI in research and writing has been a guiding principle throughout the preparation of this thesis.

I understand the importance of maintaining academic integrity and take full responsibility for the content and originality of this work.

Gonçalo Custódio, July 31st, 2025

For my godmother, Isabel,
whose love and kindness
towards others will be
remembered with warmth.

## Abstract

This dissertation offers novel insights into the persistent shortcomings of inflation forecasts made by central banks, addressing both the underlying causes and the broader implications of these errors. Using panel data analysis for the United States, the United Kingdom, and the Euro Area as a whole during 1998-2024, we employ random effects regressions to estimate the effects of uncertainty, economic information, and central bank independence on forecast errors. Results show that higher uncertainty and faster oil price inflation consistently led to underpredictions of future inflation by central bank forecasts. Robustness checks using alternative measures of uncertainty confirm the robustness of our findings.

KEYWORDS: Inflation expectations; Forecast errors; Uncertainty; Central Banks' Communication;

*JEL* CODES: E47; E52; E58; D81; D83; D84

# Sumário Executivo

Esta dissertação contribui para a bibliografia académica existente sobre as previsões dos bancos centrais, nomeadamente sobre os erros persistentes das mesmas em relação aos valores de inflação a médio prazo. Para tal, recorre-se a uma análise de dados em painel para os Estados Unidos, o Reino Unido e para a Área do Euro como um todo, compreendendo o período entre 1998 e 2024, utilizando regressões com efeitos aleatórios e erros padrão robustos para estimar os efeitos da incerteza, da informação económica e da independência dos bancos centrais nos erros de previsão. Os resultados demonstram que níveis mais elevados de incerteza, bem como uma aceleração na inflação do preço do petróleo, conduzem a subestimações da inflação futura nas previsões dos bancos centrais. Os testes de robustez realizados confirmam a estabilidade das principais conclusões, ainda que a significância estatística de alguns fatores se altere.

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## Acknowledgments

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# CENTRAL BANKS FORECASTING ERRORS

By Gonçalo Custódio

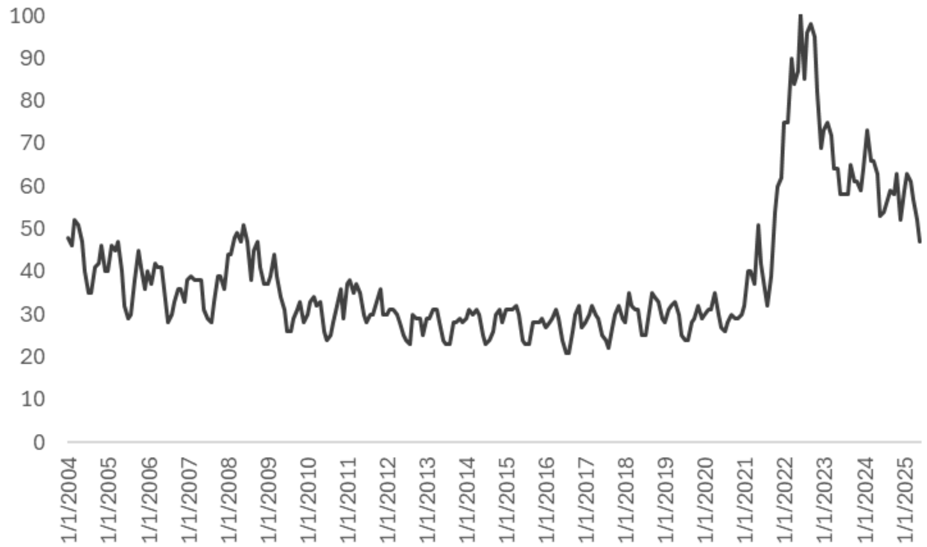
Abstract: This dissertation offers novel insights into the persistent shortcomings of inflation forecasts made by central banks, addressing both the underlying causes and the broader implications of these errors. Using panel data analysis for the United States, the United Kingdom, and the Euro Area as a whole during 1998-2024, we employ random effects regressions to estimate the effects of uncertainty, economic information, and central bank independence on forecast errors. Results show that higher uncertainty and faster oil price inflation consistently led to underpredictions of future inflation by central bank forecasts. Robustness checks using alternative measures of uncertainty confirm the robustness of our findings.

## 1. Introduction

Economies around the world have experienced high inflation following the end of COVID-19 restrictions on economic and social activities as well as the outbreak of the war in Ukraine, which has drawn attention to the decisions made by governments and central banks. At the same time, the subject of inflation has received increased media and academic attention (see figure 1 below). More attention has been paid to inflation and, in turn, to the forecasts produced by central banks following the surge in consumer prices in late 2021, when compared to the long period of low consumer price inflation in the preceding decade.

The impact of inflation on the economy is complex and can be seen from different perspectives. The increase in price levels directly affects the value of money, resulting in erosion of purchasing power, a consequence particularly significant for low- and middle-income households, who spend a higher share of their income on goods than their higher income counterparts – Engel's law. Inflation also erodes the returns of savings and lowers the cost of borrowing by influencing real interest rates – a higher inflation rate results in a larger difference between nominal and real interest rates. On another note, one which is more relevant for this dissertation, inflation and inflation expectations are also closely related. The longer inflation remains high, the more responsive expectations can be following recent price movements, such that a temporary surge in prices can lead to longer-term increases in expectations (Cagan, 1956).

Figure 1: Evolution of search engine queries for "Inflation" worldwide




Source: Google Trends. Share of search queries for the term "inflation" relative to total search queries – normalized values. Last observation: June 2025.

There is also growing awareness that unconventional monetary policy measures, such as forward guidance, play a crucial role in stabilizing inflation expectations to bring about price stability (Bernanke, 2010). By providing information about future interest rate decisions, often supported by the release of the central bank's economic forecasts, forward guidance also becomes a crucial tool to enhance monetary stimulus when conventional policy levers are exhausted, especially when a persistent shock to the natural interest rate causes economies to hit the zero lower bound (Eggertsson and Woodford, 2003).

There is abundant literature in which a clear impact of communication from central banks on financial markets can be established, for example, on exchange rates or interest rates, see Andersson *et al.* (2001) and Reeves *et al.* (2005), respectively. Lamla (2006) relates central bank communication regarding current inflation trends with policy rate expectations. This reflects the significant attention that central bank disclosures usually receive, with every word and every nuance meticulously analysed for assessing the monetary policy outlook, thus complementing monetary policy outlook models based on the Taylor rule (Heinemann and Ullrich, 2007).

Looking at the history of forecasts made by the European Central Bank (ECB) as well as other major central banks, such as the Federal Reserve (FED), the errors show persistent overprediction, or underprediction, during periods of low/high inflation, respectively. The forecasts tend to start close to 2% and are subsequently revised as new economic data becomes available. A key danger of these mistakes lies in the risk of credibility loss as a consequence of a higher public perception that central banks misjudge economic conditions, especially if their projections diverge sharply from those of other forecasters. During periods of relatively high inflation rates, the media coverage of the European Central Bank (ECB) policy turns more negative (Berger, 2006). The wider picture would be the loss of effectiveness of forward guidance, resulting in lower influence over longer-term inflation expectations, and in turn, over long-term interest rates, asset prices, and exchange rates, without forgetting, as mentioned already, the role of expectations in determining wages and future prices (Ullrich, 2008).

This dissertation offers novel insights into the persistent shortcomings of medium-term inflation forecasts by central banks, addressing both the underlying causes and the broader implications of these errors. It begins by analysing the conditions under which forecast errors occur – particularly the role of heightened uncertainty – and then examines the bias of these errors. We also offer insights on how central bank independence impacts forecast errors and investigate the implicit role of monetary policy goals on forecast errors, wherein some literature suggests that central banks may deliberately project lower (or higher) inflation when actual rates exceed (or fall below) targets, in an attempt to steer expectations.

The remainder of the dissertation is organized as follows. Section 2 reviews the relevant literature. Section 3 describes the data sources and the empirical approach we follow in our analysis. Section 4 reports and discusses the reached results. Finally, section 5 provides our conclusions and policy implications.

## 2. Literature Review

This section compiles a selection of methodologies and conclusions from relevant literature which has, in many ways, contributed to a better understanding of inflation expectations and their respective inaccuracies, whether produced by the private sector or by central banks, in particular, about the most commonly explored explanatory variables relevant to study forecast errors. Furthermore, this work also identifies and summarizes literature on error biases, and possible implications, which leads to the discussion about the existence, or not, of strategic motives by the central banks when publishing projections and possible consequences with regard to their public credibility.

The literature on inflation forecast errors often focuses on the roles of macroeconomic news. Coibion and Gorodnichenko (2015) found that the attention to new, lagged macroeconomic data (inflation, Treasury Bill interest rates, quarterly unemployment rate, and quarterly changes in real oil prices) and consequently, the scale of forecast revisions, increased during period of heightened volatility, as well as during recessions or in the aftermath of highly visible shocks (e.g. terror attacks such as the attack on World Trade Centre in 2001). In this line of thought, Reis et al. (2003) found substantial evidence across multiple surveys of forecasters that inflation expectations reflect partially and incompletely macroeconomic data updates (such as inflation, Treasury Bill interest rates, and unemployment rate) not at every instant, but rather in a staggered way. Lee (1994) carried out an analysis of the inflation expectations of the nine subsectors of manufacturing identified by the Confederation of British Industry survey. Lee's work found that the forecast errors could be explained by the lagged data of output prices, cost increases, wage costs, the fluctuations in exchange rates, GDP growth, the growth rate of money, and the aggregate unemployment rate.

Literature on central banks' forecast errors is not as widely available as it is for private sector expectations; however, it has been the focus of more recent research, often highlighting the relation these errors have with inaccuracies in conditioning technical assumptions. Darvas (2018) observed that between 2013 and 2018, much of the ECB's projections overestimated future inflation, while at the same time over- and underestimating unemployment and output, respectively, which suggested inaccuracies in the assumed relationship between growth, employment, and inflation. Lambrias and Page (2019) identified, for example, that sharp fluctuations in oil prices, which in the ECB Staff Macroeconomic Projection are assumed to follow oil price futures, have significantly influenced forecast errors for headline inflation but also for core inflation measures, due to indirect effects on non-energy consumer goods and services. Similarly, exchange rate variations contribute to forecasting discrepancies, as exemplified by the euro's depreciation in 2014-15, which counterbalanced the anticipated downward impact of lower oil prices on inflation in 2015. Commodity and import prices are also typically considered in the ECB staff macroeconomic projections as a proxy for the international effects on Euro Area prices. Lambrias and Page (2019) also highlighted the role of unaccounted-for factors that may be influencing forecast errors, such as, for example, increased model inconsistencies between inflation and labour market data resulting from structural reforms in some Euro Area countries.

The present work also analyses the tendencies and biases of the forecast errors. Economic literature on inflation expectations usually explores whether empirical estimates are consistent with rational expectations, with the primary implication being that rational expectations are efficient. More specifically, rational expectations imply (statistically) efficient forecasts with no correlation between errors. Therefore, the presence of bias rejects the rationality of expectations. Reis *et al.* (2003) observed that forecast errors were slightly biased and predictive of future errors, despite their results not being consistent with neither the rational nor the adaptive expectations models but were instead more aligned with models with information rigidities – in which expectations are updated in a staggered way. Reis's findings were broadly in line with those of the overall literature; see, for example, Coibion and Gorodnichenko's (2015), Croushore (2006), Andolfatto *et al.* (2008). If central banks' forecast models function similarly to those of private agents, e.g. professional forecasters, then their errors should be aligned. Lambrias and Page (2019) compared errors in ECB staff macroeconomic projections with those of professional forecasters and other public institutions (European Commission, IMF, and OECD) and observed similar accuracies and similar biases (slightly negative or overestimated).

Indeed, ECB's inflation projections for the Harmonized Index of Consumer Prices (HICP), excluding energy and food, have exhibited a persistent negative bias (i.e., overprediction) between 2013 and 2017, a period characterized by persistently low inflation. While these errors are of a lower magnitude compared to more volatile components, their consistency indicates underlying challenges in forecasting models. This pattern extends to headline inflation, which was systematically over-predicted between 2014 and 2016, against a backdrop of lower oil prices. Additionally, substantial underpredictions occurred in 2010-11 and 2017-18 due to unexpected increases in oil prices. Although actual inflation aligned with forecasts post-2017, Darvas (2018) argues that this was the product of two incorrect assumptions, which worked in favour of the ECB's forecasts. First, the assumption of rising core inflation, which did not happen, and second, the central bank's expected stable energy prices, which instead rose rapidly.

There are similar empirical findings related to the economic projections of the Federal Open Market Committee (FOMC). It has been documented that initial forecasts, typically three years ahead, tend to start close to 2% and are subsequently revised following the release of new economic data, in particular the monthly inflation readings. Between 2012 and 2020, a period marked by low inflation in the American economy, forecasts were persistently revised downwards following an initial projection close to the 2% level, while inflation forecasts were always revised higher for the period between 2021 and 2023, characterized by high inflation rates. Thus, the FED's forecast errors revealed a negative bias when inflation was below the 2% target (overestimation) and a positive bias when inflation was above the target (Abdelrahman et al., 2024).

On the other hand, recent research has proposed an alternative explanation: that central banks are taking advantage of their influence in managing private sector expectations to not only reduce the level of uncertainty in the public information set, but also to strategically influence expectations by intentionally over or underreporting the projected level of inflation; see, for example, Ahrens *et al.* (2023), Barrero and Polania (2014), Charemza and Ladley (2016), and Jensen (2024). Ahrens *et al.* took an experimental approach to test the aforementioned hypothesis and whether such expectations management can be used as an instrument to stabilize inflation and output in both normal and extreme economic conditions. Results confirmed that, under a laboratory setting, strategic inflation forecasts strongly affect private sector expectations, reflecting a prioritization of public information over private information by the subjects. Consequently, the forecast distribution showed a lower dispersion. Additionally, the central banks' strategic projections also helped accelerate the recovery of output and inflation towards the target levels set by the central bank, and significantly reduced the likelihood of deflationary spirals during extreme recessions. Jensen's analysis suggests that policymakers have incentives to use economic projections strategically, potentially misleading the public or deviating from prior forecasts even without deceptive intent. As a result, such projections warrant scepticism. Empirical evidence from between 2008 and 2019 revealed statistically significant discrepancies between the FOMC projections and those of professional forecasters for inflation and GDP growth, undermining the idea that such forecasts effectively anchor public expectations. Jensen's theoretical models highlight that even accurate projections can lead to unfavourable outcomes by revealing policymakers' preferences or prompting misinterpretation, potentially eroding public trust and diminishing policy effectiveness. Barrero and Polania's theoretical model predicts that for short- and long-term forecasts, central banks don't have strong incentives to influence expectations; in the short-term, publishing biased forecasts would imply higher reputational costs, as agents' expectations have already been formed, which would make it very difficult manipulate; in the long-term, the central bank lacks sufficient information about future shocks. However, the model predicts strong incentives for the central bank to misrepresent information in medium-term forecasts, even if it means incurring some reputational costs; considering a medium-term horizon, central banks have more information about the state of the economy at the end of the horizon, and medium-term private expectations are more malleable. The authors confirmed their theoretical intuition with empirical evidence for six central banks, namely Brazil, Canada, England, Iceland, New Zealand, and Sweden.

Publishing persistently biased forecasts, intentionally or not, may help stabilize price expectations when inflation deviates from the central bank's inflation target, but it may be doing so at the cost of its credibility among the public. Is credibility, or reputation, related to the central bank's capacity to manage private sector expectations?

The credibility hypothesis, that is, a more credible bank can reduce inflation at a lower cost, is supported by the conventional expectational Phillips curve; in theory, perfectly credible policy announcements will reduce inflation expectations abruptly, enabling inflation to decline without the necessity of higher unemployment (i.e., lower cost on social welfare). Blinder (1999) found that a majority of a sample of 84 surveyed central bankers strongly believed both in the credibility hypothesis and that credibility helps keep inflation low. Furthermore, central bankers largely attributed credibility to independence, transparency, track record of honest communication and inflation targeting. According to the work of Ahrens *et al.,* credibility depends on the past performance of inflation projections, and it influences the central bank's ability to stabilize expectations amid deflationary pressures, as their results showed that central bank projections were more likely to be adopted in the future if they were accurate in the past. As Jensen (2024) also highlighted, inaccurate projections, particularly if less accurate than private forecasters, could deteriorate the public credibility in the central bank's understanding of the economy, which could push expectations into worse outcomes. However, empirical evidence has shown mixed interpretations in this regard; in Sweden, Norway, New Zealand, and Czechia, inflation expectations remained anchored between 2006 and 2013, despite successive deviations between stated policy projections and interest rate decisions (Filardo and Hofmann, 2014). On the other hand, market-based long-term inflation expectations, such as the 5-year average inflation expected in 5 years decreased to 1.6% in 2018, from roughly 2.5% in 2004 (Darvas, 2018). Subsequent research on public trust concerning the ECB showed a negative correlation between trust and both inflation expectations and uncertainty about future inflation; additionally, higher trust in the ECB resulted in a stronger convergence of expectations with the target (Christelis *et al.,* 2015). Research on Canadian inflation expectations found that Bank of Canada inflation targets introduced in 1991 were credible and helped anchor inflation expectations within the target range.

In conclusion, and considering the literature reviewed, our model follows a similar design to that found in literature, for example in Reis *et al.* (2003) and Kliber *et al.* (2023), i.e., forecast errors are regressed against macroeconomic variables and a proxy for uncertainty. In this work, we also include Romelli's (2022) central bank independence index variables.

## 3. Data and Methodology

### 3.1. Data

As mentioned earlier, the research questions of this dissertation are centred on the forecast errors of three central banks, namely the FED, the BoE, and the ECB. Thus, the database created for this analysis relies on the quarterly inflation forecasts published by these banks, which were selected due to their comprehensive and extensive time series. The FED began to consistently publish its PCE price index inflation forecasts in 1997; the ECB's HICP forecasts start in 1999, while the BoE's CPI inflation projections began in 2004, resulting in an unbalanced panel. The database was compiled with forecasts[1] made in four different horizons relative to the target quarter: one quarter ahead (T-1), two quarters ahead (T-2), three quarters ahead (T-3), and four quarters ahead (T-4). The inflation measures used for each economy were: 1) the seasonally adjusted, year-over-year (YoY) percent change in the quarterly personal consumption expenditures (PCE) price index (chained) for the US; 2) the YoY percent change in the quarterly consumer price index (CPI) for the UK; 3) the YoY percent change in the quarterly HICP for the Euro area (changing composition). The dependent variable, namely the forecast errors, was computed according to the examples found in the literature, i.e., as the difference between the forecast and the observed inflation for the forecasted period ($E_{t-n}\pi_t - \pi_t$).

The data used for our independent variables can be segmented into three categories: uncertainty proxies, macroeconomic variables, and central bank independence data. Uncertainty is a somewhat ambiguous concept and is measured in various ways in academic literature. For example, Coibion and Gorodnichenko (2015) use changes in business cycles and highly visible external shocks (such as terrorist attacks) as synonyms of uncertainty, while Kliber *et al.* (2023) use instead the 12-month standard deviation of macroeconomic variables. Reis *et al.* (2003), on the other hand, use dispersion of expectations derived from survey answers as a proxy for forward-looking uncertainty. Our work uses VIX and VSTOXX, widely used market-based proxies[2] and two survey-based controls, explained in more detail below.

The VIX and VSTOXX, two market-based volatility indexes, were extracted from the online database of the Federal Reserve Bank of St. Louis (or "FRED") and from STOXX.com, a data provider of the Deutsche Borse Group, respectively; these market-based indexes are derived from real-time equity option prices that reflect current expectations of future volatility in stock prices of the S&P 500, in case of the VIX, and the Euro Stoxx 50 for VSTOXX.

[1] The FED did not publish inflation forecasts for Q1, Q2 and Q3 of each year; to fill in the missing values, we used cubic interpolation ($S_i(x) = a_i + b_i(x - x_i) + c_i(x - x_i)^2 + d_i(x - x_i)^3$). Regarding the BoE's forecasts, the missing projection for Q4 2020 was filled in with the forecast for Q3 2020. For these limitations, and others explained in further detail ahead, the results present in this dissertation should be interpreted with caution.

[2] Baker, S. R., Bloom, N., & Davis, S. J. (2016) mention VIX as the most obvious and important measure of economic uncertainty.

The Composite Business Confidence and Composite Consumer Confidence Indexes were sourced from OECD's Composite Leading Indicators dataset; these indexes tend to reflect both groups' perceived levels of economic uncertainty, and are both backward- and forward-looking.

For the macroeconomic data, we compiled variables commonly used in related literature, for example, in Coibion and Gorodnichenko (2015) and Reis *et al.* (2003), where inflation, short-term interest rates, the unemployment rate and changes in oil prices were shown to influence forecast errors and revisions, explained in more detail below, along with other macroeconomic variables[3].

The inflation rate data we use for our independent variable is the same as the data used to compute the forecast errors in our dependent variables; real GDP growth was sourced from FRED; the unemployment and labor force participation rate was sourced from FRED, the Office for National Statistics and Eurostat; Unit Labor Cost growth rates were extracted from FRED, the ECP data portal and the Office for National Statistics; oil price inflation, measured through the year-on-year growth rate of international Brent oil prices, was retrieved from FRED; lastly, for short-term interest rates we employed the 3-month interbank interest rates, which were sourced from the FRED for the three economies – Reis et al. and Coibion et al. employed the 3-month (or “3M”) Treasury Bill yields, but due to the lack of comparable financial instruments for the Euro Area as a whole, we adopted the interbank rate;

Additionally, to study the relation between forecast errors and central bank independence, two variables compiled by Romelli (2022) were added: the Central Bank Independence Index and a dummy variable that takes the numeric value “1” in periods of central bank reforms and the null value when no reforms take place.

The detailed description of the variables, including the transformations and units used, is presented in Table VII in the Appendices. The descriptive statistics of the variables mentioned above can be seen in the table below.

[3] Exchange rates may also affect the variability of the dependent variable, see Kliber (2023). For simplicity, and given that we analyze three different central banks with their own currencies, we exclude this variable from the models. Note, however, that the VIX and VSTOXX indexes capture financial instability like the exchange rate.

Table I: Descriptive Statistics For The Full Sample (1998-2024)[4]

| Variable | Obs. | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|---|
| ForecastError T-1 | 288 | -0.054 | 0.830 | -6.300 | 3.700 |
| ForecastError T-2 | 288 | -0.092 | 0.992 | -4.333 | 4.019 |
| ForecastError T-3 | 288 | -0.235 | 1.170 | -6.300 | 3.820 |
| ForecastError T-4 | 288 | -0.430 | 1.523 | -8.066 | 4.230 |
| VIX | 288 | 21.333 | 8.101 | 10.310 | 58.600 |
| BCI | 288 | 100.232 | 1.633 | 93.901 | 105.430 |
| CCI | 288 | 99.836 | 1.827 | 92.714 | 102.797 |
| $g_{GDP}$ | 288 | 1.852 | 3.406 | -21.899 | 25.652 |
| U | 288 | 6.845 | 2.357 | 3.500 | 13.000 |
| Inflation | 288 | 2.219 | 1.708 | -1.196 | 9.967 |
| LFPR | 288 | 72.147 | 7.600 | 60.800 | 84.000 |
| $\Delta$ULC | 288 | 1.788 | 2.035 | -5.100 | 9.339 |
| $\Delta$OIL | 288 | 12.556 | 37.458 | -54.249 | 135.232 |
| $i_{3M}$ | 288 | 1.998 | 2.036 | -0.566 | 6.630 |
| CBI | 288 | 0.713 | 0.146 | 0.587 | 0.912 |
| $D_{CBI}$ | 288 | 0.017 | 0.131 | 0 | 1 |

[4] Note: variable definitions are presented in Table VII in the Appendix.

### 3.2. Methodology

This analysis relies on a panel data approach, having both a cross-sectional and a time series dimension. We employ random effects regressions with cluster-robust standard errors. Using panel regressions without addressing the unique, unobserved heterogeneity can lead to biased estimates if those unobserved factors are correlated with the independent variables. In order to decide on the best approach to correct the bias stemming from unobserved heterogeneity, we test whether the unique errors are correlated with the regressors through a Hausman (1978) test. The rejection of the null hypothesis would suggest that the random effects model is inconsistent and that the fixed effects model would be more reliable. The null hypothesis was not rejected in the baseline model nor in the models used as robustness checks (results in tables VIII to XI in the Appendix); however, the p-values obtained were significantly high (p-value of 0.97 for baseline model). In light of these results, the random effects model was preferred.

Our benchmark models regress the forecast errors against the one-period lagged independent variables in equation (1) and, as a first robustness check, against the independent variables without lag in equation (2), as detailed below:

$$ForecastError_{T-n} = \beta_0 + \beta_1 VIX_{T-n-1} + \beta_2 \Omega_{T-n-1} + \beta_3 CBI_{T-n-1} + \beta_4 D_{CBI,T-n-1} + \varepsilon \quad (1)$$

$$ForecastError_{T-n} = \beta_0 + \beta_1 VIX_{T-n} + \beta_2 \Omega_{T-n} + \beta_3 CBI_{T-n} + \beta_4 D_{CBI,T-n} + \varepsilon \quad (2)$$

where *n* represents the number of quarters between the quarter when the forecast was made and the quarter of the value forecasted, and where $\Omega$ represents the set of macroeconomic data (real GDP growth, labor market data, inflation, interest rates and oil prices).

Additionally, in robustness checks, we look at different proxies of uncertainty. The main variable of interest, *VIX*, was replaced by two survey-based proxies, namely, by the Composite Business Confidence Index (*BCI*) in one case, and by the Composite Consumer Confidence Index (*CCI*) in a second test. We further test our results by replacing the unemployment rate (*U*) with the labor force participation rate (*LFPR*).

# 4. Results

## 4.1 Baseline results

The panel regression results for equation (1) are presented in Table II below. Uncertainty, as proxied by the variable *VIX*, has a statistically significant negative effect on the errors of forecasts made in T-3 and T-4. These results imply that when there is an increase of one index point in the VIX or VSTOXX indexes, projections made in T-3 and T-4 would underestimate actual inflation by about 0.03 and 0.06 percentage points, respectively, which is aligned with the empirical results of Kliber *et al.* (2023) for private expectations. The coefficients were also negative for shorter forecast horizons, such as T-2 and T-1, although the model found no statistical significance.

Regarding the set of macroeconomic variables, the coefficients estimated for oil price inflation were all negative and statistically significant across the four projection horizons, which is in line with Coibion and Gorodnichenko (2015), as well as with Kliber *et al* (2023). The magnitude of these coefficients increased with the horizon of projections, implying that an acceleration in oil price inflation causes larger negative errors when projections are made farther in the past. Inflation is seen as having statistically significant coefficients at the 1% level for T-3 and T-4 forecast errors and at the 10% level for T-2, while the coefficient estimated for T-1 did not show statistical significance. The inflation rate positively affects forecast errors, implying that central banks tend to overestimate inflation in the future if they see it increasing in the quarter previous to the forecast date, in line with Coibion and Gorodnichenko (2015). However, Reis *et al.* (2003) find that only one of the four professional forecast surveys used in their work reacts in a similar way, with the data from the other three surveys indicating that private forecasters tend to underreact to recent increases in inflation. With respect to the effect of the 3-month interbank rate on our dependent variable, all coefficients were positive but only for T-4 was it statistically significant, which is aligned with Reis *et al.* (2003), even though the variable was not the same. Both Reis *et al.* (2003) and Coibion *et al.* (2015) used interest rates of 3-month Treasury Bills, with their results showing statistically significant coefficients at the 5% and 1%, while considering T-4 and T-3 forecast horizons. Unemployment is seen as positively impacting forecasting errors across all horizons, which, although in line with Reis *et al.* (2003), fails to have any statistically significant outcome. Last in the macroeconomic variables set, GDP growth negatively impacts our dependent variable consistently across all horizons but is only significant, with 90% confidence, for T-4 forecasts, which implies that forecasters underreact to increases in output growth.

Regarding the variables related to central bank independence, the impact of reforms in central banks is negative and statistically significant with 99% confidence in all but one horizon (T-3), where it is only significant at the 10% level. Meanwhile, the central bank independence index also has a negative coefficient across all horizons but fails to achieve any statistical significance.

So, in conclusion, our baseline results reveal that heightened uncertainty and oil price shocks lead central banks to underpredict future inflation, notably at longer horizons. Conversely, interest rates and inflation contribute to overestimation in forecasts. Lastly, reforms related to central bank independence significantly drive negative forecast errors.

Table II: Random Effects Panel Model Coefficients And Cluster-Robust Standard Errors – One-Period Lagged Independent Variables

| Dependent Variable | Forecast Error | | | |
|---|---|---|---|---|
| Forecast Horizon | T-1 | T-2 | T-3 | T-4 |
| VIX | -0.003 | -0.013 | -0.032*** | -0.055*** |
| | (0.015) | (0.014) | (0.008) | (0.002) |
| gGDP | -0.020 | -0.043 | -0.039 | -0.064* |
| | (0.036) | (0.036) | (0.052) | (0.037) |
| U | 0.102 | 0.082 | 0.100 | 0.152 |
| | (0.098) | (0.133) | (0.193) | (0.225) |
| Inflation | 0.009 | 0.119* | 0.144*** | 0.205*** |
| | (0.121) | (0.067) | (0.043) | (0.057) |
| ΔUCL | 0.015 | 0.007 | 0.022 | -0.020 |
| | (0.049) | (0.047) | (0.092) | (0.099) |
| ΔOIL | -0.003*** | -0.004** | -0.006* | -0.011*** |
| | (0.000) | (0.002) | (0.003) | (0.003) |
| $i_{3M}$ | 0.080 | 0.118 | 0.109 | 0.230*** |
| | (0.069) | (0.075) | (0.119) | (0.103) |
| CBI | -1.823 | -1.219 | -1.183 | -0.776 |
| | (1.119) | (1.365) | (2.136) | (2.432) |
| $D_{CBI}$ | -0.384*** | -0.644*** | -0.875* | -0.916** |
| | (0.106) | (0.240) | (0.524) | (0.405) |
| Constant | 0.481 | 0.116 | 0.169 | -0.355* |
| | (0.364) | (0.263) | (0.189) | (0.189) |
| N | 288 | 288 | 288 | 288 |
| $R^2$ (within) | 0.0779 | 0.1098 | 0.1042 | 0.1761 |

Standard errors in parentheses
*, **, and *** denote significance levels at 10%, 5%, and 1%, respectively

### 4.2 Robustness checks

Robustness checks are important to ensure that our results are not exclusively driven by the specific design of our primary model, especially by the use of one-period lagged independent variables, or by the variables we use to measure uncertainty or labor market dynamics. By replacing VIX, our main proxy for uncertainty, with the BCI and CCI, we make sure results are robust to the way we measure uncertainty. Regarding the labor market variables, the unemployment rate measures the share of people in the total workforce who are jobless and actively seeking work, whereas the labor force participation rate measures the share of employed and unemployed in the total working-age population. By replacing the unemployment rate with the labor force participation rate, we are not only ensuring robustness of our results across different measures of labor market dynamics but also for both across different measures of the working-age population.

The panel regression results for equation (2) are presented in Table III below. The results for our uncertainty proxy remain very similar to the benchmark regression, in particular with respect to the coefficient on the T-4 forecast error, which maintains statistical significance at 1% level. Regarding the macroeconomic variables, the coefficients estimated for oil price inflation also remained little changed and the significance of the results improved in two of the horizons. For inflation, the differences are more significant; although the signal of the coefficients remains positive, the significance is much lower in this variation. Only for T-4 forecast errors do the coefficients remain statistically significant but the confidence interval decreases from 99% to 90%. For the 3-month interbank rate, the results do not change significantly and, while in the baseline, we see statistical significance only for the T-4 coefficient, in this variation, the coefficient for T-2 is also significant. GDP growth coefficients also improve when the lag is removed, with the impact on T-4 forecast errors being statistically significant at the 1% level (vs 10% in the baseline results) and the impact on T-2 forecast errors being statistically significant at the 5% level. The magnitude of the coefficient on T-4 horizon also doubled compared to the baseline results, while keeping the negative signal. Unemployment continues to positively impact forecast errors when the lag is removed, but still fails to have any statistically significant outcome.

Lastly, the statistical significance of the dummy variable related to central bank reforms also improves in the absence of lag in the independent variables vis-à-vis the forecast errors and the magnitude of its negative impact increases. The coefficients for the central bank independence index do not vary materially in terms of magnitude but the confidence interval of the estimator in T-1 to 90%.

As additional robustness checks, the market-based proxies used as a gauge for uncertainty in the benchmark model were replaced by survey-based variables, namely the BCI and the CCI. The results in Table IV show that the effect of uncertainty on forecast errors does not change materially when VIX is replaced by BCI. Its coefficient loses its statistical significance at the T-3 horizon but retains it at the T-4, while its impact also increases in magnitude. However, some of the key findings with regard to the macroeconomic drivers of forecast errors changed. Particularly, the impact of oil price inflation loses its statistical significance for two of the four horizons being studied, while the results related to the 3-month interbank rate, which found a material positive impact on T-4 forecast errors, do not hold in this specification of the model.

Substituting VIX with the CCI yields the results seen in Table V and it confirms the impact of uncertainty on forecast errors at T-3, as well as for shorter horizons, which were not statistically significant in the baseline results, but does not hold for T-4. The statistically significant coefficients found within the baseline results are mostly not significant following the change of the uncertainty proxy, with the exception of oil price inflation and the 3-month interbank rate. In both controls, the significance and signal of the coefficient related to the central banks' reforms do not change.

Table III: Random Effects Panel Model Coefficients And Cluster-Robust Standard Errors – Contemporaneous Independent Variables

| Dependent Variable | Forecast Error | | | |
|---|---|---|---|---|
| Forecast Horizon | T-1 | T-2 | T-3 | T-4 |
| VIX | 0.008 | -0.005 | -0.018 | -0.053*** |
| | (0.013) | (0.018) | (0.014) | (0.003) |
| gGDP | -0.023 | -0.058* | -0.044 | -0.131*** |
| | (0.027) | (0.033) | (0.053) | (0.030) |
| U | 0.080 | 0.081 | 0.108 | 0.117 |
| | (0.075) | (0.113) | (0.164) | (0.212) |
| Inflation | -0.050 | 0.068 | 0.088 | 0.113* |
| | (0.164) | (0.092) | (0.091) | (0.068) |
| ΔUCL | -0.017 | -0.024 | 0.013 | -0.047 |
| | (0.028) | (0.037) | (0.068) | (0.084) |
| ΔOIL | -0.005*** | -0.008*** | -0.009*** | -0.012*** |
| | (0.002) | (0.001) | (0.002) | (0.003) |
| $i_{3M}$ | 0.080 | 0.140** | 0.127 | 0.248** |
| | (0.051) | (0.066) | (0.111) | (0.098) |
| CBI | -1.735* | -1.316 | -1.456 | -0.590 |
| | (1.044) | (1.179) | (1.796) | (2.288) |
| $D_{CBI}$ | -0.713*** | -1.014*** | -1.180*** | -1.197** |
| | (0.071) | (0.099) | -0.353 | (0.506) |
| Constant | 0.577 | 0.229 | 0.175 | 0.051 |
| | (0.438) | (0.356) | (0.272) | (0.103) |
| N | 288 | 288 | 288 | 288 |
| $R^2$ (within) | 0.1811 | 0.1926 | 0.1408 | 0.2454 |

Standard errors in parentheses

*, **, and *** denote significance levels at 10%, 5%, and 1%, respectively

Table IV: Random Effects Panel Model Coefficients And Cluster-Robust Standard Errors – VIX Replaced With BCI

| Dependent Variable | Forecast Error | | | |
|---|---|---|---|---|
| Forecast Horizon | T-1 | T-2 | T-3 | T-4 |
| BCI | -0.074 | -0.065 | 0.021 | -0.162** |
| | (0.085) | (0.075) | (0.114) | (0.064) |
| gGDP | 0.001 | -0.016 | -0.022 | -0.012 |
| | (0.016) | (0.017) | (0.016) | (0.024) |
| U | 0.094 | 0.065 | 0.071 | 0.082 |
| | (0.085) | (0.120) | (0.196) | (0.225) |
| Inflation | 0.011 | 0.114* | 0.121*** | 0.162*** |
| | (0.126) | (0.062) | (0.038) | (0.060) |
| ΔUCL | 0.016 | 0.010 | 0.023 | -0.015 |
| | (0.046) | (0.042) | (0.087) | (0.072) |
| ΔOIL | -0.002*** | -0.003 | -0.005 | -0.008** |
| | (0.001) | (0.002) | (0.004) | (0.003) |
| $i_{3M}$ | 0.059 | 0.092* | 0.090 | 0.135 |
| | (0.055) | (0.056) | (0.078) | (0.112) |
| CBI | -1.787 | -1.212 | -1.274 | -0.835 |
| | (1.209) | (1.468) | (2.286) | (2.576) |
| $D_{CBI}$ | -0.578*** | -0.876*** | -1.002 | -1.243** |
| | (0.189) | -0.262 | (0.615) | (0.515) |
| Constant | 7.846 | 6.422 | -2.264 | 15.386** |
| | (8.327) | (7.363) | (11.087) | (6.950) |
| N | 288 | 288 | 288 | 288 |
| $R^2$ (within) | 0.093 | 0.1076 | 0.0703 | 0.1393 |

Standard errors in parentheses

*, **, and *** denote significance levels at 10%, 5%, and 1%, respectively

Table V: Random Effects Panel Model Coefficients And Cluster-Robust Standard Errors – VIX Replaced With CCI

| Dependent Variable | Forecast Error | | | |
|---|---|---|---|---|
| Forecast Horizon | T-1 | T-2 | T-3 | T-4 |
| CCI | -0.175*** | -0.155*** | -0.108** | -0.053 |
| | (0.028) | (0.048) | (0.043) | (0.117) |
| gGDP | 0.019 | 0.000 | 0.007 | -0.014 |
| | (0.031) | (0.028) | (0.035) | (0.011) |
| U | 0.021 | -0.001 | 0.020 | 0.076 |
| | (0.084) | (0.133) | (0.207) | (0.284) |
| Inflation | -0.148* | -0.028 | 0.026 | 0.119 |
| | (0.089) | (0.067) | (0.064) | (0.156) |
| ΔUCL | 0.018 | 0.011 | 0.026 | -0.017 |
| | (0.038) | (0.036) | (0.080) | (0.084) |
| ΔOIL | -0.002** | -0.003 | -0.004 | -0.009** |
| | (0.001) | (0.003) | (0.004) | (0.004) |
| $i_{3M}$ | 0.089 | 0.120* | 0.094 | 0.190** |
| | (0.060) | (0.069) | (0.097) | (0.075) |
| CBI | -0.927 | -0.433 | -0.688 | -0.678 |
| | (1.137) | (1.577) | (2.413) | (3.240) |
| $D_{CBI}$ | -0.284* | -0.618* | -0.983* | -1.289** |
| | (0.172) | (0.319) | (0.572) | (0.571) |
| Constant | 17.992*** | 15.518*** | 10.621** | 4.381 |
| | (2.681) | (4.744) | -4.317 | (11.816) |
| N | 288 | 288 | 288 | 288 |
| $R^2$ (within) | 0.1231 | 0.1243 | 0.1555 | 0.1144 |

Standard errors in parentheses
*, **, and *** denote significance levels at 10%, 5%, and 1%, respectively

Substituting U with the LFPR yields the results seen in Table VI and it confirms the impact of uncertainty on forecast errors at the two longest horizons in our sample as being a driver for forecast underestimations. Regarding the macroeconomic variables, consumer price and oil price inflation are also confirmed as key drivers of over- and underestimation bias of forecasts, with confidence levels between 95% and 99%. The novelty in this robustness check was found in the coefficients for LFPR and CBI;

statistically significant coefficients found for LFPR contrast with those for U in the baseline results, while keeping the same direction, i.e. both U and LFPR are likely drivers of overestimation errors in central bank forecasts. Meanwhile, the central bank independence variable was found to have a positive effect in T-4 forecast errors and negative effect for T-1 and T-2 forecast errors, with 99% confidence. inflation and the 3-month interbank rate. In both controls, the significance and signal of the coefficient related to the central banks' reforms do not change.

Table VI: Random Effects Panel Model Coefficients And Cluster-Robust Standard Errors – U Replaced With LFPR

| Dependent Variable | Forecast Error | | | |
|---|---|---|---|---|
| Forecast Horizon | T-1 | T-2 | T-3 | T-4 |
| VIX | 0.002 | -0.010 | -0.027*** | -0.050*** |
| | (0.014) | (0.012) | (0.007) | (0.004) |
| gGDP | -0.032 | -0.053 | -0.051 | -0.085** |
| | (0.035) | (0.037) | (0.057) | (0.038) |
| LFPR | 0.008*** | 0.004 | 0.008** | 0.002 |
| | (0.003) | (0.005) | (0.004) | (0.004) |
| Inflation | -0.014 | 0.103 | 0.121** | 0.178*** |
| | (0.124) | (0.066) | (0.048) | (0.045) |
| ΔUCL | -0.019** | -0.020*** | -0.011 | -0.070*** |
| | (0.010) | (0.002) | (0.027) | (0.018) |
| ΔOIL | -0.003*** | -0.004** | -0.005** | -0.010*** |
| | (0.000) | (0.002) | (0.003) | (0.003) |
| $i_{3M}$ | 0.056 | 0.099 | 0.087 | 0.195** |
| | (0.068) | (0.080) | (0.102) | (0.085) |
| CBI | -0.739*** | -0.351*** | -0.104 | 0.829*** |
| | (0.122) | (0.105) | (0.181) | (0.092) |
| $D_{CBI}$ | -0.340 | -0.582*** | -0.835*** | -0.741*** |
| | (0.220) | (0.215) | (0.250) | (0.190) |
| Constant | -0.113 | -0.170 | -0.450 | -0.438** |
| | (0.469) | (0.589) | (0.331) | (0.202) |
| N | 288 | 288 | 288 | 288 |
| $R^2$ (within) | 0.0549 | 0.1005 | 0.0935 | 0.1609 |

Standard errors in parentheses
*, **, and *** denote significance levels at 10%, 5%, and 1%, respectively

## 5. Conclusion

This dissertation has provided a comprehensive analysis of inflation forecast errors produced by the Federal Reserve, the Bank of England, and the European Central Bank over four horizons, ranging from one quarter ahead to four quarters ahead. By employing random-effects panel regressions with cluster-robust standard errors, we have identified the key drivers of forecast errors. However, these results should be interpreted with caution as the data collected covers a relatively short time horizon, as well as the panels used were unbalanced.

Our panel regressions show that higher uncertainty and spikes in oil price inflation consistently led to underpredictions of future inflation by central banks, especially at longer horizons of our sample. Interest-rates, on the other hand, were found to have a positive effect in forecast errors, resulting in central bank forecasts overestimating future inflation. Central-bank independence, in particular reforms related to central bank independence, was also found to be a key driver of negative forecast errors. Robustness checks using contemporaneous independent variables and alternative uncertainty proxies (BCI/CCI) confirm the stability of our core findings, even as the significance of some factors changes.

These results carry key implications for both policymakers and researchers. Firstly, central bank communication, as a source of public information, can exert a significance influence on private expectations. On the other hand, agents tend to overreact to public information, which may lead to the crowding out of private information. Forecast errors compromise the perceived quality of central bank communication and, in some cases, trigger suboptimal economic outcomes, particularly when more reliable private forecasts are available (Morris and Shin, 2002). The challenge for central banks is to find the right balance between providing timely and frequent information to the public, as it may be necessary for achieving monetary policy objectives, while acknowledging the inherent limitations in its disclosures and managing the risks posed by excessive noise. To address this issue, central banks should strive to better incorporate measures of uncertainty and commodity prices, especially oil prices, into their forecasting frameworks to reduce forecast errors.

It is also worth analysing the implications of our results with respect to the effect of inflation on forecast errors, given the scope of our research towards the question of whether or not the central bank forecasts have strategic inclination that might be driving forecast errors in a direction that serves the monetary policy goal of anchoring expectations around the target inflation rate. In order to find evidence of a strategic motive in the forecast errors, we would need to find a negative coefficient for inflation, meaning that when inflation accelerates, central bank forecasts would consistently underestimate future inflation. Our findings point, however, that central banks forecasts errors are not affected by inflation in the same way as this argumentation would suggest, i.e., when inflation accelerates, forecasts would tend to underestimate future inflation, and when inflation decelerated, forecasts would tend to overestimate future inflation. Barrero and Polania (2014) find the strategic factor for six-quarter ahead (T-6) forecasts from six different central banks, including the Bank of England. However, for shorter horizons like those used in our analysis, the results do not support the strategic forecasting argument. Barrero and Polania underscore that central banks face higher reputational costs when attempting to influence short-term expectations, as they're less flexible in this horizon. However, in the medium-term, private agents have less information about the future state of the economy, compared to central banks, meaning that their expectations are more likely to change.

Future research could explore what results would our model produce in longer horizons, ranging between five-quarter to eight-quarter ahead, as in Polana and Barrero (2014). In particular, it would be interesting to compare how inflation affects forecast errors in these horizons with their findings. Additionally, the rigor of our results has been limited by the short time horizon of our analysis, which, at best, spanned over 104 quarters; in the future, a replication of our models with a longer time horizon could ensure higher rigor and quality of the results. On another note, future research should also explore how forecast errors shape perceptions of credibility, evaluating not only the reliability of forecasts but also the extent to which private-sector actors interpret them as trustworthy or strategically manipulated.

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# Appendix

Table VII: Description Of Variables Used

| Variable | Definition | Unit | Source(s) |
|---|---|---|---|
| ForecastError | Forecast error computed as the difference between the forecast and realized inflation: $E_{t-n}\,\pi_t - \pi_t$ | Percentage points | Source of forecasts: Federal Reserve; European Central Bank; Bank of England. Source of inflation data: Federal Reserve Bank of St. Louis; Eurostat; Office for National Statistics |
| VIX | Options-based volatility indexes: VIX and VSTOXX | Index points | Federeal Reserve Bank of St. Louis; Deutsche Borse Group |
| BCI | Composite Business Confidence Indicator | Index points | OECD |
| CCI | Composite Consumer Confidence Indicator | Index points | OECD |
| $g_{GDP}$ | Real GDP growth | Percentage | Federeal Reserve Bank of St. Louis; |
| U | Unemployment rate | Percentage | Federeal Reserve Bank of St. Louis; Eurostat; Office for National Statistics |
| Inflation | Year-on-year percent change of PCE prices index, HICP and CPI | Percentage | Federeal Reserve Bank of St. Louis; Eurostat; Office for National Statistics |
| LFPR | Labor force participation rate | Percentage | Federeal Reserve Bank of St. Louis; Eurostat; Office for National Statistics |
| $\Delta$ULC | Year-on-year growth of Unit Labor Costs | Percentage points | Federeal Reserve Bank of St. Louis; European Central Bank; Office for National Statistics |
| $\Delta$OIL | Year-on-year growth of international Brent prices | Percentage points | Federeal Reserve Bank of St. Louis |
| $i_{3M}$ | 3-Month Interbank Rate | Percentage | Federeal Reserve Bank of St. Louis |
| CBI | Central Bank Independence Index | Index points | Romelli, D. (2022). "The Political Economy of Reforms in Central Bank Design: Evidence from a New Dataset". Economic Policy. Accessed at https://doi.org/10.1093/epolic/eiac011 |
| $D_{CBI}$ | Dummy variable for reforms in Central Bank Independence | Binary | Romelli, D. (2022). "The Political Economy of Reforms in Central Bank Design: Evidence from a New Dataset". Economic Policy. Accessed at https://doi.org/10.1093/epolic/eiac011 |

Table VIII: Baseline model Hausman test results

| Model | One-Period Lagged Independent Variables | | | |
|---|---|---|---|---|
| Forecast Horizon | $\chi^2$ | $P > \chi2$ | H0 | Decision |
| T-1 | 1.18 | 1.0000 | Not rejected | RE preferred |
| T-2 | 6.65 | 0.9192 | Not rejected | RE preferred |
| T-3 | 7.44 | 0.8780 | Not rejected | RE preferred |
| T-4 | 7.44 | 0.8782 | Not rejected | RE preferred |

Table IX: Contemporaneous independent variables model (equation 2) Hausman test results

| Model | Contemporaneous Independent Variables | | | |
|---|---|---|---|---|
| Forecast Horizon | $\chi^2$ | $P > \chi2$ | H0 | Decision |
| T-1 | 0.18 | 1.0000 | Not rejected | RE preferred |
| T-2 | 5.37 | 0.9661 | Not rejected | RE preferred |
| T-3 | 8.16 | 0.8327 | Not rejected | RE preferred |
| T-4 | 5.18 | 0.9710 | Not rejected | RE preferred |

Table X: Robustness check model with BCI, Hausman test results

| Model | One-Period Lagged Independent Variables | | | |
|---|---|---|---|---|
| Forecast Horizon | $\chi^2$ | $P > \chi2$ | H0 | Decision |
| T-1 | 5.33 | 0.7222 | Not rejected | RE preferred |
| T-2 | 3.61 | 0.8904 | Not rejected | RE preferred |
| T-3 | 8.14 | 0.4196 | Not rejected | RE preferred |
| T-4 | 7.57 | 0.4768 | Not rejected | RE preferred |

Table XI: Robustness check model with CCI, Hausman test results

| Model | One-Period Lagged Independent Variables | | | |
|---|---|---|---|---|
| Forecast Horizon | $\chi^2$ | $P > \chi2$ | H0 | Decision |
| T-1 | 3.45 | 0.9030 | Not rejected | RE preferred |
| T-2 | 2.55 | 0.9592 | Not rejected | RE preferred |
| T-3 | 9.10 | 0.3342 | Not rejected | RE preferred |
| T-4 | 4.54 | 0.8051 | Not rejected | RE preferred |

Table XII: Robustness check model with LFPR, Hausman test results

| Model | One-Period Lagged Independent Variables | | | |
|---|---|---|---|---|
| Forecast Horizon | $\chi^2$ | $P > \chi2$ | H0 | Decision |
| T-1 | 0.51 | 0.9994 | Not rejected | RE preferred |
| T-2 | 2.75 | 0.9074 | Not rejected | RE preferred |
| T-3 | 3.60 | 0.8249 | Not rejected | RE preferred |
| T-4 | 2.38 | 0.8815 | Not rejected | RE preferred |