Bank of England

Forecast accuracy and efficiency at the Bank of England – and how errors can be leveraged to do better

Staff Working Paper No. 1,078
July 2024

Derrick Kanngiesser and Tim Willems

Bank of England

Staff Working Paper No. 1,078

Forecast accuracy and efficiency at the Bank of England – and how errors can be leveraged to do better

Derrick Kanngiesser[(1)] and Tim Willems[(2)]

Abstract

We propose a systematic approach for central banks to leverage past forecasts (and associated errors) with the aim of learning more about the structure and functioning of the underlying economy. Applying this method to forecasts made by the Bank of England's Monetary Policy Committee since 2011, we find that its forecasts have tended to underestimate pass-through from wage growth, whilst also featuring a Phillips curve that is too flat. Regarding the effects of monetary policy, our results point to transmission via inflation expectations possibly having played a bigger role than attributed to it in the forecast. We also provide a more classical evaluation of forecast errors – finding inflation forecasts to have been unbiased. At the same time, however, inflation forecasts tend to be less accurate than those for real GDP growth, unemployment, and wage growth. This seems attributable to greater inherent uncertainties in the inflation process.

Key words: Forecasting, forecast error analysis, monetary policy.

JEL classification: E32, E47, E62.

---

(1) Bank of England. Email: derrick.kanngiesser@bankofengland.co.uk
(2) Bank of England. Email: tim.willems@bankofengland.co.uk

The views expressed in this paper are those of the authors and not necessarily those of the Bank of England or its committees. We would like to thank Zaar Khan and Ryland Thomas for sharing their data sets and codes. We would like to thank Daniel Albuquerque, John Barrdear, Alan Castle, Andrew Gaffney, Richard Harrison, Zaar Khan, David Latto, Huw Pill, Kate Reinold, Martin Seneca, Fergal Shortall, Ryland Thomas, Gavin Wallis and Chris Young as well as seminar participants at the Bank of England for invaluable comments and suggestions.

The Bank's working paper series can be found at www.bankofengland.co.uk/working-paper/staff-working-papers

Bank of England, Threadneedle Street, London, EC2R 8AH
Email: enquiries@bankofengland.co.uk

ISSN 1749-9135 (on-line)

1 Introduction

Recent forecast errors (particularly on inflation) have put central bank forecasts and the underlying models, under heightened scrutiny. 'Inflation targeting' is widely understood to imply 'inflation forecast targeting' which places inflation forecasting practices, and discussions thereof, right at the core of the decision-making process in many central banks (Svensson, 1997).[1] This particularly holds true for inflation forecasts at the horizon over which monetary policy is believed to be able to affect the economy, while producing accurate forecasts is furthermore thought to be important to build and maintain central bank credibility (McMahon and Rholes, 2023).

This context brings us to scrutinise the forecasts of the Monetary Policy Committee ('MPC') of the Bank of England ('BoE') since the introduction of its operational independence in 1997. What were the driving forces of the forecast errors for key variables such as inflation, wage growth, GDP growth, and unemployment? Are the MPC's forecasts 'efficient', in the sense of processing all available information in an unbiased manner?

In order to answer these questions, we collect the quarterly MPC forecasts[2] since 1997, enabling us to calculate the implied forecast errors at various horizons (up to 3 years out). We assess the accuracy and the bias of the MPC forecasts as well as the forecasting performance over time – comparing it to that of simple forecasts based on random walks and auto-regressive models. It is important to note that the MPC forecast is also used as a communication device and its performance cannot be evaluated adequately merely in terms of forecast accuracy, unbiasedness and efficiency. Moreover, as we will discuss in the paper, the conditional nature of the MPC forecast constitutes a challenge for conventional forecast performance analyses that compare forecasts and outturns. Nevertheless, given that there are likely interactions between the MPC forecast's accuracy and its communication functionality as well as the Bank of England's broader credibility, it is important to analyse potential forecast inaccuracies, inefficiencies and their drivers.

The main contribution of this paper is to introduce a systematic way for central banks to leverage past forecasts (and associated errors) with the aim of learning more about the structure and functioning of the underlying economy. Following Blanchard and Leigh (2013), we shed light on this question by analysing the relationship between forecast errors and forecasts – to gauge whether the MPC forecasts systematically over- or underestimated relationships between variables that are being forecast.

Our paper builds upon a large literature dealing with forecast evaluation (see West (2006) and Clark and McCracken (2013) for overviews; Binder and Sekkel (2023) survey the literature specific to central banks). Earlier applications include Timmermann (2007), who evaluated IMF World Economic Outlook forecasts, Tulip and Wallace (2012), focusing on Australia and Reifschneider and Tulip (2019), who analysed FOMC forecasts, and Granziera et al. (2024), who evaluate ECB forecasts – finding that the ECB is more likely to overpredict inflation when it runs below target (and vice versa). Of particular interest to us are the papers by Fawcett et al. (2015) and the report by the IEO (2015), which provided an earlier assessment of the Bank's MPC forecasts (covering the time period from 1997 to 2014) while also summarising the earlier literature on forecast evaluation concerning the BoE in particular. Given the earlier

[1] It remains to be seen how future central bank frameworks will evolve and whether there will be a greater emphasis of 'data dependence'. Normative discussions around the adequate weight attached to the central forecast in the monetary policy deliberations are beyond the scope of this paper.

[2] The forecasts released since 1997 are 'owned' by the MPC and reflect the 'best collective judgement' of committee members. In his review on 'Forecasting for monetary policy making and communication at the Bank of England', Bernanke (2024) found that the term 'best collective judgement' is *'undefined but suggests that all MPC members (or perhaps a majority) are comfortable with the forecast, or at least its broad outlines'.*

work on the BoE's MPC forecast errors, we pay particular attention to the post-2011 sub-sample. Here, November 2011 forms a natural starting date for two reasons. First, it marks the introduction of the BoE's current forecasting platform (Burgess et al., 2013). Second, by only having access to data through 2014, the IEO (2015) report was not able to calculate and analyse forecast errors for the 3-year horizon for post-2012 forecasts. By starting our main sub-sample of interest in 2011, we essentially continue where the IEO (2015) report left off.

The MPC's forecasting performance has recently also been evaluated, and put in international perspective, by Bernanke (2024). As detailed there, MPC forecast errors are similar to those made by other central banks (a conclusion echoed by Håkanson and Laséen (2024)). Across the board, however, forecasting performance worsened markedly post-pandemic, with especially inflation rising much more than expected (largely due to outturns for energy prices differing from conditioning paths[3]).

From a descriptive perspective, our key findings can be summarised as follows. First, in terms of the median forecast errors, we document that the Bank produces unbiased inflation forecasts, but it has tended to over-predict wage growth, the unemployment rate and real GDP growth. Second, the MPC forecasts for inflation are less accurate than those for wage growth, unemployment and GDP growth, especially after the 4-quarter ahead forecast horizon. While this ostensibly casts doubt on the MPC's inflation forecasting practices, our third key finding suggests that it has more to do with inherent uncertainties in the inflation process: while 'simple' forecasting models (such as a random walk forecast, or one stemming from an auto-regressive model) are able to outperform MPC forecasts for wage growth, the unemployment rate, and GDP growth, this is *not* the case for the inflation forecast – where (across all horizons) MPC forecasts consistently come with greater accuracy than their 'simple' alternatives.

Finally, our results suggest that the MPC forecasts are not fully efficient – a much tougher test in practice – in the sense of not processing all available information exhaustively. Focussing on the MPC forecasts that were released after November 2011, our analysis along the lines of Blanchard and Leigh (2013) suggests several sources of inefficiency according to this definition.

First, the 'pass-through' from wage growth to inflation may be higher than what has historically been embedded in the forecasting process. Second, the inflationary impact of increases in GDP growth seems to materialise faster than historically modelled. Third, regarding the transmission mechanism of monetary policy, we find that, relative to what is embedded in the forecast, a tightening in policy: i) has a stronger disinflationary impact over all horizons; ii) pushes up unemployment by less at the 3-year horizon; and iii) does more to slow wage growth at the 2- and 3-year horizon. Taken together, these observations could be consistent with transmission through inflation expectations having played a bigger role than attributed to it in the forecast (as the inflation expectations channel can reduce inflation and wage growth without having to rely on a significant increase in unemployment).

2 Data, Concepts and Notation

We compile a dataset of the BoE's quarterly MPC forecasts from 1997:Q3 until 2024:Q1 for CPI inflation, wage growth[4], and real GDP growth (all annual rates, calculated year-on-year) as well as for the unemployment rate. We also collect outturns and forecast conditioning paths for Bank Rate, 3-year government bond yields and energy prices. In our analysis, we focus on the forecasts since November 2011,

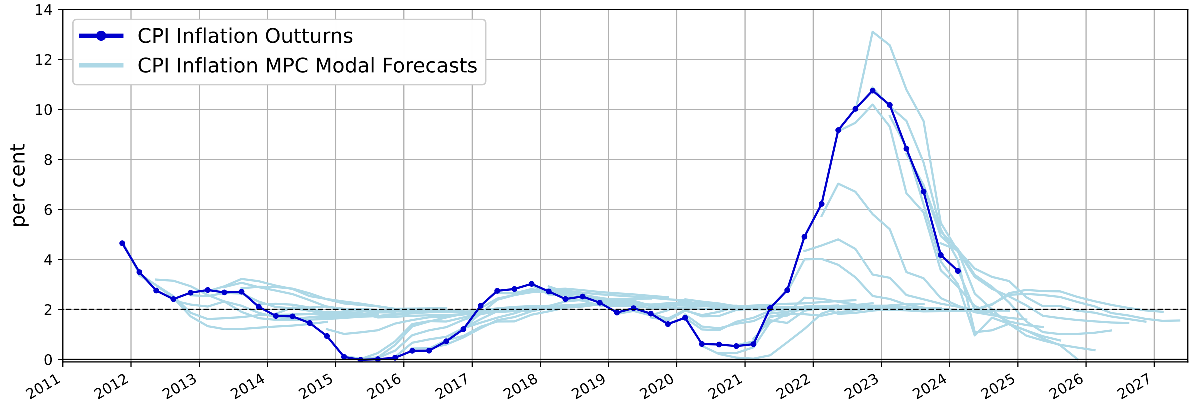
[3] In Appendix B.1, we analyse the relationship between forecast errors of inflation and of energy price growth. We show that inflation forecast errors are highly correlated with surprises in energy price growth, especially at higher forecast horizons.

[4] From 1997 until 2010 our data is based on the 'Average Earnings Index (aei)', after 2010 it is based on the 'Average Weekly Earnings (awe)' aggregate index.

since this constitutes the beginning of the current forecast infrastructure. In the Appendix, we repeat the analysis for the full sample starting in 1997.[5]

In Figure 1 we plot the outturns for inflation rates of the consumer price index (CPI, in blue). The light blue lines depict the modal inflation forecasts. Figure 1 highlights how the BoE's 2% target has anchored outturns and forecasts for CPI inflation. While the outturns have deviated materially from target in 2022 and early 2023, annual headline CPI inflation fell back to 2% in May 2024. In the Appendix, we visualise outturns and forecasts for the other variables and conditioning paths.

FIGURE 1: UK CPI INFLATION, YEAR-ON-YEAR



Notes: The solid blue line depicts the UK CPI inflation outturns. The light blue lines depict the CPI modal inflation forecasts. The depicted outturns in the blue line refer to the outturns $k = 12$ quarters after the first data release. For the last 12 quarters we take the latest available vintage.

Forecast Error Definition We define the h quarters ahead forecast error 'FE' for variable x in period t as the difference between the forecast and the outturn

$$FE_{t-h}(x_t) \equiv F_{t-h}(x_t) - x_t \tag{2.1}$$

where $F_{t-h}(x_t)$ is the h quarter ahead forecast for variable x in period t that was based on the information set in period $t - h$. x_t is the realised value of variable x in period t.

We take realisations to be the values found in the data vintage $k = 12$ quarters after the fact (but our results are robust to different choices for k). That is: the outturn for time t is taken from the data published at $t + 12$ quarters (see Table 1 for an example). This balances the arrival of more precise information over time, against limiting the impact of methodological changes (the prediction of which does not lie within the scope of the forecasting exercise we are interested in analysing; see Reifschneider and Tulip (2019)). For the forecasts of the last three years, for which the $t + 12$ realisation is not yet available, we simply use the value found in the latest available data vintage as outturns.

Root Mean Squared Error (RMSE) Definition The 'root mean squared error (RMSE)' is defined as

$$RMSE(x,h) \equiv \sqrt{\frac{1}{N}\sum_{t=1}^{N}\left(FE_{t-h}(x_t)\right)^2}, \tag{2.2}$$

[5]Since 1997, the MPC's modelling framework and forecast conventions have evolved, as has the definition of the inflation target. Originally, the published forecasts went out to two years ahead rather than three, there was a constant rate conditioning assumption for Bank Rate, and until 2003 the target was 2.5% for the year-on-year inflation rate of the retail price index (RPI) rather than 2% for the consumer price index (CPI).

where N is the total number of forecasts. We will also look at the median (RMedSE). The RMSE and RMedSE can be used to measure forecast accuracy. Average forecast errors inform the degree of forecast biasedness.

Forecast Efficiency 'Forecast efficiency' is defined as a situation in which a forecast appropriately uses all information that was available to the forecaster at the time the forecast was made (Nordhaus, 1987). An important, testable implication is that forecast errors should be uncorrelated with any information that was available to the forecaster in real time. After all, any explainability of forecast errors based on that information implies that a more accurate forecast could have been made had the forecaster exploited that correlation when constructing the forecast.

An important point regarding forecast efficiency was made by Blanchard and Leigh (2013, 2014). They noted that the information set of a forecaster forecasting multiple variables, includes the various forecasts themselves – and the principle of forecast efficiency applies there too.[6] That is to say: forecast errors (resulting from a forecast made at date t) for an outcome Y_{t+h} should not be explainable from date t forecasts for other variables Z. If they are, the forecaster is working with a model that either over- or underestimates the impact that variable Z has on Y.

Blanchard and Leigh themselves applied this insight to IMF forecasts of growth and fiscal consolidation in the Eurozone following the Global Financial Crisis, observing that forecast errors for growth were explainable from fiscal forecasts. In particular, they found that growth ended up falling short of IMF forecasts in cases where the IMF had been forecasting stronger fiscal consolidation – thus suggesting that the IMF forecasting model embedded a fiscal multiplier that was too low. We will explore this aspect of forecast efficiency in Section 4, in which we check whether MPC forecasts over- or underestimate certain relationships within the economy.

On the construction of the MPC forecast As described in detail in the review by Bernanke (2024), the Bank of England's MPC forecast is produced at quarterly frequency for the subsequent three-year period. The forecasts are 'modal' in the sense that they predict the most likely outcomes of the forecasted variables.[7] The MPC's forecast is constructed incrementally (by incorporating marginal news relative to the previous forecast) via a combination of COMPASS (a medium-scale DSGE model) and a wider suite of models (including supplementary sectoral models, and a range of models that help pin down the supply-side and wage projections), and MPC judgement; all subject to a number of conditioning assumptions, including financial market-implied paths for Bank Rate, the exchange rate and wholesale energy prices, fiscal policy measures reflected in OBR forecasts for government taxes, transfers, spending and public sector pay/employment, and the forecast for other economies.

In summary, the BoE's forecasting 'framework' which is used to construct the MPC forecast refers to a complex process that involves the combination of MPC judgements with outputs from a variety of reduced-form statistical and some structural macro-economic models. It is therefore more appropriate to speak about a forecasting 'framework' as opposed to a single forecasting model.

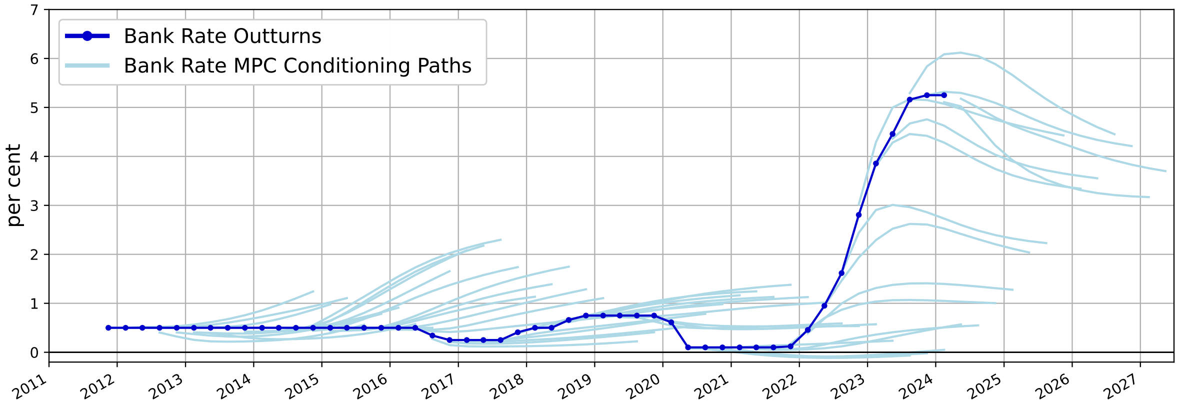
On the conditionality of the MPC forecast It is important to emphasize three notes of caution in interpreting our results. First, the MPC's forecast is conditional on the outlook for exchange rates, energy

[6] In other words, any forecast can be thought of as a transformation of the data, and hence the available information set, that was used to construct that forecast.

[7] Subjective distributions of less likely outcomes around the modal forecast are discussed as well. Furthermore, the MPC have occasionally appealed to skewed risks which, at times, have given rise to a mean forecast which differed from the modal path.

prices and *announced* fiscal policy[8] – and notably, on the future path[9] of Bank Rate as shown in Figure 2.

FIGURE 2: UK BANK RATE



Notes: The solid blue line shows Bank Rate. The light blue lines show the yield curve conditioning paths.

Most forecast evaluation is strictly only valid under an assumption that the conditioning paths coincide with the Committee's private beliefs. Second, the MPC may have occasionally used its forecast as an implicit instrument of policy, adjusting profiles in order to signal directional guidance to the market curve. Third, the MPC may have (unspoken) limits on the extent to which it is willing to publish a deviation of inflation from target at medium-term horizons, perhaps out of a concern for the possibility of contributing to an unwelcome shift in expectations. Taken together, these three points suggest that there could be situations in which a conditional forecast gives rise to 'deliberate' forecast errors.[10] A conventional forecast performance evaluation would rest on the assumption that, on average, none of these three issues has occurred.

While the full degree of divergence between the MPC-preferred path and the market-implied path may not be directly inferable from the data, Figure 3 shows that the MPC inflation forecasts have been close to target, with the average 2-year and 3-year ahead inflation forecast being close to 2%. This seems to suggest that the MPC hasn't generally viewed the market-implied Bank Rate conditioning assumption as being inappropriate on average (or it would not have projected inflation close to target).

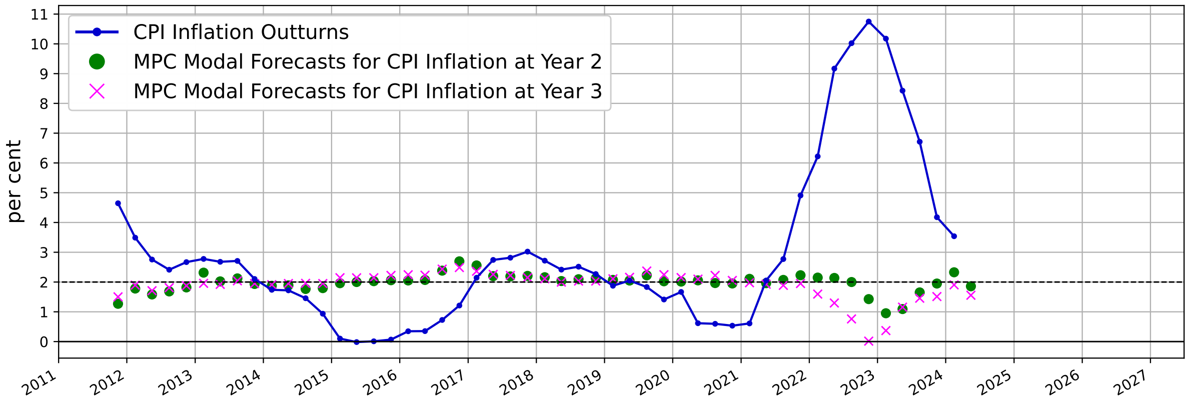
However, in 2022 and 2023 the MPC released modal inflation forecasts 2-years and 3-years ahead that were substantially below target, potentially indicating that it viewed the prevailing Bank Rate conditioning path at the time as too elevated. It is noteworthy that the MPC ended up lifting Bank Rate above the prevailing yield curve conditioning paths (with the August 2023 forecast being an exception), despite having released forecasts that could have been interpreted as a signal that the MPC viewed the

[8]The timing of shocks and the subsequent announcement of a fiscal policy measure may, at times, be of great significance. If a large shock hits the economy, and calendar conventions implied that the MPC have to release their forecast before the government has had a chance to announce their response to the shock, it would be possible that the MPC forecast was based on an 'unmitigated' state of the world which is subsequently improved upon with a government intervention and which would then give rise to a large forecast error. At the same time, financial market participants may expect a government intervention such that the market-implied paths for exchange rates and Bank Rate reflect an anticipation of fiscal policy that is, strictly speaking, inconsistent with the *announced* fiscal conditioning path that underpins the MPC forecast. Many of these challenges were highlighted in the review by Bernanke (2024).

[9]For details, refer to: https://www.bankofengland.co.uk/statistics/yield-curves.

[10]Forecasts made at times when the MPC was seemingly uncomfortable with the market-implied path for Bank Rate (as proxied by the MPC's inflation forecast being different from 2% at the 3-year horizon), have tended to give rise to greater forecast errors. When running a regression of the form $FE_{t-12}(\pi_t) = \alpha + \beta(|F_{t-12}(\pi_t) - 2\%|) + \varepsilon_t$ (that is: regressing the forecast error for inflation on the deviation in the underlying 3-year ahead inflation projection from the 2% target) the estimate for β equals 4.77, with a t-statistic of 10.15. This suggests that the MPC's forecast could have been more accurate, had the MPC been allowed to base its forecast on its own preferred path for Bank Rate. Stated otherwise: under the current practice of conditioning the MPC forecast on the market-implied path for Bank Rate, forecast errors may at times result even if the MPC works with the correct 'model' (or framework) – in that case purely stemming from the forecast being based on the 'wrong' path for Bank Rate.

FIGURE 3: UK CPI INFLATION, YEAR-ON-YEAR, OUTTURNS AND FORECASTS 2-YEARS AND 3-YEARS AHEAD



Notes: The solid blue line depicts the UK CPI Inflation outturns. The green dots (pink crosses) show the forecasts for inflation 2 (3) years ahead.

curve as 'too elevated'. In this context, it is interesting to analyse the forecasts and explore the MPC's implicit assumptions of the strength and timing of the monetary transmission mechanism, and the extent to which a change in Bank Rate affects inflation. We will cover this in Sections 4 and 5.

Even if there were episodes in which the MPC's private beliefs of the conditioning paths did not coincide with the market-implied paths, there are considerable benefits in analysing the MPC's forecast accuracy and especially its efficiency. Our main objective and contribution is to analyse whether the relationships between variables within the forecast may have been under- or over-estimated. Since these 'elasticities' can be assumed to have been set independently of the conditioning paths that were later imposed, the fact that the forecast is conditional should not detract from the information gleaned regarding elasticities.

3 Forecast Bias and Accuracy

We analyse the bias and accuracy of the Bank's MPC modal[11] forecasts over the sample period from 2011:Q4-2024:Q1. We first look at the MPC forecast biasedness before turning towards forecast accuracy in terms of root mean (and median) squared errors (RMSEs). We provide a full-sample analysis and additional visualisation of the forecast errors in the Appendix.

Bias In Figure 4 we plot the average forecast errors for inflation, wage growth, unemployment and annual GDP growth. The average forecast error measures whether the MPC forecasts tend to be biased. We plot the mean (blue lines) and the median (red lines) forecast errors, together with the 16% and 84% percentiles (grey swathe). In order to facilitate a comparison of the bias across variables we divide each forecast error by the standard deviation of the outturns of the pre-pandemic sample period for each variable.[12] Figure 4 provides two key takeaways. First, while the median forecast error for inflation is close to zero at all horizons, the Bank has tended to over-predict wage growth (at least in terms of the median error for horizons greater than $h = 4$), unemployment and GDP growth across all horizons.

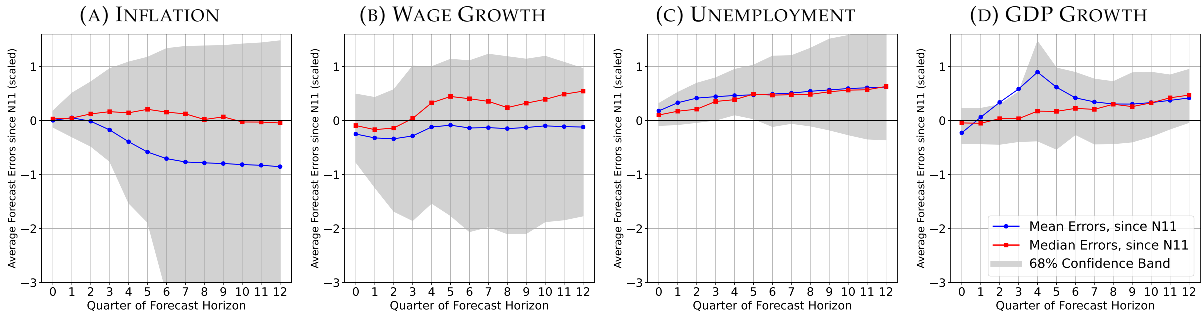
Second, there is a substantial gap between the mean and the median forecast error for inflation and real GDP growth, indicating that there are several outliers where the Bank significantly under-predicted

[11] We also looked at the mean forecasts for inflation and unemployment and found very similar results.

[12] Dividing by the full sample period standard deviation could lead to an excessive degree of down-scaling due to the very elevated volatility, especially in real GDP growth, in the period after 2020.

inflation and over-predicted GDP growth – the Covid period being an obvious example.

FIGURE 4: AVERAGE FORECAST ERRORS SINCE NOVEMBER 2011

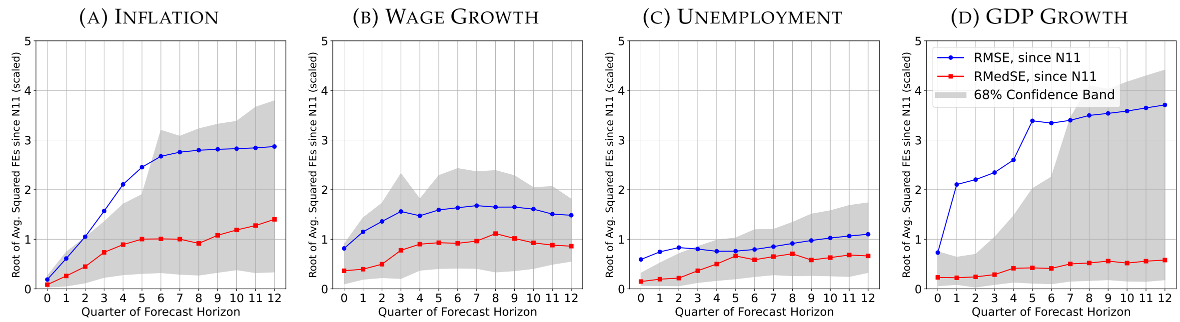


Notes: The blue (red) lines depict the mean (median) forecast error of the MPC modal forecasts since 2011. The grey swathe depicts the 68% percentiles of the sample from 2011:Q4-2024:Q1. All forecast errors have been re-scaled by the respective pre-pandemic sample standard deviation to facilitate comparability across variables and across samples. Positive values imply over-prediction, whereas negative values imply under-prediction.

Accuracy In Figure 5 we plot the root mean squared errors (RMSEs, blue lines) and the root median squared errors (RMedSEs, red lines) for annual inflation, wage growth and GDP growth and the unemployment rate. These absolute average forecast errors indicate the overall accuracy of the MPC forecasts. There are two key takeaways. First, the Bank has tended to produce comparatively accurate forecasts for inflation in the near-term, up until forecast horizon $h = 2$. At longer horizons, inflation forecast accuracy declines and then plateaus after horizon $h = 6$.

Second, based on the root median squared error, which controls for outliers, the forecast accuracy for real GDP growth is better than for the other three variables, at least at longer horizons. While the near-term forecasts for GDP are less accurate than for inflation and unemployment, the forecasts after $h = 2$ are more accurate. The inflation forecasts since 2011 have been the least accurate among the four variables under consideration, in terms of the root median squared error (the RMSEs is heavily affected by the forecasts released during the Covid pandemic).

FIGURE 5: ROOT MEAN AND MEDIAN SQUARED ERRORS SINCE NOVEMBER 2011



Notes: The blue (red) lines depict the root mean (median) squared forecast error of the MPC modal forecasts since 2011. The grey swathe depicts the 68% percentiles of the sample from 2011:Q4-2024:Q1. All forecast errors have been re-scaled by the respective pre-pandemic sample standard deviation to facilitate comparability across variables and across samples.

Our findings are consistent with those from the IEO (2015). They also found that inflation forecasts at horizons at or above one year were less accurate compared to wage growth, unemployment and GDP. Moreover, the IEO (2015) also reported that inflation forecasts tended to be below outturns, on average, but that there was no statistically significant bias.

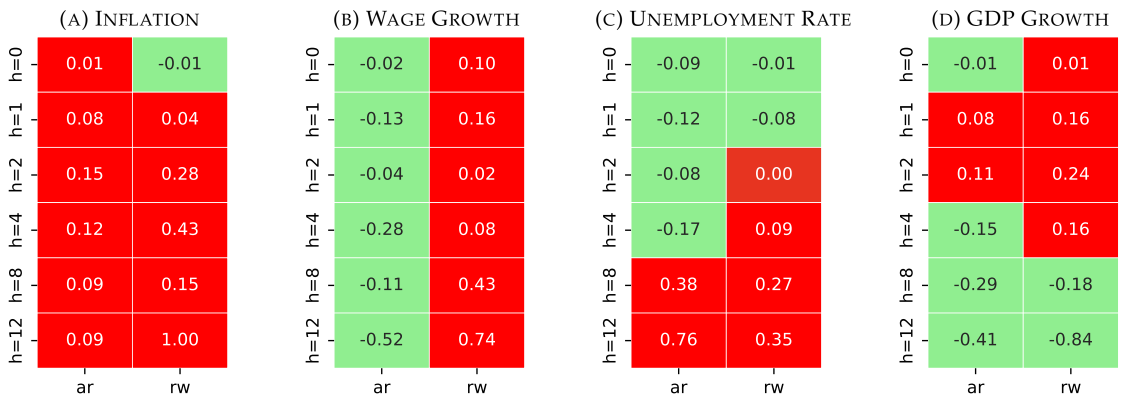
Simple Model Cross-checks: Random Walk and AR(p) Forecasts We compare the bias and the accuracy of the MPC modal forecast with two simple model-based cross-checks. First, we compare the performance of the MPC forecast against a simple random walk forecast in which we hold the forecast for each variable fixed at the latest available data point.

Second, we compare the performance of the MPC forecast against simple recursive AR(p) forecasts. We determine the lag order $p \in \{1,2,3,4\}$ using the Akaike information criterion.

In Figure 6 we compare the bias of the cross checks with the bias of the modal MPC forecasts. In order to control for outliers we use the median forecast errors as the measure of the forecast bias. We then compute absolute values[13] of the bias and calculate the difference between the cross check forecast bias and the MPC modal forecast bias.[14] Green fields indicate for which variable and at which horizon the cross-check forecast is less biased than the modal MPC forecast.

The AR(p) and the RW forecast for inflation are more biased than the MPC modal forecast. For wage growth, AR(p) forecasts are less biased than the MPC forecast after horizon $h = 0$. For unemployment, the RW forecast is less biased at horizons below $h = 8$, while the AR(p) forecast is less biased until horizon $h = 2$. For GDP growth, the the RW and the AR(p) forecasts are less biased at longer horizons.

FIGURE 6: BIAS COMPARISON, SINCE NOVEMBER 2011



Notes: The four tables 6a, 6b, 6c and 6d (from left to right for inflation, wage growth, unemployment and GDP growth) depict a comparison of the absolute values of the forecast biases in terms of the *median* forecast errors between the cross-check forecasts and the MPC modal forecasts since 2011. The right column of each table depicts the difference between the absolute value of the bias for the random walk (RW) forecast and the absolute value of the MPC modal forecast bias. If the random walk forecast is less biased than the MPC modal forecast, the corresponding field is colored in green. The left column in each table depicts the AR(p) comparison.

In Figure 7 we illustrate the comparison of forecast accuracy by plotting the difference between the root median squared errors (RMedSE) of the cross checks and the RMedSE of the MPC modal forecast. [15] Green fields highlight where the RMedSE of the cross check would be lower than the RMedSE of the MPC modal forecast. Green fields thus indicate higher accuracy of the cross-checks.

We can see that for inflation, a RW and an AR(p) forecast would not be more accurate than the MPC modal forecast. For wage growth and for GDP growth, the AR(p) forecast would be more accurate after horizon $h = 2$.

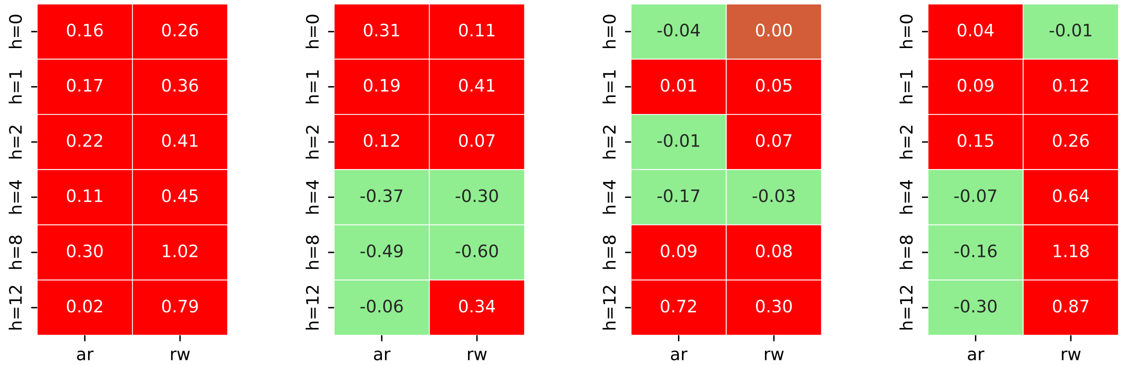
[13] Since there is no clear preference ordering with respect to the sign of the bias, we ensure comparability by taking the absolute value.

[14] The bias difference is given by: $BIAS\_gap = abs(BIAS(CrossCheck)) - abs(BIAS(MPCmodal))$, where *CrossCheck* represents the RW and AR(p) forecast, $BIAS$ represents the median forecast errors and abs represents the absolute value.

[15] The accuracy difference is given by: $RMedSE\_gap = RMedSE(CrossCheck) - RMedSE(MPCmodal)$, where *CrossCheck* represents the RW and AR(p) forecasts.

FIGURE 7: ACCURACY COMPARISON, SINCE NOVEMBER 2011

(A) INFLATION (B) WAGE GROWTH (C) UNEMPLOYMENT RATE (D) GDP GROWTH



Notes: The four tables 7a, 7b, 7c and 7d (from left to right for inflation, wage growth, unemployment and GDP growth) depict a comparison of the forecast accuracy in terms of the root median squared errors (RMedSE) between the cross-check forecasts and the MPC modal forecasts since 2011. The right column of each table depicts the deviation of the RMedSE for the random walk (RW) forecast from the RMedSE of the MPC modal forecast. If the RMedSE from the random walk forecast is lower than the MPC modal forecast RMedSE, the deviation is negative and the corresponding field is colored in green, indicating that the particular forecast at the specific horizon is more accurate than the MPC modal forecast. The left column in each table depicts the comparison between the AR(p) and the MPC modal forecast.

Taking the results depicted in Figures 6 and 7 together, we can conclude that the AR(p) forecast for wage growth and GDP growth at horizons above $h = 2$ is less biased and more accurate than the MPC modal forecast. For all other variables, the picture is more complicated as there are trade-offs between unbiasedness and accuracy – varying over different horizons.

4 Forecast Efficiency

In addition to documenting the MPC forecast's bias and accuracy, we can also analyse its efficiency. To learn more about the unbiasedness of the model (or process) that generates the forecast, we run regressions in the spirit of Blanchard and Leigh (2013, 2014). These enable us to gain a better insight regarding the driving forces behind any forecast errors.

By observing that Eurozone countries with stronger planned fiscal consolidation systematically ended up disappointing in growth relative to IMF forecasts, Blanchard and Leigh ('BL') concluded that the IMF had been underestimating the size of fiscal multipliers in the aftermath of the Global Financial Crisis. More generally, they devised a clever strategy to see whether forecasters over- or underestimate the strength of certain relationships within the economy - starting from the core principle of forecast efficiency that forecast errors should not be explainable from any information that was available at the time the forecast was made. Violation of that principle would, after all, imply that the forecast was inefficient (in the sense of not making proper use of available information, or combining it with a biased model). Our objective here is to see whether the Bank's forecasts systematically over- or underestimate the strength of 'pass-through' of certain driving variables x (like GDP growth, wage growth, or unemployment) to inflation.

The above-defined principle of forecast efficiency implies that it should not be possible to forecast a forecast error, calling for forecast errors to be uncorrelated with any information available at $t - h$ (the time at which the forecast was made). Crucially, since time $(t - h)$-forecasts for *other* variables are also in the forecaster's information set at $(t - h)$, the principle of forecast efficiency also applies to those forecasts.

In the above light, our objective is to see whether the MPC forecasts systematically over- or underestimate the strength of 'pass-through' of certain driving variables to inflation. We therefore regress the inflation forecast errors on Bank forecasts of variable x:

$$FE_{t-h}(\pi_t) = \alpha_h^x + \beta_h^x F_{t-h}(x_{t-h+j}) + \varepsilon_{h,t}^x, \qquad j = 2 \tag{4.1}$$

where x_t represents, alternatively, wage growth (π_t^w), the unemployment rate (u_t), and real GDP growth (y_t). We estimate (4.1) using the method of "robust regression", which (endogenously) down-weights observations that are considered "atypical" (in terms of the regression not producing a good fit to the data; see Berk (1990) for details on the robust regression approach). In the present context, that tends to refer to unusually large inflation forecast errors, for example induced by the unanticipated Covid-pandemic or Russia's invasion of Ukraine.

Note that we always estimate equation (4.1) with $j = 2$, thus implying that we work with the 2-quarter ahead forecast (counting from the period in which the forecast is made).[16] This balances the need to use a forecast (using outturns is problematic due to their endogeneity[17]), with the need for the forecasted development to materialise "on average" (which prevents us from picking j too large, as variables become more difficult to predict at longer horizons).[18]

The resulting estimate of β_h^x is informative as to whether the Bank's forecasts over- or underestimate the 'pass-through' of variable x to inflation at horizon h: in particular, a negative estimate for β suggests that higher values for x (e.g., GDP growth or wage growth) tend to be followed by negative forecast errors on inflation, suggesting that MPC forecasts tend to underestimate the inflationary impact of x (i.e., the forecasts embed a 'pass-through' coefficient, from x to π, that is too low); a positive estimate for β would suggest the opposite.

BL regressions for wage growth, unemployment, and output growth Figure 8 shows results when running BL regressions (always featuring inflation forecast errors as dependent variable) on forecasts for wage growth, the unemployment rate, and real GDP growth.

Panel 8a shows that, on average, forecasted wage growth is followed by inflation outturns that are higher than forecasted at the 2- and 3-year forecasting horizon. This suggests that the model-implied 'pass-through' coefficient (from wage growth to inflation) is too low at those medium-term horizons.

Panel 8b illustrates that periods in which the Bank forecasts higher unemployment tend to be followed by lower-than-forecasted inflation 2- and 3-years later. This could suggest that the actual disinflationary impact of higher unemployment is greater than what is presumed in the MPC forecasting 'framework'. Stated otherwise: the slope of the UK Phillips curve might have been steeper, at the 2- and 3-year horizon, than what was embedded in the MPC forecasting process. Alternatively, it is possible that the Bank's forecast framework relied on an estimate of u^* that is too high. This interpretation starts from a Phillips curve of the form $\pi_t = \pi_t^e - \kappa(u_t - u_t^*)$. If the estimate of u_t^* tends to be too high, the

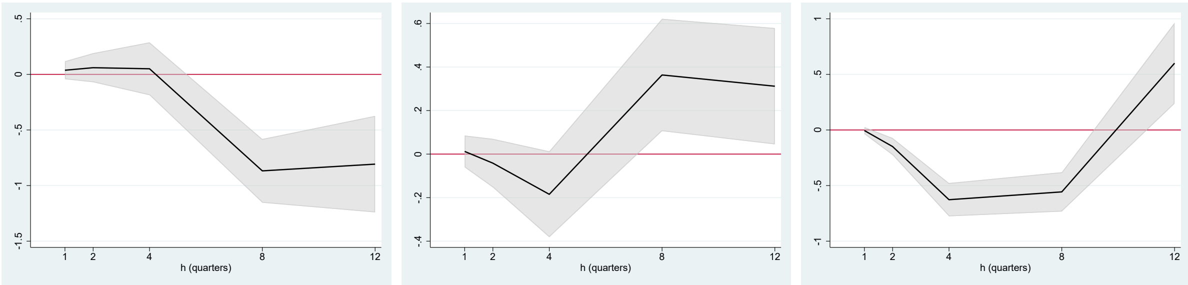
[16] For example, the MPC released its February 2019 forecast in 2019:Q1. We would then use the forecast for variable x two quarters into the future, i.e., for 2019:Q3, as regressor. For the case of $h = 12$, we would then regress the inflation error that materialised in 2022:Q1 (i.e., the difference between the 3-year ahead inflation forecast made in 2019:Q1 and the outturn in 2022:Q1) on the aforementioned regressor.

[17] In particular, there could be reverse causality, or a confounding variable could simultaneously be affecting both the dependent and independent variable of (5.1).

[18] As noted by Blanchard and Leigh, their approach would be in trouble if forecasts have no informational content for subsequent developments in the forecasted variable (leading to a "weak instrument"), but we do not find this to be the case for any of the variables depicted and discussed below.

Figure 8: BL Results for Forecast Errors of Inflation as a function of forecasts for (A) wage growth, (B) unemployment and (C) real GDP growth, sample since November 2011

(A) Wage Growth (B) Unemployment Rate (C) Real GDP Growth



Notes: The solid lines show the estimates of β_h^x when estimating $FE_{t-h}(\pi_t) = \alpha_h^x + \beta_h^x F_{t-h}(x_{t-h+2}) + \varepsilon_{h,t}^x$ for each horizon $h \in \{1,2,4,8,12\}$ over the sample period from 2011:Q4-2024:Q1, where $x \in \{w_t, u_t, y_t\}$. A positive estimate implies that higher forecasts for x tend to be followed by inflation outturns which are lower-than-forecasted (suggesting that the underlying forecasting model overestimates the inflationary impact of x). Shaded areas represent 90% confidence bands.

forecasting framework would underestimate the dis-inflationary force of a given level of u_t – even if working with an unbiased value for the slope of the Philips curve, κ. At shorter forecast horizons, there is no evidence of any miscalibration.

When looking at the rate of economic growth, as done in Panel 8c, a slightly more nuanced picture emerges – namely one suggesting that forecasted increases in real GDP growth tend to give rise to inflationary surprises up to horizons of 2 years, followed by inflation outturns which are *lower* than forecasted at the 3-year horizon. This could be due to the prospect of strong growth leading to some demand-driven inflation in the short run (more than forecasted), which is compensated by lower-than-forecasted inflation in later years (for example thanks to increased supply arriving on the market).

Results for the full sample period Results for the full sample period (August 1997 - February 2024) are shown in Appendix C.7. While they largely confirm results for the post-2011 sample, those for the rate of unemployment *reverse* – suggesting that, when judged over the full sample period, the forecasting process worked with a Phillips curve slope that was *too steep*. Since the post-2011 results are suggesting that the model's Phillips curve is *too flat*, this suggests that the model's Phillips curve was 'over-flattened', or that the actual Phillips curve has steepened over time (or a combination of the two).

BL regressions for government bond yields Of particular interest to any central bank, is the question as to whether its forecasting process works with appropriate values of the 'policy rate multiplier' which governs the impact of changes in the monetary policy stance on outcomes in key variables, like inflation and unemployment.

In case of the Bank of England, its policy rate ('Bank Rate') rested on the Effective Lower Bound (ELB) for much of the post-2011 sample period – with the Bank using Quantitative Easing (QE) alongside Forward Guidance (FG) to change its policy stance. Consequently, it is more appropriate to base the BL exercise on (forecasted) longer-term government bond yields, which are less constrained by the ELB whilst capturing these 'unconventional' elements. In addition, the stance of monetary policy is affected by the entire yield curve, of which medium-term rates are a better summary statistic (compared to only using information from the very short end of the curve). For these reasons, we base this exercise on 3-year UK government bond yields.[19] To reflect the MPC's conditioning assumption (which relies on

[19]Source: Bloomberg Finance L.P. Results are robust to using 2-year yields instead. Using rates beyond the 3-year horizon risks

market-based expectations, as discussed in Section 2), we use the associated 2-quarter ahead forward rates. Figure 9 shows BL regressions when deploying these forward rates in the RHS of equation (4.1). We show results not only for inflation, but also for real GDP growth, the unemployment rate and wage growth – to see whether the Bank's forecasting process appropriately captures the impact of monetary policy on those variables (which are considered important in their own right).

Findings imply that, relative to what is embedded in the forecast, increases in 3-year government bond yields: a) have a stronger disinflationary impact over all horizons; b) push up unemployment by less at the 3-year horizon; c) do less to slow real GDP growth at the 2-quarter horizon; and d) do more to slow wage growth at the 2- and 3-year horizon. Taken together, these observations suggest that the transmission channel might operate, to a significant extent, via lower inflation expectations (which have the potential to reduce inflation and wage growth without having to rely on a significant decrease in real activity or increase in unemployment).[20]

5 Constant rates and the 'Bank Rate multiplier' in the forecast

Our results reported in the previous section are, on average, pointing to some miscalibrations in the value of the Bank Rate multiplier. Those results are however *relative to the forecast*, which begs the question what the forecast has been imposing in this regard.

Here, we can exploit the fact that, in addition to forecasts that are conditioned on the market curve (as discussed in the previous section), the MPC also produces forecasts for a scenario which assumes that Bank Rate is held constant at the level applicable to the time the forecast is constructed.[21] The MPC publishes the constant rate forecast alongside the market rate forecast to help communicate its views on the impact of alternative policy assumptions. We outline a method that can help to infer that impact using only the published constant- and market-rate forecasts. Comparing the difference between forecasts conditioned on the market path and on the constant rate path, enables one to get a sense of the strength and time profile of the monetary transmission mechanism that has (on average) been underpinning the forecasting process.

In particular, we can run regressions of the following form:

$$F_t^{MC}(Y_{t+h}) - F_t^{CR}(Y_{t+h}) \quad = \quad \alpha_h + \beta_h(R_t^{MC} - R_t^{CR}) + \varepsilon_{h,t}, \tag{5.1}$$

where $F_t(Y_{t+h})$ is the time-t forecast for an outcome variable of interest 'Y', forecasted h quarters into the future.[22] The superscript 'MC' indicates that it reflects the forecast under the market curve, while the superscript 'CR' refers to the forecast under the constant rate scenario. On the right-hand side of the regression we take the relevant interest rate 'R' to be of a 3-year maturity (but results are fully robust to using 2 years instead). Such a medium-term rate is not only thought to be more relevant for affecting outcomes of interest (as not many entities transact overnight at Bank Rate), but can also serve as a reasonable summary statistic for the entire yield curve. For R_t^{MC} we therefore use 3-year government

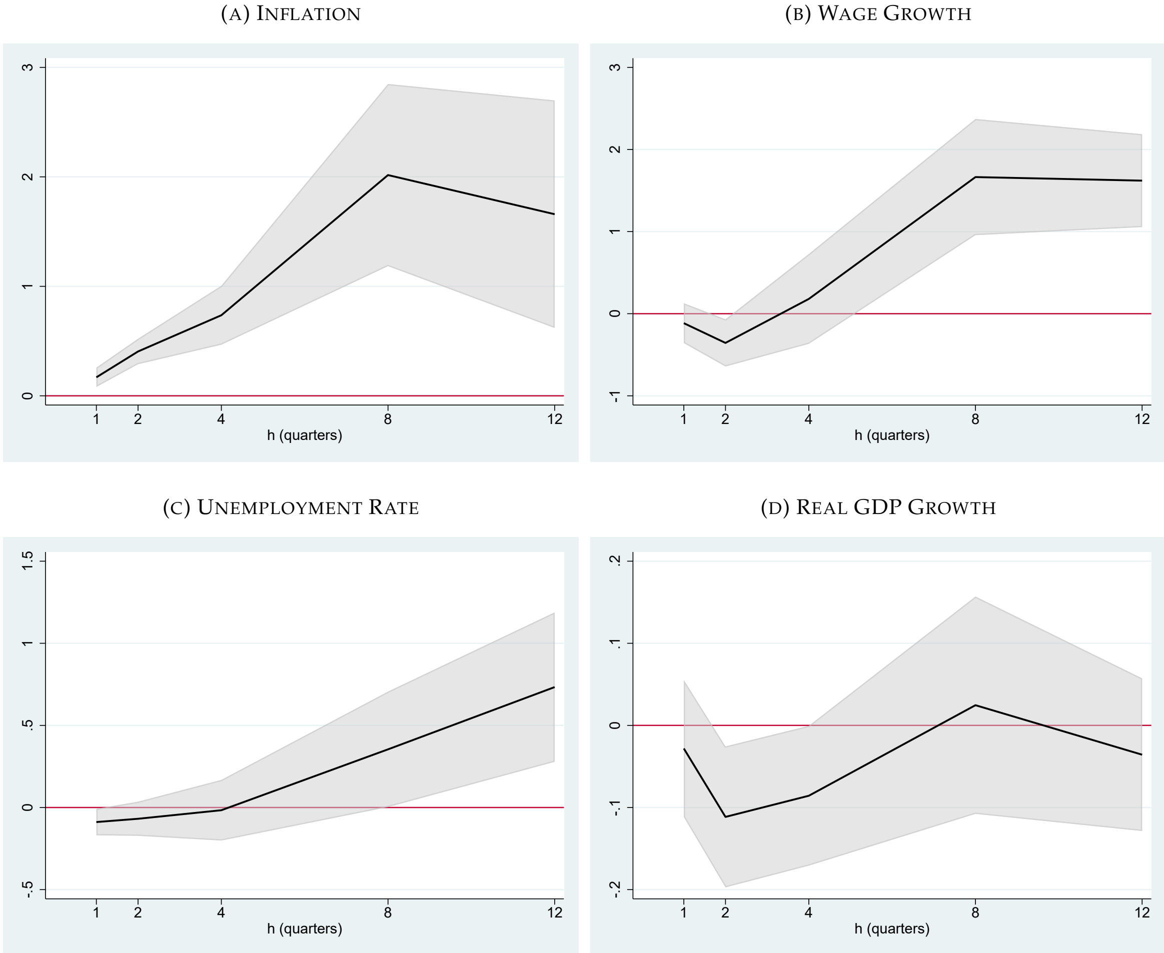
including a significant term premium, which is not the focus of this exercise.

[20] It is unlikely that this result stems from erroneous assumptions regarding the neutral rate of interest (r^*). While it is true that an under-estimation of r^* could explain why a given expected path for interest rates has a stronger dis-inflationary effect than forecasted, such a misjudgement should also be accompanied by stronger-than-forecasted adverse effects on unemployment and real GDP growth – which is not what we see.

[21] All other conditioning assumptions remain unchanged, except for the exchange rate path which endogenously responds to the different Bank Rate path.

[22] All variables 'Y' will enter the regression in natural logs, so that outcomes can be interpreted as percentage differences.

Figure 9: BL Results for Forecast Errors in (A) Inflation, (B) Wage Growth, (C) Unemployment and (D) real GDP Growth as a function of 3-year yield forecasts



Notes: The solid lines show the estimates of β^x_h when estimating $FE_{t-h}(z_t) = \alpha^x_h + \beta^x_h F_{t-h}(3yYield_{t-h+2}) + \varepsilon^x_{h,t}$ for each horizon $h \in \{1,2,4,8,12\}$ over the sample period from 2014:Q3-2024:Q1, where $z_t \in \{\pi_t, \Delta w_t, u_t, \Delta y_t\}$. A positive estimate implies that higher forecasts for the 3-year yield tend to be followed by inflation/wage growth/unemployment/GDP growth outturns which are lower-than-forecasted. Shaded areas represent 90% confidence bands.

bond yields, while R^{CR}_t is simply set equal to the current level of Bank Rate.[23]

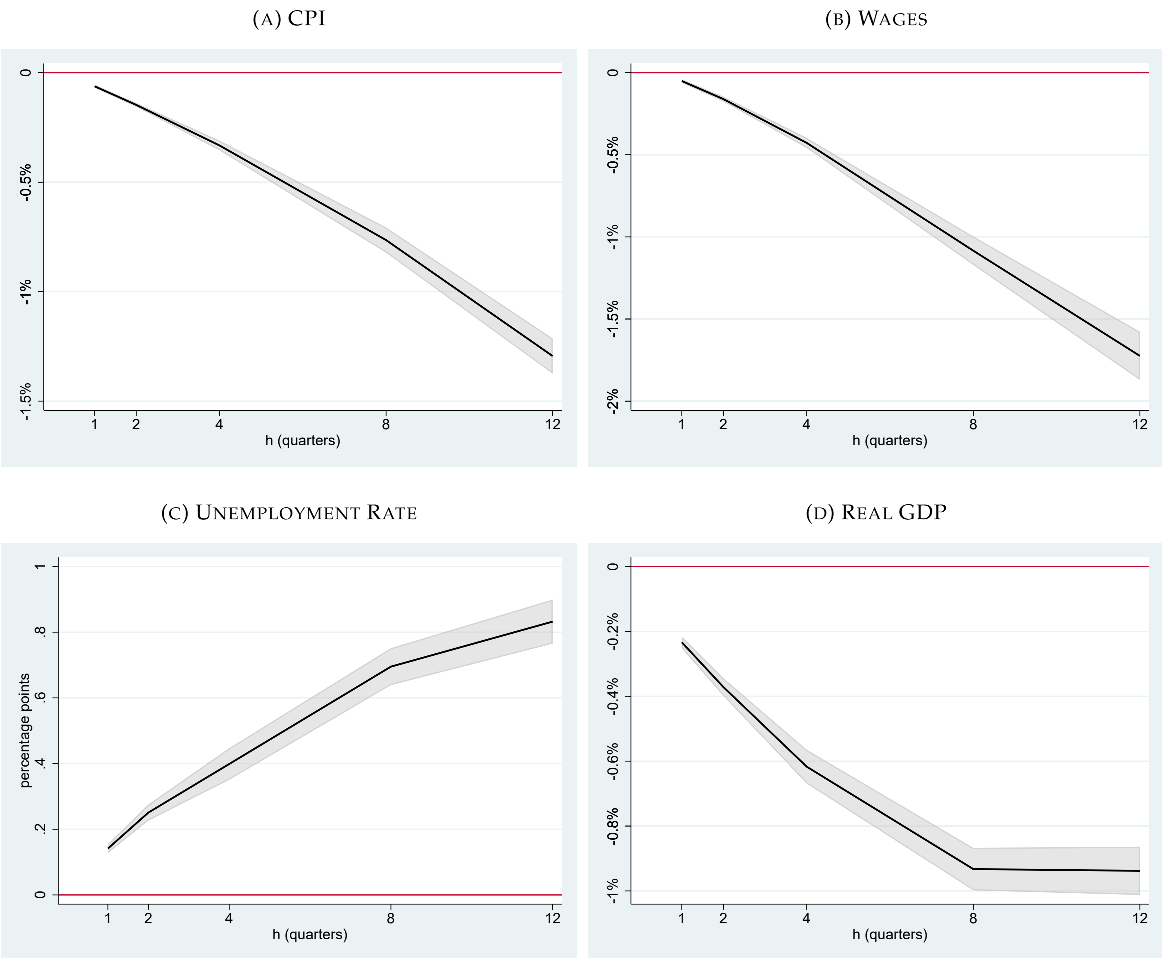
Subsequently tracing out the estimated β_h-coefficients gives us a sense about the causal impact that has, on average, been attributed to changes in Bank Rate in the forecast. It is important to keep in mind, however, that the actual multiplier underpinning the forecast may have varied over time – potentially in response to changes in the state of the economy (such as the rate of economic growth or unemployment).[24] Averaging over all time periods, however, Figure 10 gives an impression of how monetary policy has been transmitted to forecasts for CPI, wages, the unemployment rate and real GDP in the forecast (where the impulse is a +100 basis point shock to Bank Rate).

As one can see from Figure 10, monetary policy operates in the conventional way in the forecast: a higher interest rate lowers real GDP, prices, and wages, while pushing up the rate of unemployment. It

[23]This it to capture the notion that if Bank Rate is being held constant at its current level, the yield curve should be entirely flat. In reality, a term premium may render a yield curve upward sloping even if the policy rate is expected to remain constant going forward, but this is unlikely to be a major issue at the 3-year horizon.

[24]The MPC's views on the impact of policy may also have evolved alongside developments in the modelling framework over the evaluation period.

Figure 10: Forecast-implied Responses of (A) CPI, (B) Wages, (C) the Unemployment Rate and (D) Real GDP to a 100bp Increase in Bank Rate



Notes: The solid lines show the estimates of β_h when estimating $F_t^{MC}(Y_{t+h}) - F_t^{CR}(Y_{t+h}) = \alpha_h + \beta_h(R_t^{MC} - R_t^{CR}) + \varepsilon_{h,t}$ for each horizon $h \in \{1, 2, 4, 8, 12\}$ over the sample period from 2014:Q3-2024:Q1. Shaded areas represent 90% confidence bands.

is furthermore apparent that the forecast has featured notable lags in the transmission process, with the impact on all four outcome variables peaking at the end of the forecasting horizon (i.e., after 3 years). When it comes to the peak effects, it is reassuring that their magnitudes are broadly consistent with empirical estimates such as those reported in Cesa-Bianchi et al. (2020) and Braun et al. (2023), even though those empirical estimates are pointing to a transmission process that is slightly quicker relative to the one depicted in Figure 10.[25]

6 Concluding Remarks

We analyse the forecast accuracy and efficiency of the Bank of England's MPC forecasts and propose a systematic approach for central banks to leverage past forecasts (and associated errors) with the aim of learning more about the structure and functioning of the underlying economy.

[25]Cross-comparability of these estimates is however complicated by the fact that the underlying monetary policy shocks work on different parts of the yield curve. Cesa-Bianchi et al. (2020) identify a shock at the very short end of the yield curve, while Braun et al. (2023) look at three different parts of the yield curve (short, medium, and long). Of these, our approach (focused on 3-year gilt yields) is arguably closest to the medium-term "path" shock identified by Braun et al. (2023).

Our key findings can be summarised as follows. First, in terms of the median forecast errors, we document that the BoE's MPC inflation forecasts are unbiased, but wage growth, the unemployment rate and real GDP growth tend to be over-predicted. Second, the MPC forecasts for inflation are less accurate than those for wage growth, unemployment and GDP growth, especially after the 4-quarter ahead forecast horizon. While this ostensibly casts doubt on the MPC's inflation forecasting practices, our third key finding suggests that it has more to do with inherent uncertainties in the inflation process: while 'simple' forecasting models (such as a random walk forecast, or one stemming from an auto-regressive model) are able to outperform MPC forecasts for wage growth, the unemployment rate, and GDP growth, this is *not* the case for the inflation forecast – where (across all horizons) MPC forecasts consistently come with greater accuracy than their 'simple' alternatives.

Finally, our results suggest that the MPC forecasts are not fully efficient – a much tougher test in practice – in the sense of not processing all available information exhaustively. Focussing on the MPC forecasts that were released after November 2011, our analysis along the lines of Blanchard and Leigh (2013) suggests several sources of inefficiency according to this definition.

First, the pass-through from wage growth to inflation may be higher than what has historically been embedded in the forecasting process. Second, the inflationary impact of increases in GDP growth seems to materialise faster than historically modelled. Third, regarding the transmission mechanism of monetary policy, we find that, relative to what is embedded in the forecast, a tightening in policy: i) has a stronger disinflationary impact over all horizons; ii) pushes up unemployment by less at the 3-year horizon; and iii) does more to slow wage growth at the 2- and 3-year horizon. Taken together, these observations could be consistent with transmission through inflation expectations having played a bigger role than attributed to it in the forecast (as the inflation expectations channel can reduce inflation and wage growth without having to rely on a significant increase in unemployment).

While it is challenging to leverage our results to identify the structural drivers of inaccuracies and inefficiencies in the MPC's forecast process, our findings can nonetheless help shed light on areas to focus on in future model development at the Bank of England.

References

BERK, R. (1990): "A primer on robust regression." Modern Methods of Data Analysis, 292–324.

BERNANKE, B. S. (2024): "Forecasting for monetary policy making and communication at the Bank of England: a review," Independent Evaluation Office, Bank of England.

BINDER, C. C. AND R. SEKKEL (2023): "Central Bank Forecasting: A Survey," Staff Working Papers 23-18, Bank of Canada.

BLANCHARD, O. J. AND D. LEIGH (2013): "Growth Forecast Errors and Fiscal Multipliers," American Economic Review, 103, 117–120.

——— (2014): "Learning about Fiscal Multipliers from Growth Forecast Errors," IMF Economic Review, 62, 179–212.

BRAUN, R., S. MIRANDA-AGRIPPINO, AND T. SAHA (2023): "Measuring monetary policy in the UK: the UK Monetary Policy Event-Study Database," Bank of England working papers 1050, Bank of England.

BURGESS, S., E. FERNANDEZ-CORUGEDO, C. GROTH, R. HARRISON, F. MONTI, K. THEODORIDIS, AND M. WALDRON (2013): "The Bank of England's forecasting platform: COMPASS, MAPS, EASE and the suite of models," Bank of England working papers 471, Bank of England.

CESA-BIANCHI, A., G. THWAITES, AND A. VICONDOA (2020): "Monetary policy transmission in the United Kingdom: A high frequency identification approach," European Economic Review, 123.

CLARK, T. E. AND M. W. MCCRACKEN (2013): "Evaluating the accuracy of forecasts from vector autoregressions," Working Papers 2013-010, Federal Reserve Bank of St. Louis.

FAWCETT, N., L. KÖRBER, R. M. MASOLO, AND M. WALDRON (2015): "Evaluating UK point and density forecasts from an estimated DSGE model: the role of off-model information over the financial crisis," Staff Working Paper No. 538, Bank of England.

GRANZIERA, E., P. JALASJOKI, AND M. PALOVIITA (2024): "The bias of the ECB inflation projections: a State-dependent analysis," Bank of Finland Research Discussion Papers, Bank of Finland.

HÅKANSON, C. AND S. LASÉEN (2024): "Cruising to victory or a dead heat? Central Bank championships in forecasting ability 2021 and 2022," Sveriges Riksbank Economic Commentary, Sveriges Riksbank.

IEO (2015): "Evaluating forecast performance, Bank of England," Tech. rep., Independent Evaluation Office.

MCMAHON, M. AND R. RHOLES (2023): "Building Central Bank Credibility: The Role of Forecast Performance," CEPR Discussion Paper No. 18660.

NORDHAUS, W. D. (1987): "Forecasting Efficiency: Concepts and Applications," The Review of Economics and Statistics, 69, 667–674.

REIFSCHNEIDER, D. AND P. TULIP (2019): "Gauging the uncertainty of the economic outlook using historical forecasting errors: The Federal Reserve's approach," International Journal of Forecasting, 35, 1564–1582.

SVENSSON, L. E. O. (1997): "Inflation forecast targeting: Implementing and monitoring inflation targets," European Economic Review, 41, 1111–1146.

TIMMERMANN, A. (2007): "An Evaluation of the World Economic Outlook Forecasts," IMF Staff Papers, 54, 1–33.

TULIP, P. AND S. WALLACE (2012): "Estimates of Uncertainty around the RBA's Forecasts," RBA Research Discussion Papers rdp2012-07, Reserve Bank of Australia.

WEST, K. D. (2006): "Forecast Evaluation," in Handbook of Economic Forecasting, ed. by G. Elliott, C. Granger, and A. Timmermann, Elsevier, vol. 1 of Handbook of Economic Forecasting, chap. 3, 99–134.

A Outturn Definition

Example for Inflation We can construct an example to provide more intuition for the notation introduced above. For this example, we consider the modal CPI inflation forecasts from the Bank's August 2018 (A18) Monetary Policy Report (MPR)[26], depicted in Table 1.

TABLE 1: MODAL INFLATION FORECASTS, A18 IN GREEN, OUTTURNS IN RED AFTER $k = 12$ QUARTERS.

	A18	N18	F19	M19	A19	N19	F20	M20	A20	N20	F21	M21	A21	N21	F22	M22	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
2018:Q3	**2.48**	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	**2.52**	2.52	2.52	…
2018:Q4	2.29	**2.46**	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27	**2.27**	2.27	…
2019:Q1	2.32	2.18	**1.82**	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	**1.87**	…
2019:Q2	2.34	2.32	1.94	**2.08**	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	…
2019:Q3	**2.15**	2.13	1.76	1.83	**1.68**	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	…
2019:Q4	2.17	**2.10**	1.97	1.63	1.56	**1.43**	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	…
2020:Q1	2.15	2.40	**2.35**	1.98	1.95	1.67	**1.80**	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	…
2020:Q2	2.13	2.31	2.17	**1.72**	1.77	1.20	1.32	**0.54**	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	…
2020:Q3	**2.09**	2.24	2.15	1.74	**1.90**	1.17	1.24	0.22	**0.25**	0.60	0.60	0.60	0.60	0.60	0.60	0.60	…
2020:Q4	2.04	**2.12**	2.05	1.98	2.11	**1.51**	1.43	0.07	0.26	**0.57**	0.53	0.53	0.53	0.53	0.53	0.53	…
2021:Q1	2.03	2.10	**2.07**	2.04	2.15	1.67	**1.53**	0.03	0.48	0.72	**0.82**	0.61	0.61	0.61	0.61	0.61	…
2021:Q2	2.04	2.06	2.09	**2.05**	2.19	1.95	1.84	**0.16**	1.48	1.72	1.57	**1.69**	2.05	2.05	2.05	2.05	…
2021:Q3	**2.03**	2.04	2.10	2.09	**2.23**	2.00	1.91	0.69	**1.81**	1.75	1.46	1.86	**2.70**	2.77	2.77	2.77	…
…		…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

Notes: Table 1 shows the Bank's modal inflation forecasts. Each column represents a specific forecast, from August 2018 (A18) until May 2022 (M22). For the A18 forecast, which was released on 02.08.2018, 2018:Q3 is the 'nowcast' quarter, the blue-colored field, the $h = 4$ quarter ahead forecast (Y1 forecast) is marked in orange, the Y2 forecast is marked in light blue and the Y3 forecast is marked in magenta. In red we show the respective outturns for the A18 forecast. The outturn is defined as the $T + k$ vintage of the data in T where $k = 12$. If $T + k$ is not yet available we take the latest available vintage.

The A18 forecast was released on 2^{nd} of August 2018. The time of release thus falls into 2018:Q3. The $h = 0$ quarters ahead forecast, the 'nowcast', is thus $F_{2018:Q3}(\pi_{2018:Q3}) = 2.48$. The $h = 1$ quarter ahead forecast would be $F_{2018:Q3}(\pi_{2018:Q4}) = 2.29$. Note that the BoE produces forecasts 12 quarters into the future. Based on the outturn definition above, $\pi_t = \pi_{t|t+k}$, the corresponding outturns for the A18 forecast would be the data vintages after $k = 12$ quarters, starting from the August 2021 forecast, highlighted in red in Table 1. This would imply that the A18 'nowcast' error for $h = 0$ is $FE_{2018:Q3}(\pi_{2018:Q3}) = 2.48 - 2.52 = -0.04$. The A18 one-quarter ahead forecast error for $h = 1$ would be $FE_{2018:Q3}(\pi_{2018:Q4}) = 2.29 - 2.27 = 0.02$. The example illustrates that a positive (negative) value of the forecast error indicates that inflation was over-estimated (under-estimated), the forecast was higher (lower) than the actual outturn.

Example for GDP Growth As discussed above, the definition of the outturn can affect the forecast errors, especially for variables that are revised substantially such as GDP. In Tables 2 and 3 we illustrate how the forecast errors for GDP growth would depend on the outturn definition. In Table 2 we show how the outturns would look like if we took them $k = 12$ quarters after the time period T in which the data materialises. In Table 3 we show the case for $k = 4$. One can calculate the forecast errors for different outturn definitions. The example illustrates that for the A19 forecast the outturn definition does matter, however, for many forecast horizons the forecast errors are quite similar across the three different outturn definitions $k \in \{4, 8, 12\}$.

[26] In 2018 it was still called 'Inflation Report'. From November 2019 the Inflation Report became the Monetary Policy Report.

TABLE 2: MODAL GDP GROWTH FORECASTS, A19 HIGHLIGHTED IN GREEN, OUTTURNS IN RED AFTER $k = 12$.

	A19	N19	F20	M20	A20	N20	F21	M21	A21	N21	F22	M22	A22	N22	F23	M23	A23
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2019:Q3	**0.27**	0.40	0.41	0.38	0.37	0.33	0.51	0.51	0.51	0.46	0.46	0.46	0.46	0.61	0.61	0.61	0.61
2019:Q4	0.17	0.23	-0.03	0.14	0.12	0.21	0.22	0.22	0.22	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03
2020:Q1	0.32	0.25	0.17	-2.86	-2.19	-2.52	-3.02	-2.85	-2.85	-2.70	-2.64	-2.53	-2.53	-2.64	-2.64	-2.64	-2.64
2020:Q2	0.43	0.42	0.27	-25.03	-21.04	-19.81	-18.75	-19.47	-19.47	-19.57	-19.45	-19.43	-19.43	-20.99	-20.99	-20.99	-20.99
2020:Q3	**0.50**	0.44	0.35	12.67	18.31	16.15	16.00	16.95	16.95	17.44	17.57	17.60	17.60	16.61	16.61	16.61	16.61
2020:Q4	0.57	**0.43**	0.42	12.13	3.52	-1.99	0.60	1.27	1.27	1.11	1.50	1.48	1.48	1.21	1.21	1.21	1.21
2021:Q1	0.60	0.42	**0.33**	4.43	1.72	2.40	-4.20	-1.60	-1.59	-1.36	-1.26	-1.17	-1.17	-1.17	-1.05	-1.05	-1.05
2021:Q2	0.61	0.46	0.35	**3.01**	1.71	3.08	5.23	4.30	5.00	5.51	5.43	5.56	5.56	6.54	6.53	6.53	6.53
2021:Q3	**0.62**	0.47	0.37	1.31	**1.44**	3.20	4.63	3.87	2.92	1.53	1.06	0.94	0.94	1.77	1.73	1.73	1.73
2021:Q4	0.62	**0.48**	0.40	0.85	1.24	**1.90**	2.68	1.99	1.99	0.96	1.14	1.28	1.28	1.62	1.53	1.53	1.53
2022:Q1	0.62	0.51	**0.43**	0.53	0.63	1.44	**1.00**	0.89	1.10	1.23	0.04	0.92	0.77	0.69	0.62	0.49	0.49
2022:Q2	0.62	0.50	0.46	**0.49**	0.58	0.59	0.36	**0.25**	0.44	0.64	0.96	0.06	-0.20	0.23	0.06	0.05	0.05
2022:Q3	**0.62**	0.51	0.48	0.43	**0.54**	0.52	0.29	0.23	**0.43**	0.50	0.44	0.58	0.40	-0.50	-0.31	-0.09	-0.09
...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

TABLE 3: MODAL GDP GROWTH FORECASTS, A19 HIGHLIGHTED IN GREEN, OUTTURNS IN RED AFTER $k = 8$.

	A19	N19	F20	M20	A20	N20	F21	M21	A21	N21	F22	M22	A22	N22	F23	M23	A23
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2019:Q3	**0.27**	0.40	0.41	0.38	0.37	0.33	0.51	0.51	0.51	0.46	0.46	0.46	0.46	0.61	0.61	0.61	0.61
2019:Q4	0.17	0.23	-0.03	0.14	0.12	0.21	0.22	0.22	0.22	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03
2020:Q1	0.32	0.25	0.17	-2.86	-2.19	-2.52	-3.02	-2.85	-2.85	-2.70	-2.64	-2.53	-2.53	-2.64	-2.64	-2.64	-2.64
2020:Q2	0.43	0.42	0.27	-25.03	-21.04	-19.81	-18.75	-19.47	-19.47	-19.57	-19.45	-19.43	-19.43	-20.99	-20.99	-20.99	-20.99
2020:Q3	**0.50**	0.44	0.35	12.67	18.31	16.15	16.00	16.95	16.95	17.44	17.57	17.60	17.60	16.61	16.61	16.61	16.61
2020:Q4	0.57	**0.43**	0.42	12.13	3.52	-1.99	0.60	1.27	1.27	1.11	1.50	1.48	1.48	1.21	1.21	1.21	1.21
2021:Q1	0.60	0.42	**0.33**	4.43	1.72	2.40	-4.20	-1.60	-1.59	-1.36	-1.26	-1.17	-1.17	-1.17	-1.05	-1.05	-1.05
2021:Q2	0.61	0.46	0.35	**3.01**	1.71	3.08	5.23	4.30	5.00	5.51	5.43	5.56	5.56	6.54	6.53	6.53	6.53
2021:Q3	**0.62**	0.47	0.37	1.31	**1.44**	3.20	4.63	3.87	2.92	1.53	1.06	0.94	0.94	1.77	1.73	1.73	1.73
2021:Q4	0.62	**0.48**	0.40	0.85	1.24	**1.90**	2.68	1.99	1.99	0.96	1.14	1.28	1.28	1.62	1.53	1.53	1.53
2022:Q1	0.62	0.51	**0.43**	0.53	0.63	1.44	**1.00**	0.89	1.10	1.23	0.04	0.92	0.77	0.69	0.62	0.49	0.49
2022:Q2	0.62	0.50	0.46	**0.49**	0.58	0.59	0.36	**0.25**	0.44	0.64	0.96	0.06	-0.20	0.23	0.06	0.05	0.05
2022:Q3	**0.62**	0.51	0.48	0.43	**0.54**	0.52	0.29	0.23	**0.43**	0.50	0.44	0.58	0.40	-0.50	-0.31	-0.09	-0.09
...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Note: Tables 2 and 3 show the Bank's modal GDP q-o-q growth forecasts. Each column represents a specific forecast, from August 2019 (A19) until August 2023 (A23). For the A19 forecast, which was released on 01.08.2019, 2019:Q3 is the 'nowcast' quarter, the blue-colored field, the $h = 4$ quarter ahead forecast (Y1 forecast) is marked in orange, the Y2 forecast is marked in light blue and the Y3 forecast is marked in magenta. In red we show the respective outturns for the A19 forecast. The outturn is defined as the $T + k$ vintage of the data in T where $k = 12$ in the upper table and $k = 8$ in the lower table. If $T + k$ is not yet available we take the latest available vintage. For this example we assumed that A23 is the latest available vintage.

B Forecast Errors over Time

In Figures B.1 to B.3 we plot the unscaled forecast errors for inflation, wage growth, unemployment and GDP growth at different horizons $h \in \{0,1,2,4,8,12\}$. While the Bank's inflation nowcasting performance has been quite stable over time, the largest nowcast errors were made in the November 2021 and February 2022 forecast for 2021:Q4 and 2022:Q1 respectively, just as inflation started to accelerate. The November 2023 inflation nowcast for 2023:Q4 produced the largest over-prediction on record.

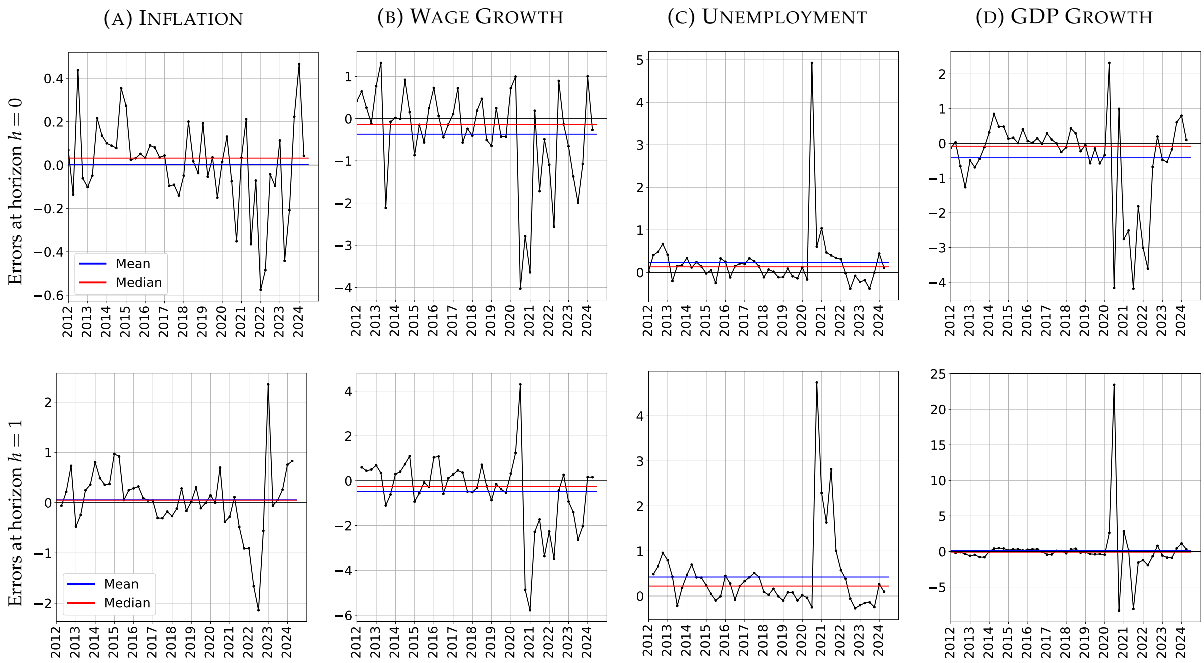
At the one-quarter ahead forecast horizon, the February 2022 forecast produced the largest under-prediction of inflation so far. Inflation for 2022:Q2 was predicted to be 7% but turned out to be 9.2%. The August 2022 forecast produced a substantial over-prediction of inflation, since inflation for 2022:Q4 was predicted to be 13.1 % but turned out to be 10.75%. In fact, the one-quarter ahead over-prediction of inflation in August 2022 was larger than the under-prediction of inflation in February 2022.

At horizons $h \in \{4,8,12\}$ the forecast errors are larger than at the shorter horizons. Again, the largest under-predictions of inflation were recorded for the recent inflationary episode in 2021-23. Inflation forecasts from 2019-20 at the two- and three-year horizon of around 2% and outturns of around 11% in 2022 gave rise to forecast errors of around -9%.

In the second panel of Figures B.1 to B.3 we show the forecast errors of the MPC's wage growth projections for forecast horizon $h \in \{0,1,2,4,8,12\}$. At shorter horizons $h \in \{0,1,2\}$ the forecast errors tend to fluctuate around zero. While the Bank has tended to under-predict wage growth in the post-pandemic period since 2020, the median forecast error for wage growth has actually been positive, at least at horizon $h = 4$ and above, indicating that over-prediction was more common pre-Covid.

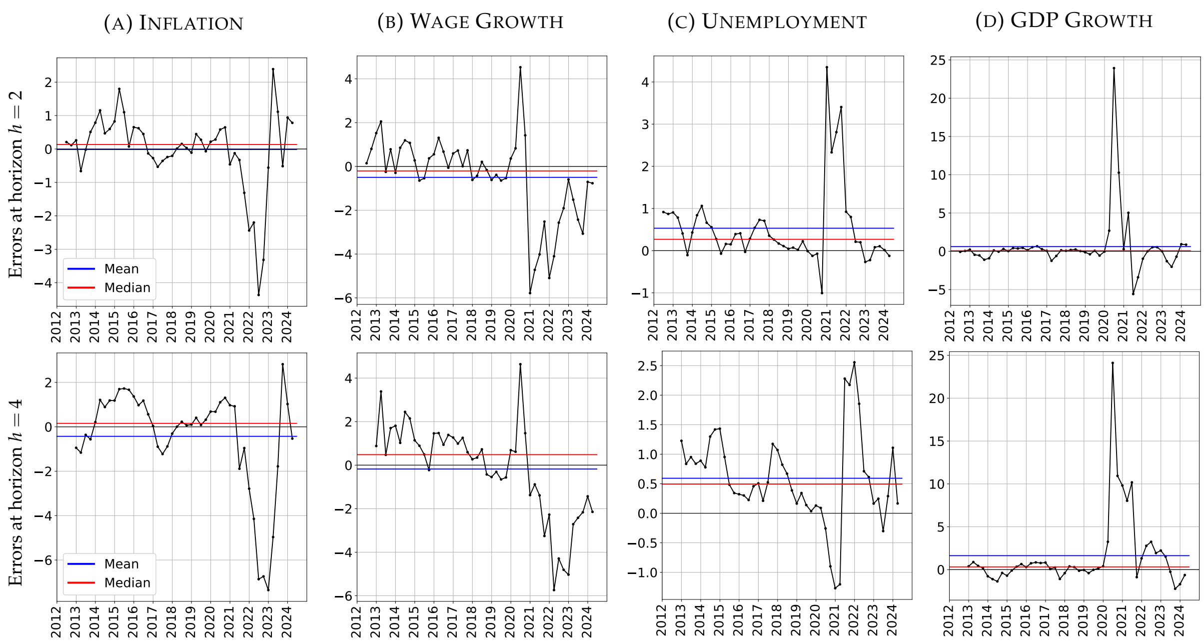
The third panel of Figures B.1 to B.3 shows the forecast errors of the MPC's modal unemployment projections. Until the outbreak of the Covid pandemic in 2020:Q1, the BoE's nowcasting performance

FIGURE B.1: FORECAST ERRORS AT HORIZON $h \in \{0,1\}$



Notes: This figure shows the forecast errors at horizon $h = 0$ (nowcast error, upper row) and at horizon $h = 1$ (lower row) for inflation, wage growth, unemployment and GDP growth, from left to right. The forecast errors in this Figure are not scaled.

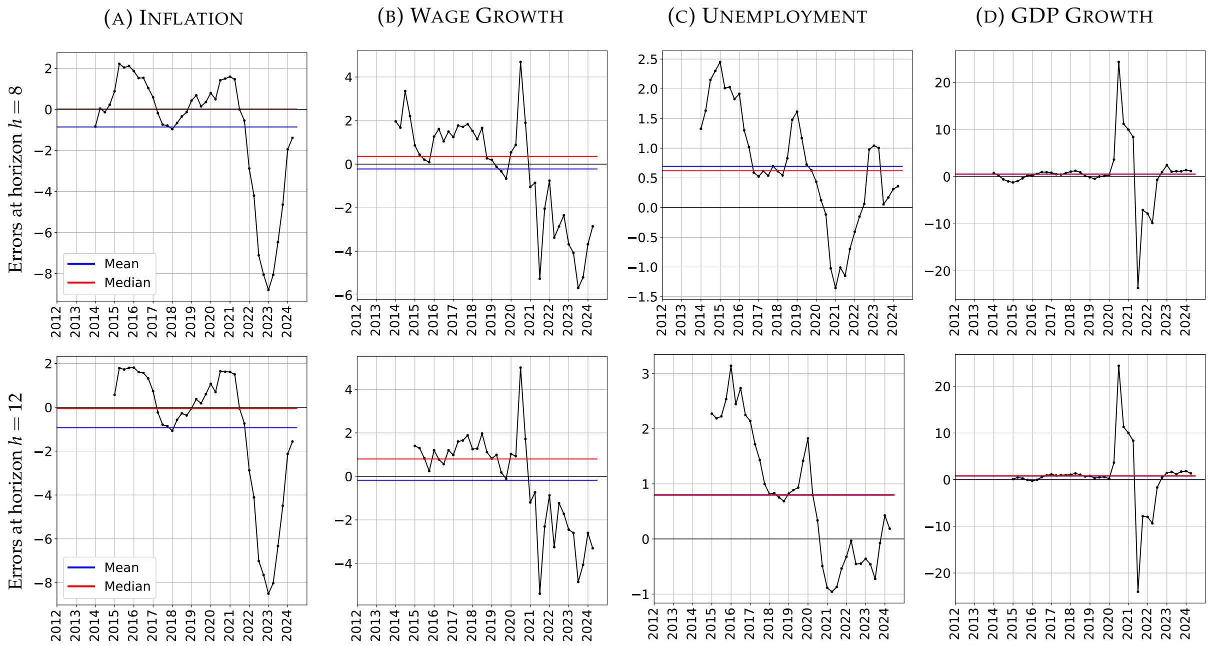
FIGURE B.2: FORECAST ERRORS AT HORIZON $h \in \{2,4\}$



Notes: This figure shows the forecast errors at horizon $h = 2$ (upper row) and at horizon $h = 4$ (lower row) for inflation, wage growth, unemployment and GDP growth, from left to right. The forecast errors in this Figure are not scaled.

was quite stable (with moderate over-prediction being common). Following the outbreak of Covid, the Bank released its May 2020 Monetary Policy Report on 7th of May 2020 and predicted that the unemployment rate in 2020:Q2 would reach 9%. Since the outturn for the 2020:Q2 unemployment rate was 4.1% this gave rise to a very large nowcast error. Nowcast errors for unemployment remained elevated until end-2021. The forecasts at horizon $h = 1$ and $h = 2$ produced in 2020 and 2021 featured

FIGURE B.3: FORECAST ERRORS AT HORIZON $h \in \{8, 12\}$



Notes: This figure shows the forecast errors at horizon $h = 8$ (upper row) and at horizon $h = 12$ (lower row) for inflation, wage growth, unemployment and GDP growth, from left to right. The forecast errors in this Figure are not scaled.

the largest ever forecast errors at the respective horizons.

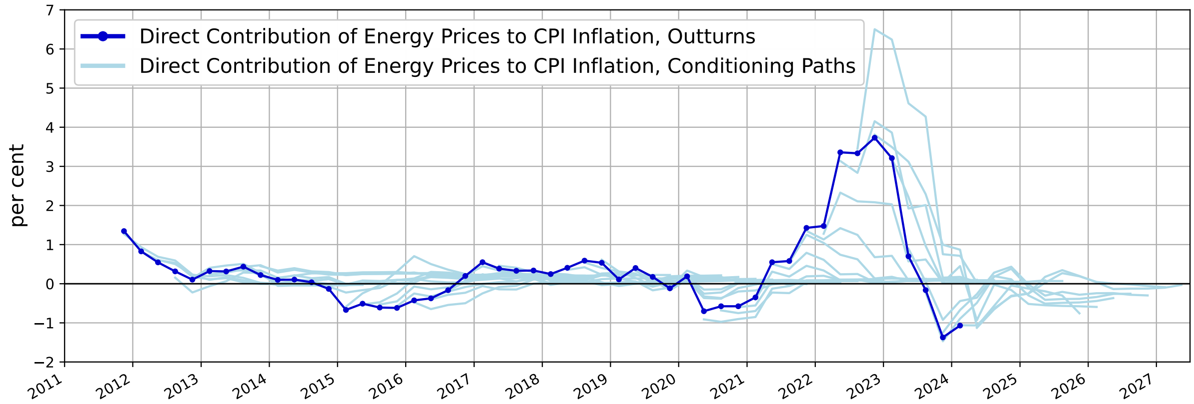
The last panel in each Figure shows the forecast errors of the MPC's modal GDP growth (year-over-year) projections for forecast horizon $h \in \{0, 1, 2, 4, 8, 12\}$. Again, at horizons $h = 1$ and $h = 2$ the forecasts produced in 2020/21 featured very large forecast errors. It is striking, however, that the largest negative non-pandemic forecast errors at the $h = 1$ and the $h = 2$ forecast horizon were recorded in late 2022 and early 2023. This suggests that in 2022 and in 2023 the Bank under-estimated GDP growth.

B.1 Inflation Forecast Errors and Energy Price Growth

The Bank of Englands's MPC forecast is a conditional forecast. One of the key conditioning assumptions is the path for the future development of energy price growth.

Energy Prices In Figure B.4 we show the outturns and conditioning paths for energy price growth. The key energy price growth conditioning paths in the Bank of England's MPC forecast is the 'direct contribution of energy prices to annual CPI inflation'. This measure is constructed using oil and natural gas price futures data. Until the November 2022 forecast, the energy price conditioning path would be constructed by taking the first six months from the respective futures curve, and thereafter an average over the next year, which was held constant throughout the rest of the forecast horizon. This methodology implied that after the sixth quarter of the forecast horizon, expected energy price growth would be zero.[27] Since the November 2022 forecast, the convention has been to use the full futures curve for oil and gas prices, which allows for energy price growth movements after the sixth quarter of the forecast horizon.

FIGURE B.4: ENERGY PRICE GROWTH



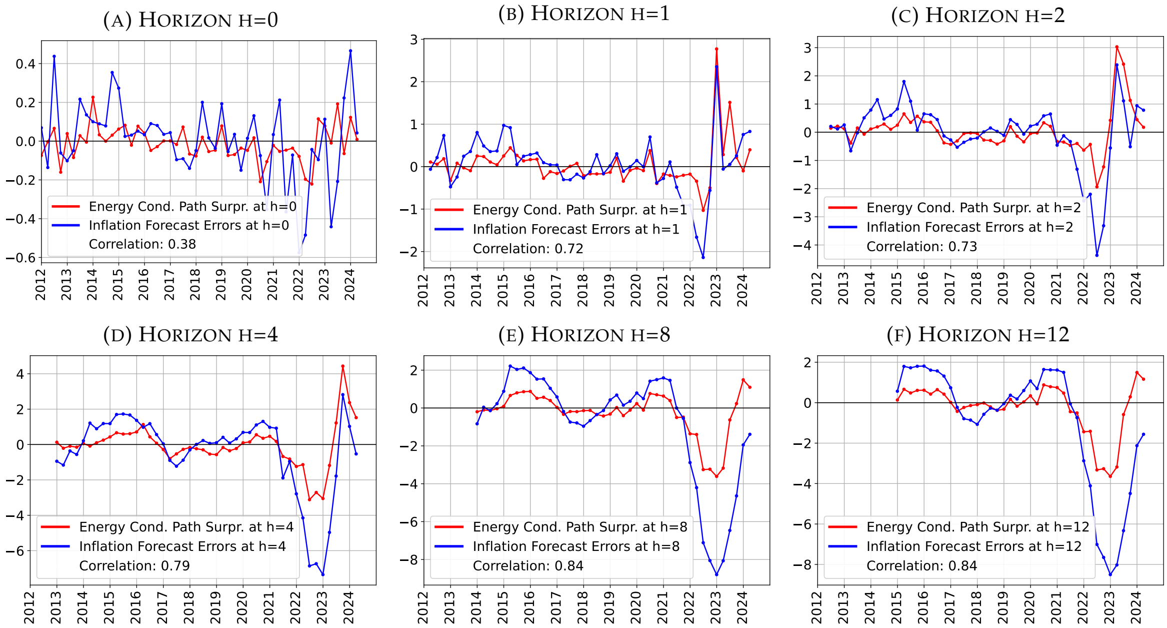
Notes: The solid blue line depicts the outturns for the 'direct contribution of energy price growth to annual CPI inflation'. The light blue lines depict the energy contribution conditioning paths.

We analyse the relationship between the inflation forecast errors and the surprises in the energy price growth conditioning paths by first looking at correlations and then at results from simple regressions.

Correlation between Inflation Forecast Errors and Surprises in Energy Price Growth In Figure B.5 we visualise the strong comovement and calculate the correlation between inflation forecast errors and surprises in the energy price growth conditioning path at horizons $h \in \{0,1,2,4,8,12\}$. The higher the forecast horizon, the higher is the correlation (at $h = 0$ we have a correlation of 0.38, at $h = 12$ we have a correlation of 0.84). This is explained by the fact that the outturns for inflation and energy price growth are highly correlated.

[27]Minor movements after the sixth quarter in the expected energy price growth conditioning paths would be explained by changes in non-wholesale costs and delayed effects from Error Correction Models for petrol prices.

FIGURE B.5: CORRELATION BETWEEN SURPRISES IN ENERGY PRICE GROWTH AND INFLATION FORECAST ERRORS



Notes: Panels A to F show the forecast errors at horizon $h \in \{0,1,2,4,8,12\}$ for CPI inflation (in blue) and the direct contribution of energy price growth to annual CPI inflation (in red). Positive (negative) values imply that the forecast (or conditioning path) was higher (lower) than the actual outturn.

Variability of Inflation Forecast Errors explained by Surprises in Energy Price Growth In addition to calculating the correlation, we can also run simple regressions of the form

$$FE_{t-h}(\pi_t) = \alpha_h + \beta_h FE_{t-h}(\pi_t^{en}) + \epsilon_{h,t}$$

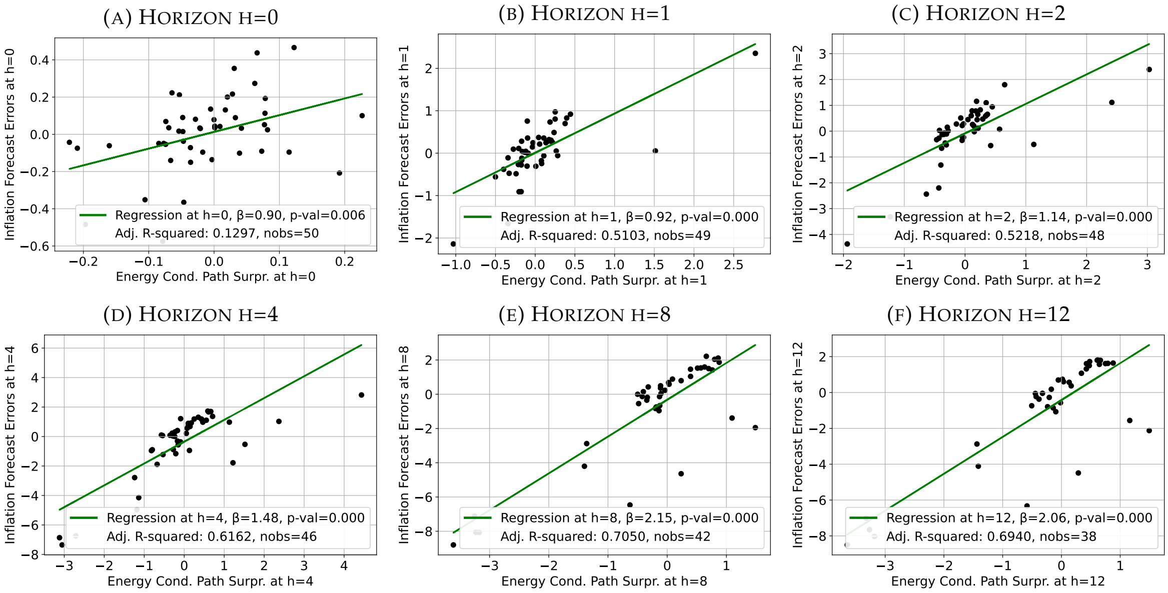
to estimate the linear regression coefficients, test whether the relationship is significant and calculate R^2, the measure of the variability of inflation errors explained by the surprises in energy price growth conditioning paths. In Table 4 and in Figure B.6 we show that the regression coefficients are positive and significant and that R^2 increases with the forecast horizon, from $R^2_{h=0} = 0.13$ to $R^2_{h=12} = 0.69$.

TABLE 4: REGRESSION RESULTS.

	β_h	Observations	Adj. R^2
h=0	0.90*** (0.32)	49	0.13
h=1	0.92*** (0.13)	48	0.51
h=2	1.14*** (0.16)	47	0.52
h=4	1.48*** (0.17)	45	0.61
h=8	2.15*** (0.21)	41	0.71
h=12	2.06*** (0.22)	37	0.69

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

FIGURE B.6: REGRESSION OF INFLATION FORECAST ERRORS ON SURPRISES IN ENERGY PRICE GROWTH



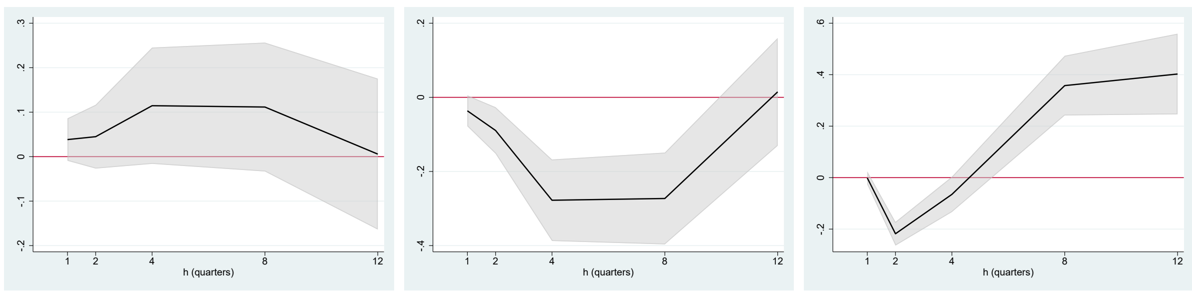
Notes: Panels A to F show results for simple OLS regressions when regressing the inflation errors on the surprises in the energy conditioning path at horizon $h \in \{0, 1, 2, 4, 8, 12\}$.

C Results for the Full Sample Period

C.1 Blanchard Leigh Regressions for the Full Sample Period

Figure C.7: BL Results for Forecast Errors in Inflation as a function of forecasts for (A) wage growth, (B) unemployemnt and (C) real GDP growth, full sample

(A) Wage Growth (B) Unemployment Rate (C) GDP Growth

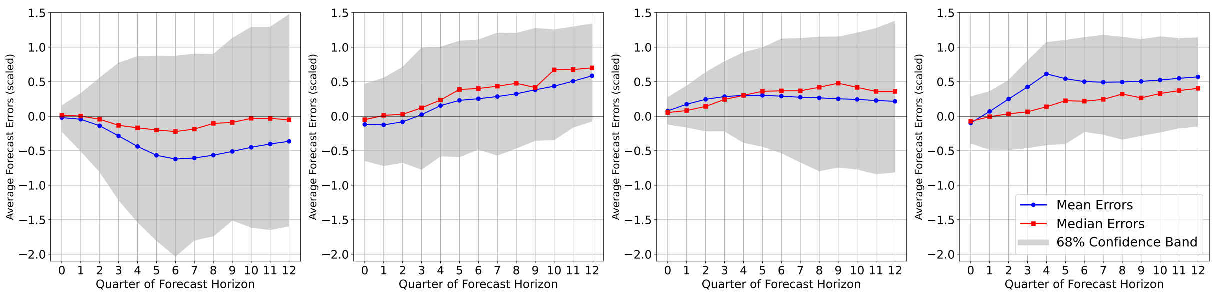


Notes: The solid lines show the estimates of β_h^x when estimating $FE_{t-h}(\pi_t) = \alpha_h^x + \beta_h^x F_{t-h}(x_{t-h+2}) + \varepsilon_{h,t}^x$ for each horizon $h \in \{1,2,4,8,12\}$. A positive estimate implies that higher forecasts for x tend to be followed by inflation outturns which are lower-than-forecasted (suggesting that the underlying forecasting process overestimates the inflationary impact of x). Shaded areas represent 90% confidence bands.

C.2 Forecast Bias and Accuracy since 1997

Figure C.8: Average Forecast Errors over the Full Sample

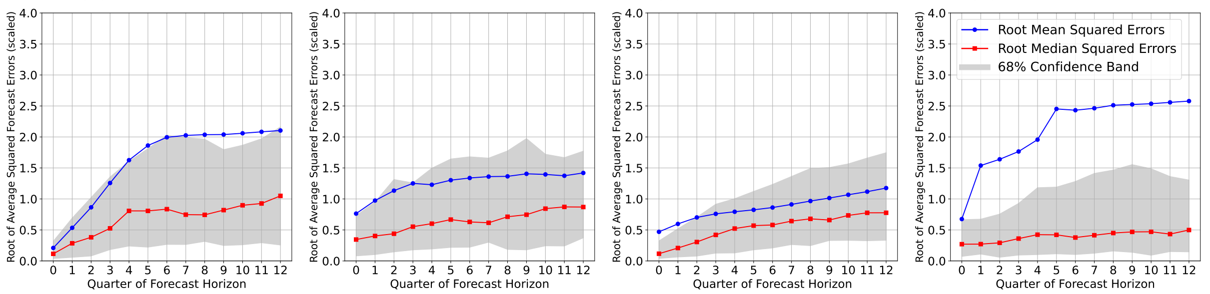
(A) Inflation (B) Wage Growth (C) Unemployment (D) GDP Growth



Notes: The blue (red) lines depict the mean (median) forecast error of the MPC modal forecasts since 1997. The light blue swathe depicts the 68% percentiles. All forecast errors have been re-scaled by the respective pre-pandemic sample standard deviation to facilitate comparability across variables and across samples. Positive values imply over-prediction, whereas negative values imply under-prediction.

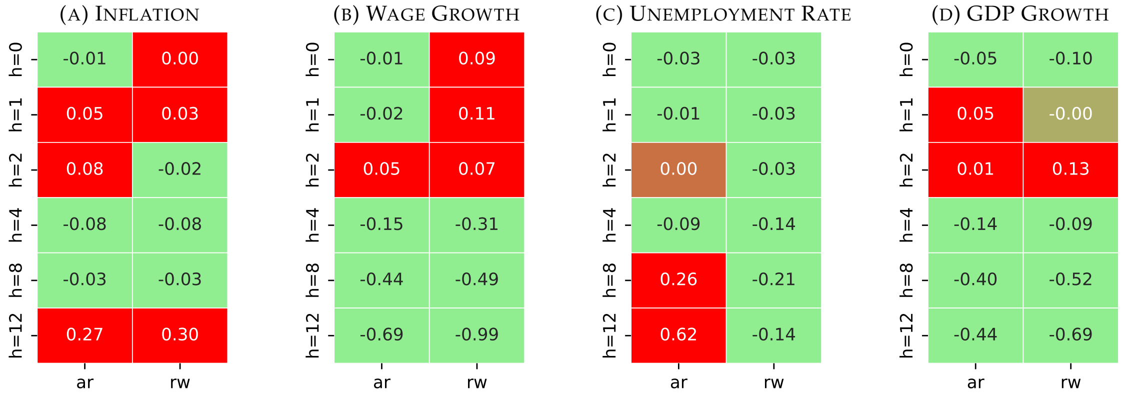
Figure C.9: Root Mean and Median Squared Errors over the Full Sample

(A) Inflation (B) Wage Growth (C) Unemployment (D) GDP Growth



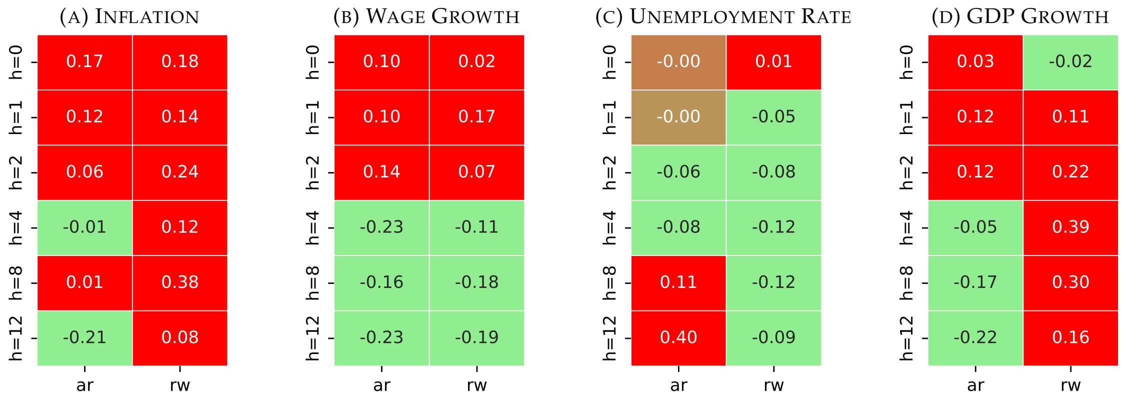
Notes: The blue (red) lines depict the root mean (median) squared forecast error of the MPC modal forecasts since 1997. The light blue swathe depicts the 68% percentiles. All forecast errors have been re-scaled by the respective pre-pandemic sample standard deviation to facilitate comparability across variables and across samples.

FIGURE C.10: BIAS COMPARISON FOR THE FULL SAMPLE



Notes: The four tables C.10a, C.10b, C.10c and C.10d (from left to right for inflation, wage growth, unemployment and GDP growth) depict a comparison of the absolute values of the forecast biases in terms of the *median* forecast errors between the cross-check forecasts and the MPC modal forecasts since 1997. The right column of each table depicts the difference between the absolute value of the full-sample bias for the random walk (RW) forecast and the absolute value of the full-sample MPC modal forecast bias. If the random walk forecast is less biased than the full-sample MPC modal forecast the corresponding field is colored in green. Green colors thus indicate that the particular forecast at the specific horizon is less biased than the full-sample MPC modal forecast. The left column in each table depicts the AR(p) comparison.

FIGURE C.11: ACCURACY COMPARISON FOR THE SULL SAMPLE



Notes: The four tables C.11a, C.11b, C.11c and C.11d (from left to right for inflation, wage growth, unemployment and GDP growth) depict a comparison of the forecast accuracy in terms of the root median squared errors (RMedSE) between the cross-check forecasts and the MPC modal forecasts since 1997. The right column of each table depicts the deviation of the full-sample RMedSE for the random walk (RW) forecast from the RMedSE of the full-sample MPC modal forecast. If the RMedSE from the random walk forecast is lower than the full-sample MPC modal forecast RMedSE, the deviation is negative and the corresponding field is colored in green. Green colors thus indicate that the particular forecast at the specific horizon is more accurate than the full-sample MPC modal forecast. The left column in each table depicts the comparison between the full-sample AR(p) and the full-sample MPC modal forecast.