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Central Bank Forecasting: A Survey

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Abstract

Central banks' forecasts are important monetary policy inputs and tools for central bank communication. We survey the literature on forecasting at the Federal Reserve, European Central Bank, Bank of England and Bank of Canada, focusing especially on recent developments. After describing these central banks' forecasting frameworks, we discuss the literature on central bank forecast evaluation and new tests of unbiasedness and efficiency. We also discuss evidence of central banks' informational advantage over private sector forecasters—which appears to have weakened over time—and how central bank forecasts may affect private sector expectations even in the absence of an informational advantage. We discuss how the Great Recession led central banks to evaluate their forecasting frameworks and how the COVID-19 pandemic has further challenged central bank forecasting. Finally, we consider directions for future research.

Topic: Monetary policy
JEL codes: E47, E52, E58

Résumé

Les prévisions des banques centrales contribuent de façon importante à la formulation des politiques monétaires et aux communications de ces institutions. Nous effectuons un survol des travaux sur les prévisions effectuées par la Réserve fédérale, la Banque centrale européenne, la Banque d'Angleterre et la Banque du Canada, en nous intéressant principalement aux évolutions récentes. Nous commençons par décrire les cadres de prévision de ces banques, et discutons ensuite des recherches publiées concernant les évaluations de leurs prévisions ainsi que les nouveaux tests d'efficience et d'absence de biais. Nous examinons aussi l'avantage sur le plan de l'information que détiennent les banques centrales par rapport aux prévisionnistes du secteur privé – lequel avantage semble s'être estompé au fil du temps – et l'incidence possible des prévisions des banques centrales sur les attentes du secteur privé, et ce, même sans avantage informationnel. Nous analysons comment la Grande Récession a amené les banques centrales à revoir leurs cadres de prévision et comment la pandémie de COVID-19 a encore plus compliqué les prévisions des banques centrales. Pour conclure, nous envisageons des pistes de recherche pour l'avenir.

Sujet : Politique monétaire
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1 Introduction

Forecasts play an important role in the policy process at central banks. Over the last two decades, forecasts have also become a key communication tool for central banks and may influence expectations of market participants and the public. The following quote from former Bundesbank President Weber (2009) alludes to this double role of central bank forecasts:

> The reason why central bankers have a strong interest in forecasting is straightforward: because of substantial and variable lags in the monetary policy transmission mechanism, central banks cannot influence current inflation and output. Given these time lags, it is widely recognised that monetary policy should be forward-looking and take a medium-term perspective. Furthermore, the publication of forecasts helps to anchor the expectations of firms and households, thereby making the central bank more effective in fulfilling its objective.

Because of the critical importance of central bank forecasts, researchers have studied a number of dimensions of central bank forecasting. We think, for several reasons, that the time is ripe for a review and synthesis of this literature. First, some central banks have increased the frequency and variety of forecasts and projections that they publish as part of their communication strategies; such changes merit evaluation. Second, econometric and methodological advancements have changed how researchers assess the quality of these forecasts and their effects on private sector expectations. Third, recent events, including the COVID-19 pandemic, the Russian invasion of Ukraine, and high inflation have increased public attention to central bank forecasts, and at times put a spotlight on forecasting errors. Going forward, it is important to understand, to the extent possible, where these errors come from and how they might affect central bank credibility and monetary policy effectiveness.

To conduct this review, we focus on four major central banks: the Federal Reserve (Fed), the European Central Bank (ECB), the Bank of England (BoE), and the Bank of Canada (BoC). We aim to provide readers with an overview of the forecasting frameworks of these central banks and how they have evolved in recent years. We also synthesize advancements in how researchers evaluate the quality of the forecasts themselves and their effects on private sector expectations. We then discuss challenges to central bank forecasting in recent years. Throughout this review, we provide brief summaries of the themes and results from earlier literature, focusing more attention on recent work, especially work conducted since

the Great Recession. In addition, we highlight open questions and promising avenues for future research.

As we discuss in Section 2, the Fed, ECB, BoE, and BoC share several key features in terms of their forecasting process and frameworks, including intensive data collection and monitoring and reliance on both models and judgment. But there are also important differences, in particular with respect to the roles of staff, policymaking committees, and individual policymakers in producing the forecasts, and with respect to the conditionality of the forecasts. The central banks also vary in terms of the type of forecasts they produce, such as interest rate projections and fan charts.

Section 3 begins by briefly summarizing the more classic tests of forecast optimality and their application to central bank forecasts. Then we discuss how more recent work uses more sophisticated tests and larger samples, and in some cases allows for asymmetric loss functions or relaxed stationarity assumptions. This often leads to substantially different results regarding bias and efficiency (Clements et al., 2007; Capistran, 2008; Rossi and Sekhposyan, 2016). Recent work also evaluates the density forecasts provided most notably by the Bank of England (Dowd, 2007; Gneiting and Ranjan, 2011; Knuppel and Schultefrankenfeld, 2019).

In Section 4, we discuss the literature on the comparison of and relationship between central bank and private sector forecasts. Romer and Romer (2000) show that Greenbook inflation forecasts are more accurate than private sector forecasts. Moreover, monetary policy actions reveal some of the Fed's private information about the economic outlook to the public, helping to explain the response of long-run interest rates to monetary policy. Subsequent work updates and extends these results, generally confirming the central banks' informational advantage over private forecasters. This literature has recently gained renewed interest as central banks are making greater use of forecasts as communication tools and incorporating them into their forward guidance policies. Even if a central bank does not have an informational advantage over private forecasters, central bank forecasts can influence private sector expectations (and, in turn, asset prices) by revealing information about monetary policy strategy or preferences (Hubert, 2015a).

In Section 5, we review how central bank researchers reflected on and responded to forecast errors made in the Great Recession and present new evidence on forecasting during the COVID-19 pandemic. Section 6 concludes and discusses promising recent and future research directions.

2 Forecasting Frameworks

The forecasting processes and frameworks at the Fed, ECB, BoE, and BoC have much in common with each other and with other central banks. For most central banks, the key forecast variables are inflation, aggregate output, and unemployment, though "intermediate" forecasts for variables such as consumption, investment, productivity, and international conditions are often used to construct and explain the key forecasts (Robertson, 2000). All four of the central banks publish forecasts four times per year. Central banks rely heavily on data as input to the forecasting process. Bernanke and Boivin (2003, p. 525-526) describe central bankers as "data-friends," emphasizing that "the Fed actively monitors literally thousands of economic time series." This data-friend role is not new; research departments have long been engaged in data collection and monitoring at central banks (Binder and Skinner, 2021).

This data is input into models and combined with expert judgment to produce the forecasts. Sims (2002) interviews staff and policymakers at the Fed, the Swedish Riksbank, the European Central Bank (ECB), and the Bank of England, and determines that each uses a primary forecasting model but also relies on sectoral experts to assist with "subjective" forecasting. Central banks often refer to conditional forecasts as "projections." Alessi et al. (2014) note that the central bank forecasting process often includes "the wide use of conditioning assumptions, the involvement of a variety of models, a frequent assessment for reasonableness and consistency of the outputs and a prominent role assigned to expert judgement" (p. 3).

All four of the central banks rely on a variety of models that they update over time. For example, Federal Reserve Tealbooks (formerly known as Greenbooks) include model-based forecasts from the the Estimated, Dynamic, Optimization-based (Edo) model (Edge et al., 2009). The Board staff also produces forecasts based on the FRB/US model, which are also published in the Tealbooks and released with a five-year delay. The ECB relies on various models to construct their projections, including time series models, the New-Euro Area Model II, and the semi-structural model ECB-BASE (Coenen et al., 2018; Angelini et al., 2019). The suite of models used by the BoE has changed significantly over the years. In 2003, the BoE substituted the semi-structural medium-term macro model (MTMM) for the more structural BEQM model (Harrison et al., 2005). Since 2005, the BoC staff has used different versions of ToTEM, an open-economy New Keynesian DSGE model that itself has been regularly updated over time (Corrigan et al., 2021). Since 2015, the BoC staff has also used a semi-structural forecasting model, LENS, similar in nature to the FRB/US model (Gervais and Gosselin, 2014).

2.1 Role of Staff and Policymakers

At most central banks, the research staff present forecasts to policymakers, though policymakers' own forecasts may differ from those of their staff, and individual policymakers' forecasts may differ from the committee consensus forecasts (Reifschneider et al., 1997; Edison and Marquez, 1998). The differences between staff and policymaker forecasts, and the heterogeneity of policymakers' forecasts, have both been studied, particularly for the Federal Reserve.

The staff of the Board of Governors of the Fed produces Greenbook forecasts (now called Tealbook forecasts) before each of the eight annual Federal Open Market Committee (FOMC) meetings. FOMC members use these staff forecasts to help make their own forecasts. The staff forecasts are made available to the public after five years. Romer and Romer (2008) compare the accuracy of staff forecasts to FOMC members' forecasts from 1979 to 2001. They find that policymakers do not add useful information to the forecasts, and suggest that it may be more effective for the policymakers to take staff forecasts as given. Romer and Romer (2008, p. 230) also show that differences between staff and FOMC forecasts help predict monetary policy shocks, which "may indicate that the FOMC's attempts to add information to the staff forecast are not just unsuccessful, but may lead to inappropriate actions."

Subsequent literature has been less condemning of FOMC forecasters (Binder and Wetzel, 2018; Hogan, 2021). Ellison and Sargent (2012, p. 1047) defend the FOMC, arguing, first, that the differences between staff and FOMC forecasts are minimal, and second, that the FOMC forecasts may actually "depict a worst-case scenario that it uses to design decisions that are robust to misspecification of the staff's model." Nunes (2013) suggests that one reason that the policymakers' forecasts differ from the staff forecast is due to the policymakers' incorporation of other public forecasts and views into their own forecast. The weight that FOMC members place on public views is larger than would be optimal to minimize mean squared error, but may reflect policymakers' desire to represent a variety of public views.

Romer (2010) introduces a dataset on individual FOMC members' forecasts. Heterogeneity in members' forecasts can be partially explained by the economic conditions in the members' own districts (Sheng, 2015) and by members' lifetime inflation experiences (Malmendier et al., 2021). This heterogeneity is important, as it helps explain members' policy preferences (Fendel and Rülke, 2012; Sheng, 2015). Ellis and Liu (2016) find that the policy preferences of voting Reserve Bank presidents, but not of non-voting presidents and governors, are influenced by other FOMC members' forecasts. Eichler and Lahner (2018)

find that regional biases in Reserve Bank presidents' forecasts are more pronounced prior to their elections. They also document that governors submit lower inflation and higher unemployment rate forecasts than presidents, and that career backgrounds or political affiliations influence forecasts.[1] Moreover, presidents' forecasts add value to the Greenbook real economy forecasts, while governors add value to the Greenbook inflation forecasts (Ellis and Liu, 2013).

This work on the forecast heterogeneity of monetary policy committee members is related to a broader literature about monetary policy disagreement based on political affiliation (Bordo and Istrefi, 2018), career backgrounds (Eichler and Lahner, 2014), and regional conditions (Meade and Sheets, 2005; Coibion and Goldstein, 2012; Jung and Latsos, 2015). Policy preferences and forecast disagreement interact in important ways; for example, hawkishness is associated with higher-than-consensus inflation forecasts (McCracken, 2010; Eichler and Lahner, 2014; Bennani et al., 2018; Schultefrankenfeld, 2020). Moreover, non-voting FOMC members may have strategic motives in forecasting, as they systematically overpredict inflation relative to the consensus if they prefer tighter monetary policy (Tillmann, 2011) and "anti-herd" their inflation forecasts (Rülke and Tillmann, 2011). Disagreement in FOMC forecasts is smaller than disagreement among professional forecasters (Banternghansa and McCracken, 2009), and increased markedly in the Great Recession (Marquez and Kalfa, 2021). Even disagreement about longer-run projections of unemployment increased in the years following the Great Recession, as FOMC participants disagreed about the natural rate of unemployment (Binder, 2021).

BoC staff projections are a crucial part of the analysis presented to the bank's Governing Council ahead of the release of the Monetary Policy Report (MPR). After the presentation of the staff projections, during the weeks leading up to the publication of the MPR, Governing Council receives additional important information, such as an analysis of risks around outlook, the Business Outlook Survey, and the Canadian Survey of Consumer Expectations, as well as an update on the current economic and financial conditions. The Governing Council then publishes a *consensus* view of the economy and their projections in the MPR. The underlying staff forecasts, like the Greenbook forecasts, are only available to the public with a five-year delay. Champagne et al. (2020) find that the Governing Council forecasts are more accurate than the staff forecasts for inflation but not for GDP growth. The BoE Monetary Policy Report (MPR) forecasts reflect the views of the Monetary Policy Committee (MPC)

[1] Among expert forecasters in the Bloomberg Survey of Professional Forecasters, those with previous experience in central banking are less likely to forecast deflation (Benchimol et al., 2021).

aided by advice from the staff. While the BoE releases the voting records for the policy rate decision of each member of the MPC, there is not an individual member forecast for GDP and inflation, for example. If an independent staff forecast is produced at any point in the forecasting process, it is not made available to the public. Thus, differences between staff and policymaker forecasts cannot be studied, nor can heterogeneity of policymakers' forecasts.

The forecasting framework of the ECB reflects the fact that it is the central bank of 19 different European Union countries, combining both individual country and Euro area-wide perspectives. The Eurosystem/ECB staff projections reflect the views of the Eurosystem/ECB staff and play an important role in the ECB Governing Council's conduct of monetary policy, but they are neither endorsed nor do they necessarily conform with the views of the ECB Governing Council. The March and September projections are produced solely by the ECB staff, while the June and December ones are made together with staff from the Eurosystem national central banks. These jointly produced projections also contain projections for the individual member countries (ECB, 2016). The ECB Governing Council does not produce a projection of its own.

2.2 Conditional Projections and Density Forecasts

Central banks continue to evaluate the types of forecast products that they release to the public, occasionally introducing new ones. For example, in 2007, quarterly projections of inflation, growth, and unemployment began to be published in the Federal Reserve's Summary of Economic Projections (SEP) at alternating regularly-scheduled FOMC meetings. In April 2009, longer-run projections were also added. A detailed summary of the projections, including the range and central tendency (which excludes the three highest and three lowest projections), is released three weeks after the associated FOMC meeting. After a five-year delay, individual participants' projections are released without attribution, and after a 10-year delay, they are released with attribution (Kalfa and Marquez, 2021; Marquez and Kalfa, 2021).

Shortly after the SEP was introduced, Rudebusch and Williams (2008) argued that for the sake of transparency, the Fed should follow the central banks of New Zealand, Norway, and Sweden in providing numerical interest rate projections as well. At the time, the Fed and most other central banks were reluctant to do so out of concern that financial markets would take such projections as unconditional commitments; instead, the FOMC issued qualitative statements about its policy rate inclinations beginning in 2003 (Rudebusch, 2008).

Projections of the federal funds rate—the so-called "dot plots"— were finally added to the SEP in 2012. Each dot represents an individual FOMC participant's projection, without attribution. The interest rate projections are not linked with individual inflation, unemployment, and growth projections, limiting their use in inferring individual participants' reaction functions (Kohn, 2016).

The projections in the SEP are not unconditional forecasts, but rather are conditional on each participant's view of appropriate monetary policy (Kahn and Palmer, 2016). For an evaluation of the conditionality of the Greenbook forecasts, see Berge et al. (2019). The nature of conditionality differs across central banks. Similar to the SEP, the Bank of Canada staff economic projections, as well as its governing council forecasts presented at the MPR, are conditional on their respective paths for the policy rate. Alternatively, the ECB staff condition their macroeconomic projections on market expectations of future interest rates. The Bank of England, on the other hand, produces two sets of forecasts: one conditional on market expectations of future interest rates and another based on constant interest rates. Knuppel and Schultefrankenfeld (2017) show that the choice of underlying interest rate assumptions makes little difference for the accuracy of Bank of England forecasts. Finally, for small open economies like Canada and the U.K., forecasts are also crucially conditional on assumptions for the exchange rate and commodity prices.

The central banks vary in whether they produce "fan charts," or density forecasts that quantitatively assess the uncertainty surrounding their projections (Fawcett et al., 2015). The BoE has a long history of producing such fan charts. From 1993 to 1996, the confidence bands around the inflation forecasts were based on the forecast errors of the previous 10 years. As discussed by (Britton and Fisher, 1998), the symmetric nature of those bands "encouraged the reader to concentrate on an apparently precise central projection, ignoring the very wide degree of uncertainty surrounding it. Hence, small changes in the projection were given too much prominence relative to the risk assessment"(p. 30). Since 1997, the BoE forecasts for inflation is expressed as a probability distribution with the aim of providing the public with a more accurate description of the MPC's subjective assessment of medium-term inflationary pressures (Britton and Fisher, 1998).

The FOMC does not provide fan charts, but only provides qualitative information about the uncertainty associated with their projections (Reifschneider and Tulip, 2019).[2] However,

[2]Simulations of the FRB/US model are used to construct fan charts that are published in the Tealbook as an indicator of the uncertainty surrounding the model-based forecasts (Brayton et al., 2014; Reifschneider and Tulip, 2019), but these reflect model uncertainty rather than subjective uncertainty and are released with a long delay.

after the Global Financial Crisis, staff at the ECB and Federal Reserve Bank of New York (FRBNY) recognized the importance of taking macroeconomic tail risks into account, and the FRBNY began producing density forecasts based on scenario-driven forecasts (Alessi et al., 2014). Neither the ECB nor the BoC currently provides a measure of uncertainty in its staff projections and monetary policy report, respectively.

3 Forecast Evaluation

Central bank forecasts are often evaluated with respect to possible biases and their efficiency (Mincer and Zarnowitz, 1969; Mankiw and Shapiro, 1986; Nordhaus, 1987; Croushore and van Norden, 2018). Identifying departures from these benchmarks, or departures from rationality, can point to possibilities for forecast improvement, which could improve macroeconomic management, especially in recessions (Jones and Ogden, 2017). This has motivated many studies using classic tests of unbiasedness and efficiency, frequently extended as additional forecast data has become available, and with more recent developments in methodological approaches.

3.1 Unbiasedness and Efficiency

Early studies of forecast unbiasedness, relying on the Mincer and Zarnowitz (1969) test, find no significant evidence of bias in the Fed's inflation forecasts, and at most minor bias in real output forecasts (Scotese, 1994; Jansen and Kishan, 1996; Joutz and Stekler, 2000; Romer and Romer, 2000). Likewise, Elder et al. (2005) find that BoE point projections for growth and inflation show little evidence of bias, though they note that their sample is too small to draw firm conclusions.

An efficient forecast incorporates all available information to the forecaster at time t (Nordhaus, 1987). Several different notions and implications of efficiency are typically studied. Weak-form efficiency requires that forecasts fully incorporate previous movements of the forecasted variable, whereas semi-strong-form efficiency requires that the forecast cannot be improved by the incorporation of any publicly available data. It is common to test for weak-form efficiency by testing for serial correlation in forecast errors or in forecast revisions. For example, Scotese (1994) finds that Greenbook forecast errors are serially correlated—a sign of inefficiency—and suggests that this forecast smoothing might reflect forecasters' attempts to build reputation by reducing the variance of their forecasts as information arrives (Tillmann, 2012). Some studies consider both unbiasedness and efficiency. Clements et al. (2007)

use a pooled approach that considers Greenbook forecasts at all horizons together, rather than individually, revealing bias in inflation, growth, and unemployment forecasts and serial correlation in inflation revisions. Baghestani (2008) also rejects the null of unbiasedness for Greenbook unemployment forecasts, but finds that they are efficient in the sense that they incorporate all useful predictive information from an ARIMA model of unemployment.

In more recent years, increased data availability has enabled additional tests of unbiasedness and efficiency. For the Fed, Arai (2016) finds that efficiency is generally accepted for SEP inflation projections but rejected for projections of real variables, especially unemployment, as forecast revisions are strongly autocorrelated. Jones and Ogden (2017) find that FOMC forecasts fail a semi-strong-form efficiency test since economic policy uncertainty measures can help predict forecast errors. Sinclair et al. (2010) include a recession dummy variable as a regressor in a Mincer and Zarnowitz (1969) regression. For current quarter Greenbook forecasts of inflation, growth, and unemployment, the coefficients on the regression dummies are not statistically significant, but for next-quarter forecasts they are statistically significant, implying that the Fed either lacks information on the state of the economy in the next quarter, or fails to incorporate this information into their forecasts. Tien et al. (2021) find that Greenbook inflation and growth forecasts are unbiased even though errors are sometimes large. Croushore and van Norden (2018, 2019) find mixed evidence of bias but little evidence of inefficiency when considering Greenbook forecasts of fiscal variables.

For the BoE, MPC forecasts show evidence of bias only for certain variables, including unemployment, house price growth, and wage growth; BoE efficiency test results depend on the variable and horizon under consideration and on whether 2008 and 2009 data are included (Independent Evaluation Office, 2015). ECB long-term GDP projections from 1999Q1 to 2018Q4 are persistently upward biased and inefficient (Kontogeorgos and Lambrias, 2022). The evidence for HICP inflation, on the other hand, is more mixed. This is consistent with the findings of Granziera et al. (2021). Champagne et al. (2020) provide a thorough evaluation of the Bank of Canada staff forecasts for GDP and inflation. They find large and significant upward biases for the staff's GDP growth forecasts. Moreover, they show that these biases are not only due to the staff's inability to forecast recessions many quarters ahead. Interestingly, they find no evidence of biases for the staff's CPI inflation forecasts. Binette and Tchebotarev (2017) find evidence that the longer horizon forecasts for GDP growth published in the BoC MPR since 1997 tend to be positively biased. The same is not true for shorter-horizon forecasts.

3.2 Recent Advancements

More recent work uses alternative approaches to extend the evidence on biases and inefficiencies of central bank forecasts. For example, Ericsson et al. (2015) test for bias in Greenbook forecasts of foreign output growth in nine countries from 1999 to 2008, and show that while standard tests fail to detect bias, recently developed indicator saturation techniques do detect substantial bias. Chang and Levinson (2020) construct a higher frequency dataset of the forecasts produced roughly weekly by the Federal Reserve Board staff between Greenbook forecasts and test for efficiency by regressing forecast errors on forecast revisions. This reveals larger inefficiencies for GDP than for inflation forecasts. Forecasts made in the two weeks before an FOMC meeting are more efficient, as the staff may devote more effort to these forecasts.

Standard tests of forecast optimality are based on an assumption that forecasters have a quadratic loss function, but this assumption has been questioned. Asymmetric (and time-varying) loss functions can help reconcile apparent departures from rationality in central banks forecasts when assuming a quadratic loss function. Indeed, a large literature has tested for asymmetric loss functions in central bank forecasts. Capistran (2008) finds evidence, since the Volcker disinflation, that the Fed attaches a higher cost of having inflation above target than below. There is also evidence for asymmetric forecast errors for the Fed's forecasts of GDP and unemployment (Chang, 2018; Galbraith and van Norden, 2019). The Bank of England, ECB, Bank of Canada, and Swedish Riksbank have also been shown to have asymmetric preferences for their inflation forecast (Ruge-Murcia, 2003; Nobay and Peel, 2003).[3]

Tests of forecast optimality also implicitly rely on stationarity assumptions that may not hold in reality (Rossi, 2021). Rossi and Sekhposyan (2016) introduce regression-based forecast rationality tests for unstable environments, and show that they more strongly reject the unbiasedness of Greenbook forecasts than do traditional tests. They explain that "the Fed was consistently underestimating inflation in the 1970s, due to recurrent and unpredictable oil price shocks, and overestimating inflation in the 1980s, during Volker's disinflation period. Clearly, traditional forecast unbiasedness tests applied over the full sample do not reject forecast unbiasedness because underpredictions, on average, cancel out overpredictions" (p. 508). Similarly, the Eurosystem/ECB staff macroeconomic projections of inflation are unbi-

[3]Similarly, recent evidence for central banks in Latin America and Asia have also pointed to asymmetric preferences, again finding a higher cost associated with positive inflation forecast errors (inflation above target) than negative ones (inflation below target) (Pierdzioch et al., 2015; Ahn and Tsuchiya, 2019).

ased over the full sample, but inflation was persistently underpredicted before the financial crisis, and overpredicted after 2013 (Kontogeorgos and Lambrias, 2022; Granziera et al., 2021). Champagne et al. (2020) apply Rossi and Sekhposyan (2016)'s test and find that for GDP growth, the test shows a significant and persistent breakdown in unbiasedness in the mid-1990s, while for CPI inflation the test points to a small bias in the early 1990s.

The literature discussed above evaluates the point forecasts of central bank staff and policymakers. As the availability of probabilistic or density forecasts proliferates, techniques for comparing and evaluating these forecasts continue to be developed (Gneiting and Ranjan, 2011). Properties that are often considered include probabilistic calibration, sharpness, and resolution; for a review and discussion, see Mitchell and Wallis (2011). The fan charts of the BoE are the best-known density forecasts from a central bank, and many studies have evaluated the inflation fan charts (Wallis, 2003; Clements, 2004; Elder et al., 2005; Casillas-Olvera and Bessler, 2006; Dowd, 2007; Gneiting and Ranjan, 2011). A few have also studied the GDP fan charts (Dowd, 2008; Galbraith and van Norden, 2012; Mitchell and Weale, 2019). Knuppel and Schultefrankenfeld (2019) study the inflation density forecasts of the Bank of England, the Banco Central do Brasil, the Magyar Nemzeti Bank, and the Sveriges Riksbank, and find that the forecasts tend to display underconfidence at short horizons and overconfidence at longer horizons.[4]

Overall, the results of the literature reflect the significant challenges faced by central banks when forecasting, such as the long announcement lags for macroeconomic indicators, the presence of structural breaks, the difficulty in forecasting recessions in real-time and accounting for trends, and low-frequency movements in economic activity. The results are forecasts and projections of economic activity, such as real GDP growth and unemployment, which often look optimistic ex-post. Interestingly, the properties of central banks' inflation forecasts are usually better, a likely consequence of the success of many central banks in keeping inflation close to their targets.

4 Central Bank Forecasts and the Private Sector

Because of central banks' large research staffs and resources devoted to economic monitoring and forecasting, Blinder et al. (2008, p. 915) note that "the central bank may have, or may be believed to have, superior information on the economic outlook." Many macroeconomic

[4]While the FOMC does not provide such fan charts, the SEP includes qualitative assessments of uncertainty, discussed in Reifschneider and Tulip (2019).

models posit some informational advantage for the monetary authority that enables countercyclical monetary policy even in a rational expectations context (Sargent and Wallace, 1975; Barro and Gordon, 1983; Cukierman and Meltzer, 1986). Asymmetric information between monetary policymakers and market participants could explain a variety of other empirical phenomena, including the response of the yield curve to monetary policy and the puzzling increase in output following a contractionary monetary policy shock (Nakamura and Steinsson, 2018). Thus, much of the literature on central bank forecasting focuses on the informational advantage of central banks.

A seminal paper by Romer and Romer (2000) shows that Federal Reserve staff forecasts of inflation in the Greenbook are more accurate than private sector forecasts from Blue Chip, Data Resources, Inc., and the Survey of Professional Forecasters (SPF), and that access to Greenbook forecasts could have helped commercial forecasters improve forecasts. Indeed, "someone with access to both the Federal Reserve and commercial forecasts should not just put positive weight on the Federal Reserve forecast, but put little weight on the commercial one" (Romer and Romer, 2000, p. 438). Correspondingly, the mean squared errors of the Greenbook forecasts are around 25% lower than those of commercial forecasters at most horizons. For real GNP growth, the Fed's informational advantage is most prominent at short horizons but varies at longer horizons.

To demonstrate the implications of the informational advantage they document, Romer and Romer (2000) show that the Fed's monetary policy actions reveal some of their private information about the economic outlook. Thus, when the Fed raises the federal funds rate, forecasters revise their inflation expectations upward, which can help explain why interest rates at long horizons respond to monetary policy. Subsequent research has continued to probe the informational advantage of central banks and to examine how central bank expectations influence private sector expectations, even in the absence of a clear informational advantage.

4.1 Probing the Informational Advantage of Central Banks

In follow-ups to Romer and Romer (2000), Sims (2002) and Gavin and Mandal (2003) confirm the Greenbook forecast outperforms private sector forecasts. Sims (2002) considers three possible sources of the Greenbook forecast superiority. One possibility is that the Fed makes better use of the same data than other forecasters. A second is that the Fed's knowledge of its own likely policy actions gives it a forecasting advantage. A third is that the Fed collects better information about price developments than other forecasters. Sims embeds

the Greenbook inflation forecasts in vector autoregression (VAR) models and formulates these possibilities as restrictions on the model, finding tentative support for the second and third possibilities. Peek et al. (2003) suggest that the Fed's informational advantage comes from its role as a supervisor and regulator of banks. They show that confidential bank supervisory data can substantially improve private sector forecasts of inflation and unemployment.

As economic volatility declines in the Great Moderation, inflation and output become more predictable and Greenbook forecast errors decline (Tulip, 2009). Gamber and Smith (2009) find that this decline in volatility "evened the playing field" between the Fed and the private sector. While Greenbook forecast errors remain smaller than SPF forecast errors, the gap declines, especially after 1994. D'Agostino and Whelan (2008) similarly find that from 1992 to 2001, the Greenbook advantage is only at short horizons and only for inflation. Baghestani (2008) considers unemployment forecasts rather than inflation or growth forecasts, and finds that Greenbook and private forecasters have similar mean squared errors, and that the private sector forecasts are slightly more informative.

Subsequent work continues to find an informational advantage of Federal Reserve forecasts only in certain contexts or for certain variables and horizons (Gavin and Pande, 2008; Rossi and Sekhposyan, 2016; Eksi and Tas, 2017). Kishor (2010) shows that if recessions are excluded from the pre-1991 period, the Greenbook forecasts no longer outperform private sector forecasts. El-Shagi et al. (2014) find that the Greenbook inflation and output forecasts from 1968 to 2006 are more accurate than SPF forecasts, particularly in times of heightened uncertainty, but that this relative outpeformance is not robust to certain large macroeconomic shocks. Sheng (2015) evaluates *individual* FOMC members' forecasts of real GDP, inflation, and unemployment from 1992 to 2003. Though committee members tend to underpredict real GDP, they do improve upon commercial forecasters' forecasts. Paul (2019) uses data updated through 2013, and finds that Blue Chip and Tealbook forecasts are similar at shorter horizons, but the Tealbook forecasts are more accurate at longer horizons. Hoesch et al. (2020) show that the Fed's information advantage has disappeared in recent years for all target variables and horizons, and suggest that this is related to improved communication by the Fed.

Other central banks also seem to have similar or slightly better forecasting ability compared to private sector forecasters, though the literature is more limited than it is for the Fed.[5] Hubert (2015b) finds that the ECB inflation projections for the current year horizon

[5]Pincheira (2010) compares the Banco Central de Chile GDP growth forecasts with the private sector

are more accurate than private forecasts, but for next-year forecasts, there is no significant difference between ECB and private forecasts. From 2010 through 2018, ECB growth and inflation forecast performance is similar to that of private forecasters (Lambrias and Page, 2019). For long-run GDP, private forecasts outperform ECB forecasts (Kontogeorgos and Lambrias, 2022).

For the BoE, the MPC one-year forecasts of inflation and growth are more accurate than those of most individual Consensus Economics forecasts, but MPC one-year forecasts of unemployment, consumption growth, and investment growth tend to be less accurate, as are all MPC two-year forecasts (Independent Evaluation Office, 2015). Using data from 1999 to 2013, Hubert (2015a) studies the relative forecasting performance of the central banks of Sweden, the United Kingdom, Canada, Switzerland, and Japan, and finds that only in Sweden are the central bank forecasts more accurate than private forecasts. Champagne et al. (2020) find an advantage of Bank of Canada staff forecasts over the ones from private forecasters, especially for GDP growth forecasts, from 1994 to 2015. Similar to the U.S. case, the BoC staff economic projections of inflation and GDP growth have smaller forecast errors after the 1991 adoption of inflation targeting (Champagne et al., 2020). Binette and Tchebotarev (2017) also find that the BoC MPR forecasts for GDP growth since 1997 are superior to professional forecasters.

4.2 Effects on Private Sector Expectations

If the central bank has an informational advantage over private forecasters, then the release of central bank forecasts—or any other central bank actions and communications that reveal information about the economic outlook of the central bank—should affect market expectations and, in turn, asset prices (Miranda-Agrippino, 2016; Lakdawala and Schaffer, 2019).[6] For example, the Fed's informational advantage and reputation as an effective forecaster help explain the response of the yield curve to FOMC statements and other communications (Kohn and Sack, 2004; Andersson et al., 2006; Boeck and Feldkircher, 2021). But even if the central bank does not possess more accurate information about the economic outlook, central bank forecasts can still influence private sector expectations by conveying information about

from 1991 to 2009, and finds that the difference in accuracy between the two are modest and not statistically significant. Reserve Bank of Australia forecasts of inflation are slightly more accurate, and forecasts of growth slightly less accurate, than those of private sector forecasters (Tulip and Wallace, 2012).

[6]Croushore and Koot (1994) suggest that the correspondence between the central bank's and the private sector's inflation forecast is an indicator of central bank credibility, and that by this measure, Fed credibility was quite high in the late 1970s.

monetary policy preferences and strategies. This may explain why central bank forecasts influence private forecasts in the United Kingdom, Canada, Switzerland, and Japan, even though they are not more accurate (Hubert, 2015a).

As mentioned in Section 2.2, some central banks have begun releasing interest rate projections in addition to projections of inflation, growth, and unemployment. In 2008, Blinder et al. (2008, p.928) note that "our knowledge of the effects of central bank interest rate projections on the market's understanding of monetary policy is minimal—which is inevitable given the short time span and the small number of central banks that have revealed such information. As more experience is accumulated, e.g., in Norway and Sweden, this will be a high priority area for future research. Already, Norwegian data show that markets do not always uncritically adopt the central bank's projection."[7] This becomes an even higher priority research area as central banks increase their use of forward guidance, which is closely related to, and sometimes accompanied by, interest rate projections.[8]

Many have responded to this call for research, with mixed findings (Detmers and Nautz, 2012; Beechey and Österholm, 2014; Ahl, 2017; Gerlach and Stuart, 2019; Couture, 2021a; Brubakk et al., 2021; Galati and Moessner, 2021). For a survey on central bank communication about future policy rates in theory and in practice, see Moessner et al. (2017). Here we summarize some of the more recent work. Bundick and Herriford (2017) measure uncertainty about future interest rates in one-day windows around FOMC meeting dates using Eurodollar options prices, finding that interest rate uncertainty falls after interest rate projections begin to be released. However, uncertainty increases when there is more disagreement in the participants' projections. Using an event study approach and SEP data from 2011 to 2019, Couture (2021b) finds that a change in the median FOMC federal funds rate projection affects Treasury yields, but changes in median projections of other variables do not. In Sweden but not in Norway, central bank publication of interest rate projections reduces market participants' forecast errors (Natvik et al., 2020). Jain and Sutherland (2020) consider the effects of central bank projections on private sector forecasts for a panel of 23 countries, and find that central bank policy rate projections reduce neither errors nor dispersion of private-sector interest rate forecasts, though central bank inflation projections reduce dispersion and errors of private-sector interest rate forecasts.

[7] For a discussion of the Reserve Bank of New Zealand's early experiences with publishing interest rate projections, see Archer (2005).

[8] Campbell et al. (2012, p. 2) explains that "Delphic forward guidance publicly states a forecast of macroeconomic performance and likely or intended monetary policy actions based on the policymaker's potentially superior information about future macroeconomic fundamentals and its own policy goals. Such forward guidance presumably improves macroeconomic outcomes by reducing private decision-makers' uncertainty."

Other recent work compares the effects of quantitative central bank projections with other forms of forward guidance or statements about the economic outlook (Baranowski et al., 2021; Detmers et al., 2021). Bongard et al. (2021) find that both FOMC forward guidance and SEP interest rate projections influence private sector expectations. Sutherland (2021) collects data on forward guidance and macroeconomic projections from eight inflation-targeting central banks from 1990 to 2020. Private forecasters revise their interest rate forecasts by about five basis points following a change in forward guidance, but not in response to revisions to central bank macroeconomic projections. This suggests that information effects do not drive the response of private forecasts to forward guidance. New theoretical models, featuring heterogeneous agents, bounded rationality, and adaptive learning, are also being developed to study the effects of the release of central bank forecasts (Ferrero and Secchi, 2010; Goy et al., 2020; Cole, 2021).

5 Recent Challenges

During recessions and other crises, forecasting becomes considerably more difficult, at the same time that central banks' policy decisions and communication have higher stakes. Central banks—like other professional forecasters—face difficulty forecasting recessions or turning points (Ahir and Loungani, 2014; Stekler and Symington, 2016). The Great Recession highlighted this difficulty and led many central bankers to review their forecasting processes with greater scrutiny.

5.1 The Financial Crisis and Great Recession

The forecasting performance of the BoE's Monetary Policy Committee (MPC) during the Great Recession was not only worse than prior to the crisis, but also "marginally worse than that of outside forecasters," as Stockton (2012) reported to the Court of the BoE. Stockton explains why the MPC persistently over-predicted output growth and underpredicted inflation in the Great Recession:

> As a practical matter, virtually all regular economic forecasting exercises exhibit a degree of inertia, and that is the case with the forecast of the MPC. Some of that inertia is procedural; the starting point for a forecast round relies heavily on a staff update of the MPC's previous forecast for incoming data and news. But some of the inertia exhibited by forecasts simply reflects the slowness with

> which forecasters spot deeper structural problems with the stories underlying their forecasts. In the MPC's forecasting process, there are few mechanisms capable of acting as a trigger for a fundamental reassessment of the outlook (p. 7).

The ECB and Federal Reserve Bank of New York (FRBNY) forecast performance was also worse during the financial crisis than before, but these central banks performed comparably with—or even slightly better than—professional forecasters (Alessi et al., 2014).[9] ECB researchers point to a neglect of various financial and uncertainty indicators and nonlinear dynamics in forecasting during the crisis, remarking that "there would appear to be a case for relying more on judgement than on the results of mechanical tools, particularly in the immediate aftermath of unprecedented events" (Kenny and Morgan, 2011, p. 5). Similarly, Potter (2011) discusses the failure of the FRBNY staff to forecast the Great Recession, attributing large forecast errors in late 2007 to a misunderstanding of the housing boom and new forms of mortgage finance, and to insufficient recognition of the feedback loop between the financial sector and the real economy. He concludes that "the unexpected events for which policymakers need to make provision have the characteristic of being the most likely unlikely bad event" Potter (2011, p. 4).

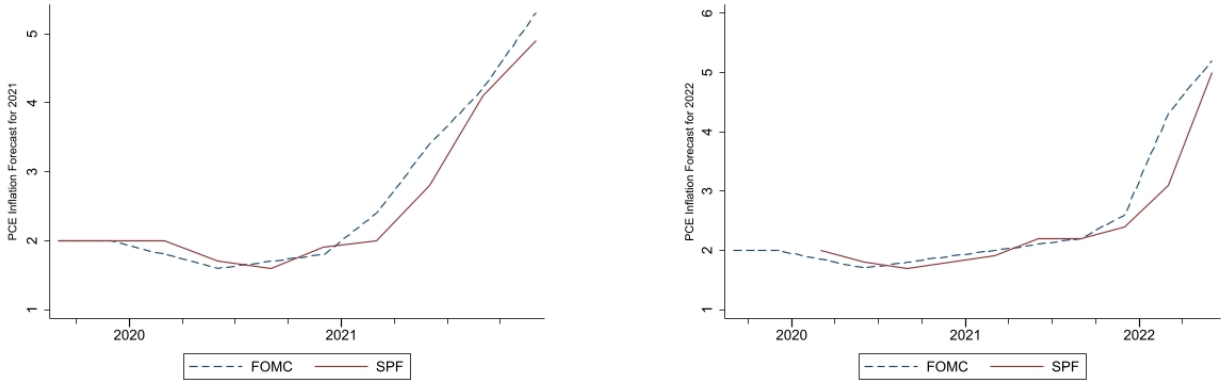
5.2 The Pandemic and its Aftermath

The COVID-19 pandemic caught the world by surprise, and central banks were no exception. The unprecedented nature and magnitude of the shock continues to make macroeconomic forecasting more challenging. At the onset of the pandemic during the early weeks of March 2020, some central banks revisited their plans for the publication of their usual forecasts. For example, the FOMC called off the publication of their March 2020 SEP. Similarly, the Bank of Canada abandoned its policy of announcing a forecast for inflation and GDP growth in its April 2020 MPR, and chose to focus on scenarios conditional on the evolution of the pandemic.

It is not surprising, then, that the COVID-19 shock has led to large forecast errors since 2020. Forecasting inflation since the onset of the pandemic, in particular, has been a great challenge for central banks. Figure 1 below shows the FOMC and the Survey of Professional Forecasters from the Philadelphia Fed PCE inflation forecasts for 2021 and

[9]The FRBNY and the ECB made similar mean forecast errors (MFEs) and mean squared forecast errors (MSFEs) for growth in 2008 to 2012, but the FRBNY made much smaller inflation MFEs and MSFEs than the ECB (Alessi et al., 2014).

Figure 1: FOMC and SPF Forecasts for 2021 and 2022 PCE Inflation



(a) 2021 **(b)** 2022

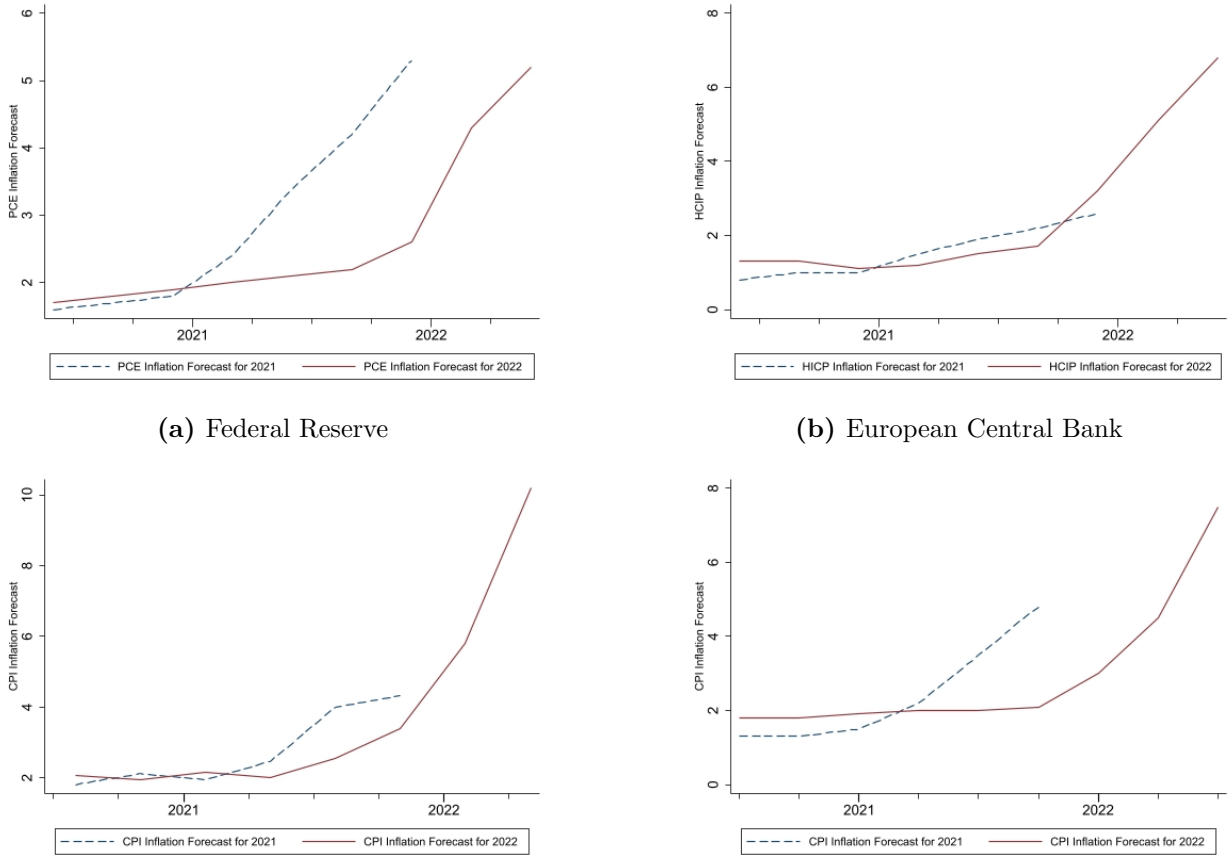
Notes: Figure shows the midpoint of the central tendency of the PCE inflation projection for the 2021 and 2022 target horizon from the FOMC Summary of Economic Projections and median Survey of Professional Forecasters (SPF) forecast.

2022, respectively. FOMC and private sector forecasters alike under-predicted inflation as it rose in 2021, expecting the price pressures of 2021 to dissipate rather quickly. Figure 2 shows that the challenges to inflation forecasts were not restricted to the Fed. It shows the 2021 and 2022 CPI inflation forecasts made by the Fed, ECB, BoE, and BoC. Their forecasts follow a similar dynamic as that of the Fed discussed above. Throughout much of 2021, as most central banks raised their forecasts for that year, forecasts for 2022 were little changed. It was only towards the end of 2021 and more significantly, after the Russian invasion of Ukraine in February 2022, that inflation forecasts for that year were markedly increased.

Central banks' underestimates of inflation in 2021 were matched by speeches and language explaining why they expected inflation to be transitory. In August 2021, for example, Chairman Powell (2021) stated that his concern about elevated inflation was "tempered by a number of factors that suggest that these elevated readings are likely to prove temporary" (p. 4). These explanations had to be walked back as inflation forecasts were revised upwards. In Powell's November 2021 testimony to the Senate Banking Committee, he declared it "time to retire" the word transitory, adding that "Forecasting is not a perfect art, as you may have noticed."

Central bank staff have begun to reflect on the forecast errors made since the pandemic. Mohammed et al. (2022) note that the ECB projections of HICP inflation were more accurate than those made during the global financial crisis through the second quarter of 2021. Beginning in the third quarter, however, "unexpected developments in energy prices, coupled with

Figure 2: CPI inflation forecasts for 2021 and 2022 from the Fed, ECB, BoE and BoC



(a) Federal Reserve

(b) European Central Bank

(c) Bank of England

(d) Bank of Canada

Notes: Figure shows the CPI inflation projection for the 2021 and 2022 target horizon for the Federal Reserve, European Central Bank, Bank of England and Bank of Canada.

both the effects of reopening following the removal of coronavirus-related restrictions and the effects of global supply bottlenecks, led to unprecedented increases in HICP inflation" (p. 1) that greatly increased forecast errors. They suggest that "a more detailed assessment of the energy market" should be incorporated into future projections. They also note that ECB forecast accuracy was similar to that of the FOMC and BoE over the same time period. A more detailed assessment of the macroeconomic models used within the Eurosystem and how they fared during the pandemic can be found in Paries et al. (2021). Finally, Kryvtsov et al. (2023) examine the drivers behind the 2021-22 inflation surge in Canada and offer some lessons learned during this period. They argue that "central bank models should allow for more state-dependent, asymmetric and accelerated inflation dynamics, such as nonlinear Phillips curves and time-varying volatility" (Kryvtsov et al., 2023, p. 14).

6 Conclusions

Central banks communicate with the public in a variety of qualitative and quantitative ways. Macroeconomic forecasts or projections constitute a component of the communication strategy, as well as an input into policy decisions. This paper reviews an expansive literature on central bank forecasts, revealing several important takeaways and open questions.

The four central banks we considered share some common features of their forecasting frameworks, including reliance on many sources of data and a variety of models, combined with judgment. In all cases, the research staff provide forecasts to policymakers, who may modify the forecasts. Some, but not all, central banks release the staff forecasts and individual policymakers' forecasts with a lag. This has facilitated work evaluating whether policymakers add value to staff forecasts and the sources of heterogeneity in policymakers' forecasts. These and other central banks also provide *conditional* forecasts, or projections, though the nature of the conditionality varies across banks.

A classic literature evaluating the bias and efficiency of central bank forecasts has recently expanded with new sources of data and econometric methods for forecast evaluation. Results are often quite sensitive to the samples and tests that are used due to small sample sizes and instabilities in the forecasting environment. Still, central bank forecasts are generally of high quality, at times outperforming those of professional forecasters. However, central banks' information advantage over private forecasters has varied over time, and appears small or negligible in recent years or appears only for certain target variables and horizons. Even if central banks' information advantage is limited, central bank macroeconomic projections do seem to influence private sector expectations, likely because they reveal information about monetary policymakers' preferences and plans. Thus, a growing number of central banks are incorporating the publication of macroeconomic and interest rate projections into their communication strategies.

Macroeconomic forecasting is especially difficult in a crisis, and this was certainly the case during the COVID-19 pandemic. An important question going forward is how the recent surge in inflation and subsequent forecast errors by central banks worldwide will affect their credibility and capacity to successfully control inflation. Finally, much of the literature evaluating central banks forecasts still relies on data from the major central banks in advanced economies. As more central banks in emerging countries facilitate access to their forecasts, research examining the quality and domestic influence of those forecasts would be of great interest.

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