Quantitative forward guidance through interest rate projections*

Boris Hofmann
BIS
boris.hofmann@bis.org

Fan Dora Xia
BIS
dora.xia@bis.org

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Abstract

We assess quantitative forward guidance through interest rate projections along four key dimensions: (i) predictability, (ii) credibility, (iii) consistency and (iv) redundancy. Based on data for the Reserve Bank of New Zealand, the Norges Bank, the Swedish Riksbank and the Federal Reserve we find that the interest rate projections released by these four central banks are predictable and credible. Market expectations of the future path of interest rates anticipate changes in the central bank projection path and adjust to path surprises. The adjustment is, however, not one to one and decreases with the projection horizon. Moreover, high uncertainty around the projection path reduces the impact of path surprises. We also find the interest rate projections to be consistent with the macro projections that are released by the central banks in parallel as these projections are empirically linked by a stabilising Taylor rule. Finally, interest rate projections are not redundant as they impact market expectations also when controlling for the effects of macro projections.

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1 Introduction

Forward guidance on the future path of policy rates has become a key element of central banks' monetary policy toolbox over the past decade. The objective of forward guidance is to clarify the central bank's intended future path of policy rates, thereby strengthening the grip on longer-term market rates and ultimately the transmission of monetary policy to the real economy. In this vein, forward guidance has become a key tool for central banks, together with large-scale balance sheet policies, to provide additional monetary accommodation when policy rates were at their effective lower bound (ELB). [1] Blinder, Ehrmann, de Haan and Jansen (2017) present survey evidence suggesting that the overwhelming majority of central bank governors and academics think that forward guidance should continue being part of central banks' toolkit going forward. However, there is much less agreement on how forward guidance should be implemented in practice, in particular whether guidance should be of qualitative or quantitative nature (see e.g. Ehrmann, Gaballo, Hoffmann and Strasser (2019)).

Against this background, this paper analyses quantitative forward guidance through the publication of interest rate projections by central banks. The standard practice amongst central banks has been to provide forward guidance via a projection or forecast of their target variables (mainly inflation and real economic activity) and verbal communication of policy assessments and intentions

[1] Forward guidance is assumed to influence long-term interest rates mainly via the expected path of policy rates while asset purchase announcements are widely seen as affecting mainly term premia in long-term interest rates via a portfolio rebalancing channel (Bernanke, 2013). Woodford (2012) suggests however that asset purchases also mainly work through a signalling channel, shifting the expected path of future policy rates. This would imply that forward guidance could achieve the same effect as asset purchases, but without the large scale accumulation of assets on the central bank's balance sheet. That said, asset purchases could be a more effective signalling tool as the central bank could be regarded as "putting its money where its mouth is". Addressing this question is however beyond the scope of this paper.

in policy decision statements, press conferences and speeches. A few inflation-targeting central banks have gone one step further and provide quantitative forward guidance by publishing their own projection of the future path of policy rates. The Reserve Bank of New Zealand (RBNZ) introduced interest rate projections in 1997, the Norges Bank in 2005, the Riksbank in 2007, and the Federal Reserve in 2012. In the case of the Federal Reserve, its policy rate projections as part of the Survey of Economic Projections (SEP), referred to as the "dot plot", has become one of the most closely watched news release among investors.

Based on the experiences of these four central banks, this paper aims to assess the effectiveness of quantitative forward guidance along four key dimensions: (i) predictability, (ii) credibility, (iii) consistency and (iv) redundancy.

Predictability refers to the extent to which markets are able to anticipate the central bank path. Svensson (2015) has explored predictability of the RBNZ's and the Riskbanks' path as well as of the the FOMC dot plot in a descriptive way. We assess these points quantitatively. Specifically, we assess predictability by examining to which extent new releases of central bank interest rate projections are anticipated by markets, as reflected in market rates.

Credibility refers to the ability of central banks to steer market interest rate through the quantitative guidance provided. We assess credibility by examining to which extent market rates adjust to surprises in the central banks interest rate path. We also explore the factors that affect the pass-through of the central bank's interest rate path to market rates, focusing on the role of the length of the forecast horizon and the uncertainty surrounding the central bank's interest rate path projection as e.g. captured by the width of the confidence band around the central projection.

Consistency refers to the question whether the interest rate projections are consistent with the projections of the target variables published by the central bank at the same time. This consideration is related to the point that interest rate projections enhance the accountability of the central bank as the public can assess whether the intended path of policy rates is in line with a policy that is conducive to achieving the central bank's mandates. We assess this point by testing whether central banks' interest rate projections and macro projections are consistent with a stabilising monetary policy rule. To this end, we estimate a simple Taylor rule for the central bank projections, regressing the projected paths of interest rates on inflation and the output gap projections.

Finally, redundancy refers to the question whether the interest rate projections of central banks provide information that goes beyond that already provided through the publication of projections of key target variables, specifically of inflation and the output gap. If that were not the case, the publication of an interest rate path would be redundant at least with respect to the effectiveness of controlling market expectations through the release of projections. We assess this point by testing whether interest rate projections impact market expectations also after controlling for the effect of the projections of the target variables.

Our main findings are as follows. First, interest rate projections released by the four central banks under investigation are predictable and credible. Market expectations of the future path of short-term interest rates anticipate changes in the central bank projection path to a significant extent. At the same time, market forward rates also adjust to path surprises. The adjustment is, however, not one to one, and decreases with the projection horizon. Moreover, high uncertainty around the projection path reduces the impact of path surprises. We also find the interest rate projections to be consistent with the macro projections. The projections are consistent with a stabilising Taylor rule linking interest rates to inflation and the output gap. Finally, interest rate projections are not redundant. Their impact on market expectations remains significant when controlling for the effects of macro projections.

Literature review Our paper contributes to the broad literature on central bank transparency and communication. Over the past two decades, central banks around the world have gradually moved towards establishing more transparency in their conduct of monetary policy, see Geraats (2009) and Dincer and Eichengreen (2014). Against this background, communication about goals and tools, the assessment of the economic outlook and forward guidance on the future path of policy rates have become increasingly important aspects of monetary policy (Blinder, Ehrmann, Fratzscher, de Haan and Jansen, 2008).

A small number of central banks have embraced quantitative forward guidance through own interest rate projections and there is an evolving literature exploring the lessons learnt from this practice. Goodhart and Lim (2011) suggest, based on RBNZ interest rate forecasts for NZ and market-based forecasts for the United Kingdom, that interest rate forecasts by both central banks and markets are pathological. They find that both central bank and market paths poorly predict future interest rates beyond the very short-term and they are biased.

Other papers instead focused on the question whether the central banks projections enhanced the market's ability to predict future policy rates or were themselves predictable. Andersson and Hofmann (2010) conclude based on data for New Zealand, Norway and Sweden that quantitative forward guidance did not yield a measurable improvement in market's predictive ability. Similarly, Natvik, Rime and Syrstad (2020) do not find an improving effect through the release of interest rate paths for Norway and Sweden.[2] Gerlach and Stuart (2020) explore the factors predicting the FOMC's interest rate forecasts and find that the dot plots can be predicted in particular by labour market variables.

Another strand of literature explored the market impact of quantitative forward guidance through interest rate projections. Svensson (2015) provides a descriptive assessment of the Swedish, New Zealandean, and U.S. experience of publishing an interest rate path, comparing the published interest path with market expectations before and after the release. His findings suggest a mixed record for all three countries. Formal evidence on market impact is also mixed, depending on the methodology and sample period covered. Detmers and Nautz (2012) and Åhl (2017) find for New Zealand and Sweden, respectively, significant effects of surprises in the central bank interest rate projections on market expectations up to one year ahead. Brubakk, ter Ellen and Xu (2021) find that interest rate projection releases increase the central banks' leverage over the market paths in Norway and Sweden. Detmers, Karagedikli and Moessner (2018) do not find any difference for New Zealand in market reaction when comparing policy announcement with and without interest rate path release in New Zealand. Finally, Galati and Moessner (2021) find that, over the ELB period, surprises to the Fed's SEP interest rate path affected real yields but not breakeven inflation rates.

2 Data

Key variables used in our analysis are policy rate projections from central banks and policy rate expectations derived from financial market prices.

[2] Jain and Sutherland (2020) find that central banks' publication of policy rate path projections also does not matter much for private-sector forecast disagreement.

2.1 Central bank interest rate projections

New Zealand The Reserve Bank New Zealand (RBNZ) has been publishing projections of the quarterly average of the 90 day bank bill rate or the official cash rate (OCR) for more than 20 years. Between June 1997 and August 2016, RBNZ provided regular forecasts of the 90 day bank bill rate. After August 2016, the central bank forecasts are based on the OCR.[3] To account for this change, we adjust the OCR forecasts by subtracting the spread between the OCR and the 90 day bank bill rate. The RBNZ makes projections from the current quarter up to 12 quarters ahead. The projections are released four times a year in the Monetary Policy Statement (MPS), see for example Graph 1, top left panel, which was taken from the November 2019 MPS.

The RBNZ's projections are based on a structural model, currently the New Zealand Structural Inflation Model (NZSIM), that is used to summarise all relevant information from macroeconomic and financial markets data as well as discussion with businesses. While the published projections are model-based, they also incorporate judgemental adjustments. The interest rate path, as well as the other macroeconomic projections, are published without confidence or uncertainty bands.

Norway Norges Bank has been publishing projections for quarterly average of the policy rate, i.e. the interest rate on banks' overnight deposits at the central bank, since 2005. The Norges Bank policy rate projections, which are released with the Monetary Policy Report, are for the current quarter and up to 12 quarters ahead. They have been released three times a year till 2013 and four times a year thereafter. For an example, see for Graph 1, top right panel, taken from

[3] The projections released in May and August 2020 are not included in most of our analyses as they are based on unconstrained OCR, i.e. the rate assuming no ELB.

the December 2019 Monetary Policy Report.

The Norges Bank's construction of the interest rate path and the forecasts of key economic variables are based on several macroeconomic models, a core model, the Norwegian Economy MOdel (NEMO), and a number of smaller models for cross checking. In addition, Norges Bank also takes into account information provided by its regional network. The final forecasts incorporate judgemental adjustments. The confidence bands of the interest rate forecast are calculated on the basis of the core model.

Sweden The Swedish Riksbank has been publishing projections for the quarterly average policy rate, i.e. the interest rate at which banks can borrow or deposit funds at the central bank for a period of seven days, since 2007. The Riksbank's forecast path of the repo rate range from the current quarter up to 12 quarters ahead. The projections are released six times a year in the Riksbank's Monetary Policy Report. An example from the December 2019 Monetary Policy Report is provided in Graph 1, bottom left panel.

The Riksbank's forecasts are constructed on the basis of both formal models and judgement. The models used include the core general equilibrium model of the Swedish economy called RAMSES, as well as empirical models. Smaller models and judgement are then applied to make adjustments to the initial model-based forecasts. The Riksbank publishes the main scenario together with uncertainty bands, which are calculated from historical forecast errors for implied forward rates with an adjustment for the systematic forecast error in order to capture the existence of risk premia.

United States The Federal Reserve has been publishing the Federal Open Market (FOMC) members' individual projections of the Federal Funds rate since

January 2012 together with the FOMC members' projections of macroeconomic variables in the Summary of Economic Projections (SEP). These projections have become known as the "dot plot", see Graph 1, bottom right panel, taken from the December 2019 SEP as an example. Each dot in the forecast chart indicates the value of an individual participant's judgment of the appropriate level (before September 2014) or the midpoint of the appropriate target range (since September 2014) for the federal funds rate at the end of the specified calendar year or over the long run. To adjust for the change, we adjust the forecasts for the specified calendar years that are made before September 2014 by subtracting 0.125%. These projections are released four times a year.[4]

For the first half of each year, projections are made for current year, one- and two-years ahead and the long run. For second half of each year, projections are made for current year, one-, two- and three-years ahead and the long run. In the analysis, we are using the median of the individual FOMC members' projections, as published in Table 1 of the SEP.

2.2 Market expectations

To gauge markets expectations of the future policy rate path, there are two main options. One is making use of survey data, similar to Hubert (2014). However, survey data is often at low frequency, say monthly, which complicates the identification of the interaction between central bank projections and market expectations. For this reason, we opt for price-based measures of market expectations of future interest rates using relevant financial instruments, i.e. futures or forward rate agreements in line with Moessner and Nelson (2008), Åhl (2017) and Brubakk et al. (2021). Note that market prices reflect markets' risk-neutral expectations, from which time-varying risk premia need to be teased out to obtain

[4] 2012 and 2020 are exceptions when these projections were released five times and three times respectively.

a measure of expectations. Considering that risk premium estimates are highly model-dependent, we use unadjusted market prices, thus assuming constant risk premia.

New Zealand For New Zealand, we use prices for the 90-day New Zealand bank bill futures. The contracts are available for March, June, September and December up to three years ahead.[5] The settlement at expiry is based on the 90-day bank bill rate on the expiry day - the first Wednesday after the ninth day of the relevant settlement Month. We proxy markets expectation of quarterly average 90 day bank bill rate or the adjusted official cash rate with the prices of bank bill futures expiring at the relevant quarter.

Noway and Sweden For Norway and Sweden, we use prices for the 3-month Nibor/Stibor Forward Rate Agreements (FRAs). These contracts are available for March, June, September and December up to three-years ahead. The settlement at expiry is based on the 3-month Nibor/Stibor rate on the expiry day - the third Wednesday of the relevant settlement month. We proxy market expectations of the quarterly average of the policy rate with the FRA rates as they are adequate measures of the expected average overnight interbank rate. To account for the difference between the policy rate and the interbank rate, FRA rates are adjusted by the quarterly average spread between the two short rates.

United States For the United States, we use prices of fed funds futures. The contracts are available for each month up to three-years ahead with the settlement at expiry based on average daily effective fed funds rate in the relevant settlement month. For current year, one- and two-years ahead expectations, we use average prices of forecasting years' December futures and following Janu-

[5] The contracts before June 2007 were available only up to two years ahead.

ary futures. For three-years ahead expectations, we use prices of forecasting years' August futures. This is because three year ahead December futures are not available till month-end of December. When three-years ahead projections become available in September, the furthest future available is used for August three-year ahead. While the effective fed funds rate tracks the mid point of the fed funds rate target range closely, there is a spread between the two. We adjust the fed funds futures prices accordingly.

3 Forecasting track record

Before turning to the core analysis of the paper on the predictability, credibility, consistency and redundancy of central bank policy rate projections, we want to assess the track record of central bank interest rate projections in predicting actual outcomes and how it compares to market projections. In doing so, we extend Goodhart and Lim (2011) who have addressed the question based on RBNZ interest rate projections and UK market-based rate projections.

We assess the track record of the central bank interest rate projection by comparing projected interest rate levels with rate outcomes at the quarterly frequency for New Zealand, Norway and Sweden and at the annual frequency for the U.S. We do the same for market-based projections based on the market-based interest rate path on the day before the release of the central bank path. Due to data availability for the market-based forecasts, we assess forecasts up to 3 years or twelve quarters ahead for the U.S. and Sweden and for up to eight quarters ahead for Norway and New Zealand. We base the assessment of the track record on a few standard statistics for forecast performance assessment: mean error (ME), root mean square error (RMSE) and the modified Diebold-Mariano statistic to test for statistical significance of differences in the RMSE.

The results of this exercise which are reported in Table 6 are in line with the conclusions of Goodhart and Lim (2011) that both central bank and market interest rate projections are quite accurate for the next quarter but then increasingly off track further out into the future. The forecasts are increasingly upward biased as the projection horizon lengthens as reflected in the MEs. This could reflect the downward trend in nominal rates over the past couple of decades that was apparently systematically underpredicted by both central banks and markets. At the same time, the size of forecast errors captured by the RMSEs rises considerably beyond the first quarter forecast horizon.

Comparing central bank and market-based forecasts, no clear picture emerges. Statistically significant differences between the two forecasts are indicated only for the U.S., where market projections provide a better forecast up to one year ahead. In all other cases, the difference between the central bank and the market RMSE is not statistically significant.[6]

4 Predictability and credibility

The predictability and the credibility of central banks' interest rate paths refer respectively to the extent to which markets have anticipated the path and adjust to the path after its publication. Svensson (2015) suggests that, ideally, central banks should be so predictable that the policy rate path priced in by markets the day before the release of the new central bank policy rate path already reflects to a large extent the to-be-published path. At the same time, monetary policy should be so credible that market expectations of the future policy rate

[6] We also assessed whether the release of the central bank interest rate path enhances the market forecast. To do so, we compare the forecast performance of the market path from the the day before the release of the central bank path with that of the market-path of the the day after the release which incorporate the new information from the central bank path. The forecast performance of the pre- and post-release market path turned out to be virtually indistinguishable. The results of this additional exercise are available upon request.

path align with the newly announced path. However, Morris and Shin (2018) argue that financial markets functioning may be impaired by the circular flow between market prices and central bank forecasts. Market prices, which place a dominant weight on public forecasts, would be less informative when central banks take cues from markets in formulating their forecasts. Our empirical evaluation of predictability and credibility would shed light on the effectiveness and possible adverse impact of the forward guidance through interest rate projections on market functioning.

To gauge predictability of central bank interest rate paths, we examine to which extent central bank policy rate paths were anticipated by markets prior to their release. To this end, we model the new central bank policy rate paths as a weighted average of the market policy rate path on the day before its publication and the previous central bank policy rate path, i.e.

$$i^c_{t_i,\tau} = \alpha_0 + \alpha i^m_{t_i-1,\tau} + (1-\alpha) i^c_{t_{i-1},\tau} + e_{t_i,\tau}, \tag{1}$$

where $i^c_{t,\tau}$ and $i^m_{t,\tau}$ represent the policy rate at τ expected by central banks and markets at t respectively, and t_i denotes the release date of the central bank policy rate path. α measures the weight attached to the market pricing just before central bank releases. A predictable central bank policy rate path would be reflected in a significant and high weight on market expectations, corresponding to a statistically significant and large positive α.

To gauge the credibility of the central bank paths, we evaluate how markets have responded to surprises in the central bank path similar to Moessner and Nelson (2008):

$$\begin{aligned} i^m_{t_i,\tau} - i^m_{t_i-1,\tau} &= \beta\left[i^c_{t_i,\tau} - \mathbb{E}_{t_i-1}(i^c_{t_i,\tau})\right] + e_{t_i,\tau} \\ &= \beta\left[i^c_{t_i,\tau} - \alpha_0 - \alpha i^m_{t_i-1,\tau} - (1-\alpha) i^c_{t_{i-1},\tau}\right] + e_{t_i,\tau}. \end{aligned} \tag{2}$$

A credible central bank policy rate path would shift the market path in its direction, corresponding to a statistically significant and sizeable positive β.

We estimate Equation 1 and Equation 2 using least squares regressions separately without imposing the same relative weight on the previous market path α across the two equations. That said, the separately estimated weights are broadly similar (Table 2), which justifies our estimation approach.

Table 2 reports the estimation results. For predictability, captured by the coefficient α, we find that for all four central banks, policy rate forecasts are anticipated by markets to a significant but less than complete extent. For the Norges Bank, almost 80% of the variation in the new central bank policy rate path can be forecast by markets using public information on the day prior to the release. The new path largely reflects the market path on the day before the publication with the relative weight close to 0.8. Also for the other three central banks, predictability is high and statistically significant. Yet, their policy rate paths are predicted to a lesser extent (around 40-50%) and with a smaller weight on the market pricing (0.3-0.5).

For credibility, captured by the coefficient β, we find that surprises in the four central banks' policy rate projections move the market path in a statistically significant but quantitatively limited way. The pass through of a policy rate path surprise is around 0.1-0.2 and significantly different from zero. The policy path surprises contribute 15-30% to the overall variation in markets' repricing. At the same time, the information flow between central banks and markets, especially the flow from central banks to markets, is not perfect. The by far less than complete pass-through from central bank path surprises to market paths suggests limited credibility. At the same time, this results also implies a very limited impairment of independent price discovery in markets by the release of a central bank interest rate path.

4.1 The role of forecasting horizon

The results reported so far refer to the predictability and credibility on average across all forecast horizons. However, both predictability and credibility might however not be invariant to the forecast horizon length. The central banks' intended policy rate path is probably easier to predict over the near term than over longer horizons into the future. Similarly, a surprise in the central bank path might be more relevant for near term expectations than for longer horizons when new paths are scheduled for release in the future.

In order to test these conjectures, we re-estimate Equation 1 and Equation 2 for individual forecast horizons τ. The results reported in Figure 2 and Figure 3 are consistent with the notion of declining predictability and credibility as the forecast horizon lengthens. That said, also at longer forecast horizons beyond eight quarters ahead, both predictability and credibility of the central bank path remains statistically larger than zero in most cases.

Figure 2 suggests that predictability, captured by the coefficient α in Equation 1, falls from around 0.8 at very short horizons to about 0.3 at longer horizons of beyond 8 quarters except for Norway where the fall is less pronounced (0.6 at beyond 8 quarters).

Similarly, Figure 3, reporting coefficient β from Equation 2 for different horizons, suggests that also credibility falls the further the central bank projections extends into the future. The short-term credibility of the central bank path, measured through the market path response to the central bank path surprise is highest for Sweden at about 0.5, compared to around 0.2 for the other three central banks.

4.2 The role of uncertainty around quantitative forward guidance

Central banks that provide policy rate projections often emphasize the conditional and uncertain nature of the projections. The Norges Bank and the Swedish Riksbank publish uncertainty intervals around the central forecast. The Federal Reserve publishes the forecast dispersion of the individual committee members. In contrast, the RBNZ does not provide any indication of forecasts uncertainty and publishes only the point projection of the policy rate.

While it is important for central banks to acknowledge the uncertain nature of their forecasts, larger uncertainty may go hand-in-hand with less ability to move market expectations. If markets update their beliefs about future policy rates in a Bayesian way, they would put less weight on the central bank projections in formulating their posterior if the projections are associated with larger variance.

In this subsection, we empirically examine how uncertainty around the policy rate projections, measured either by the uncertainty interval or the dispersion by individual committee members, affect the credibility of the central bank path, i.e. the pass-through of path surprises to market expectations of the future path of policy rates. For the uncertainty surrounding the path, we use published 70% and 75% confidence bands for the Norges Bank and the Sveriges Riksbank respectively, and 25-75 interquartile range of FOMC individual projections for the Federal Reserve. With these uncertainty measures, we estimate the following model to gauge how uncertainty affects the pass-through, or credibility, of central bank path surprises to market rate expectations:

$$i^m_{t_i,\tau} - i^m_{t_i-1,\tau} = (\beta + \beta_{U^c} U^c_{t_i,\tau}) \left[i^c_{t_i,\tau} - \alpha_0 - \alpha i^m_{t_i-1,\tau} - (1-\alpha) i^c_{t_{i-1},\tau} \right] + e_{t_i,\tau}, \quad (3)$$

where $U^c_{t,\tau}$ captures the central bank uncertainty at t around the policy rate at

τ.

Table 3 reports the estimated effect of path uncertainty. Consistent with the Bayesian updating principle, the pass-through of the central bank path surprise to the market path is negatively related to the central bank uncertainty around the policy rate path. However, only in the case of the Sveriges Riksbank, the impact is statistically significant, suggesting that a 1% increase in the confidence band around the central bank path translates into a 0.1 percentage points decrease in pass-through, which accounts for more than 50% of the unconditional pass-through.

Re-estimating Figure 3 by individual forecasting horizon reveals that higher uncertainty around the central bank path impacts credibility only in the very short-term at best. The results shown in Figure 4 suggest that both for the U.S. and Sweden there is a large and highly significant negative effect on credibility at the shortest forecasting horizon, while the effects at longer horizons are insignificant. For Norway, there is no evidence of a significant negative effect for any forecasting horizon.

5 Consistency and redundancy

Consistency and redundancy refer to the relationship between central banks' policy rate projections and their macroeconomic forecasts. In addition to policy rates, central banks also release forecasts for key macroeconomic variables, e.g. unemployment, GDP growth, the output gap and inflation. In fact, the publication of macro forecasts is generally a common practice among central banks, as opposed to publishing interest rate projections which is pursued only by few central banks (Svensson (2009)). Two natural questions emerge when central banks publish both policy rate and macroeconomic projections. First, are the interest rate projections consistent with the macroeconomic forecasts (consistency)? Second, do the interest rate projections provide information beyond the macroeconomic forecasts (redundancy)? On the one hand, the interest rate projections should be consistent with the macroeconomic forecast. This would help central banks to reinforce the public's perception about their reaction function. On the other hand, the interest rate projections should not be fully spanned by the macro forecasts so that they become redundant.

In order to assess consistency, we estimate Taylor-type interest rate reaction functions relating policy rate projections and macroeconomic projections:

$$i^c_{t_i,\tau} = \gamma_0 + \gamma_g X^g_{t_i,\tau} + \gamma_\pi \pi_{t_i,\tau} + e_{t_i,\tau}, \tag{4}$$

where $X^g_{t,\tau}$ and $\pi_{t,\tau}$ denotes the output or unemployment gap and inflation at τ forecast by the central bank at t respectively. We focus our analysis on the Norges Bank and the Federal Reserve as these central banks consistently release output/unemployment gap forecasts.

Table 4 lists the macroeconomic projections used in the analysis and reports the regression results. The results suggest that there exists a significant link between the policy rate and the macro projections which are consistent with a Taylor-type reaction function. In both the case of Norges Bank and of the Federal Reserve, macro projections explain around 70% of the variation in policy rate projections. At the same time, the estimated projection reaction functions are consistent with a stabilising Taylor-type rules. A higher output gap or lower unemployment gap and a more elevated inflation forecast correspond to higher policy rate projections. In particular, policy rate projections rise more than one-for-one with inflation projections, so that the projection reaction functions are consistent with the Taylor principle that interest rates should rise more than proportional with the inflation rate. This is the case also in a statistically significant way in the case of Norges Bank, but in the case of the Fed.

In order to test sensitivity of the results to the ELB constraint that affected policy rates over parts of the sample period, we re-estimate the Taylor-type rules with an effective lower bound constraint. Specifically, we estimate the following Tobit model:

$$i^c_{t_i,\tau} = max(\underline{r}, \gamma_0 + \gamma_g X^g_{t_i,\tau} + \gamma_\pi \pi_{t_i,\tau}) + e_{t_i,\tau}. \tag{5}$$

Table 4 shows the effective lower bound $\underline{r}$ that applied to the two central banks over the sample period (0 for Norges Bank and 0.125 for the Fed), and the estimation results obtained through this constrained estimation. It turns out that the results do not change much. In the case of the United States, we find larger impact of the macro forecasts on the policy rate projections when taking the effective lower bound into consideration. In particular, the inflation reaction coefficient is now significantly larger than one so that the Taylor principle is now fulfilled also in terms of statistical significance.

We also test variation in consistency over different forecasting horizons. To this end, we estimate Equation 4 for different forecasting horizons. The results reported in Figure 5 suggest that consistency increase as the forecasting horizon lengthens. In particular, for both Norway and the U.S. we find that the policy rate projection rises more strongly with the inflation forecast. The long-horizon inflation response coefficient is around 2 and 3, respectively, while the short-horizon response coefficient is below one.

Since these results suggest that the policy rate projection follows a Taylor-type rule with the macro forecasts as inputs, the natural follow-up question is whether publishing the macro forecasts would be sufficient in guiding the market expectation. Put differently, is publishing the policy rate projection redundant taking into account the information content of the macro forecasts?

To answer this question, we first check whether the market paths respond to revisions in the macro forecasts using the following regression:

$$i^m_{t_i,\tau} - i^m_{t_i-1,\tau} = \beta_0 + \beta_g(X^g_{t_i,\tau} - X^g_{t_{i-1},\tau}) + \beta_\pi(\pi_{t_i,\tau} - \pi_{t_{i-1},\tau}) + e_{t_i,\tau}, \tag{6}$$

The results reported in Table 5 suggest that macro forecasts affect market expectations in the expected direction. Higher output gap or lower unemployment rate gap as well as higher inflation forecasts lead to upward revisions in market expectations of the future policy rate path. The gap impact is significant in the case of Norway; and the inflation impact is significant for both the Norges Bank and the Fed. However, despite these significant effects, the regressions with the macro forecasts have much lower explanatory power than the regressions including the policy rate projections.

To further illustrate the point, we examine the impact of policy rate projections on the market expectations controlling for the central bank macro forecasts, i.e.

$$\begin{aligned} i^m_{t_i,\tau} - i^m_{t_i-1,\tau} = {} & \beta_r\left[i^c_{t_i,\tau} - \alpha_0 - \alpha i^m_{t_i-1,\tau} - (1-\alpha)i^c_{t_{i-1},\tau}\right] \\ & + \beta_g(X^g_{t_i,\tau} - X^g_{t_{i-1},\tau}) + \beta_\pi(\pi_{t_i,\tau} - \pi_{t_{i-1},\tau}) + e_{t_i,\tau}. \end{aligned} \tag{7}$$

The results (Table 6) suggest that the policy rate projections remain significant in these regressions. By contrast, the macro forecasts are insignificant in most cases, suggesting that their information content for market expectations has been subsumed by the policy rate projections.

The insignificance of macro forecasts suggests the same pass-through of an information shock (through macro projections) and a monetary policy shock (through a path surprise) on market expectations. The recent literature suggests that central bank communication on future interest rates consists of two components. One is news about the economic outlook (information shock), and the other is news about the central bank's future policy stance (monetary policy shock), see Nakamura and Steinsson (2018) for example. Information shocks can be purged with central bank forecasts of macroeconomic variables, say Greenbook projections as in Miranda-Agrippino and Ricco (2018). [7] In a similar vein, information shocks can be separated out with macro projections. As these forecasts do provide more information for market pricing in addition to interest rate projections, the pass-through of information shocks and monetary policy shocks is not materially different.

6 Conclusion

Based on data for the Reserve Bank of New Zealand, the Norges Bank, the Swedish Riksbank and the Federal Reserve we find that the interest rate projections released by these four central banks are predictable and credible. Market expectations of the future path of interest rates anticipate changes in the central bank projection path and adjust to path surprises. The adjustment is, however, not one to one, and decreases with the projection horizon. Moreover, high uncertainty around the projection path reduces the impact of path surprises. We also find the interest rate projections to be consistent with the macro projections that are released by the four central banks in parallel as these projections are empirically linked by a stabilising Taylor rule. Finally, interest rate projections are not redundant as they impact market expectations also when controlling for the effects of macro projections. Overall, these findings suggest that quantitative forward guidance through interest rate projections is effective, but that it also faces limitations.

There are other aspects of publishing an own interest rate path on top of those considered in our analysis. There are, for instance, further potential advantages such as avoiding a number of technical problems associated with the

[7] An alternative way to separate the two components is based on their opposite impact on financial instruments other than interest rates such as equity prices (Jarociński and Karadi (2020)) and inflation breakeven rates (Andrade and Ferroni (2021)).

adoption of the constant interest rate (CIR) or the market interest rate (MIR) approach in the construction of central banks' macroeconomic forecasts and the establishment of a more forward looking framework for internal policy deliberations Goodhart (2009). At the same time, there are also potential drawbacks. Ever more transparency may result in crowding out of private information (Morris and Shin (2002), Gosselin, Lotz and Wyplosz (2008)). Also, there is the concern that publishing an own interest rate forecast might be interpreted by the public as an unconditional promise so that not delivering on it might raise reputational risks. However, the fact, which we have also documented in this paper, that central bank interest rate projections have often differed substantially from interest rate outcomes without causing major set backs for credibility points to a limited practical relevance of this issue.

Tables and Figures

Table 1: Forecasting track record of central bank and market interest rate paths

	Horizon	Mean Error		RMSE		Modified DM Test	
		CB	market	CB	market	statistics	p-value
United States	Current year	0.07	0.00	0.21	0.15	-1.37	0.08
	1 year	0.59	0.27	0.97	0.73	-1.56	0.00
	2 years	1.09	0.51	1.48	1.18	-1.17	0.09
	3 years	1.47	0.43	1.69	0.97	-1.08	0.12
Sweden	1 quarter	0.08	0.34	0.31	0.57	3.29	1.00
	4 quarters	0.51	0.72	1.09	1.26	1.71	0.95
	8 quarters	1.46	1.40	1.85	1.83	-0.17	0.43
	12 quarters	2.30	1.95	2.51	2.18	-0.83	0.20
New Zealand	1 quarter	0.08	0.11	0.87	0.69	-1.42	0.08
	4 quarters	0.47	0.56	2.14	2.12	-0.23	0.41
	8 quarters	1.53	1.71	2.54	2.56	0.54	0.71
Norway	1 quarter	0.06	0.54	0.30	0.73	4.11	1.00
	4 quarters	0.38	0.74	0.98	1.20	1.90	0.97
	8 quarters	1.14	1.40	1.64	1.76	1.15	0.87

Notes: The table compares forecasting errors from central bank projections and market expectations prior to central bank meetings at selected horizons. RMSE refers to the root mean square error. Modified DM test refers to the modified Diebold-Mariano test based on Harvey, Leybourne and Newbold (1997).

Table 2: Predictability and credibility of the central bank policy rate path

		New Zealand	Norway	Sweden	United States
Predictability	α	**0.499**	**0.750**	**0.323**	**0.383**
		(0.025)	(0.039)	(0.021)	(0.077)
	R^2	48%	74%	39%	39%
	N	841	438	850	107
Credibility	β	**0.123**	**0.153**	**0.189**	**0.199**
		(0.022)	(0.012)	(0.020)	(0.058)
	α	**0.310**	**0.768**	**0.288**	0.169
		(0.069)	(0.038)	(0.025)	0.(119)
	R^2	16%	31%	27%	18%
	N	817	438	844	107

Notes: The table reports estimation results of Equation 1 and Equation 2. Standard errors are in parentheses. Numbers in bold face indicate statistically significance at a 10% confidence level.

Table 3: The role of uncertainty in the pass-through from central bank to market path

	Norway	Sweden	United States
Central banks uncertainty β_{U^c}	-0.015	**-0.096**	-0.051
	(0.017)	(0.014)	(0.067)
N	426	844	107

Notes: The table reports estimated β_{U^c} in Equation 3. Standard errors are in parentheses. Numbers in bold face indicate statistically significance at a 10% confidence level.

Table 4: Central bank policy rate projections and macro forecasts - Taylor rule estimates

	Norway	United States
X^g	Output gap	Unemployment gap
π	CPI-ATE	PCE gap
	without ELB	
γ_g	**1.281**	**-0.660**
	(0.047)	(0.095)
γ_π	**1.710**	**1.162**
	(0.082)	(0.152)
R^2	68%	71%
N	726	118
	with ELB	
γ_g	**1.295**	**-1.165**
	(0.036)	(0.084)
γ_π	**1.694**	**1.409**
	(0.079)	(0.170)
N	726	118

Notes: The table reports regressors and estimated coefficients from Taylor rule without ELB (Equation 4) and Taylor rule with ELB (Equation 5) respectively. For the Taylor ruel with ELB, $\underline{r}$ is 0 for Norway and 0.125 for United States. CPI-ATE stands for CPI adjusted for tax changes and excluding energy products. Unemployment/PCE gap is the deviation from its corresponding long-run projection. Except unemployment rate, all the other variables are measured in annual growth rate. Standard errors are in parentheses. Numbers in bold face indicate statistically significance at a 10% confidence level.

Table 5: Market response to central bank macro forecast revisions

	Norway	United States
β_g	**0.040**	-0.009
	(0.014)	(0.015)
β_π	**0.029**	**0.115**
	(0.014)	(0.059)
R^2	6%	3%
N	438	107

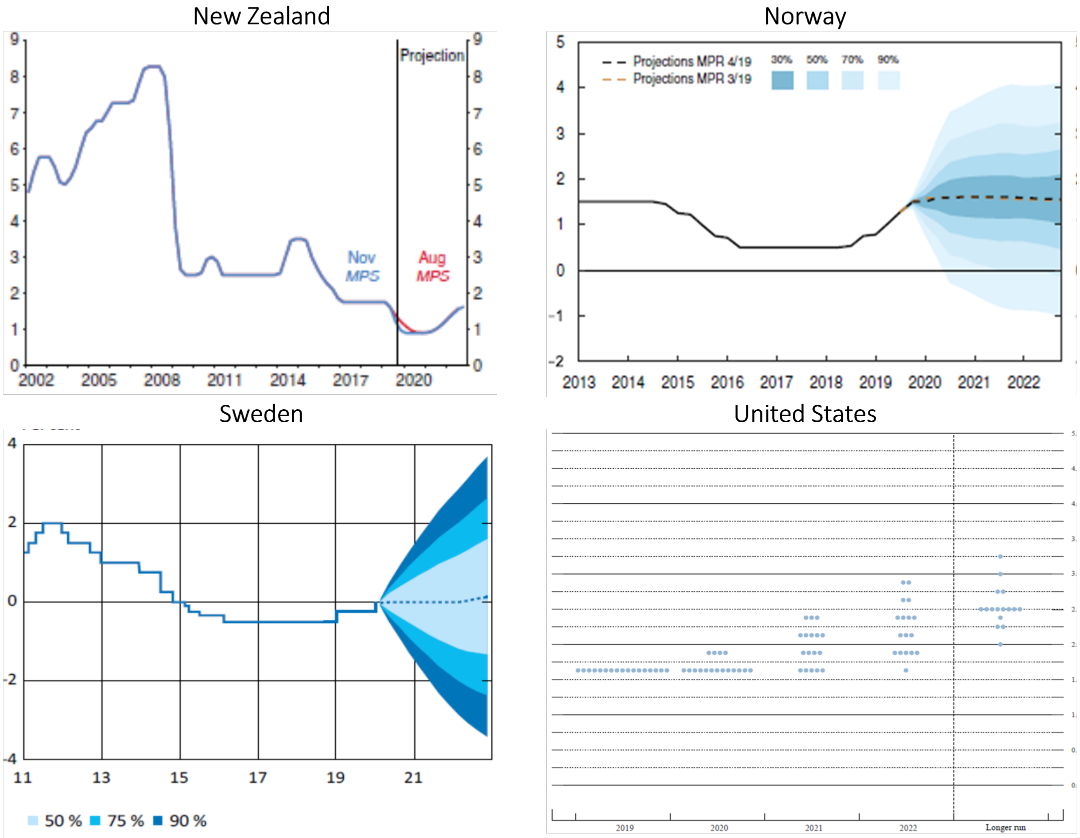
Notes: The table reports regressors and estimated coefficients from Equation 6. Standard errors are in parentheses. Numbers in bold face indicate statistically significance at a 10% confidence level.

Table 6: Market response to central bank macro forecasts and policy rate projections combined

	Norway	United States
β_r	**0.161**	**0.292**
	(0.016)	(0.075)
β_g	-0.007	**0.079**
	(0.012)	(0.024)
β_π	-0.012	0.070
	(0.013)	(0.056)
R^2	31%	24%
N	438	107

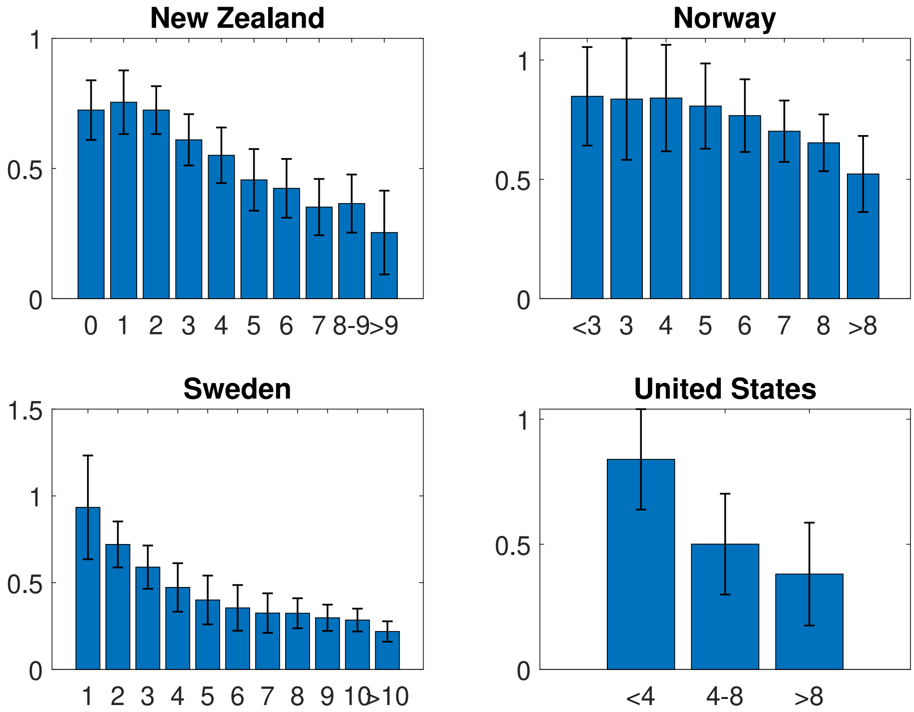
Notes: The table reports regressors and estimated coefficients in Equation 7. Standard errors are in parentheses. Numbers in bold face indicate statistically significance at a 10% confidence level.

Figure 1: **Central bank interest rate projections**



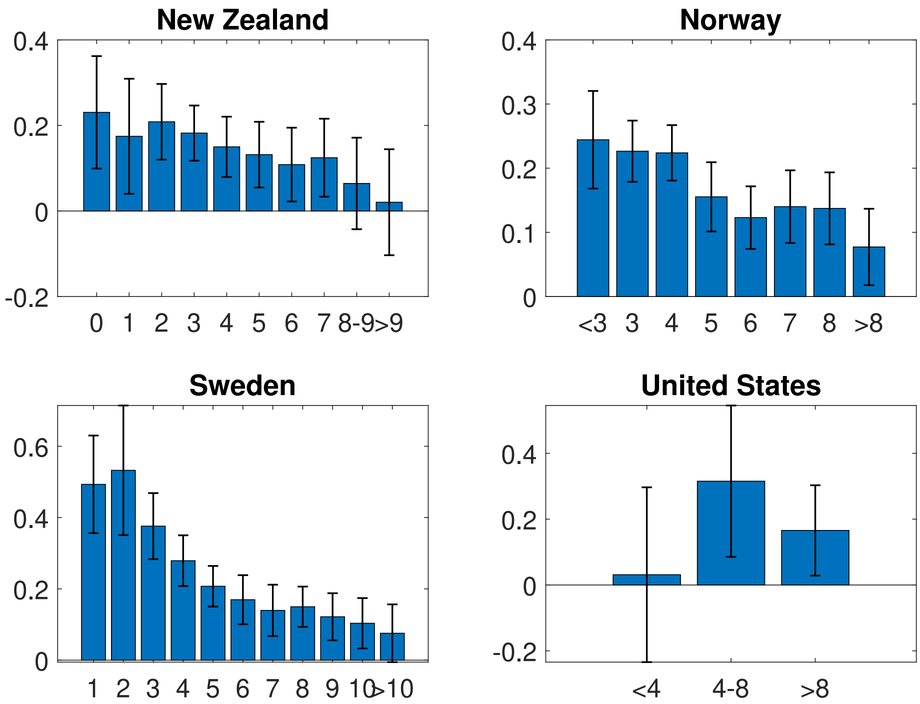
Sources: Reserve Bank of New Zealand Monetary Policy Statement November 2019; Norges Bank Monetary Policy Report December 2019, Sveriges Riksbank Monetary Policy Report December 2019, Federal Reserve Board Survey of Economic Projections December 2019.

Figure 2: Horizon-dependent predictability



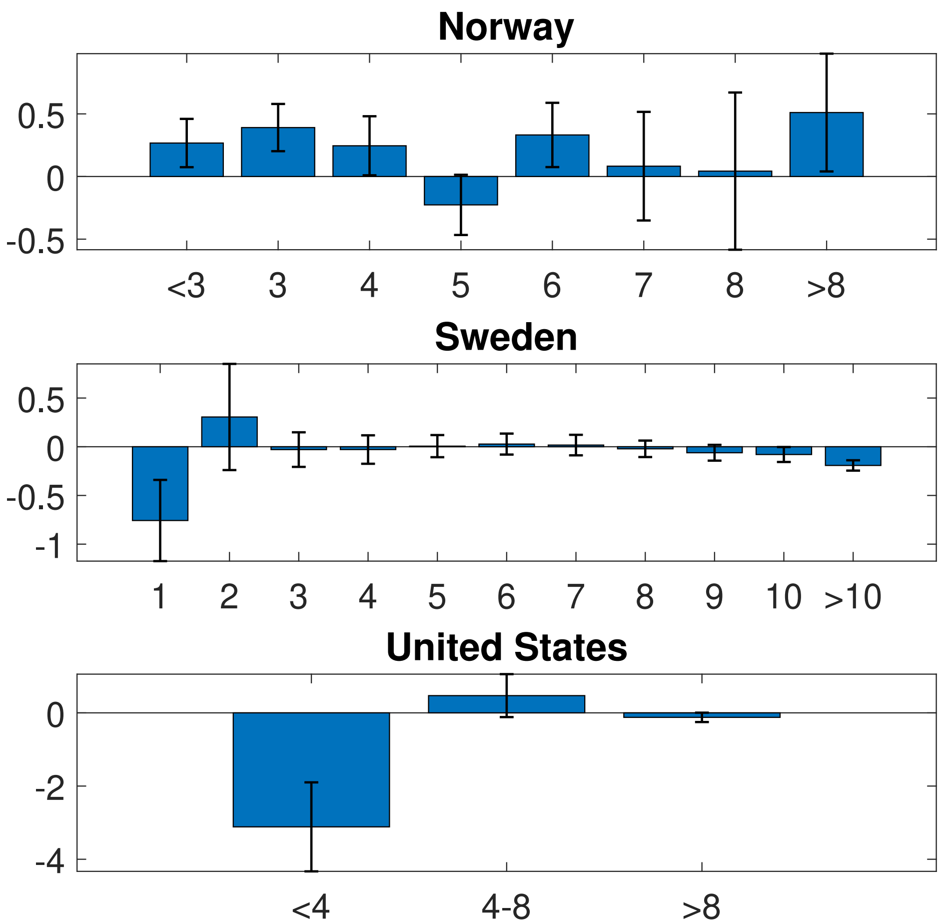
Notes: The figure plots the estimated α from Equation 1 over different forecasting horizon. The X-axis shows the forecasting horizons in quarters. The bars represent the point estimates; black lines indicate 90% confidence intervals.

Figure 3: Horizon-dependent credibility



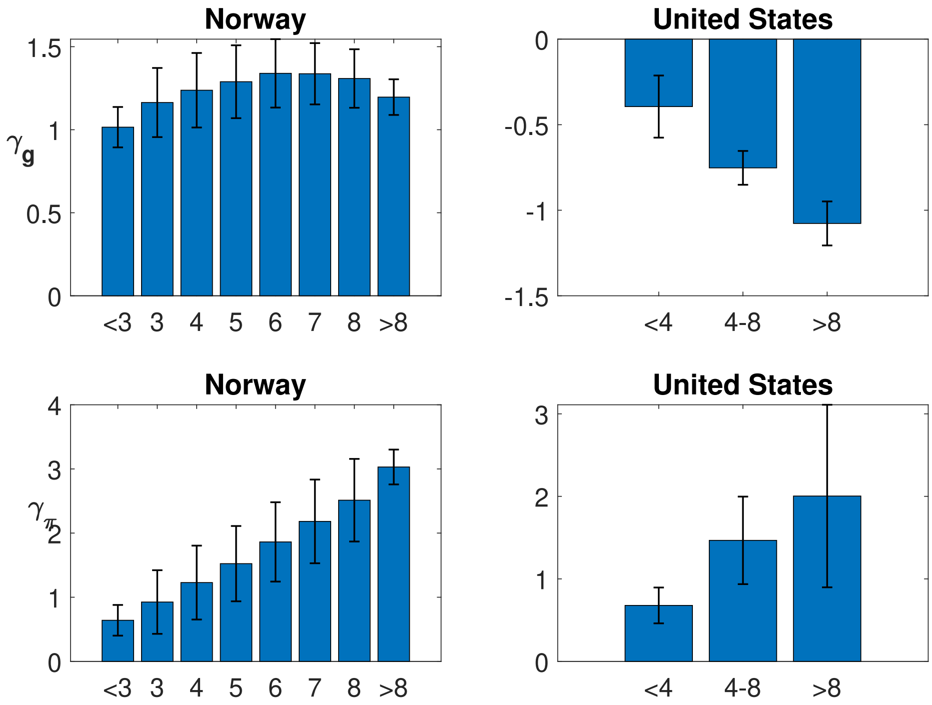
Notes: The figure plots the estimated β from Equation 2 over different forecasting horizon. The X-axis shows the forecasting horizons in quarters. The bars represent the point estimates; black lines indicate 90% confidence intervals.

Figure 4: Horizon-dependent role of uncertainties around the policy rate projections



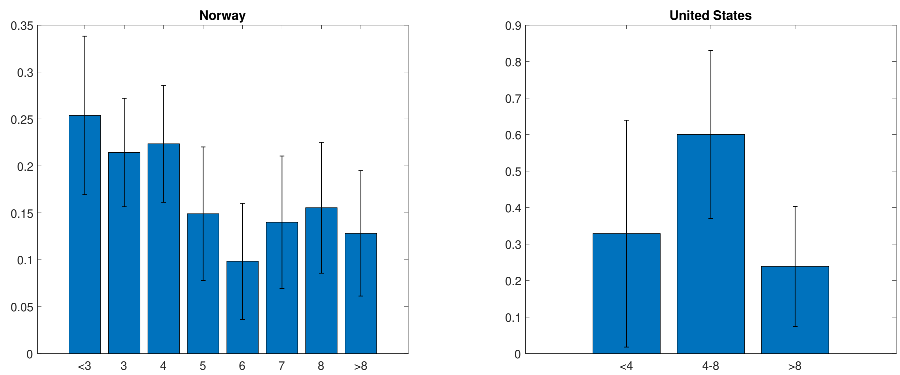
Notes: The figure plots the estimated β_U from Equation 3 over different forecasting horizon. The X-axis shows the forecasting horizons in quarters. The bars represent point estimates; black lines indicate 90% confidence intervals.

Figure 5: Horizon-dependent consistency



Notes: The figure plots the estimated γ_g (upper panels) and γ_π (bottom panels) from Equation 4 over different forecasting horizon. The X-axis shows forecasting horizons in quarters. The bars represent point estimates; black lines indicate 90% confidence intervals.

Figure 6: Horizon-dependent redundancy



Notes: The figures plot how estimated β_r in Equation 7 change over forecasting horizon. X-axis shows forecasting horizons in quarters. The bars represent point estimates; and black lines indicate 90% confidence intervals.

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