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E43, E47, E58

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Interest rate forecasts, Central bank communication, Asymmetric loss

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April 26, 2017

Abstract

In this paper, we study the bias in interest rate projections for four central banks, namely for Czech Republic, New Zealand, Norway, and Sweden. We examine whether central bank projections are based on an asymmetric loss function and report evidence that central banks perceive an overprojection of their longer-term interest rate forecasts as twice as costly as an underprojection of the same size. We document that rationality is consistent with biased interest rate projections which contribute to explaining the central banks' behavior.

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1 Introduction

Over the past 20 years central banks have embarked on a stance of more transparent policymaking and open central bank communication. While traditional views on central bank communication had advocated the publication of as little specific information as possible, the acknowledgement of the role that public expectations play in macroeconomic stabilization has brought about a shift towards more openness in communicating policy intentions and decisions (Rudebusch and Williams, 2008). Against this background, a number of innovative, new instruments has recently been introduced by several central banks as part of their efforts to guide and lead financial market expectations into the desired direction.

One of the latest innovations in this context and one considered to be the “new frontier” in central bank communication is the publication of interest rate projections (Blinder et al., 2008). The publication of such forecasts was first introduced by the Reserve Bank of New Zealand in 1997, when it issued a forecast of the future 90-day bank bill rate as part of its Monetary Policy Statements aiming at providing some strong guidance for interest rate expectations. This approach was followed by a few other central banks. In 2005, the Norges Bank began to issue projections of its own key policy rate. In 2007 the Swedish Riksbank began to publish forecasts of the future repo rate and the CNB followed in 2008 with forecasts of the Prague Interbank Offered Rate (PRIBOR). Iceland’s Sedlabanki Islands published projections of its own policy rate starting in 2006, but discontinued this policy in 2010. Most lately, in 2012, the U.S. Federal Reserve System started publishing forecasts of its target federal funds rate, which can also be interpreted as increased interest in this means of central bank communication. Even though the publication of projected interest rate paths has so far been only practiced by a handful of central banks, by now enough data has accumulated for empirical research, making this a “high-priority area” for academic research in general (Blinder et al., 2008).

In the context of this innovative approach to more transparent central bank communication, the academic literature on these interest rate projections is still in a nascent stage. Rudebusch and Williams (2008) and Gosselin et al. (2008) discuss the value of publishing interest rate projections. More specifically, Rudebusch and Williams (2008) find that “communication of interest rate projections can better align the public’s and the central bank’s expectations” and that this improved “alignment of expectations generally leads to improvements in macroeconomic performance.” However they point out that a misinterpretation by the public of such interest rate forecasts as “unconditional commitments” might present a significant pitfall to this instrument of central bank communication. Gosselin et al. (2008) use this argument and formulate conditions under which central bank transparency leads to welfare losses: Assuming a significant degree of information heterogeneity between a central bank and the public, this communication policy should not be pursued if the central bank shows signs of time inconsistency. Detmers and Nautz (2014) find that interest rate projections do appear to be helpful in the overall market expectations management of a central bank, but, at the same time, such projections tend to become stale quickly which then contributes to increasing market uncertainty. They also show that interest rate projection horizons beyond four quarters do not provide much useful information to markets and might even lead to higher interest rate volatility (Detmers and Nautz, 2013).

Building upon the existing literature, this paper aims at contributing to the investigation of interest rate projections as a new means of more transparent central bank communication by comparing them against actual outcomes and in this context, examining what kind of loss function interest rate forecast publications are possibly based on. More specifically, we are keen to identify whether central banks' interest rate projections truly follow a symmetric loss function and can therefore be assumed to be unbiased.

We study the interest rate projections of the central banks of the Czech Republic, New Zealand, Norway and Sweden, all of which have been publishing such projections for at least the last decade within their inflation-targeting framework. We focus on the forecast errors (i.e. the difference between the realized interest rate s_t and the interest rate forecast f_t for period t) across different forecast horizons and make use of an approach developed by Elliott et al. (2005) to determine whether these forecast errors follow a symmetric or an asymmetric loss function. From a theoretical perspective, a number of reasons might warrant central banks to over- or underestimate future policy rates, e.g., to secure greater leeway for the effects of counter-inflationary or counter-deflationary policies in times of need.

In the economic literature, the analysis of macroeconomic projections has gained considerable attention in recent years. Studies have typically focused on projections published by financial markets participants (Dovern, 2015), international organizations (Frenkel et al., 2013) or macroeconomic models (Wieland and Wolters, 2011). Our analysis of interest rate projections by central banks is relevant for a number of economic reasons. First, financial market participants closely follow the general communication of central banks to form expectations about future interest rate decisions (Neuenkirch, 2012). If central banks provide fairly accurate interest rate forecasts, financial market participants may use such forecasts in forming their expectations rather than trying to infer future developments from the verbal and, thus, more qualitative communication. The analysis is also interesting from an economic policy makers view due to the fiscal-monetary-policy interaction (Davig et al., 2011). Hence, fiscal policy should be aware of the future interest rate path which is reflected in central bank's interest rate projections. If central banks do not bind themselves to their projections, the effects of fiscal policy become more uncertain. Finally, the analysis of interest rate projections might be useful, because households and firms make bad consumption-savings decisions when monetary policy is unanticipated (Leeper et al., 2011). In this regard, our paper contributes to the discussion about monetary foresight and forward guidance of monetary policy.

To the best of our knowledge, our study is the first one that empirically compares interest rate projections of central banks and their actual outcomes. Although there are a number of studies that investigate the issue of rules versus discretion and the central bank's desire to improve monetary foresight, research has not yet provided empirical evidence of the underlying loss function of central banks' interest rate projections. To this end, our study applies the concept of an asymmetric loss function which has been used in other studies to, for example, investigate forecasts of oil prices (Pierdzioch et al., 2015), exchange rates (Fritsche et al., 2015), and other macroeconomic variables (Frenkel et al., 2012).

In addition to the issue of asymmetry in central banks' loss functions regarding a positive or negative forecast error, we also insinuate that policymakers are facing a trade-off when it comes to forecast accuracy across different projection horizons. On the one hand, preserving credibility

can be considered to be a goal of every policymaker, on the other hand it cannot be ruled out that policymakers pursue strategic motives, when policy intentions and decisions are communicated. Applying these considerations to the interest rate projections of central banks suggests that central banks may want to issue accurate projections, but perhaps also pursue economic policy goals. The resulting trade-off could lead to a time-inconsistent pattern and central banks may possibly try to be more accurate (and therefore credibility-preserving) in the shorter run and rather strategically motivated in the longer run. In this respect, our study is a first attempt at exploring the field of central banks' interest rate projections and the myriad of possible interpretations on central banks' intentions and motives that might play a role with regards to their forecasting behavior and ultimately affect sign and magnitude of the forecast errors.

The remainder of this paper is organized as follows: Section 2 gives an overview of the interest rate projection data of the central banks of the Czech Republic, New Zealand, Norway and Sweden. Section 3 shows some stylized facts of the projections. Section 4 lays out the econometric model that allows us to estimate the loss function of the central bank. Section 5 presents the results of our analysis. Section 6 includes some robustness tests for our findings and section 7 offers some conclusions.

2 The Data Set

Our data set consists of interest rate projections as published by the central banks of the Czech Republic, New Zealand, Norway and Sweden. The publication of these projections differ in their starting point, their forecast horizons, as well as the interest rate type that is projected.

The data set for the Czech National Bank (CNB) starts 2008 on a quarterly basis and refers to the 3-months PRIBOR which is a wholesale interbank rate in the Czech Republic. The CNB's projections therefore refer to an interest rate that the central bank can only influence indirectly (as opposed to e.g. the key interest rate that is directly set by the central bank). When examining these PRIBOR projections, we thus have to keep in mind that the actual realization might not exclusively depend on monetary policy. Although the interbank rate is a fairly short-term interest rate, it may well be influenced also by other factors such as the overall prevailing business sentiment, the business cycle, and the degree of confidence among bankers. Accordingly, this might have implications for the forecast error that is at the center of interest in this study. Projection data of the CNB start at the time of the outbreak of the global financial crisis of 2008/09 and span the entire post-crisis period which is reflected in a more or less steadily declining interest rate trend (see Figure 1). When compared to the three other central banks, the graph for the CNB seems to show a trend of overpredicting interest rates even though overall, there is visibly more volatility in the CNB's forecast errors than with the other central banks.

For New Zealand, the first projection was published in the last quarter of 1997 and the Reserve Bank of New Zealand (RBNZ) has ever since published interest rate forecasts every quarter for forecast horizons between 1 month and up to 36 months. The Reserve Bank of New Zealand (RBNZ) has long been known for pioneering new, innovative instruments in monetary policy and central bank communication. For instance, the concept of inflation targeting and the two per cent

inflation goal both originated in New Zealand in 1989 before this became best-practice in monetary policy for many central banks across the globe (Archer, 2005). As with inflation targeting, the publication of central bank interest rate projections was first introduced by the RBNZ. It initially released forecasts for the 90-day bank bill rate starting in its December 1997 Monetary Policy Statement edition. However, only as of December 2000 the RBNZ has consistently published projections with a forecast horizon of at least 12 months. The projected 90-day bank bill rate is a wholesale interbank rate within New Zealand, i.e. a market reference interest rate. The projections are therefore comparable in its character to those of the CNB concerning pitfalls and factors to account for when analyzing and interpreting the corresponding forecast errors.

In contrast to the RBNZ, the Norges Bank's interest rate projections are not on a wholesale interbank rate but on its own key interest rate, i.e. an interest rate that the central bank directly influences. This represents the interest rate paid on overnight bank deposits¹ with the Norwegian central bank and is therefore a monetary policy instrument which the Norges Bank directly influences. The first forecasts were published in late 2005 as part of the last Monetary Policy Statement of that year. The Norges Bank published three Monetary Policy Reports per year with forecasts in the same format until the end of 2012 and increased the publication frequency to four times per year starting in 2013.

Similar to the projections in Norway, the Swedish Riksbank publishes forecasts of its own repo rate. The Swedish repo rate is the interest rate at which commercial banks can borrow or deposit money for a period of 7 days with the central bank. Even though the Swedish Riksbank has long included forward rate-implied projections of the repo rate in its inflation reports, it is only in its February 2007 issue of the Monetary Policy Report that an actual repo rate *forecast* is published.

For reasons of consistency we only use data with forecast horizons of up to 27 months for our analysis except for the Czech Republic where only 18 months forecast data is available. All four countries maintain a managed float currency regime.

3 Some Descriptive Statistics

This section studies some general characteristics of the interest rate forecast errors. To this end Figure 1 plots the interest rate path (solid line) and the interest rate projections (dotted line) for each central bank. The figure suggests that there are periods of interest rate projections consistently above or below the actual interest rate path. The Czech Republic (upper left panel) shows a somewhat ambiguous development as the forecast errors tend to be mostly positive between 2009 and 2012 and turn out flat after 2012, possibly suggesting a particularly strong case of forward guidance in the low interest rate period. In the case of New Zealand, findings are more distinctive and it is obvious that the forecast errors are negative for the period from roughly the beginning of the 2000s until the global financial crisis in 2008. The forecast errors become mostly positive as of 2009, broadly reflecting the business cycle and the associated high- and low-interest rate environments. Detmers and Nautz (2012) already pointed out that most projection paths

¹Since October 2011, Norges Bank imposes quotas determining the size of deposits that commercial banks can place with the central bank. Deposits in excess of these quotas yield the sight deposit rate minus 100 basis points.

seem to show a “mean-reverting” behaviour and suggest that the RBNZ published long-term interest rate projections in order to stabilize expectations whenever actual interest rates are seen as extraordinarily high or low. Norway and Sweden (lower panels) offer similar findings, albeit the pre-crisis tendency of underpredicting is not as distinctively visible compared to New Zealand due to the shorter time horizon. For the period after the global financial crisis in 2008 until today however, a pattern of overpredicting the repo rate again clearly manifests itself. In case of Sweden, being a member of the European Union and given the proximity to the Euro area, an indirect impact of the economic conditions and the monetary policy conducted by the European Central Bank cannot be ruled out entirely. The Swedish Krona, however, is officially a free-floating currency and Sweden has no plans to join the euro in the near future as reflected by its renunciation to join the European Exchange Rate Mechanism II, which is a requirement for joining the euro area later.

To empirically investigate the bias in central banks projections, Table 1 reports the results when regressing the forecast error $s_{t+1} - f_{t+1}$ defined as the difference between the realized s_{t+1} and the projected interest rate f_{t+1} on a constant for different forecast horizons. For the Czech Republic, a statistically significant positive bias for the end-of-the month and 3-months horizons reflects that the CNB seems to have underpredicted interest rates. Compared to this, beyond the 9 month interest rate horizon, the CNB has systematically overpredicted the interest rate. For New Zealand, we find that with an increasing forecast horizon, significant non-zero biases emerge in the forecast errors. More specifically, a negative bias in the forecast errors becomes visible and statistically significant starting at a 6-months forecast horizon. This result intensifies with an increasing forecast horizon. In other words, the Reserve Bank of New Zealand shows a tendency to overpredict interest rates which is also applicable to the forecast error bias regression results for Norway. Albeit somewhat weaker in both effect and statistical significance especially for the shorter forecast horizons. Table 1 reveals that a negative bias in Norges Bank’s interest rate forecasts manifests itself at a statistically significant level for all forecast horizons beyond 9 months. The case of Sweden repeats the findings already reported for New Zealand and Norway. As for New Zealand, a negative bias in forecast errors becomes statistically significant for forecast horizons beyond 6 months. Again, with increasing horizons, the bias becomes stronger in both size and statistical significance.

– insert Figure 1 and Table 1 here –

4 The Econometric Model

In this section, we examine the bias in forecast errors in more detail by assuming that central banks are based on an asymmetric loss function. Unlike traditional tests of forecast rationality which regress the forecast error on a set of variables, the asymmetric loss function renders it possible to weight over- and underprojections differently. More formally, we apply the approach developed by Elliott et al. (2005) which indicates that a central bank minimizes the observed forecast errors by assuming the following general central bank’s loss function, \mathcal{L} :

$$\mathcal{L} = [\alpha + (1 - 2\alpha)I(s_{t+k} - f_{t,t+k} < 0)]|s_{t+k} - f_{t,t+k}|^p, \quad (1)$$

where I refers to an indicator function which accounts for the asymmetric forecast error, p reflects the functional form with $p = 1$ ($= 2$) representing a linear (quadratic) loss function and k denotes the forecast horizon. In case of $\alpha = 0.5$ and $p = 1$ the loss function is symmetric and reduced to $\mathcal{L} = 0.5|s_{t+k} - f_{t,t+k}|$ which is consistent with the traditional tests for rationality. In this case, forecasts that turn out to be higher than the observed value later (i.e., overpredictions) lead to the same loss as equivalent forecasts that turn out as too low (i.e., underpredictions). In both cases, the loss is linear in the forecast error and its graph is V-shaped. If, however, $p = 2$ the quadratic symmetric loss function underlies a traditional Mincer-Zarnowitz regression of forecast unbiasedness and the loss increases overproportionately with the size of the overpredictions and underpredictions. In this case, the loss function takes on the shape of a parabola. However, as long as $\alpha = 0.5$, it is symmetric around the zero forecast error. For values of α smaller or greater than 0.5, the loss function becomes asymmetric. If, for example, $\alpha = 0.4$ the loss function (for $p = 1$) becomes $\mathcal{L} = [0.4 + 0.2 \cdot I(s_{t+k} - f_{t,t+k} < 0)]|s_{t+k} - f_{t,t+k}|$. In this case, if $s_{t+k} - f_{t,t+k} > 0$ (underprediction) the expression in brackets is 0.4. However, if $s_{t+k} - f_{t,t+k} < 0$ (overprediction) the expression in brackets is 0.6. Hence, an overprediction is more harmful than an underprediction. The asymmetry is in the opposite direction if $\alpha > 0.5$. In our empirical analysis, we follow the notion to look for the shape of the loss function that is most consistent with the observed forecast errors of a central bank. If we find α not to be significantly different from 0.5 we will conclude that central banks have a symmetric loss function. Any value for α significantly different from 0.5 in reverse indicates the existence of an asymmetric loss function. We also assume that the loss from interest rate forecast errors can be modeled separately from the loss from, for example, inflation rate forecast errors.

Elliott et al. (2005) report that given the functional form of the loss function p , the general method of moments estimator yields a consistent and unbiased estimate of the asymmetry parameter $\hat{\alpha}$. To this end we use as instruments a constant and the lagged actual interest rate. Additionally, we also test for rationality of forecasts by computing a J-test statistic as proposed by Elliott et al. (2005). To produce a forecast error different from zero may seem irrational at first glance, however, the rationality hypothesis might change when considering an underlying, asymmetric loss function. More specifically, a test for rationality can be performed by computing a J-test statistic using a χ^2 distribution:

$$J(\hat{\alpha}) = \hat{E} \frac{1}{T} (x_t' \hat{S}^{-1} x_t) \sim \chi_d^2, \quad (2)$$

where $x_t = \sum_{t=\tau}^{T+\tau-1} v_t [I(s_{t,t+k} - f_{t,t+k} < 0) - \hat{\alpha}] |s_{t,t+k} - f_{t,t+k}|^{p-1}$ and d is the number of instruments. To conduct the test under the assumption of symmetric loss, we set $\alpha = 0.5$ and examine the J-test statistic, which is in this case distributed as $J(0.5) \sim \chi_d^2$. In case forecast rationality is rejected, this may well be caused by the underlying symmetry assumption, which is why another test statistic is computed by allowing for asymmetric loss, i.e. $\alpha \neq 0.5$. Upon comparing $J(\hat{\alpha})$ with $J(0.5)$, we can assess whether using an estimated asymmetric loss function rather than an invoked symmetric loss function weakens evidence against forecast rationality.

5 Estimation Results

Table 2 reports the estimation results of the asymmetry parameters $\hat{\alpha}$ and for forecast rationality under a symmetric $J_2(0.5)$ and asymmetric $J_2(\hat{\alpha})$ loss for all central banks considered. Estimates were performed for seven forecast horizons and for both a linear and quadratic loss function and refer to the estimates of the asymmetry parameter $\hat{\alpha}_1$, in which a constant is used as an instrument.²

– insert Table 2 here –

Four main findings can be highlighted. First, for the current-month³ forecasts, only the estimates for New Zealand suggest (independent of the linearity or non-linearity of the assumed loss function) that the parameter α is 0.5 and, thus, the central bank of New Zealand values overpredictions and underpredictions equally. For the other central banks, the picture is more mixed and does not rule out an asymmetric loss function. This finding is valid for three month forecasts as well. Again the Bank of Norway exhibits an asymmetry coefficient of lower than 0.5 in the linear specification while symmetry is prevalent for the other central banks.

Second, comparing the different $\hat{\alpha}$ estimates across all forecast horizons as illustrated in Figure 3 suggests that for the 6 months forecast horizon the $\hat{\alpha}$ estimates are consistently closer to 0.5 than for other forecast horizons. This suggests that this is the time frame for which central banks aim at making as accurate forecasts as possible. A possible explanation for this could be that central banks consider the 6 months forecast horizon to be a “sweet spot” for forward guidance, possibly based on their experience that this forecast horizon is most effective in steering expectations.

Third, for forecast horizons of more than 6 months the central banks examined here show asymmetry parameters that are greater than 0.5 in the majority of the cases. This indicates that the central banks associate underprojections of their interest rate forecast with higher costs. Apparently they prefer to overpredict the future interest rate path. Perhaps they use their interest rate forecasts to leave room for unannounced interest rate cuts at the expense of a lower forecast accuracy. This would be in line with our initial theoretical considerations, according to which there may be a trade-off between providing accurate forecasts and pursuing macroeconomic stability. Such considerations are likely to play a role only for longer forecast horizons for which monetary policy can be expected to generate real effects. Further testing for rationality confirms for most cases that rationality of central banks’ forecasts cannot be rejected at a statistically significant level when assuming an asymmetric loss function. More specifically, the Hansen J-tests for overidentification performed for all $\hat{\alpha}$ estimations shown in Table 2 indicate that for 38 out of 56 cases the significance level of the J_2 test statistic decreases and the rationality hypothesis therefore becomes harder to reject.

Fourth, the results do not indicate that the loss function is generally linear or quadratic. In about 60% of the cases, the estimates of the loss function for a given central bank and forecast horizon are relatively similar for the two specifications and for the rest of the cases there is no clear sign

²The estimates in which the lagged actual interest rate is used as an instrument yield qualitatively very similar results and are shown as $\hat{\alpha}_2$.

³Interest rate projections with a one-month forecast horizon, i.e. predicting the interest rate for the end of the month.

which specification dominates. The similarity of the estimates for the linear and the quadratic specification may be a result of the generally small magnitude of the forecast errors; in this case large errors, which would weigh heavily in a quadratic specification, are very much the exception.

Figure 2 visualizes the estimated linear loss functions for all central banks. If α is estimated to be smaller than 0.5 the graph of the loss function is steeper for negative values of the forecast error $s_{t+k} - f_{t,t+k} < 0$ (overprediction) than for positive values of the forecast error (underprediction). This can be found more often for shorter than for longer forecast horizons. For example, the panel “current month” indicates that a 10 per cent underprojection of the interest rate (point A) yields the same loss as a 3.6 per cent overprojection (point B). With increasing forecast horizons the graphs of most loss functions clearly turn counter-clockwise. For quadratic loss functions (which have been omitted for the purpose of clarity), the convergence effect is even more pronounced. As a consequence, for the 18-month forecast horizon, the central banks have the highest preference of overprojection. Here, point C indicates that a 3.35 per cent underprojection yields the same loss for the Bank of Norway as a 10 per cent overprojection (point D).

– insert Figure 2 here –

Tables 4 and 5 report the results of orthogonality tests conducted on a variety of economic variables in order to identify possible systematic relationships between central bank forecast errors and some economic measure of interest. More specifically, we test for orthogonality of interest rate forecast errors and the lagged actual interest rate, the actual inflation rate, the real GDP growth rate, and the actual unemployment rate. To conduct the test, we estimate the following regression model:

$$s_t - f_t = \alpha + \beta X_t + \epsilon, \quad (3)$$

where $s_t - f_t$ denotes the forecast error and X_t a vector of economic variables. Orthogonality between forecast errors and the economic variable in question is tested for by computing an F test statistic hypothesizing $\alpha = \beta = 0$. This null hypothesis implies rationality since an α - and β -coefficient of 0 indicate no influence of the economic variable on the forecast error. In other words, all information that is intended to have an influence on the forecast is already included therein. The results shown in tables 4 and 5 for the 3-months forecast horizon suggest that in 9 out of 12 cases, the statistical significance of the F test statistic decreases when switching from symmetric to asymmetric loss functions, making it harder to reject the null hypothesis and therefore indicating movement towards rationality. This finding is visualized in Figure 6, plotting the p-values of the F statistic under a symmetric loss function on the x-axis against those under an asymmetric loss function on the y-axis. The large majority of p-value pairs is located above the 45 degree line, indicating an increase in p-values from when moving from $\alpha = 0.5$ to $\alpha \neq 0.5$. This reflects that the hypothesis of forecast rationality of central bank’s interest rate projections is more supported by an asymmetric loss function than a standard symmetric loss function.

6 Some Robustness Tests

6.1 Rolling Window Regression

In order to test for robustness of our results and to possibly identify time-varying or other structural patterns in our α -parameter estimates, we conduct a rolling window regression. We define a window of 25 observations rolling through the respective observation periods for each central bank. The rolling window estimation is conducted for all forecast horizons as set out in section 3, i.e., from one month to 27 months for New Zealand, Sweden and Norway and one month to 18 months for the Czech Republic. We apply the original regression model specified in section 4 to each regression window.

Figures 4 and 5 provide a graphical overview of the results of these rolling window regressions for New Zealand and Sweden for forecast horizons up to 9 months.⁴ Four main observations emerge from this analysis: (1) The asymmetry parameter estimates tend to increase with the forecast horizon. This is in line with our previous findings of increasing asymmetry in central banks' loss functions for increasing forecast horizons. (2) The α -parameter increases over time. In the examples displayed in Figures 4 and 5, the α parameter estimates show a clear trend of increasing along the time axis, meaning that estimates for more current observations tend to yield a higher asymmetry parameter than for older observations. (3) The volatility of the α -parameter estimates is remarkably low. Besides the established time trend under (2), the parameter estimates show only little variation across all regression windows. (4) Asymmetry parameters estimated with a linear loss function (solid lines) tend to be lower compared to the ones estimated with a quadratic loss function (dotted lines).

– insert Figures 4 and 5 here –

The main observations of the rolling window regressions are in line with our previous findings. Moreover, the absence of a structural pattern apart from the identified time trend can be interpreted as robustness of our main empirical analysis. The indication of a time trend for the α -parameter, however, is noteworthy. A possible explanation can be related to the respective time periods included in this analysis. For New Zealand, an entire business cycle is mapped in the data from late-1997 until the end of 2015. By contrast, data for Sweden start in Q1 2007 and therefore basically represent the period of the global financial crisis of 2007-08 with all its ramifications on markets and institutions thereafter. It can be assumed that the exceptional economic circumstances created by the global financial crisis also had an impact on monetary policy and therefore also on the way it was communicated. A changing stance of central bank communication during crisis periods has been scrutinized by a growing body of related academic literature and consistently finds that priorities in central bank communication have shifted (Siklos, 2015). Former governor of the Bank of Canada and current governor of the Bank of England Mark Carney (2009) stipulated that "an effective communications strategy for normal states may prove counterproductive in exuberant states." Siklos (2015) as well as Vayid (2013) also find that price stability concerns have

⁴For reasons of clear arrangement we have refrained from including visual representations for all forecast horizons and central banks; however these are available upon request.

at least temporarily lost some ground to financial stability matters in central bank communications. Consequently, we can assume that also in the case of the four central banks considered in our study, the different economic conditions created by the global financial crisis led central banks to adjust their communications strategy accordingly. With a higher weight being put on strategic (financial stability) considerations, the inclination towards giving out forecasts that are rational under an asymmetric loss function increases, as briefly pointed out in section 5. Therefore, even though the discussed ideas in section 5 are far from proven, the observation of a time trend in the forecast data revealed by this rolling window regression is at least conformable with the mechanisms discussed.

6.2 Pooled Crisis Dummy Regression

We perform an additional test for robustness by examining whether there is a different forecasting behavior during crisis and non-crisis periods. A first visual appraisal of forecast errors on the basis of Figure 1 suggests a potential correlation between high- and low-interest phases with systematic underprediction and overprediction, respectively. In order to identify a possible systematic relationship, we conduct a regression incorporating a crisis dummy, dividing the dataset into two parts. Following conventional wisdom, we define a quarter to be in “crisis” when two consecutive quarters of negative real GDP growth have previously occurred and there has not been any positive growth yet. Given the limited number of observations for each central bank and the even more limited number of crisis quarter observations within the dataset, we pool all observations before running the regression.

Table 3 reports the resulting α parameter estimates for the dataset divided in crisis and non-crisis periods. The results reveal a considerable difference in α parameter estimates between crisis and non-crisis periods for shorter forecast horizons. For longer forecast horizons however, the estimates seem to converge and a differentiation between the two period types becomes less meaningful. In line with the arguments brought forward at the end of section 6.1, these findings suggest that there might indeed be reason to believe in a different stance in central bank communication in crisis times. Moreover, this modified behavior seems to hold especially for communication of macroeconomic indicators in the short-term future, as indicated by the large difference in α parameter estimates for crisis and non-crisis periods for the current, three, and six months forecast horizons. Archer (2005) elaborates on the various components included in generating an interest rate projection from the perspective of the RBNZ. Among a number of other factors, he specifically also points out ad-hoc adjustments to the underlying central bank reaction function based on changing assessments on overall risk and uncertainty. It seems reasonable to assume that during an economic downturn as experienced during the last global financial crisis the assessment of exactly those factors might have changed and led to a corresponding alteration of central banks’ forecasting models. In contrast, the convergence of the α parameter estimates for longer forecast horizons regardless of crisis or non-crisis situations can be interpreted as indicative of long-term targets of central banks which are supposed to be more or less constant and not subject to ad-hoc reactions to current circumstances.

– insert Table 3 here –

In conclusion, the robustness of our initial results under section 5 are complemented by a differ-

entiated view on the impact that crises can have on central bank communication in general and interest rate projections in particular.

7 Conclusion

Starting from considerations on why it might be rational for central banks to give out biased or inaccurate projections, this paper examines a very recent and innovative central bank communication instrument, yet to be covered more extensively by the academic literature. Forecast rationality of central bank interest rate projections is rejected for most central banks and respective forecast horizons considered in this paper when assuming a symmetric loss function. This however needs to be reconsidered when an asymmetric loss function is assumed. We cannot reject rationality for most interest rate forecast errors when emanating from an asymmetric loss function and even find that with increasing forecast horizons, the asymmetry of the estimated central bank loss functions becomes more pronounced. Especially with regards to the potential explanations of the detected bias and asymmetry in central banks' interest rate projections, a number of further research questions could be considered. For instance, given that all central banks examined in this paper are under an inflation targeting regime, an approach to explain the implied asymmetry by non-linear Taylor rules could look into the question whether interest rate projections are internally consistent with the Taylor principle. Moreover as mentioned in section 3, the sheer visual representation of actual and projected interest rate paths raise the question whether there is a relationship between business cycle positions and interest rate forecast errors.

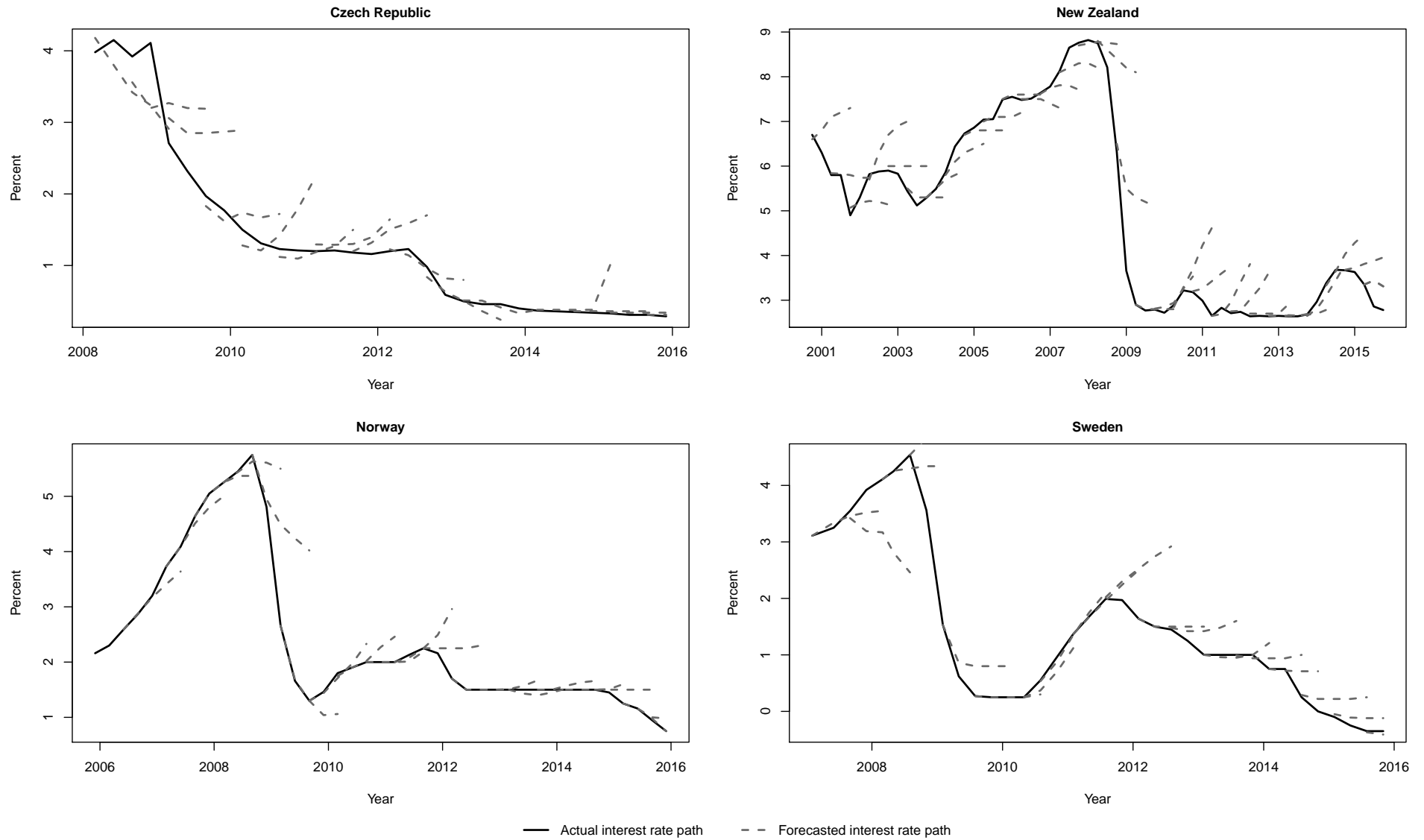
What could explain our findings of an asymmetric loss function of central banks? No direct measurement of the motivation of the central banks is possible in this context and interest rate projections of central banks are still a relatively new phenomenon. However, some considerations could at least suggest some answers to this question. In a situation of relatively strong economic activity and relatively high inflation, which is associated with high interest rates, central banks may want to signal with their longer-term projections that such an undesirable period will not last too long. After all, such situations would not be in line with the central bank targets and a central bank perceive it as its task to use monetary policy to correct these economic developments. If central banks are convinced that their policies are effective, they will project interest rates to decline again in the medium to long run. Likewise, in a situation of low economic activity and relatively low inflation, which is associated with low interest rates, central banks may want to signal that such periods are also short-lived, because they are not in line with the objectives of the central bank. If monetary policy is successful in combating such an undesirable situation the presumption that such periods do not last too long is justified. Consequently, interest rate projections indicate that interest rates will eventually increase again. There may even be an important strategic element involved. In times of very low or even negative interest rates, it would be make monetary policy more difficult in the future if the public began to believe that inflation rates stay very low for a longer period. Then the public may reduce its aggregate demand and, thereby, prolong the period of economic weakness. To avoid such developments, it could be rational for a central bank to prefer too high interest rate predictions to low interest rates predictions. This would mean that the loss function of the central bank is asymmetric. In addition, this phenomenon should show

up in empirical analyses even more strongly if the data includes relatively longer periods of very low inflation and interest rates. This is the case in our investigation, because our analysis covers largely periods of low economic activity and very low inflation rates. These considerations could also explain why we find significant results when we include a crisis dummy in our estimation model.

Another reason for the asymmetry that we find in our analysis may be related to the differences in the speed with which central banks adjust their policy rates downwards compared to upwards. There seems to be a tendency of central banks to be relatively quick in stepping in with loose monetary policy in times of a downward pressure on the economy and to be more reluctant to tighten policy stances fast, when price stability risks become more imminent (Weidmann, 2017). Many observers have noticed such relatively fast interest-rate reductions in strong economic downturns. In what became known as the ‘Greenspan put’ or subsequently the ‘Bernanke put’, the US Federal Reserve was believed to intervene in financial markets to prevent asset prices to fall too fast (Hall, 2011). The studies of Miller et al. (2002), Goodhart (2008) and De Nicolò et al. (2010) examined this phenomenon. It is usually used as an argument to explain the excessive risk-taking behavior of banks and financial institutions in the run-up to the global financial crisis in 2008, but can also be considered against the background of central banks’ interest rate projections (Cecchetti, 2007). Assuming that such a mechanism does indeed exist within central banks’ objective functions, an asymmetry in adjusting the interest rate might result in a tendency to overpredict future interest rate paths when the projections do not anticipate this reluctance at the time of publication of the projection. In other words, a discrepancy between a more or less symmetric forecasting behavior and a subsequent asymmetric interest rate setting behavior may lead to a forecast error different from zero in this scenario. The assumption of a ‘Greenspan put’ might, therefore, be another useful concept to explain the examined overprediction tendency that we have detected in central banks interest rate projections.

Going forward, central bank interest rate projections are still a relatively new and unexplored field within economic research and should be studied in further detail, especially as more data become available.

Figure 1: Actual vs. projected interest rate paths



Note: Figure 1 plots the actual interest rate paths (solid lines) against projected interest rate paths (dotted lines), beginning with the first published data of the respective central bank. Data are taken from the websites of the Česká Národní Banka, the Reserve Bank of New Zealand, the Norges Bank, and Sweden's Riksbank.

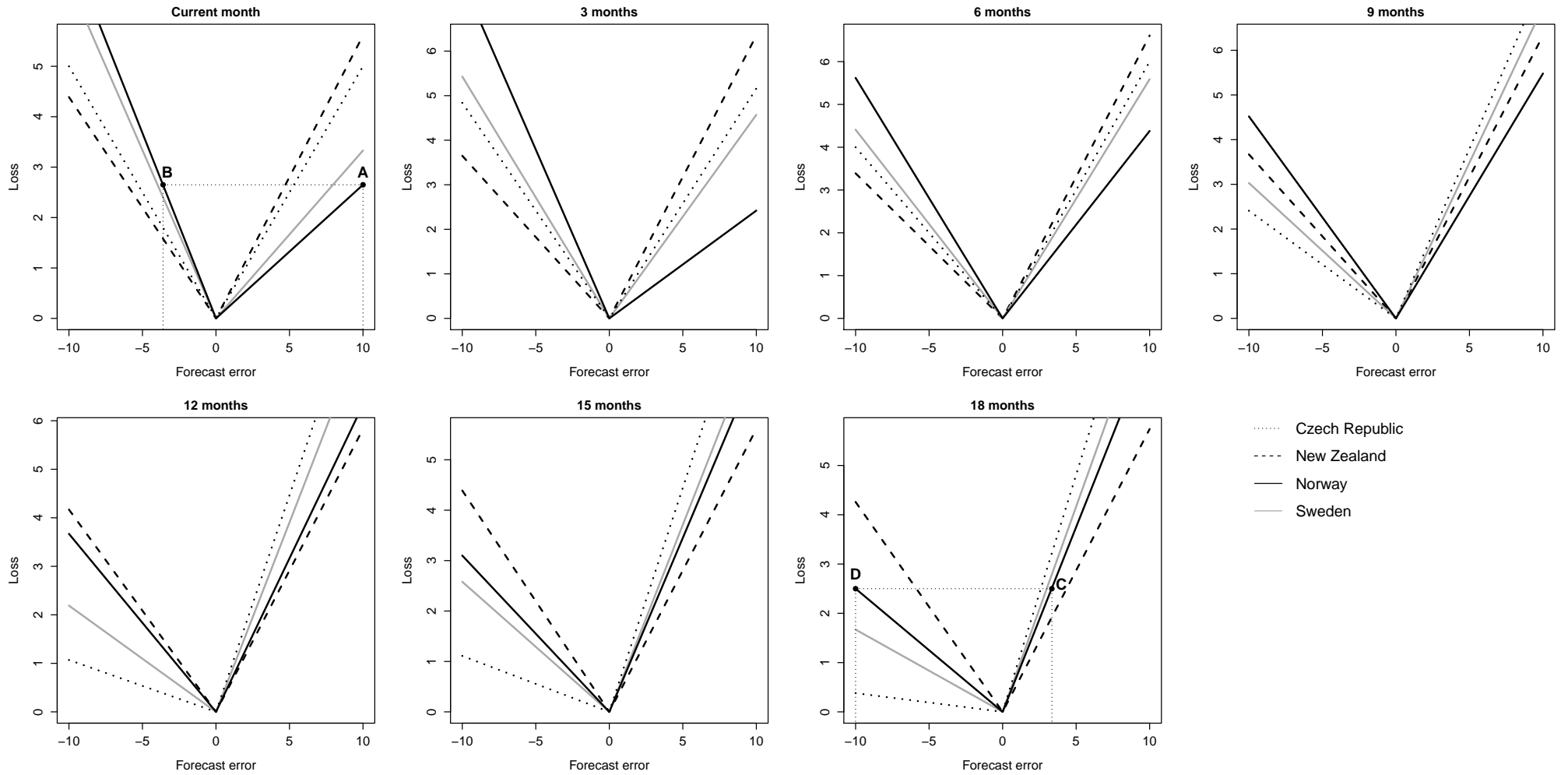
Table 1: Forecast error bias regression results

	Forecast horizon	0M	3M	6M	9M	12M	15M	18M	21M	24M	27M	
Czech Republic	Constant	0.140** (0.051)	0.116* (0.059)	0.002 (0.074)	-0.186** (0.079)	-0.452*** (0.087)	-0.711*** (0.112)	-0.991*** (0.130)				
	Standard error	1.013	0.735	0.636	0.116	-0.409	-0.089	-0.162				
	Skewness	3.919	4.141	5.206	4.176	2.650	2.137	2.502				
	Kurtosis	28	27	26	25	24	23	22				
	Observations											
New Zealand	Constant	0.002 (0.018)	-0.090 (0.055)	-0.251** (0.106)	-0.441*** (0.162)	-0.544*** (0.200)	-0.663*** (0.236)	-0.791*** (0.270)	-0.911*** (0.294)	-1.026*** (0.321)	-1.239*** (0.339)	
	Standard error	2.157	-1.068	-2.109	-2.048	-1.497	-1.248	-1.035	-0.813	-0.555	-0.238	
	Skewness	12.705	9.874	9.258	7.319	4.998	4.203	3.506	2.943	2.323	1.891	
	Kurtosis	62	59	58	56	56	53	50	48	45	42	
	Observations											
Norway	Constant	0.000 (0.002)	-0.009 (0.009)	-0.104 (0.080)	-0.280* (0.163)	-0.449* (0.233)	-0.584** (0.269)	-0.812** (0.292)	-1.131*** (0.314)	-1.426*** (0.346)	-1.639*** (0.348)	
	Standard error	1.189	-1.317	-2.972	-2.378	-1.819	-1.550	-0.848	-0.196	-0.196	-0.379	
	Skewness	15.608	4.436	11.701	8.139	5.624	4.779	3.084	2.169	2.172	2.442	
	Kurtosis	30	29	28	27	26	25	24	23	22	22	
	Observations											
Sweden	Constant	-0.013 (0.013)	-0.135 (0.081)	-0.322** (0.151)	-0.517** (0.210)	-0.753*** (0.259)	-1.023*** (0.285)	-1.334*** (0.290)	-1.698*** (0.282)	-2.030*** (0.261)	-2.286*** (0.239)	
	Standard error	-3.869	-2.369	-2.460	-1.783	-1.049	-0.889	-0.693	-0.362	-0.026	0.261	
	Skewness	21.258	10.363	9.491	6.544	4.493	3.091	2.721	2.421	2.518	2.760	
	Kurtosis	32	31	30	29	28	27	26	25	24	23	
	Observations											

Note: Table 1 reports the results of a simple OLS-regression of the interest rate forecast errors of all four central banks against a constant for different forecast horizons. We find a tendency for all central banks that with increasing forecast horizon, significant non-zero biases emerge in the forecast errors, indicating a systematic over- or understatement of interest rate forecasts ($H_0 : \beta \neq 0$). For New Zealand, such a bias is significant at the 99% confidence level for all forecast horizons beyond 9 months, for Sweden beyond 21 months and beyond 12 months for the Czech Republic. New Zealand forecasts its 90-day bank bill rate (an interbank lending rate), Sweden its rate paid on central bank deposits by commercial banks for up to seven days, Norway its central bank overnight deposit rate and the Czech Republic the 3-months Prague Interbank Offered Rate. Interest rate projections for the Czech Republic are only available for forecast horizons of up to 18 months.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Figure 2: Estimated linear loss functions for all forecast horizons



Note: Figure 2 plots the estimated linear loss functions for all four central banks across different forecast horizons. The forecast error is defined as the difference between the actual interest rate and the central bank's projection, i.e. $s_{t+k} - f_{t,t+k}$. While some variance among the four central banks is visible for shorter forecast horizons, a clear trend of moving towards left-sided asymmetry becomes apparent for longer horizons. This implies that underprediction is costlier than overprediction, as discussed in section 5. Corresponding figures based on quadratic loss functions are available upon request.

Table 2: Asymmetry parameter and rationality test

Forecast Horizon	Loss Function Central Bank	Linear ($p=1$)		Quadratic ($p=2$)		Linear ($p=1$)		Quadratic ($p=2$)	
		$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$J_2(0.5)$	$J_2(\hat{\alpha})$	$J_2(0.5)$	$J_2(\hat{\alpha})$
Current month	Czech Republic $n = 32$	.500 (.09)	.500 (.09)	.158 [†] (.08)	.144 [†] (.07)	2.125 [.35]	2.125 [.15]	6.339 [†] [.04]	.169 [.68]
	New Zealand $n = 66$	.561 (.06)	.572 (.06)	.538 (.10)	.604 (.10)	6.282* [.04]	5.289* [.02]	3.023 [.22]	1.884 [.17]
	Norway $n = 34$	.265* (.08)	.121* (.05)	.413 (.14)	.094 [†] (.11)	9.882* [.01]	6.457* [.01]	6.309 [†] [.04]	4.998 [†] [.03]
	Sweden $n = 36$	.333* (.08)	.333* (.08)	.580 (.14)	.679 [†] (.13)	4.075 [.13]	.080 [.78]	3.271 [.19]	3.354 [†] [.07]
	Czech Republic $n = 31$	.516 (.09)	.518 (.09)	.258 [†] (.10)	.254 [†] (.09)	1.800 [.41]	1.750 [.19]	3.476 [.18]	.014 [.91]
3 months	New Zealand $n = 63$	.635* (.06)	.653* (.06)	.708 [†] (.09)	.777 [†] (.07)	8.069* [.02]	3.640* [.06]	7.582 [†] [.02]	1.154 [.28]
	Norway $n = 33$	.242* (.07)	.242* (.07)	.519 (.16)	.433 (.13)	8.767* [.01]	.015 [.90]	.976 [.61]	.617 [.43]
	Sweden $n = 35$	.457 (.08)	.457 (.08)	.754 [†] (.11)	.737 [†] (.09)	.257 [.88]	.000 [1.00]	4.274 [.12]	.058 [.81]
	Czech Republic $n = 30$	.600 (.09)	.600 (.09)	.506 (.14)	.520 (.13)	1.233 [.54]	.032 [.86]	.078 [.96]	.050 [.82]
6 months	New Zealand $n = 62$	.661* (.06)	.687* (.06)	.770 [†] (.07)	.784 [†] (.06)	10.16* [.01]	4.306* [.04]	10.23 [†] [.01]	0.182 [.67]
	Norway $n = 32$	.438 (.09)	.437 (.09)	.735 [†] (.12)	.624 (.13)	.592 [.74]	.089 [.77]	1.642 [.44]	1.870 [.17]
	Sweden $n = 34$	.559 (.09)	.559 (.09)	.838 [†] (.08)	.813 (.07)	.596 [.74]	.126 [.72]	7.764** [.02]	.282 [.60]
	Czech Republic $n = 29$	.759* (.08)	.770* (.08)	.800 [†] (.10)	.814 [†] (.08)	8.238* [.02]	.629 [.43]	7.131 [†] [.03]	.047 [.83]
9 months	New Zealand $n = 60$	.633* (.06)	.659* (.06)	.798 [†] (.06)	.791 [†] (.05)	8.535* [.01]	4.867* [.03]	11.85 [†] [.00]	0.105 [.75]
	Norway $n = 31$	.548 (.09)	.549 (.09)	.783 [†] (.09)	.718 [†] (.10)	.500 [.78]	.231 [.63]	3.009 [.22]	2.783 [†] [.10]
	Sweden $n = 33$	.697 (.08)	.697* (.08)	.860 [†] (.07)	.839 [†] (.06)	5.123* [.08]	.002 [.97]	10.22 [†] [.01]	.417 [.52]
	Czech Republic $n = 28$	.893* (.06)	.992* (.02)	.958 [†] (.03)	.999 [†] (.00)	17.92* [.00]	2.815* [.09]	15.51 [†] [.00]	2.928 [†] [.09]
12 months	New Zealand $n = 60$	.583* (.06)	.592* (.06)	.773 [†] (.06)	.761 [†] (.06)	4.203 [.12]	2.808* [.09]	10.15 [†] [.01]	0.418 [.52]
	Norway $n = 30$	.633* (.09)	.634 (.09)	.802 [†] (.08)	.783 [†] (.09)	2.194 [.33]	.083 [.77]	3.936 [.14]	2.648 [†] [.10]
	Sweden $n = 32$	.781* (.07)	.784* (.07)	.874 [†] (.07)	.855 [†] (.06)	10.22* [.01]	.127 [.72]	12.00 [†] [.00]	.511 [.47]
	Czech Republic $n = 28$	.893* (.06)	.992* (.02)	.958 [†] (.03)	.999 [†] (.00)	17.92* [.00]	2.815* [.09]	15.51 [†] [.00]	2.928 [†] [.09]

Table 2: Asymmetry parameter and rationality test

Forecast Horizon	Loss Function	Linear ($p=1$)		Quadratic ($p=2$)		Linear ($p=1$)		Quadratic ($p=2$)	
	Central Bank	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$J_2(0.5)$	$J_2(\hat{\alpha})$	$J_2(0.5)$	$J_2(\hat{\alpha})$
15 months	Czech Republic	.889*	.992*	.983 [†]	1.001 [†]	17.06*	2.834*	18.96 [†]	2.45
	$n = 27$	(.06)	(.02)	(.01)	(.00)	[.00]	[.09]	[.00]	[.12]
	New Zealand	.561	.565	.774 [†]	.767 [†]	2.477	1.725	10.72 [†]	0.145
	$n = 57$	(.07)	(.07)	(.06)	(.06)	[.29]	[.19]	[.00]	[.70]
	Norway	.690*	.692*	.820 [†]	.964 [†]	4.267	.167	5.447 [†]	5.517 [†]
$n = 29$	(.09)	(.09)	(.08)	(.03)	[.12]	[.68]	[.07]	[.02]	
Sweden	.742*	.753*	.906 [†]	.904 [†]	7.827*	.667	14.68 [†]	.730	
$n = 31$	(.08)	(.08)	(.05)	(.05)	[.02]	[.41]	[.00]	[.39]	
18 months	Czech Republic	.962*	1.00*	.995 [†]	1.00 [†]	22.19*	.923	19.61 [†]	1.00
	$n = 26$	.04	.00	(.00)	(.00)	[.00]	[.34]	[.00]	[.32]
	New Zealand	.574	.579	.778 [†]	.775 [†]	2.678	1.663	11.11 [†]	.027
	$n = 54$	(.07)	(.07)	(.06)	(.05)	[.26]	[.20]	[.00]	[.87]
	Norway	.750*	.750*	.851 [†]	.946 [†]	7.006*	.016	8.386 [†]	3.537 [†]
$n = 28$	(.08)	(.08)	(.07)	(.04)	[.03]	[.90]	[.02]	[.06]	
Sweden	.833*	.903*	.945 [†]	.969 [†]	15.01*	2.599	17.89 [†]	2.23	
$n = 30$	(.07)	(.05)	(.03)	(.02)	[.00]	[.11]	[.00]	[.14]	

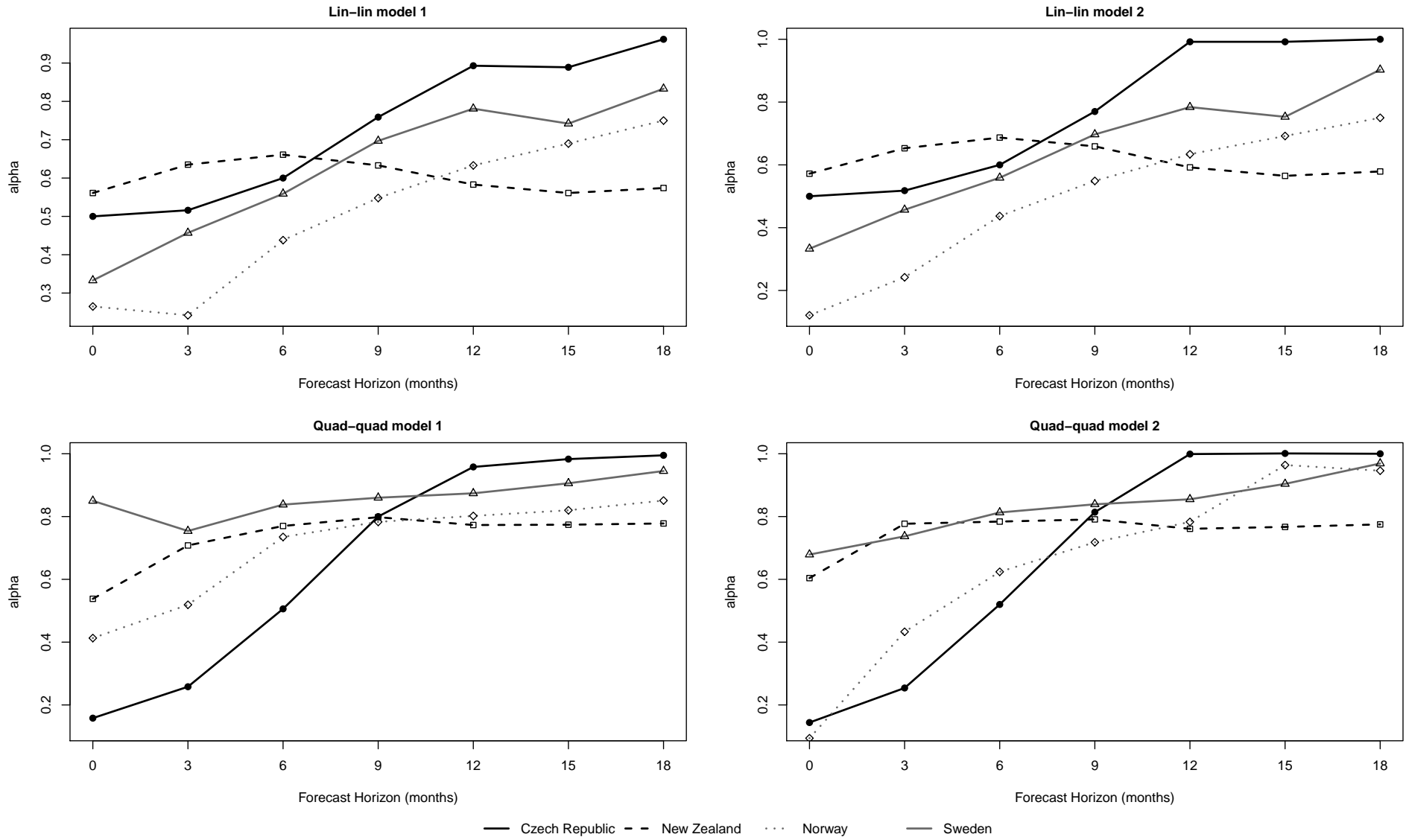
Note: Table 2 reports the results of a GMM estimation of the α -parameter indicating the degree of asymmetry in central banks' loss functions, together with the rationality test results in the last four columns. The instruments used for the GMM estimation are a constant (model 1) and the one-month lagged actual interest rate (model 2). Standard errors for the asymmetry parameter (α) estimations are provided in parentheses. P-values for the rationality test statistic (J_2) are quoted in square brackets. Results are shown for forecast horizons of up to 18 months. Further forecast horizon results are available upon request.

* Estimate under the linear model specifications with a statistical significance $> 90\%$

[†] Estimate under the quadratic model specifications with a statistical significance $> 90\%$

n Number of observations

Figure 3: Asymmetry parameter estimates across forecast horizons



Note: Figure 3 plots the α estimates along forecast horizons for the four different model specifications. By visual appraisal, 6 months seem to be most consistently the forecast horizon where the α estimates are closest to 0.5 across central banks and models.

Table 3: Pooled crisis dummy regression results

Forecast Horizon	Crisis Dummy	Linear ($p=1$)		Quadratic ($p=2$)		Linear ($p=1$)		Quadratic ($p=2$)	
		$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$J_2(0.5)$	$J_2(\hat{\alpha})$	$J_2(0.5)$	$J_2(\hat{\alpha})$
same month	NO CRISIS $n = 141$	.411* (.04)	.411* (.04)	.350 [†] (.07)	.351 [†] (.07)	4.63* [.10]	.202 [.65]	3.98 [.14]	.027 [.87]
	CRISIS $n = 27$	.593 (.09)	.621* (.09)	.857 (.16)	1.03 [†] (.12)	3.24 [.20]	3.18* [.07]	3.15 [.21]	4.89 [†] [.03]
3 months	NO CRISIS $n = 135$	.467 (.04)	.467 (.04)	.552 (.07)	.536 (.07)	.697 [.71]	.097 [.76]	.795 [.67]	.529 [.47]
	CRISIS $n = 27$	.630* (.09)	.767* (.08)	.864 [†] (.08)	1.00 [†] (.01)	5.92* [.05]	6.94* [.01]	3.03 [.22]	4.98 [†] [.03]
6 months	NO CRISIS $n = 131$	.550 (.04)	.550 (.04)	.728 [†] (.06)	.718 [†] (.05)	1.47 [.48]	.180 [.67]	9.21 [†] [.01]	.308 [.58]
	CRISIS $n = 27$	.741* (.08)	.951* (.04)	.901 [†] (.06)	1.00 [†] (.01)	10.94* [.00]	6.30* [.01]	4.88 [†] [.09]	3.45 [†] [.06]
9 months	NO CRISIS $n = 126$	.651* (.04)	.660* (.04)	.805 [†] (.04)	.801 [†] (.04)	15.05* [.00]	3.72* [.05]	20.74 [†] [.00]	.111 [.74]
	CRISIS $n = 27$	.667* (.09)	.739* (.08)	.854 [†] (.07)	.984 [†] (.03)	5.98* [.05]	4.07* [.04]	5.26 [†] [.07]	5.34 [†] [.02]
12 months	NO CRISIS $n = 123$	.691* (.04)	.723* (.04)	.822 [†] (.04)	.827 [†] (.04)	26.04* [.00]	8.79* [.00]	28.01 [†] [.00]	.192 [.66]
	CRISIS $n = 27$	.704* (.09)	.721* (.09)	.818 [†] (.08)	.855 [†] (.07)	5.19* [.07]	1.03 [.31]	5.74 [†] [.06]	3.18 [†] [.07]
15 months	NO CRISIS $n = 117$	.692* (.04)	.726* (.04)	.842 [†] (.03)	.857 [†] (.03)	25.37* [.00]	8.73* [.00]	36.03 [†] [.00]	1.35 [.25]
	CRISIS $n = 27$	.667* (.09)	.696* (.09)	.839 [†] (.07)	.884 [†] (.06)	4.52 [.10]	1.99* [.02]	7.41 [†] [.02]	2.66 [.10]
18 months	NO CRISIS $n = 111$	.739* .04	.801* .04	.858 [†] (.03)	.881 [†] (.03)	35.20* [.00]	11.54* [.00]	42.43 [†] [.00]	2.77 [†] [.10]
	CRISIS $n = 27$	.741* (.08)	.783* (.08)	.896 [†] (.05)	.953 [†] (.03)	7.53* [.02]	2.01 [.16]	10.7 [†] [.00]	2.83 [†] [.09]

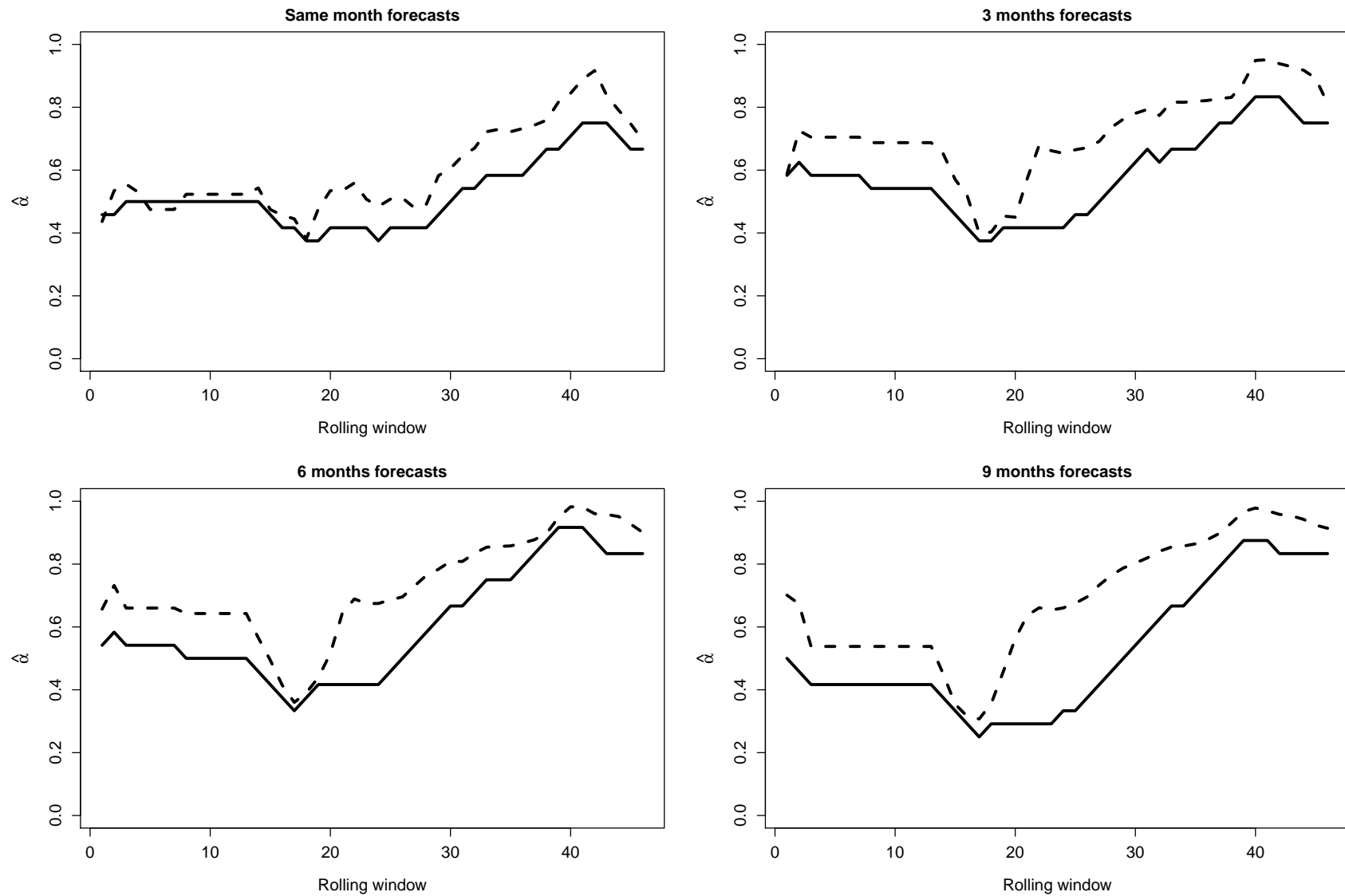
Note: Table 3 reports the estimates of the α parameters for the dataset divided into crisis and non-crisis periods. *NO CRISIS* indicates non-crisis periods whereas *CRISIS* refers to recession periods following at least two consecutive quarters of negative growth. The instruments used for the GMM estimation are a constant (model 1) and the one-month lagged actual interest rate (model 2). Standard errors for the asymmetry parameter ($\hat{\alpha}$) estimations are provided in parentheses. P-values for the rationality test statistic (J_2) are quoted in square brackets. Results are shown for forecast horizons of up to 18 months. Further forecast horizon results are available upon request.

* Estimate under the linear model specifications with a statistical significance > 90%

† Estimate under the quadratic model specifications with a statistical significance > 90%

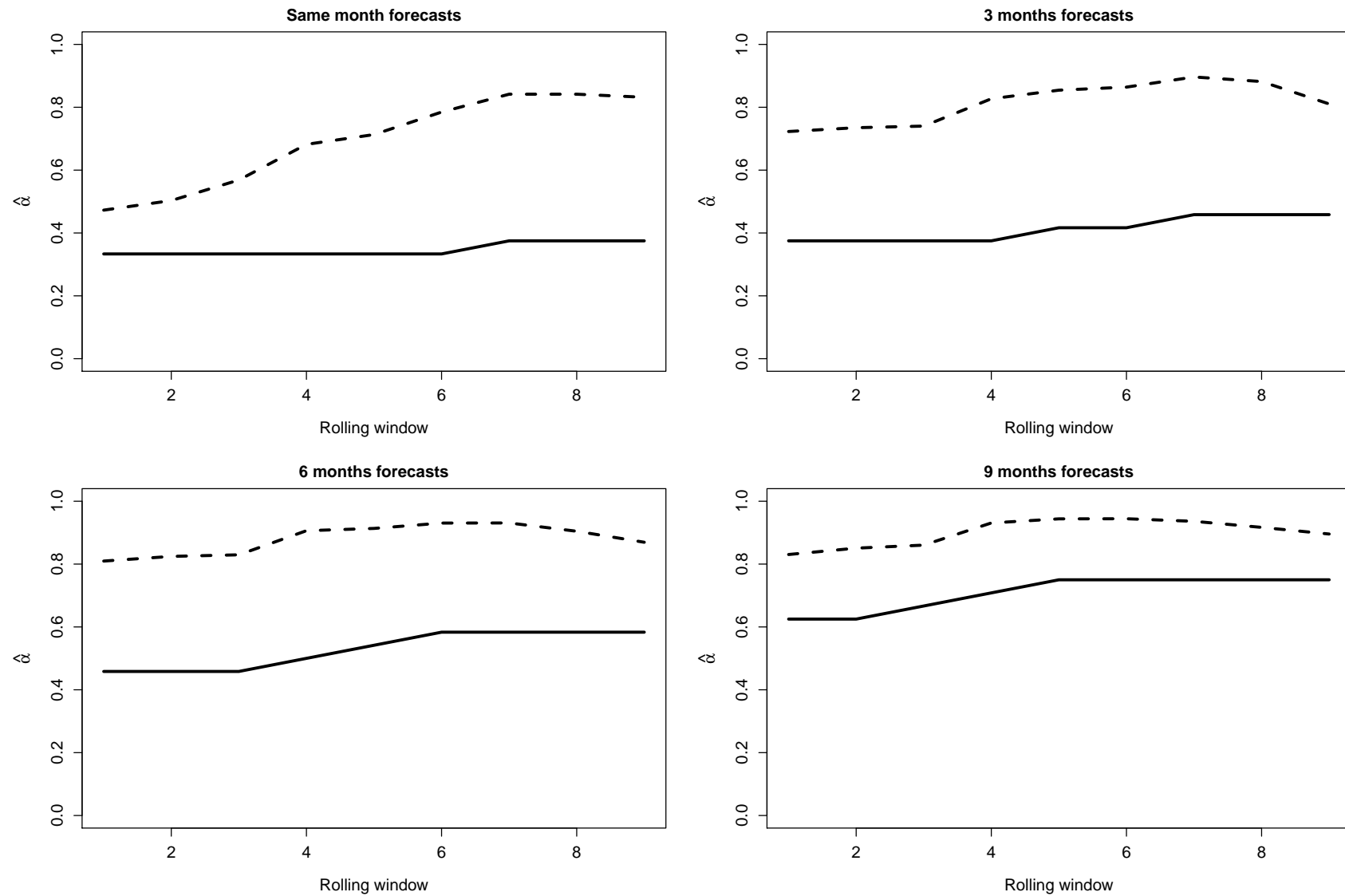
n Number of observations

Figure 4: Rolling Window Regression Results for New Zealand



Note: Figure 4 plots the estimated α -parameters from a rolling window regression for New Zealand for different forecast horizons. The rolling window size is 25 observations and both linear (solid lines) as well as quadratic (dotted lines) loss function estimations are presented. The rolling α -parameter estimates seem to increase with increasing forecast horizons and also show an upward tendency over time. Further results and interpretations thereof are provided in section 6

Figure 5: Rolling Window Regression Results for Sweden



Note: Figure 5 plots the estimated α -parameters from a rolling window regression for Sweden for different forecast horizons. The rolling window size is 25 observations and both linear (solid lines) as well as quadratic (dotted lines) loss function estimations are shown. Again, the rolling α -parameter estimates seem to increase with increasing forecast horizons and also show an upward tendency over time. Overall however, the plots are fairly flat due to the small number of observations available for Sweden.

Table 4: Orthogonality tests for 3-months forecast horizon

		Symmetric				Asymmetric				
		Constant	Coefficient	F test	R^2	Constant [†]	Coefficient [†]	F test	R^2	
	Obs.									
CPI change	Czech Republic	32	-0.069 (0.069)	0.051** (0.025)	4.10** (0.03)	.126	-0.006 (0.062)	0.053* (0.028)	2.98* (0.07)	.130
	New Zealand	64	0.058 (0.110)	-0.071* (0.043)	3.53** (0.04)	.043	0.085 (0.097)	-0.054 (0.040)	1.10 (0.34)	.029
	Norway	34	0.158** (0.067)	-0.084*** (0.030)	3.92** (0.03)	.194	0.165 (0.138)	-0.115 (0.081)	1.44 (0.25)	.205
	Sweden	36	-0.080 (0.104)	-0.043 (0.055)	1.53 (0.23)	.018	-0.093* (0.049)	-0.051 (0.063)	2.08 (0.14)	.022
	Czech Republic	32	0.062 (0.057)	0.037 (0.033)	2.43 (0.11)	.042	0.067* (0.037)	0.039 (0.037)	2.06 (0.15)	.044
GDP growth rate	New Zealand	64	-0.305*** (0.084)	0.079*** (0.027)	6.59*** (0.00)	.121	-0.199* (0.112)	0.064* (0.032)	1.97 (0.15)	.093
	Norway	34	-0.040 (0.043)	0.021 (0.020)	0.58 (0.57)	.032	-0.109 (0.081)	0.032 (0.032)	1.16 (0.33)	.042
	Sweden	36	-0.228*** (0.081)	0.064*** (0.022)	5.97*** (0.01)	.207	-0.255* (0.130)	0.068* (0.038)	1.93 (0.16)	.203

Note: Table 4 reports the orthogonality test results for 3-months interest rate projections against the actual inflation rate and the real GDP growth rate. The regression model is $FE = \alpha + \beta X + \epsilon$, where FE denotes the forecast error. Standard errors are quoted in parentheses for constant and coefficient estimates. For the F-test statistic, p-values are provided in parentheses and $H_0 : \alpha = \beta = 0$ applies. For the rationality test on the basis of an asymmetric loss function we employ Newey-West standard errors. The asymmetry itself is given by the α -parameter estimated in the regression reported in Table 2.

[†] Newey-West standard errors

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 5: Multivariate Orthogonality Test

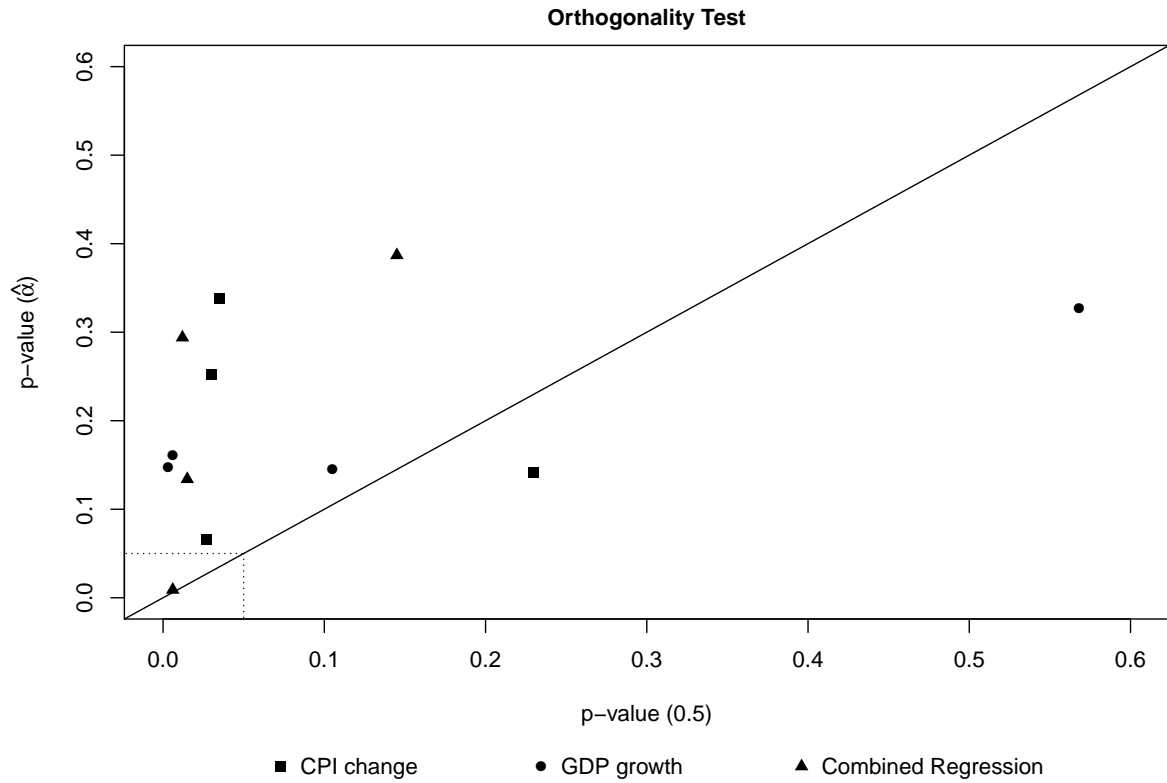
	Obs.	Constant	CPI	GDP	UNEMP	F test	R^2	
Symmetric	Czech Republic	32	-1.844** (0.698)	0.135*** (0.039)	0.105** (0.039)	0.243** (0.094)	4.60*** (0.01)	0.328
	New Zealand	64	-0.309 (0.384)	-0.037 (0.048)	0.076** (0.030)	0.019 (0.055)	3.55** (0.01)	0.138
	Norway	34	0.120 (0.191)	-0.084** (0.034)	0.002 (0.021)	0.010 (0.052)	1.85 (0.15)	0.195
	Sweden	36	0.232 (0.905)	-0.095 (0.066)	0.072** (0.022)	-0.048 (0.112)	3.66** (0.02)	0.266
	Czech Republic	32	-1.862** (0.754)	0.138*** (0.038)	0.107** (0.044)	0.246** (0.103)	4.22*** (0.01)	0.333
Asymmetric†	New Zealand	64	-0.242 (0.387)	-0.024 (0.034)	0.063* (0.034)	0.020 (0.063)	1.26 (0.29)	0.105
	Norway	34	-0.014 (0.196)	-0.114 (0.085)	0.005 (0.022)	0.050 (0.091)	1.07 (0.39)	0.220
	Sweden	36	0.151 (0.790)	-0.102 (0.060)	0.076* (0.039)	-0.040 (0.095)	1.90 (0.13)	0.267
	Czech Republic	32	-1.862** (0.754)	0.138*** (0.038)	0.107** (0.044)	0.246** (0.103)	4.22*** (0.01)	0.333

Note: Table 5 reports the orthogonality test results for 3-months interest rate projections in a multivariate regression including the actual inflation rate, and the real GDP growth rate and the unemployment rate. The regression model is $FE = \alpha + \beta X + \gamma Y + \delta Z + \epsilon$, where FE denotes the forecast error. Standard errors are quoted in parentheses for constant and coefficient estimates. For the F-test statistic, p-values are provided in parentheses and $H_0 : \alpha = \beta = \gamma = \delta = 0$ applies. For the rationality test on the basis of an asymmetric loss function we employ Newey-West standard errors. The asymmetry itself is given by the α -parameter estimated in the regression reported in Table 2.

† Newey-West standard errors

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Figure 6: Orthogonality Test Scatter Plot



Note: Figure 6 plots the p-values for the F statistic resulting from the orthogonality test regressions. The p-value for the F statistic under a symmetric loss function is plotted on the x-axis, whereas the corresponding p-value for the same regression under an asymmetric loss function is plotted on the y-axis. P-values from the orthogonality tests against actual inflation, real GDP growth and a combination of inflation, GDP growth and unemployment are shown as reported in tables 4 and 5. Any marker above the 45-degree line suggests that by moving from a symmetric to asymmetric loss function, evidence against rationality is weakened. The dotted square at the lower left-hand corner indicates the “zone of statistical significance” at the 95% confidence level.

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