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Quantitative forward guidance through interest rate projections*

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Abstract

We assess quantitative forward guidance through interest rate projections along four key dimensions: (i) predictability, (ii) credibility, (iii) redundancy and (iv) consistency. Based on data for the Reserve Bank of New Zealand, the Norges Bank, the Sveriges Riksbank and the Federal Reserve, we find that the interest rate projections released by these four central banks are predictable and credible, but in limited ways. Market expectations of the future path of interest rates predict changes in the central bank projection path, but far from fully. Central bank paths' credibility is limited as markets adjust to path surprises, but far from a one-to-one basis. Both predictability and credibility decrease with the projection horizon. We further find that central bank interest rate projections are not redundant as they impact market expectations also when controlling for the effects of central bank macro projections that are released in parallel. Finally, the interest rate projections are consistent with the macro projections as they are empirically linked by a stabilising Taylor rule.

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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. In the wake of the Great Financial Crisis, all major central banks resorted to policy rate forward guidance in order to enhance the effectiveness of monetary policy at the zero lower bound, see e.g. Filardo and Hofmann (2014). According to survey evidence, the overwhelming majority of central bank governors and academics think that forward guidance should continue being part of central banks' toolkit going forward (Blinder, Ehrmann, de Haan and Jansen, 2017). 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 ((Ehrmann, Gaballo, Hoffmann and Strasser, 2019).

Against this background, this paper analyses quantitative forward guidance through the publication of central bank interest rate projections. The standard practice amongst central banks has been to provide qualitative forward guidance via projections of their main target variables (mainly inflation and real economic activity) and verbal communication of policy assessments and intentions 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. In particular, the Reserve Bank of New Zealand (RBNZ) introduced interest rate projections in 1997, the Norges Bank in 2005, the Sveriges 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 releases amongst investors.

Based on the experiences of these four central banks, this paper assesses quantitative forward guidance through interest rate projections along four key dimensions: (i) predictability, (ii) credibility, (iii) redundancy and (iv) consistency.

Predictability refers to the extent to which markets are able to anticipate the central bank path (Svensson, 2015). It is a key objective of central bank communication, so as to mitigate misperceptions about policy intentions and to avoid causing market volatility. This also applies to central banks' quantitative forward guidance. We assess predictability by testing to which extent central bank paths were already priced in by markets before their release.

Credibility refers to the ability of central banks to steer market interest rates through the quantitative guidance provided (Svensson, 2015). Higher credibility means greater traction on market rates. We assess credibility by examining to which extent market rates adjust to surprises in the central banks' interest rate paths. We also explore the factors that affect the pass-through of path surprises to market rates. Specifically, we analyse the role of the length of the forecast horizon and the role of uncertainty surrounding the central bank interest rate path projection as captured e.g. by the width of the confidence band around the central projection.

Redundancy refers to the question whether the central bank interest rate projections provide, in the eyes of markets, information beyond that provided through projections of key target variables (e.g. inflation or output growth) published at the same time. If that was not the case, the publication of an interest rate path would be redundant at least with respect to the the central bank's influence on 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 central bank projections of main target variables.

Finally, consistency refers to the question whether central bank interest rate projections are consistent with the published projections of policy target variables. 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 mandate. 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 output gap projections.

Our main findings are as follows. First, the interest rate projections released by the four central banks under investigation are predictable, but in a limited way. Market expectations of the future path of short-term interest rates anticipate changes in the central bank projection path to a significant yet far from full extent. Moreover, predictability decreases with the projection horizon. Second,central bank interest rate paths are credible, but also only to a limited extent. Market interest rates adjust in a significant way to central bank path surprises. The adjustment is, however, far from one to one, and decreases with the projection horizon. Moreover, high uncertainty around the projection path reduces the impact of path surprises. Third, interest rate projections are not redundant. Their impact on market expectations remains significant also when controlling for the effects of central bank macro projections. Finally, central bank interest rate projections are consistent with central bank macro projections. The two projections are consistent with a stabilising Taylor rule linking interest rates to inflation and the output gap.

The remainder of the paper is organised as follows. This section closes with a short review of the relevant literature. Section 2 describes the data. Section 3 reports the results of a preliminary analysis of the forecast performance of central bank and market-implied interest rate paths. In Section 4, we analyse predictability and credibility. Redundancy and consistency are assessed in Section 5. Section 6 concludes.

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).

There is a growing literature exploring the implications of and lessons learnt from quantitative forward guidance through interest rate projections. Goodhart and Lim (2011) suggest, based on central bank interest rate projections for New Zealand and market-based interest rate forecasts for the United Kingdom, that the predictive ability of interest rate forecasts by both central banks and markets is very low. They find that both central bank and market paths poorly predict future interest rates beyond the very short-term and that they are biased.

Other papers instead focus on the question how central bank interest rate projections affect the market's ability to predict future policy rates and to which extent the paths are 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 of central banks' interest rate paths on markets' predictive ability in Norway and Sweden.[1] Svensson (2015) provides a descriptive assessment of the predictability of the Riksbank's, the RBNZ's and the Federal Reserve's interest rate paths, assessing the extent to which the paths are reflected in market paths before their release. He concludes that the performance of the three central banks in terms of predictability is mixed and uneven. 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 explores 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 in terms of credibility as market adjustment appears limited.

Formal evidence on market impact is also mixed, depending on the methodology and sample period covered. Detmers and Nautz (2012) for New Zealand and Åhl (2017) and Iversen and Tysklind (2017) for Sweden find, respectively, significant effects of surprises in the central bank interest rate projections on market rates. Brubakk, ter Ellen and Xu (2021) also 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 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.

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

2 Data

The key variables for our empirical analysis are interest rate projections from central banks and interest rate expectations derived from financial market prices.

2.1 Central bank interest rate projections

New Zealand The RBNZ has been publishing interest rate projections for more than 20 years. Between June 1997 and August 2016, the RBNZ provided regular forecasts of the quarterly average 90 day bank bill rate. After August 2016, the central bank forecasts refer to the OCR.[2] To account for this change in the reference interest rate, 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 discussions 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 of the quarterly average policy rate, i.e. the interest rate on banks' overnight deposits, since 2005. The Norges Bank policy rate projections, which are released with the Monetary

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

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 Graph 1, top right panel, taken from 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, including 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 forecasts are calculated on the basis of the core model.

Sweden The Sveriges Riksbank has been publishing projections of the quarterly average policy rate, i.e. the repo rate at which banks can borrow or deposit funds 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. Judgement is 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 account for 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) of the federal funds rate at the end of the specified calendar year or over the long run. To take this change into account, we adjust the forecasts for the specified calendar years that are made before September 2014 by subtracting 0.125%. The FOMC projections are released four times a year.[3]

For the first half of each year, projections are made for the current year, one- and two-years ahead, and the long run. For the second half of each year, projections are made for the 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 are often available only 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

[3] 2012 and 2020 are exceptions when these projections were released five times and three times respectively.

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 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.[4] 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 market expectations of the 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

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

settlement month. For current year, one- and two-years ahead expectations, we use average prices of the forecasting years' December futures and the following January futures. For three-years ahead expectations, we use prices of the 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 years 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, redundancy and consistency of central bank policy rate projections, we want to assess the track record of central bank interest rate projections and how it compares to market-implied forecasts. In doing so, we extend Goodhart and Lim (2011) who have addressed the question based on RBNZ interest rate projections and UK market-based interest rate forecasts.

We assess the track record of the central bank interest rate projection by comparing projected interest rate levels with interest 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 forecasting 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 of central bank projections and market forecasts.

The results of this exercise which are reported in Table 1 confirm, based on a larger group of countries, the conclusions of Goodhart and Lim (2011). For all four countries, both central bank and market interest rate forecasts are quite accurate for the next quarter (current year for the U.S.) but then off by wide margins 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 sample period 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.

When 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.[5]

4 Predictability and credibility

The predictability and the credibility of central banks' interest rate paths refer to the extent to which markets respectively have anticipated the path and adjust to the path after its publication. Svensson (2015) argues that, ideally, central banks should be so predictable that the policy rate path priced in by markets

[5]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 incorporates 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.

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 path align with the newly announced path. However, Morris and Shin (2018) suggest that financial market 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 sheds light on these issues.

To gauge predictability of central bank interest rate paths, we examine to which extent central bank policy rate paths were reflected in market expectations on the day prior to their release.[6] To this end, we model the 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.

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

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 expectations prevailing on the day prior to the release in newly released central bank interest rate projections, reflecting the degree of predictability. 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. Full predictability would correspond to α=1.

To gauge the credibility of the central bank paths, we evaluate how markets

[6]Higher frequency data to assess movements in market expectations before and after the release time of the central bank path are not available for most of the countries covered by our study, so we stick to daily data throughout.

have responded to path surprises similar to Moessner and Nelson (2008):

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

A credible central bank policy rate path would be a strong attractor for the market path, reflected in a statistically significant and large positive β. Full credibility would correspond to β=1.

We estimate Equation 1 and Equation 2 jointly using maximum likelihood estimation. As a cross check, 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. The coefficients estimated separately are very similar to those estimated jointly.

Table 2 reports the estimation results. The jointly and separately estimated weights are broadly similar. 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, 75% 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 of 0.75. 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 (between 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 5-30% to the overall variation in markets' repricing (based on the joint estimations). 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 result 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 the 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 not be invariant to the length of the forecast horizon. The central bank's 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.

In order to test these conjectures, we re-estimate jointly by maximum likelihood 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 the predictability and the credibility of the central bank path remain statistically larger than zero in most cases.

Figure 2 suggests that predictability, captured by the coefficient α in Equation 1, falls from around 0.7 at very short horizons to about 0.3 at longer horizons of beyond 8 quarters in Sweden, New Zealand and the U. S.. In Norway, the decline in predictability at longer forecast horizons is less pronounced. The coefficient α is estimated at 0.9 at short horizons and at 0.7 at longer horizons beyond eight quarters.

Similarly, Figure 3, reporting coefficient β from Equation 2 for different horizons, suggests that also credibility falls the further the central bank projections extend into the future. The market path response to the central bank path surprise at short horizons is highest for Sweden at about 0.5, compared to around 0.2 and 0.3 respectively for Norway and New Zealand. At longer horizons, the impact of the path surprise falls to below 0.1 for all three central banks.

In the U.S., we observe a slightly different pattern of the path surprise impact over different horizons. The impact in the current year is essentially zero, while it is 0.4 for the next year and 0.2 for the year after next. The low credibility for the current year probably reflects the limited and declining information content of current year projections the further the year progresses.[7]

4.2 The role of uncertainty around quantitative forward guidance for credibility

Central banks that provide policy rate projections emphasise the conditional and uncertain nature of the projections. In this vein, 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 projections, larger uncertainty may go hand-in-hand with less traction on 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

[7] Specifically, the further advanced the year is, the more do the current year projections reflect the level of rates that has already materialised and is common knowledge, so that the new projection does not add much additional information.

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 across individual committee members, affects 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. To measure uncertainty surrounding the central bank interest rate 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 projection for τ.

Table 3 reports the estimated effect of path uncertainty on path credibility. Consistent with the Bayesian updating principle, the pass-through of the central bank path surprise to the market path is negatively related to the degree of uncertainty around the policy rate path. However, only in the case of the Sveriges Riksbank, the impact is statistically significant. The estimates suggest that, in Sweden, a 1 percentage point 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 Equation 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 Redundancy and consistency

Redundancy and consistency refer to the relationship between central banks' policy rate projections and their macroeconomic forecasts. In addition to policy rate projections, central banks also release forecasts for key macroeconomic variables, e.g. inflation, unemployment, GDP growth and the output gap. 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, do the interest rate projections provide information beyond the macroeconomic forecasts (redundancy)? Second, are the interest rate projections consistent with the macroeconomic forecasts (consistency)? On the one hand, the interest rate projections should not be fully spanned by the macro forecasts as they would otherwise be redundant in terms of information content for the public. On the other hand, the interest rate projections should be consistent with the macroeconomic forecasts in the sense that the two should be linked by a meaningful monetary policy reaction function. This would help the central bank to reinforce the public's perception that its reaction function is consistent with its mandate.

Since it is more common among central banks to publish macro forecasts, the natural question is whether publishing the macro forecasts would be sufficient to guide market expectations. 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 interest rate paths respond to revisions in the macro forecasts using the following regression:[8]

$$i^m_{t_i,\tau} - i^m_{t_i-1,\tau} = \beta_0 + \beta_g(X^g_{t_i,\tau} - X^g_{t_{i-1},\tau}) + \beta_\pi(\pi_{t_i,\tau} - \pi_{t_{i-1},\tau}) + e_{t_i,\tau}, \tag{4}$$

Table 4 lists the macroeconomic projections used in the analysis and reports the estimation results. Our results suggest that macro forecasts affect market paths in the expected direction. Higher output 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 the Norges Bank, the Riksbank 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 directly test redundancy of the policy rate path, we examine the impact of policy rate projections on the market expectations controlling for the central bank macro forecasts, i.e.

$$\begin{aligned} i^m_{t_i,\tau} - i^m_{t_i-1,\tau} = {} & \beta_r\left[i^c_{t_i,\tau} - \alpha_0 - \alpha i^m_{t_i-1,\tau} - (1-\alpha)i^c_{t_{i-1},\tau}\right] \\ & + \beta_g(X^g_{t_i,\tau} - X^g_{t_{i-1},\tau}) + \beta_\pi(\pi_{t_i,\tau} - \pi_{t_{i-1},\tau}) + e_{t_i,\tau}. \end{aligned} \tag{5}$$

As before, we estimate Equation 5 individually by OLS and jointly with Equation 1 by maximum likelihood. The results reported in Table 5 suggest that the

[8]Ideally, we would want to use the surprise element in the central bank macro projections. However, there are no market instruments that would enable us to extract market expectations on the day before and the day after the release. Survey-based expectations of the relevant macro variables are generally not available in the required timing and frequency.

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 is dominated by that of the policy rate projections. Quantitatively, the estimated impacts of the path surprises also do not change materially compared to those reported in Table 2, except for New Zealand, where the coefficient more than halves.

We next estimate Equation 5 for different forecasting horizons, jointly with Equation 1. The results reported in Figure 5 suggest that also across the different forecast horizons, including changes in macro forecasts does not make interest rate projections redundant. Comparison with Figure 3 suggests that also quantitatively the horizon-dependent impact of path surprises does not change materially when changes in macro forecast are added to the estimating equations. The exceptions is again New Zealand where also for individual forecast horizons we find a notable reduction in the impact of path surprises when macro projections are included in the regressions.

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

$$i^c_{t_i,\tau} = \gamma_0 + \gamma_g X^g_{t_i,\tau} + \gamma_\pi \pi_{t_i,\tau} + e_{t_i,\tau}, \tag{6}$$

where $X^g_{t,\tau}$ and $\pi_{t,\tau}$ denotes respectively the central bank's output or unemployment gap and inflation forecast for τ at t. We focus our analysis on the Norges Bank and the Federal Reserve as these central banks consistently release output/unemployment gap forecasts, providing measures of forecast economic slack that are needed for the estimation of Taylor rules.

Table 6 reports the regression results. They suggest that there exists a significant link between the policy rate and the macro projections 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 interest rate projection reaction functions are consistent with a stabilising Taylor-type rules. A higher output gap or lower unemployment gap and a higher 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 not in the case of the Federal Reserve.

In order to test the 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:

$$i^c_{t_i,\tau} = max(\underline{r}, \gamma_0 + \gamma_g X^g_{t_i,\tau} + \gamma_\pi \pi_{t_i,\tau}) + e_{t_i,\tau}. \tag{7}$$

Table 6 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 Federal Reserve), 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 a larger impact of the macro forecasts on the policy rate projections when taking the effective lower bound into account. 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 6 for different forecasting horizons. The results reported in Figure 6 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 as the forecast horizon lengthens. The long-horizon inflation response coefficient is around 2 and 3, respectively, while the short-horizon response coefficient is below one. This result can be interpreted as reflecting a strong forward looking element in the construction of interest rate projection paths.

6 Conclusion

Based on data for the Reserve Bank of New Zealand, the Norges Bank, the Sveriges Riksbank and the Federal Reserve we find that the interest rate projections released by these four central banks are predictable and credible albeit to a limited extent. Market expectations of the future path of interest rates anticipate changes in the central bank projection path, but far from fully. And market expectations adjust to path surprises, but at a rather small scale far from one-to-one. Both predictability and credibility decrease with the projection horizon. We further find that interest rate projections are not redundant as they impact market expectations also when controlling for the effects of macro projections. Finally, interest rate projections are consistent with central bank macro projections as these projections are empirically linked by a stabilising Taylor rule. Overall, these findings suggest that quantitative forward guidance through interest rate projections is effective along the dimensions considered by our analysis, but that it also faces limitations.

There are however also other important aspects of publishing an own interest rate path on top of those we have considered in this paper. On the one hand, there are further advantages which we do capture. These include avoiding technical problems associated with the constant or the market interest rate (CIR/MIR) approach to forecasting 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)). Moreover, 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 (Filardo and Hofmann (2014)). 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 reputational issues points to limited practical relevance of this risk.

Tables and Figures

Table 1: Forecasting track record of central bank and market-implied 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-implied expectations of the day prior to central bank meetings at selected horizons. ME refers to the mean forecast error and RMSE 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
	α	**0.499**	**0.750**	**0.323**	**0.383**
Predictability		(0.025)	(0.039)	(0.021)	(0.077)
	R^2	48%	74%	39%	39%
	N	841	438	850	107
	β	**0.123**	**0.153**	**0.189**	**0.199**
		(0.022)	(0.012)	(0.020)	(0.058)
Credibility	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
	β	**0.125**	**0.153**	**0.191**	**0.231**
		(0.007)	(0.008)	(0.008)	(0.035)
Joint	α	**0.468**	**0.756**	**0.314**	**0.350**
		(0.012)	(0.013)	(0.008)	(0.031)
	$R^2_{\text{predictability}}$	47%	74%	38%	37%
	$R^2_{\text{credibility}}$	15%	30%	26%	5%
	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 least at the 10% confidence level.

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

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

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

Table 4: Market response to central bank macro forecast revisions

	New Zealand	Norway	Sweden	United States
X^g	GDP	Output gap	GDP	Unemployment gap
π	CPI	CPI-ATE	CPIF	PCE gap
β_g	0.010	**0.040**	-0.009	-0.009
	(0.008)	(0.014)	(0.017)	(0.015)
β_π	-0.001	**0.029**	**0.052**	**0.115**
	(0.009)	(0.014)	(0.018)	(0.059)
R^2	0.4%	6%	2%	3%
N	652	438	839	107

Notes: The table reports regressors and estimated coefficients from Equation 4. CPI-ATE stands for CPI adjusted for tax changes and excluding energy products. CPIF stands for CPI with a fixed interest rate. Unemployment/PCE gap is the deviation from the corresponding long-run projection. Except for the unemployment rate, all variables are measured in annual growth rates. Standard errors are in parentheses. Numbers in bold face indicate statistically significance at least at the 10% confidence level.

Table 5: Market response to central bank macro forecasts and policy rate projections combined

	New Zealand	Norway	Sweden	United States
	Stand-alone estimation			
β_r	**0.052**	**0.161**	**0.193**	**0.292**
	(0.023)	(0.016)	(0.020)	(0.075)
β_g	-0.001	-0.007	**-0.027**	**0.079**
	(0.008)	(0.012)	(0.012)	(0.024)
β_π	**-0.018**	-0.012	-0.002	0.070
	(0.011)	(0.013)	(0.013)	(0.056)
R^2	4%	31%	28%	24%
N	624	438	839	107
	Joint estimation			
β_r	**0.049**	**0.159**	**0.194**	**0.341**
	(0.009)	(0.009)	(0.008)	(0.042)
β_g	0.004	-0.004	**-0.024**	**0.069**
	(0.005)	(0.006)	(0.006)	(0.021)
β_π	-0.010	-0.010	0.004	-0.019
	(0.007)	(0.007)	(0.009)	(0.055)
α	**0.485**	**0.750**	**0.312**	**0.312**
	(0.013)	(0.014)	(0.008)	(0.030)
$R^2_{\text{predictability}}$	53%	74%	38%	35%
$R^2_{\text{Redundancy}}$	2%	30%	27%	14%
N	624	438	839	107

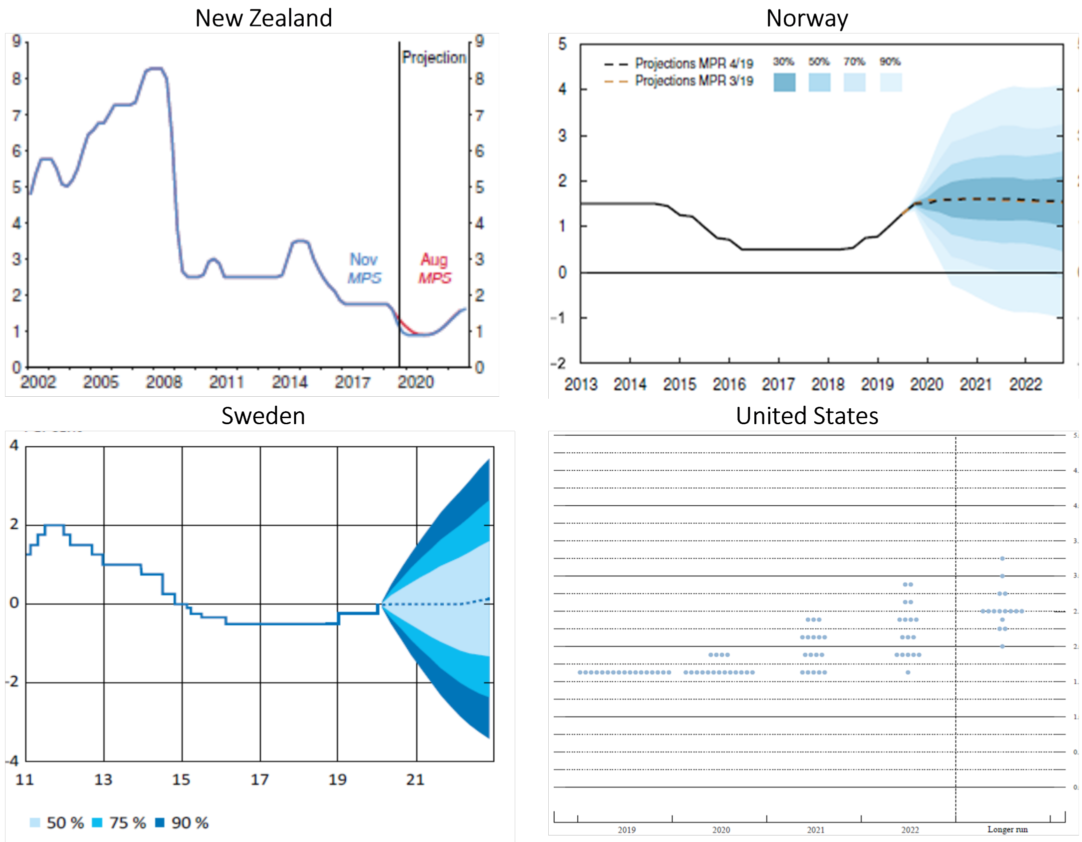
Notes: The table reports estimated coefficients from Equation 5. Results from stand-alone regression and joint estimation with Equation 1 are both reported. Standard errors are in parentheses. Numbers in bold face indicate statistically significance at a 10% confidence level.

Table 6: Central bank policy rate projections and macro forecasts - Taylor rule estimates

	Norway	United States
	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

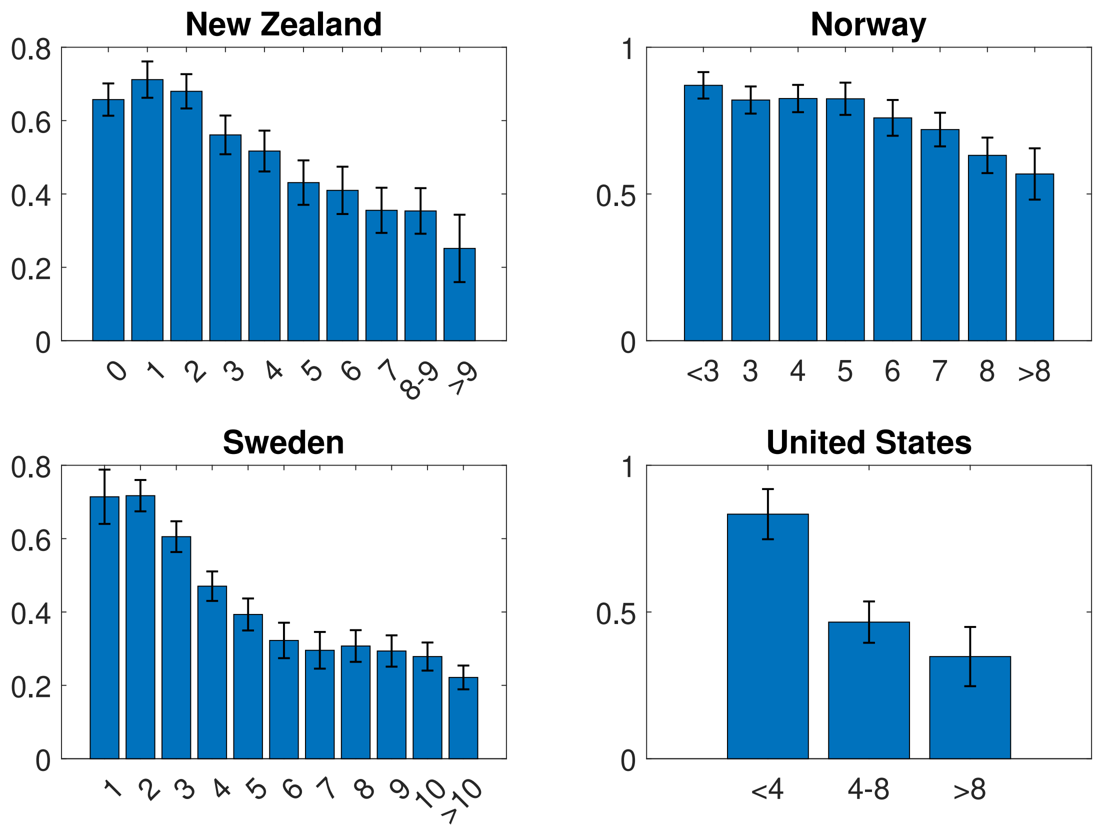
Notes: The table reports regressors and estimated coefficients from the Taylor rule without ELB (Equation 6) and the Taylor rule with ELB (Equation 7) respectively. For the Taylor rule with ELB, $\underline{r}$ is 0 for Norway and 0.125 for United States. Standard errors are in parentheses. Numbers in bold face indicate statistically significance at least at the 10% confidence level.

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



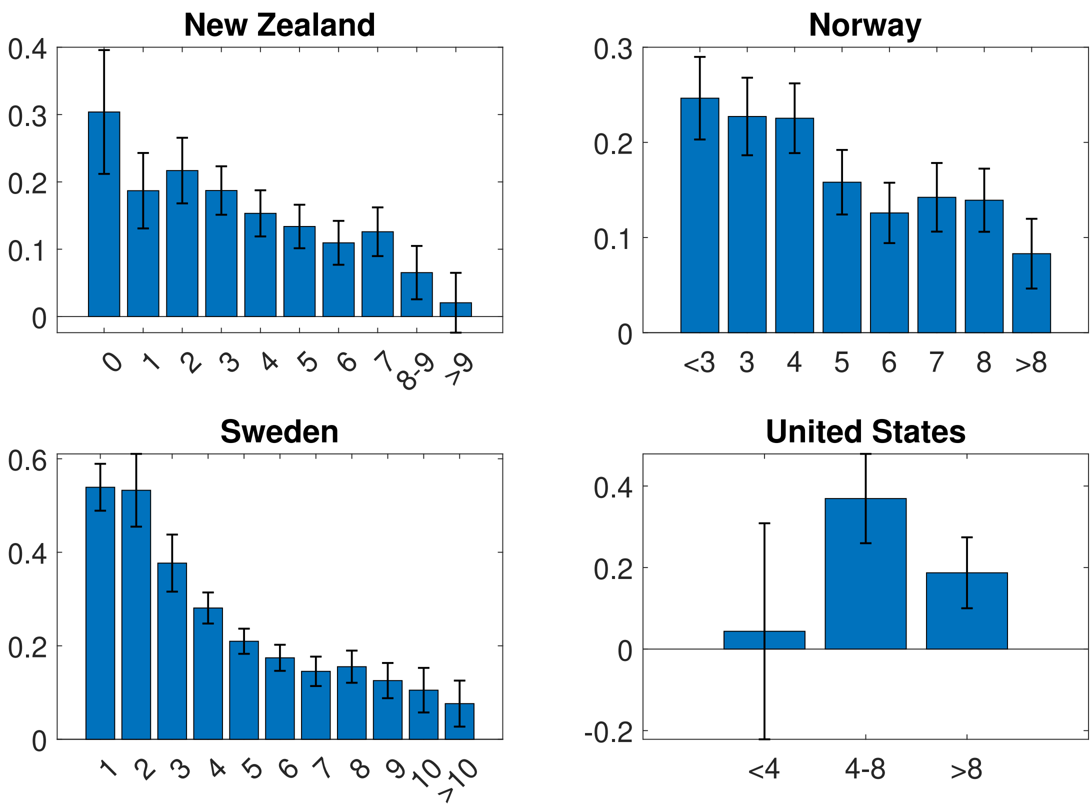
Sources: Reserve Bank of New Zealand Monetary Policy Statement November 2019; Norges Bank Monetary Policy Report December 2019, Sveriges Riksbank Monetary Policy Report December 2019, Federal Reserve Board Survey of Economic Projections December 2019.

Figure 2: Horizon-dependent predictability



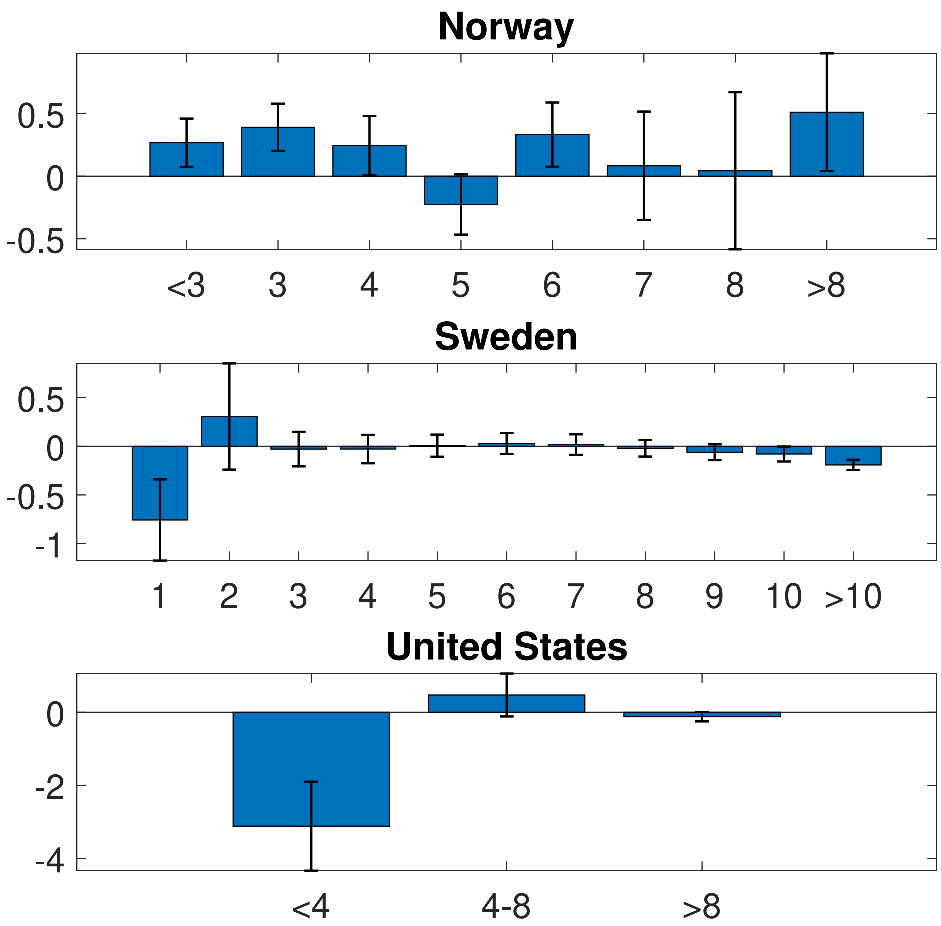
Notes: The figure plots the estimated α from Equation 1 over different forecasting horizon. The X-axis shows the forecasting horizons in quarters. The bars represent the point estimates; black lines indicate 90% confidence intervals.

Figure 3: Horizon-dependent credibility



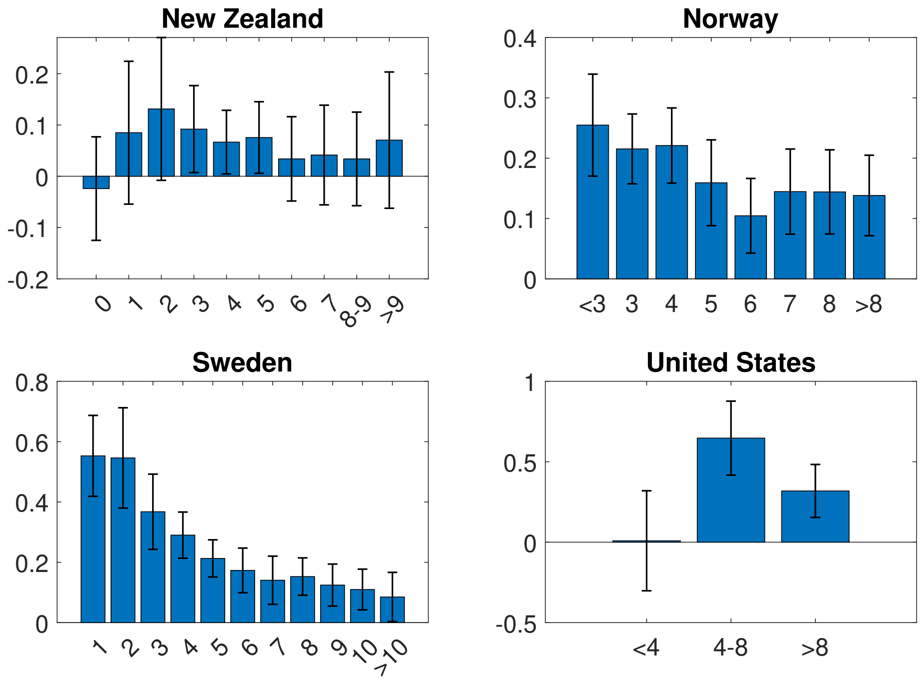
Notes: The figure plots the estimated β from Equation 2 over different forecasting horizon. The X-axis shows the forecasting horizons in quarters. The bars represent the point estimates; black lines indicate 90% confidence intervals.

Figure 4: Horizon-dependent role of uncertainty around policy rate projections for credibility



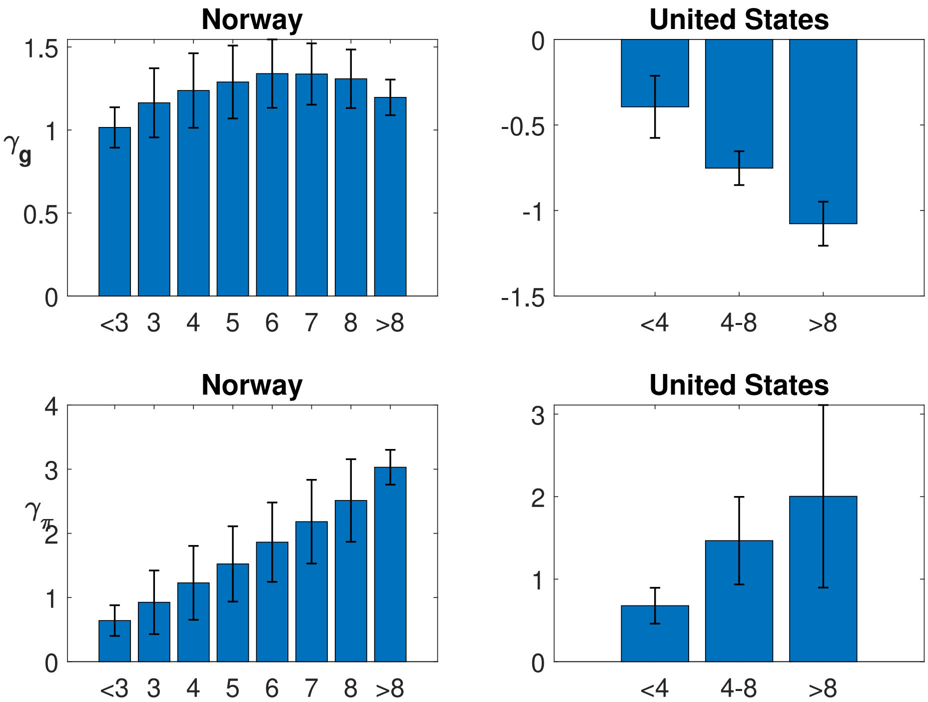
Notes: The figure plots the estimated β_U from Equation 3 over different forecasting horizon. The X-axis shows the forecasting horizons in quarters. The bars represent point estimates; black lines indicate 90% confidence intervals.

Figure 5: Horizon-dependent redundancy



Notes: The figures plot how estimated β_r in Equation 5 change over forecasting horizon. The X-axis shows forecasting horizons in quarters. The bars represent point estimates; and black lines indicate 90% confidence intervals.

Figure 6: Horizon-dependent consistency



Notes: The figure plots the estimated γ_g (upper panels) and γ_π (bottom panels) from Equation 6 over different forecasting horizon. The X-axis shows forecasting horizons in quarters. The bars represent point estimates; black lines indicate 90% confidence intervals.

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