DOCUMENTOS DE TRABAJO

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N° 881 Junio 2020
BANCO CENTRAL DE CHILE

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Documentos de Trabajo del Banco Central de Chile
Working Papers of the Central Bank of Chile
Agustinas 1180, Santiago, Chile
Teléfono: (56-2) 3882475; Fax: (56-2) 3882231

Documento de Trabajo
N° 881

Working Paper
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Back testing fan charts of activity and inflation: the Chilean case*

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Abstract

Any forecast has associated a measure of predictive uncertainty. The Central Bank of Chile (CBoC) communicates with fan charts the projections' uncertainty of inflation and GDP growth in the Monetary Policy Report (MPR). This work aims at evaluating ex post their properties with empirical techniques. In general, we find that fan charts have been a relatively accurate in illustrating the true density generated by the conditional mean within forecasting horizons of up to one year. While inflation forecasts are unbiased, forecasts of GDP growth have been optimistic on average. The analysis of a recent sub-sample in which risks for GDP growth was made explicit, we graphically examine whether asymmetric fan charts are more accurate ex –post than symmetric fan charts. For these cases, the median projection seem to have provided a better guide than the mode.

Resumen

Toda proyección puntual tiene asociada una medida de incertidumbre predictiva. El Banco Central de Chile (BCCh), comunica la incertidumbre de la proyección de la inflación y crecimiento del PIB usando fan charts en el Informe de Política Monetaria (IPoM). Este trabajo se propone evaluar empíricamente las propiedades de los fan charts ex post. En general, encontramos que los fan charts han resultado una guía relativamente precisa respecto a la verdadera densidad generada por proyecciones dentro de horizontes de proyección de hasta un año. Mientras que las proyecciones puntuales de inflación son insesgadas, las de crecimiento del PIB han resultado en promedio optimistas. Para la sub-muestra reciente donde se hizo explícito un balance de riesgos para el crecimiento, examinamos gráficamente si los fan charts asimétricos resultan más certeros ex – post. Para estos casos, la proyección mediana parece entregar una mejor guía que la proyección modal.

* We thank comments from Juan Guerra, Roberto Zúñiga and Francisco Bullano and an anonymous referee. The opinions expressed in this work corresponds to the authors and do not necessarily reflect those of the members of the Board of the Central Bank of Chile. Andrés Gatty participated in the project while he worked as an analyst in the Medium Term Projections Department during 2017. Emails: jfornero@bcentral.cl; andres.gatty@gmail.com.

1 Introduction

Macroeconomic projections inevitably involve a measure of predictive uncertainty sourced in the unpredictable nature of the future. There is uncertainty on the exact origin, scope and propagation of unanticipated shocks. Sometimes the shock takes place abroad and uncertainty translates into the estimation of trading partners' expected demand. In addition, uncertainty may lead to question the right model specification and the validity of its parameters, including those that affect the long run (e.g. potential growth), etc. Hence, the farthest the forecasting horizon, the larger the amount of uncertainty due to multiplicity of causes.

Fan charts are useful to communicate the uncertainty surrounding macroeconomic projections, based on all information available. Briefly defined, the fan chart, reports iso-probability contour lines enclosing the likely space in which the projected variable will lie in the future. Section 3 below provides more details.

The Bank of England (BoE) pioneered the use of fan charts for communicational purposes in 1996. Latter, other central banks adapted and implemented the methodology. Currently, many central banks and international organizations publish fan charts in their official reports. In addition, policymakers provide a qualitative description of risk scenarios to enrich the analysis that fan charts help to communicate. Normally, the description of risks hinges on or assumes the occurrence of hypothetical shocks, which will carry economic consequences and policy reactions. The negative or optimistic implications of risk scenarios under analysis typically lead to policymakers to conclude with a risks' balance assessment. To sum up, fan charts quantify, in general, the existence of uncertainty in projections.

A few studies analyze the predictive accuracy of fan charts as well as other properties. A majority of empirical studies have examined the predictive properties of fan charts published by the BoE; see for example Wallis (2003, 2004); Clements (2004); Elder et al. (2005); Dowd (2007, 2008); Knüppel and Schultefrankenfeld (2008); Gneiting and Ranjan (2011); Galbraith and van Norden (2012).

This is the first study that analyzes the properties of fan charts published in Monetary Policy Reports (MPR) for the Chilean case. There is existing literature that evaluates statistical properties of projections that are implicit in the fan charts. Albagli *et. al.* (2003) evaluates the accuracy of gross domestic product (GDP) growth and inflation projections in terms of the mean error and the root mean square error of projections. They consider projections from the Inflation Report to the Senate in the 1990s and MPR's projections from 2000 to 2002. Projections' accuracy is confronted with that of professional forecasters and with projections by other central banks. Pincheira (2010), examines GDP growth projections from 1991 to 2009 to analyze projection errors' properties. The accuracy of projections is compared with those of professional forecasters and with forecasts produced by time series models. To make fair comparisons using time series models' forecast the author considers real time, i.e. the data available at times of forecasting, and final estimates. The study also examines projection of intervals of annual GDP growth, considering the practice of communicating intervals. Recently, Zuñiga *et al.* (2019) considers a sample of projections extended to 2017, they study projections' precision, efficiency and unbiasedness with classical linear regressions.

The Central Bank of Chile (CBoC) has published inflation and GDP growth fan charts since May 2000 onwards in the MPR. The CBoC committed to provide projections with more transparency and started to distribute all excel files including fan charts of MPRs since March 2018.

The objective of the paper is to document the methodology, construction and parameterization of fan charts published in the MPRs of the CBoC and then to evaluate empirically its main statistical properties. In addition, we examine projections of GDP growth for specific MPRs that explicitly emphasized downward or upward risks to baseline scenario's projections. In these few cases, we analyze whether biased fan charts and the median projection were more informative than the most likely projection (mode).

Therefore, this work contributes to the empirical literature that evaluates the accuracy of projections and its uncertainty using fan charts extensively. Although the methodology applied is standard by now, this paper's results are novel and useful for understanding the uncertainty surrounding macroeconomic projections of the CBoC.

By examining projections and applying reverse engineering, we recover the size of the average forecasting errors and standard deviations (root mean square forecasting errors, RMSFE). These are relevant inputs to conduct a so-called partial analysis, which means to check fan chart's main properties separately. Besides, we undertake a joint analysis using goodness of fit tests of Kolmogorov-Smirnov (KS) and Berkowitz (2001), which intuitively assess how close the forecast density expressed in the fan chart (given the point projection and its standard deviation) is with respect to the true data density of the data.

The MPR reports projections associated with the mode or the most likely outcome of prediction density. Notice that it equals (differs from) the average and median projection when the fan charts are symmetric (asymmetric). The CBoC provides also a detailed analysis of alternative forecasting scenarios, which influence an optimistic/pessimistic view on GDP growth projections. This analysis have consequences for the asymmetry of fan charts. We back test the choice of asymmetry by using graphs for ranges of growth.[2]

After the outbreak of the Covid-19 disease in the world, strategies for communicating risks to projections are under revision. A primary point is that due to such a large and negative shock, unprecedented policy stimulus were provided by several countries to stabilize economies and help recovering business confidence, but considerable uncertainty remains. For Chile, projections of the MPR of March and June 2020 recognized higher uncertainty. In June CBoC increased ranges of projected GDP growth, provided forward guidance for the policy rate and augmented non-conventional monetary policies. Other Central Banks and institutions emphasized higher uncertainty in different ways. For example, some Central Banks provided three alternative scenarios in recent MPRs (see MPR of April by Central Bank of Canada or of May for New Zealand). There are pros and cons of providing alternative projection scenarios in times of high uncertainty. The analysis of these innovations in the communication is currently under development and study. It may have implications for the calibration of fan chats, which we leave for future agenda.

[2] We wish we had more data points to evaluate formally RMSFE using the median versus the mode for the cases in which asymmetry in GDP growth was communicated.

A summary of main results follows. First, for inflation, defined as year on year change in the consumer price index (CPI inflation for short), it is found that projections of the MPR have been unbiased for all the horizons. This means that despite forecasts errors are nonzero in general in each period, on average are not different from zero. Regarding the width of the fan chart, it had been consistent with the ex - post RMSFE in the short-term. From a joint analysis, we confirm above results using goodness of fit tests: concluding that fan chart have been a reasonably good guide to measure uncertainty in the short term. For horizons of one year and more, the MPR have exaggerated the uncertainty of inflation. Wallis (2003) and Elder *et al.* (2005) for other economies report similar results.

Second, for GDP growth, projection errors calculated with the mode were on average positive, which would reveal the optimistic nature of projections from CBoC's MPRs. This evidence matches results from other official institutions that project activity (see for example Hellwig, 2018; Frankel, 2011; McNees, 1995) and confirms findings by Pincheira (2010) and Zuñiga *et al.* (2019) for the Chilean case. Turning to uncertainty, the ex - ante calibration of fan charts is consistent with the ex - post RSMFE at horizons of up to one year, meaning that these fan charts have been a relatively good guide to the true density of the data.

Third, as it is well-known, when there are downward (upward) risks, the median is smaller (larger) than the mode. In these instances, we construct counterfactual growth intervals with center in the median to evaluate whether that strategy was ex-post more accurate than using the mode. The collected evidence seem to be favorable with that view.[3] These last results are based on the analysis of 13 episodes communicated between 2009 and 2018, which suggests caution in its interpretation and extrapolation.[4]

The structure of this paper is as follows. In section 2 we analyze two episodes where the initial conditions changed significantly the projections, which triggered some communication challenges. Section 3 briefly reviews the theoretical foundations of fan charts, section 4 describes the data, and section 5 explains the evaluation methodology. The section 6 reports main results. Finally, section 7 concludes.

2 Motivation

Policy officials make decisions in real time using projections (Orphanides, 2001). Naturally, changes and updates in the information set cause revisions of projections. This section illustrates the uncertainty that surrounds projections by analyzing two episodes ex post.

First, we consider the Subprime Crisis in the US and its effects in Chile's annual GDP growth. Figure 1 plots revisions of average projections from Consensus Forecasts considering updates in the information set. In terms of growth rates, the crisis was acute, reaching the minimum growth in 2009, and took some time to realize the "V" shape. In the recovery phase, professional forecasters revised gradually upward growth for years 2010-11. Another reason to examine this episode is the exogeneity of the shock, which surprised all domestic professional forecasters with "large" projection errors. Finally, the standard

[3] This suggests that GDP growth intervals can also be calculated using the median and the mean as mid-points.
[4] We leave to future work to explore additional strategies to communicate risks with the median along with asymmetric fan charts.

deviation of next year forecasts increased from 47 basis points in 2008 IV to 70 basis points in 2009 III, reflecting an increase in uncertainty.

This example motivates us to consider implications for communicating projections and the surrounding uncertainty. A first strategy is to adjust the width of the fan chart with flexibility to reflect periods of greater uncertainty. A different communication strategy is to increase the mass of probability on the left tail of the distribution, which is equivalent to an increase in the likelihood of alternative scenarios that are bad for real activity (asymmetric fan chart).

Expert's judgment typically guide adjustments in fan charts' parameters to enhance communication of projections.[5] There are different strategies to adjust fan charts, some are guided by rules others by judgement. Turner *et al.* (2018) formalizes a rule to adjust the fan chart following a methodology based on a leading indicator that signals that change. The decision to adjust the fan chart follows from a prediction of a Probit model feed with macroeconomic and financial variables as regressors. The absence of implementations like this when the Subprime Crisis erupted, leaded to rely on experts' judgment to change fan charts' parameters, as we mentioned.

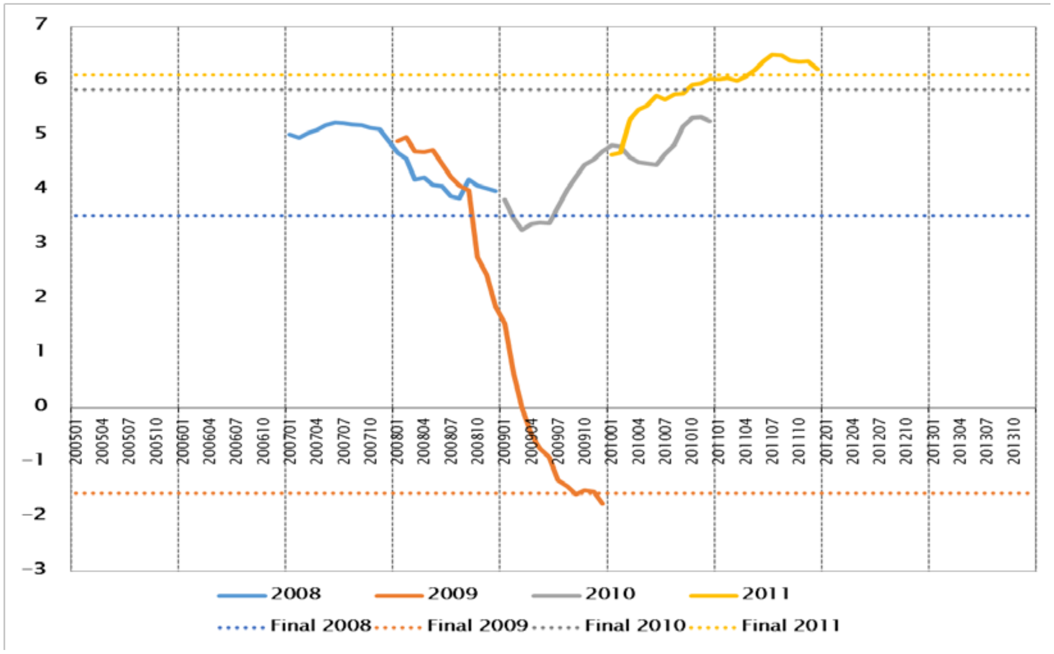
Expert's judgement is supported by evidence from general equilibrium macroeconomic models and the other way around. For example, models could rule out shocks to the economy's productive capacity. If this is the case, a shy projected recovery due to uncertainty may justify communicating wider fan charts.

Sometimes expert's judgment is not always that clear when a supply shock hits the economy, as in the Taper Tantrum episode that took place in May 2013. Briefly, Bernanke's announcement concerning US monetary policy normalization changed the expectations of market agents and triggered rapid reactions on a global scale along with turbulences in financial markets elsewhere. Thus, prices of financial assets quickly adjusted; capital flows redirected back into advanced countries, the dollar appreciated with respect to all other currencies and financial conditions in emerging markets narrowed. The consensus view of market analysts and policy makers was that, despite some transitory and turbulent adjustments, fundaments changed to reflect an improvement in macroeconomic conditions of advanced economies. Notwithstanding this, Chile experienced significant upward revisions in the exchange rate with consequences on expected inflation and downward revisions of activity (exacerbated by downward adjustment of the mining investment cycle). Even for free floaters like Chile, this set of dynamics leaded to nontrivial trade-offs of monetary policy. In this episode, fan charts communicated changes in projections with upward risks in inflation and downward risk in growth, consistent with a supply shock.

[5] Experts' judgements are based on the analysis of dozens of variables, including hard data, surveys and sentiment leading indicators that complement projections of key variables from structural models. See CBoC (2020a) for further details on the use of macroeconomic models for policy decisions.

Figure 1: GDP annual growth projections: 2008 - 2011

Projections for the current year and for the following year (survey each month).



Note: Average projections. Source: Consensus Forecasts.

As illustrated in these examples, the exact source of uncertainty is due to multiplicity of causes, which makes the use of this methodology interesting. In summary, each projection revision includes uncertainty, which has value to measure and communicate to the market.

3 Theoretical underpinnings of *fan charts*

Fan charts illustrate estimates of projection intervals in which an economic variable will be realized in a future horizon. The BoE pioneered the use of this technique in 1996 and its purpose is to improve the communication of the uncertainty that surrounds projections.

Following Box A in Britton *et al.* (1998), the two-piece normal distribution function depends on three parameters: the mode (m), which is the most likely projection, the standard deviation (σ), which represents the size of the mean forecasting error, and the asymmetry (γ), which indicates the disequilibrium of the error with respect to the central projection. Mathematically, the two-piece normal distribution writes as:

$$f(x,m,\sigma^2,\gamma) = A(2\pi\sigma^2)^{-1/2} exp\left[-\frac{1}{2\sigma^2}\left\{(x-m)^2 + \gamma\left(\frac{x-m}{|x-m|}\right)(x-m)^2\right\}\right] \qquad (1)$$

where 'A' is calibrated to make sure that, the integral of the density adds up to the unity.

The central projection represents the most likely projection in the probabilistic sense. This projection, in practice is produced by the Central Banks using as inputs forecasts from one or more macroeconomic models as well as expert's judgement. The standard deviation of the projection errors reflects the uncertainty surrounding forecasts of the central scenario.[6] Finally, asymmetry in predictive densities is the probabilistic belief that the projection acquires a greater probability of being located above or below the central scenario.

Figure 2 presents examples of predictive densities and the corresponding fan charts. On the left, the flatted distribution drawn in red reflects a hypothetical case that assumes a point projection of 2 percent, standard deviation of 1 percent and asymmetry γ =+0.68. In addition, this particular distribution for a given horizon is consistent with an asymmetric fan chart that emphasizes downside risks for the projection (on the right). In contrast, if γ = 0 the predictive density is the normal distribution drawn in blue, which will produce a symmetric fan cart (not shown) that communicates balanced risks to the projection. By symmetry, the implication is that mode (m), mean (μ) and median (δ) projections are the same.

The construction of the fan chart with asymmetry in practice requires calibrating $\gamma \in (-1,1)$. The tradition is to set γ to reflect different alternative scenarios under discussion by the CBoC's board, which are described with more or less detail in the summary of the MPR. The pessimistic or optimistic tone of alternative scenarios may support asymmetry in fan charts.[7]

The CBoC publishes fan charts of inflation and GDP growth since May 2000, after adopting the BoE methodology. The framework for policy analysis and forecasting have been strengthened with newer and richer models to produce projections.[8] For purposes of fan charts' implementation since March 2018, we use historical RMSFE to calibrate them.[9]

[6] Forecasting errors come from either models' simulations or historical RMSFE. If models are correct and we have a sufficiently large sample of projections, both alternatives yield similar fan charts, under standard assumptions. The advantage of using historical RMSFE is that they include past expert's judgement.

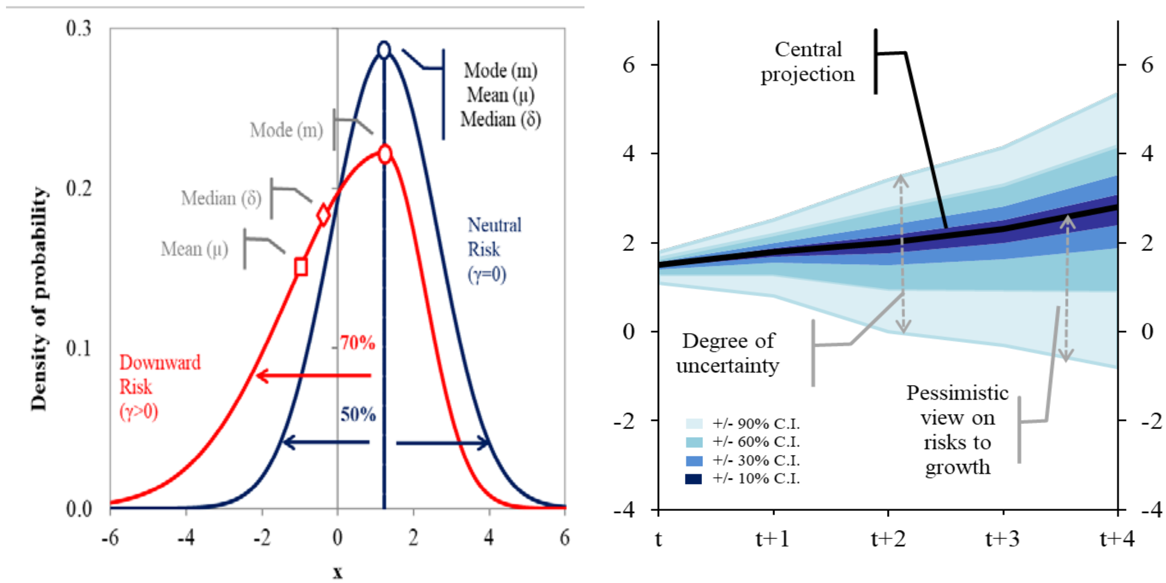
[7] A clarification on alternative scenarios. From MPR of June 2019 onwards, a distinction is made for sensitivity and risk scenarios. Sensitivity are quite likely to become the central scenario if a change in an assumption takes place. Risk scenarios, in contrast, are less likely and represent larger deviations from baseline scenarios. The characteristics of risk scenarios is that projections can go out the fan chart and sources of shocks are typically exogenous, such as the price of copper, oil, etc.

[8] The MEP is the first official structural projection model, CBoC (2003). It was in production since 2003. Since 2009 the Model of Analysis and Simulation (MAS) is also used, see Medina and Soto (2006, 2007). From December 2009 onwards, the central projection of the MPR results from combining the projections of these two models with weight ½. The latest update of the semi-structural projection model is documented in Arroyo Marioli et al. (2020). Likewise, in García et al. (2019) an extended version of the MAS, called XMAS. Finally, CBoC (2020a) describes updated methodologies in use by the CBoC's staff.

[9] A larger volume of data is a necessary condition for the calculation of more accurate statistics, which result in greater discernment between hypotheses to be tested. The current sample collects projection errors from the MPR of December 2009 onwards produced with structural models. Previously, from mid 2010 to 2017, we used simulated standard deviations from an estimated semi-structural model for Chile, see Alonso *et al.* (2010) for details on a simplified version of the MEP.

Figure 2: Predictive density and *fan chart*

Predictive density | ***Fan chart***



Source: Author's elaboration.

4 Data

Following CBoC (2020a) the economic analysis and projections presented in the MPR combine experts' judgement, forecasts produced by macroeconomic models complemented with additional data. The latter include surveys of expectations, leading and coincident indicators, financial surveys, financial information, etc.

For this study, data comes from CBoC's projection records for inflation and GDP growth in quarterly frequency. In addition, we collect the widths of fan charts and the degree of asymmetry, when risks to projections ware explicitly reported. The sample begins with the MPR of May 2000 and ends in the MPR of September 2019.[10] From 2000 to 2009, the CBoC published the MPRs in the months of January, May and September. Since December 2009 onwards, the frequency of release is quarterly: March, June, September and December.

Table B.1 in Annex B briefly reports the balance of risks communicated in MPRs. Due to data limitations, we consider asymmetric fan charts for a sub sample that comprise the MPR of December 2009 to December 2018.[11] This enables us to examine 13 episodes of asymmetric fan charts for GDP growth. [12]

[10] The collection of projections is complete, except for *fan charts* of MPRs of May and September 2004, January, May and September 2005 and January 2006. For each of them we count with point projections, and we assume that the width of *fan charts* uses parameters of MPR of January 2004 (latest available). Instead, to use parameters of MPR of May 2006 do not change results.

[11] Notice that the last data point available for the MP Report of September 2019 is the second quarter of 2019.

[12] In the sample, MRPs project two-year inflation on target (anchor) complemented with symmetric fan charts.

5 Methodology

The previous section stated that this paper uses a unique dataset of projections for Chile. The methodology to evaluate the quality and accuracy of these projections is standard.

First, we evaluate two dimensions of the forecast density of fan charts: (i) the overall accuracy of point projections, and (ii) the calibration adopted for the predictive uncertainty of the fan chart (or width) compared with expected uncertainty at different horizons *h* measured by:

$$\text{RMFSE}_h \equiv \sqrt{\frac{1}{N}\sum_{\text{t=MPR May00}}^{\text{MPR Sep19}}\left(m_{t+h|\text{t}} - y_{t+h}\right)^2} \tag{2}$$

where *m* denotes the mode projection at horizon *h* made at *t*, *y* is the realization and *N* is the number of MPRs analyzed in the sample. This statistic yields the average standard deviation of the projection errors, but it cannot reveal whether projections are unbiased. To check this, we regress the forecasting error on a constant as follows:

$$e_{t+h|t} = \alpha + u_t \tag{3}$$

where $e_{t+h|t} \equiv m_{t+h|t} - y_{t+h}$. If the null that states that the average of the projection error is zero is rejected, then we conclude that the forecast is on average optimistic (pessimistic) when $\alpha > 0$ ($\alpha < 0$). MPRs' stored projections made at *t* for horizons *h*: 0,1,…,8 quarters. The horizon zero is known as nowcast, $t + 1$ denotes next quarter forecast, $t + 4$ one-year ahead and $t + 8$ two-years ahead forecasts.[13]

Then, we study whether the uncertainty illustrated by the fan chart's width has been calibrated properly. To assess this, we compare the average uncertainty that the staff of the CBoC ex - ante assumed for each forecasting horizon, $\overline{\sigma_h}$, with RMFSE calculated ex – post.

Second, we carry out a joint evaluation of the projection density by means of implementing standard goodness-of-fit tests. The intuition behind these tests is to assess how close the forecast density evaluated in the fan charts is with respect to the true density of the data.[14] The tests' implementation requires the calculation of Probability Integral Transforms, *p.i.t.s* for short, defined on the left panel of Figure 3.

Figure 3 on the right panel illustrates how to interpret *p.i.t.s*. The darkest blue area of the fan chart represents the most likely expected scenario for the macroeconomic realization. For simplicity, it is assumed that uncertainty is balanced. Point A corresponds to a realization that resulted nearly equal to what was projected, which is consistent with a *p.i.t.s* value around 0.5; meanwhile, points B and C correspond to realizations below and above the projection, consistent with *p.i.t.s* values of 0.35 and 0.60, respectively.

[13] Results remain similar for other horizons, which to save space we omitted.

[14] For simplicity, it is standard to assume that projections follow a data generating process that is stationary with well-defined ergodic distribution.

Figure 3: Illustration of Probability Integral Transforms (*p.i.t.s*, *z*-value)

Definition

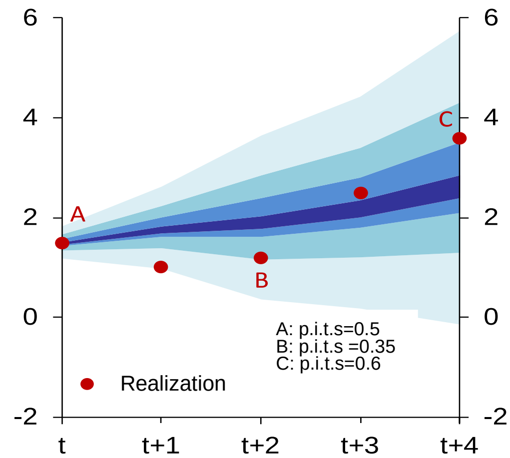
$$z_t = \int_{-\infty}^{y_t} p_{Y,t-h}(u)du \equiv P_{Y,t-h}(y_t)$$

where, $p_{Y,t-h}$ is the forecast density made in period $t-h$, y_t is the realized data point and z_t stands for the *z*-value ϵ (0, 1).

For realized values of the variable, Y_t, we may rewrite the previous equation as:

$$Z_t = \int_{-\infty}^{Y_t} p_{Y,t-h}(u)du \equiv P_{Y,t-h}(Y_t)$$

Examples



Goodness-of-fit tests help the researcher to measure how close the forecast density is to the true data density. We follow the literature and compute two standard statistical tests. First, the Kolmogorov-Smirnov (KS) test states the null that Z_t ~ U (0,1). This test increasingly orders the empirically estimated *z*-values and compares the fit of such distribution with a uniform theoretical cumulative distribution (that is, the area below the 45 degrees line). The KS test presents limitations as it ignores the interdependence of observations and it has little statistical power against the null in small samples, see Elder *et al.* (2005). Second, we implement the extension of the KS test advocated by Berkowitz (2001) that is robust under dependent observations and offers greater power on small samples.

Third, we narrow down the focus by examining MPRs in which relevant risks to projections of GDP growth were explicit. As stated in Adrian *et al.* (2019) "policy markers are often concerned with the downside and upside risk to the forecasts or, in other words, how vulnerable the predicted path of GDP growth is to unexpected shocks". The CBoC following best practices used MPRs as vehicle to communicate these risks by describing in "words" what are the potential shocks that yield the risks along with asymmetric fan charts (See Table B.1. in Annex B for details). In order to evaluate whether asymmetric fan charts were more informative than the alternative of symmetric fan charts, we compare whether the median projection of GDP growth is more accurate than the mode forecast ex - post.

6 Results

This section summarizes main results. Following the same order of the previous section, Table 1 reports estimates of parameter α of regression (3) together with *p*-values. The estimates support the view that projections for inflation were unbiased, with $\alpha < 0$ but not significant. In addition, the evidence suggests optimistic projections of GDP growth, more clearly for $t + 4$ and $t + 8$. The table reports RMSFE calculated with the full sample, 2000 II – 2019 II, and two partitions of it, as follows: (i) a sample that ends up just before the

Subprime crisis erupted: 2000 II to 2008 II; and (ii) a post- Subprime crisis sample, 2009 IV – 2019 II.

The RMSFE calculated with the full sample show increases in size as the horizon increases, a typical pattern. Projection errors are smaller for inflation than for GDP growth. In terms of size, projection errors of MPRs are slightly lower than forecasting errors of Consensus Forecast and leading inflation targeting central banks; see Laxton *et al.* (2019), Annex 4.

The separation in two sub-samples reveals that average projection errors of inflation and growth have decreased. In particular, for inflation the RMSFE reduces significantly for all forecasting horizons, for example for $t + 2$ the reduction is from 0.91 to 0.57 percent, for $t + 4$ the drop is from 2.15 to 1.08 percent, etc. In relative terms, for horizons reported we obtain an average drop of about 35 percent less forecasting error compared with pre-crisis results.[15] For GDP growth, relative improvements in forecasting accuracy are smaller in terms of size, in the post-Crisis sample RMSFE reduce on average of around 10 percent for the evaluated horizons, but for horizons t+1 and t+4 projections are more accurate, i.e. they show larger drop.

Table 1: Bias and RMSFE

	Inflation				GDP growth			
	t	t+1	t+4	t+8	t	t+1	t+4	t+8
α	-0.04	-0.11	-0.16	-0.05	0.12	0.40	1.41	1.64
p-value (H_0: α = 0)	0.37	0.40	0.66	0.88	0.24	0.06	0.00	0.00
RMSFE	0.33	0.85	1.91	1.60	0.71	1.33	2.36	2.76
RMSFE (2000 II-2008 II)	0.43	0.91	2.15	1.32	0.73	1.25	2.35	2.39
RMSFE (2009 IV-2019 II)	0.20	0.57	1.08	1.17	0.69	1.08	1.80	2.35

Notes: Forecasting error is defined as the difference between the projected value and the realization. *p-values* larger than 0.05 must be interpreted as absence of evidence to reject the null hypothesis that assumes unbiased errors on average, α = 0. Robustness errors following Newey and West (1987). For baseline results we used the full sample 2000 II to 2019II, unless stated otherwise. Source: Authors' elaboration.

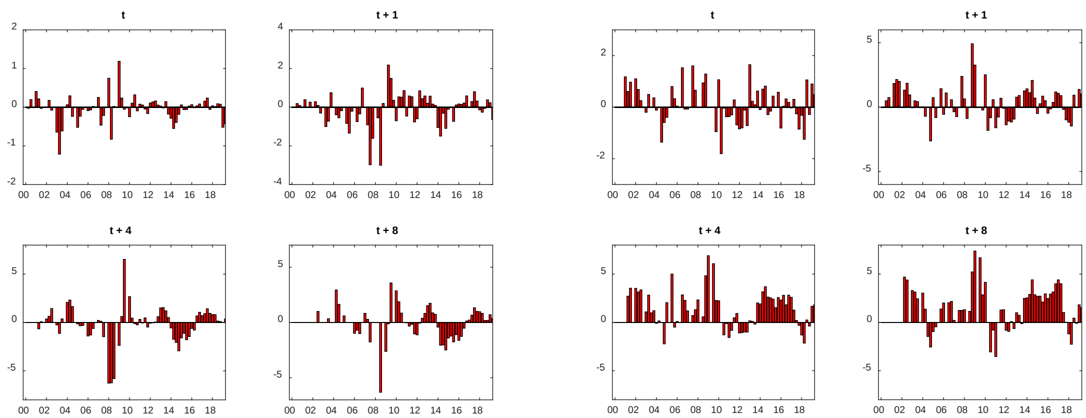
Figure 4 complements previous results as it reports projection errors, defined as the difference of the central projection and the realization, in real time. Beginning with the case of inflation, the errors in the short-term show small persistence, consistent with well-behaved (white noise) errors, with increasing volatility as the projection horizons increase. In the medium term, the projection errors show more autocorrelation, because the projections tend to be smooth, reflecting estimated persistence of the data.[16] For example, in the period 2014-15, negative projection errors for inflation in the mid-term tend to show persistence because the main driver of surprises was the exchange rate depreciation due to the announced normalization of US monetary policy (see section 2 above).

[15] Many possible causes may explain this result; at least two are worth mentioning. First, an observed lower volatility of inflation in recent years (Carlomagno and Sansone, 2019). Second, improvements in forecasting models and the development of better tools at the CBoC as well as richer datasets available for estimation.

[16] Two core models provide medium-term projections along with experts' judgement; see Arroyo *et al.* (2020) and García *et al.* (2019) for details. Forecast typically show persistence because shocks take time to die out.

Figure 4: Forecasting error (multi-step)
(Sample: 2000 II – 2019 II)

Inflation **GDP growth**



Note: Authors' elaboration. Source: various MPRs, CBoC.

For GDP growth, we find that α has been positive on average and the hypothesis of unbiasedness is rejected at the usual levels except for nowcasting and, on the margin, t+1. For horizons $t + 4$ and $t + 8$, the projections of GDP growth have been optimistic on average. The right panel of Figure 5 illustrates that there were periods in which errors correlated more. In particular, in the 2014-2016 period, projected GDP growth at the two-year horizon was optimistic due to at least two reasons. First, the overestimation of potential and trend GDP growth because of mining investment boom of 2010-12 (See Fornero *et al.*, 2016). The MPR of September 2015 proposed a methodological change that dissociated the measurements of potential GDP and trend GDP (See Albagli and Naudon, 2015 and Albagli *et al.* 2015 and 2015b).[17] This enabled a temporary and gradual reduction in potential GDP. Second, the cyclical GDP growth and investment lacked dynamism due to a large and persistent negative shock of mining investment (see Albagli and Luttini, 2015 and Albagli *et al.* 2019).

Next, Table 2 compares the width of fan charts implemented by the CBoC with ex-post predictive errors. Inflation is reported on the left whereas GDP growth on the right. We distinguish results considering the full sample and post Subprime crisis subsample. Beginning with inflation, results suggest that the average calibration in the short term has been close to the uncertainty observed in forecasting errors, with more supportive evidence in the post Subprime crisis subsample. For the medium term, however, there has been an overestimation of the width of the fan chart, which may be explained by the large inflation

[17] Trend GDP is a concept that relates to the growth capacity of the economy in the medium term, for example, five years. Potential GDP is a relevant concept to measure the pressures that could divert inflation from its 3 percent target, since the output gap (difference between the level of effective product and its potential level) is a key determining factor for inflation in the short term. Thus, in the short term, potential GDP will fluctuate around its trend counterpart, temporarily deviating in response to shocks that affect productive capacity in the short term, while in the long term, the potential and trend growth rate converge to the same number.

episode experienced before the financial crisis (and the posterior fall). We believe that the high volatility of that short subsample translated into exaggerated uncertainty.

Table 2: Width of *fan charts* and RMSFE

		Inflation				GDP growth			
Sample	*Statistic*	*t*	*t*+1	*t*+4	*t*+8	*t*	*t*+1	*t*+4	*t*+8
2000 II-2019 II	*Avg. σ MPRs*	0.2	0.6	1.4	1.8	0.4	1.0	2.0	3.1
	RMSFE	0.3	0.8	1.9	1.6	0.7	1.3	2.4	2.8
	S.E. error eq.(3)	0.3	0.8	1.9	1.6	0.7	1.3	1.9	2.2
2009 IV-2019 II	*Avg. σ MPRs*	0.2	0.7	1.7	1.9	0.4	1.3	2.3	2.9
	RMSFE	0.2	0.6	1.1	1.2	0.7	1.1	1.8	2.3
	S.E. error eq.(3)	0.2	0.6	1.1	1.2	0.7	1.1	1.6	1.8

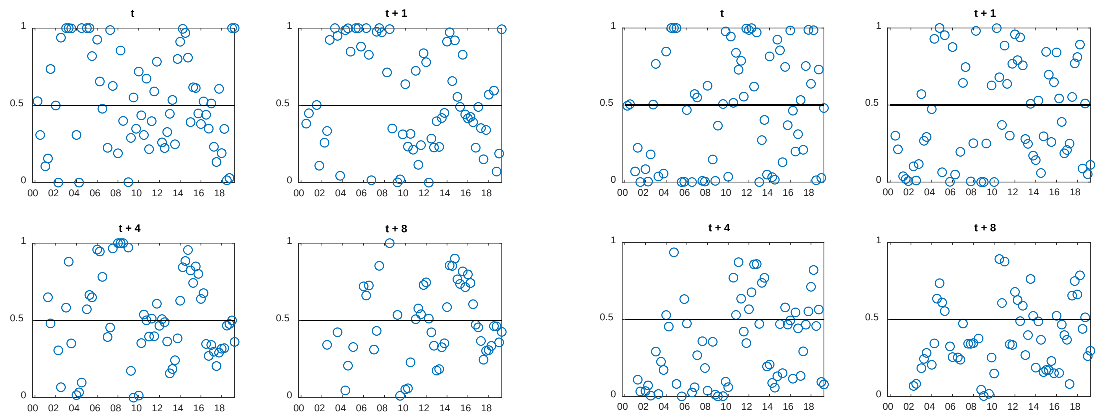
Note: For comparison purposes RMSFEs are taken from Table 1.
Source: Authors' elaboration.

The results analyzed so far considered conditional mean forecasts and fan charts' uncertainty separately. To overcome a potential inefficiency, we turn to *p.i.t.s*, a joint density measure. Figure 5 illustrates observed dispersion of *p.i.t.s* and provide useful intuition for interpreting evidence from statistical tests reported in Table 3. In particular, KS and Berkowitz (2001) tests are goodness of fit tests based on *p.i.t.s.* Following the literature and for completeness, we examine projection's error independence test using the Ljung-Box statistic. The table reports *p*-values for these tests and separate results for the complete sample from a most recent subsample that is interesting since the CBoC started to average projections form two macroeconomic models.

Beginning with inflation, standard deviations of errors have been consistent with the fan chart's width in the short-term. KS and Berkowitz tests confirms this, as we cannot reject the null hypothesis for t and $t + 1$ for the recent subsample. For farther forecasting horizons, only the KS test is rejected (complementary evidence also illustrates this in Figures A1 and A2 in Annex A). However, when analyzing the full sample, the Ljung-Box and Berkowitz tests reject the null hypothesis in most horizons. The results with the complete sample should be examined with caution because data of inflation observed before the Crisis seem to come from different distributions than those represented in fan charts. In effect, Figure 5 illustrates some problems for the early 2000s for horizon $t + 1$ as sequences of dots locate close to zero and suddenly jump to one. However, when looking at the results using the second subsample, fan charts appear to have provided reasonable guidance especially in the short term, confirming results previously reported in Table 2. As other studies have documented, we find wider inflation fan charts for mid-term horizons (Wallis, 2003 and Elder *et al.*, 2005).

Figure 5: z-value dispersion (*P.i.t.s*)
(Sample: 2000 II – 2019 II)

Inflation | **GDP growth**



Source: Various MPRs.

Table 3: Goodness of fit tests on *P.i.t.s*
(*p*-values)

	Inflation				GDP growth			
	t	*t* + 1	*t* + 4	*t* + 8	*t*	*t* + 1	*t* + 4	*t* + 8
Complete sample (2000.II-2019.II)								
Test independence								
Ljung-Box	0.13	0.00	0.00	0.00	0.53	0.07	0.00	0.00
Test distribution								
K-S U(0,1)	0.16	0.08	0.69	0.54	0.01	0.01	0.00	0.01
Berkowitz IN(0,1)	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00
Post-method. change (2009.IV-2019.II)								
Test independence								
Ljung-Box	0.24	0.18	0.00	0.00	0.69	0.01	0.01	0.28
Test distribution								
K-S U(0,1)	0.81	0.42	0.34	0.25	0.15	0.95	0.43	0.16
Berkowitz IN(0,1)	0.00	0.64	0.00	0.00	0.00	0.40	0.07	0.00

Note: The Ljung-Box independence test assumes as null hypothesis that z-values or *p.i.t.s* do not present serial correlation. The K-S denotes the Kolmogorov-Smirnov uniformity test that assumes as null hypothesis that *p.i.t.s* are uniformly distributed. The Berkowitz test is a normality test with 3 degrees of freedom (mean zero, unit variance and zero autocorrelation) on the cumulative transformation, or normal inverse of *p.i.t.s*. The full sample includes data from MPRs of May 2000 to September 2019. The subsample begins in December 2009.
Source: Authors' elaboration.

Turning to GDP growth results are quite similar to inflation for the complete sample. For the second subsample, results for horizons of up to one year confirm the appropriate calibration of fan charts. The latter because the KS test cannot reject the null hypothesis of correct density at 5 percent significance, likewise the Berkowitz test for horizons of *t* + 1 and *t* + 4. These results accord with findings about the width of fan charts reported further above in Table 2. For example, it can be contrasted that the average calibration of σ for the projection at $t + 1$ was found at 1.3 percent while the RMSFE was 1.1 percent. Whereas, for $t + 4$ the average calibration was 2.3 percent with a RMSFE of 1.8 percent. Statistically, the ex-ante calibration compared to what actually happened with the ex-post RMSFE is similar. However, for the cases in which the null hypothesis was rejected at the usual statistical levels, t and $t + 8$, the average calibration was 0.4 and 2.9, while the RMSFE 0.7 and 2.3, respectively.

To sum up, results suggest that fan charts of inflation seems to be correct in relation to projections, with exaggerated size of uncertainty in mid-term projections. For GDP growth, the density is affected by optimistic bias in projections, but widths of fan charts are fine.

GDP growth: asymmetric fan charts and ranges

So far, the symmetry assumption simplified the analysis because it considers that the baseline projection contains all the information to communicate. Next, we move on to consider projections from MPRs that communicated downside / upside risks to the baseline scenario. Communicating bias in the distribution of variables to forecast breaks the identity between the mode, conditional mean and median projection.

Furthermore, to reflect the uncertainty in MPRs' projections the CBoC publishes GDP growth ranges that communicate a kind of "fat" punctual forecast. This range of GDP growth have been revised in the past to communicate in a flexible way the uncertainty surrounding the projections.

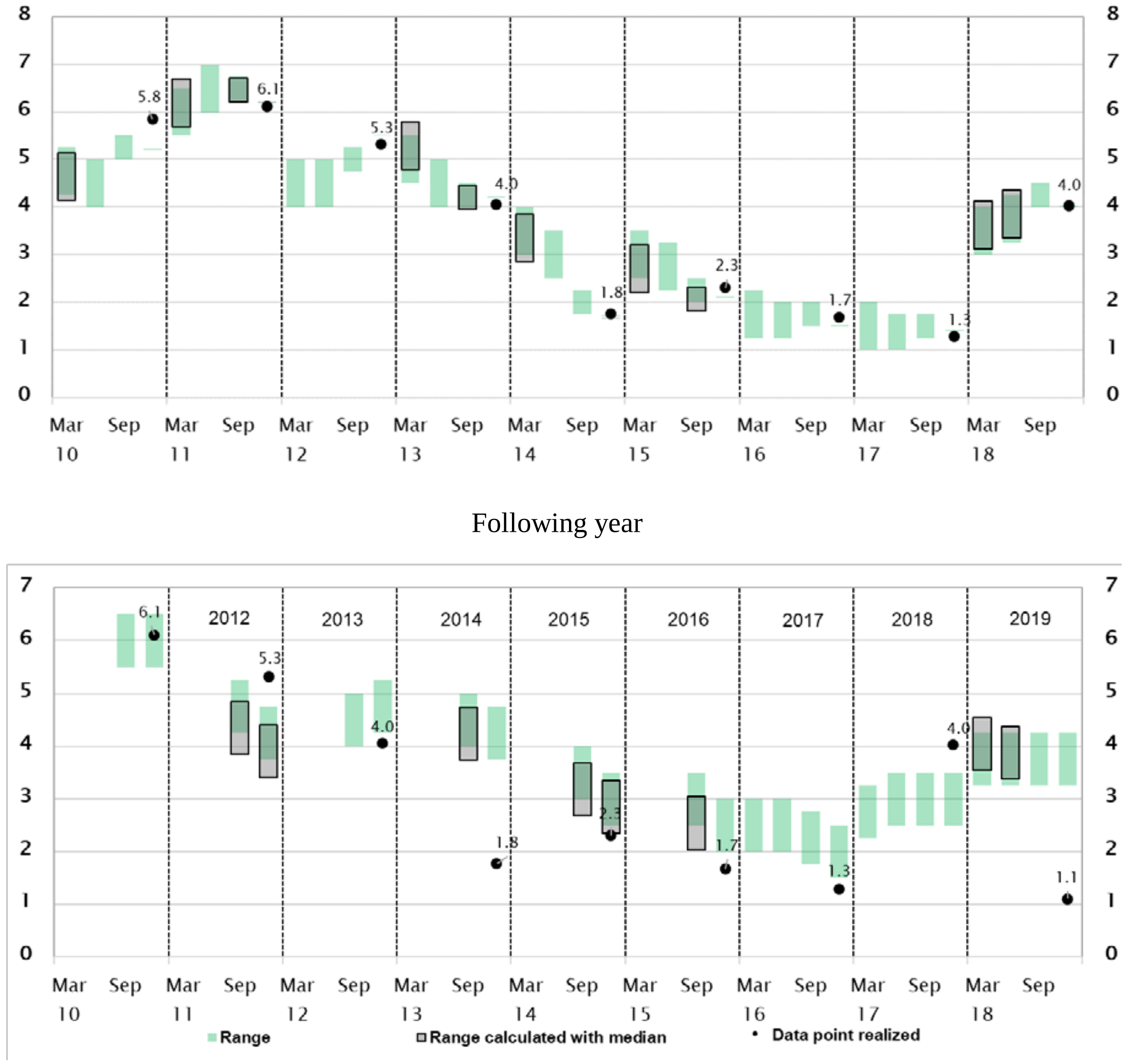
As the year transpires and more information is available, the projection becomes more accurate; hence, the range reduces its size for the current year. MPRs used to announce ranges of one percentage point in GDP growth both in releases of March and June, then reduced to 50 basis points in September and communicated the point forecast in the MPR of December. In 2016 the rule was updated as follows: in March, it has an amplitude of 1 percent, in June it drops to 0.75 percent, in September it further drops to 0.5 percent and maintains a point projection communicated in December. For the following year, the amplitude is 1 percent; see Box V.1 Central Bank of Chile (2016). Table A.3 in Annex A documents with more detail that ranges' sizes were chosen with the purpose to match approximately one standard deviation of the average projection error.

The MPR of June 2020 increased the projected domestic growth range from 0.75 to 2 percent for the current year due to a considerable rise of uncertainty (due to the outbreak of the global pandemic Covid-19). This, in a context where worldwide activity indicators dramatically deteriorated as well as projections. The CBoC communicated that there could be more alternative scenarios depending on the evolution of the pandemic, thus they increased the size of ranges for GDP growth to account for the huge size of uncertainty, that surrounds forecasts in this particular juncture, see Box V.2 Central Bank of Chile (2020b).

Figure 6 illustrates announced GDP's annual growth ranges for each MPR (soft green bars). The upper (lower) graph display projections for the current (next) year.

Figure 6: Range of forecast for GPD growth

Current year



Source: various MPRs CBoC. Authors' elaboration.

Next, we analyze the subset of 13 episodes in which upward / downward risks were explicitly communicated along with the baseline projection.[18] The traditional practice is to publish the projection in terms of ranges of growth that embraces the most likely (mode) forecast. We wonder whether a counterfactual range of growth based on the median instead of the mode is more accurate using these 'real life' episodes. For the sake of concreteness, for example we ask whether the GDP growth projection for 2015 communicated in the first MPR of the year would have been more accurate if ranges had been constructed with the median instead of with the mode. In September of the same year, the CBoC insisted in the communication of downward risks to the baseline, but the realization resulted closer to the mode. In the first two MPRs of 2018, on the other hand, the median reflected greater optimism than the mode,

[18] The period considered is between MPR of December 2009 to December 2018.

which is equivalent to assume an upward risk in projections' distribution. The latter communication strategy ex-post helped bringing the forecast closer to the realized observation. In this case, the qualitative information available together with the experts' judgment explains an improvement in terms of accuracy when communication of risks to the forecast was made. For the projection of the following year, the announced risks helped the ranges constructed with the median to approach more closely realized data, except in 2012 and 2019. These conclusions are based on a small number of data points, which suggests some caution in extrapolating them.[19]

7 Conclusions

In this paper we studied projections' properties of fan charts published in the MPRs issued by the CBoC. The existing literature examined with particular intensity the methodology and properties of fan charts published by the Bank of England. This work contributes to fill a gap in the analysis for the Chilean case.

In the case of inflation, it is found, from a partial analysis, that baseline point projections of the MPR have been unbiased. Regarding the calibration of the width of the fan chart, it is consistent with average projection errors in the short term and somewhat larger in the medium term. We conclude that the inflation fan chart graphs have been a reasonably good guide. The latter is consistent with evidence already reported by other Central Banks.

In the case of GDP growth, the projections have been optimistic on average, except in the short term. However, examining the whole density of forecasts, fan charts have been a relatively close guide to the true density generated by the data at projection horizons of up to one year.

Finally, reported "risks" in distributions of GDP growth projections are analyzed. The evidence of 13 episodes is favorable to construct ranges with the median since the range would have been more accurate than with the mode. This makes sense because the risk evaluation is based on expert's judgment.

[19] In future agenda, we plan to calculate RMSFE and to examine more formally if communicating risks to projections help to produce forecasts with the median that are more accurate than with the mode on average.

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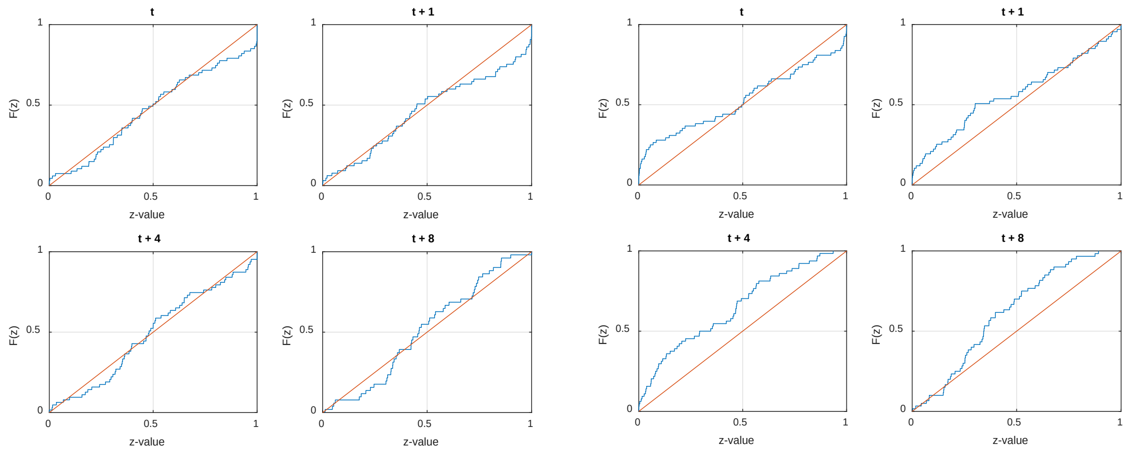
Annex A

Figure A1: Distribution z-value vs theoretical uniform distribution

(Sample: 2000 II – 2019 II)

Inflation **GDP growth**

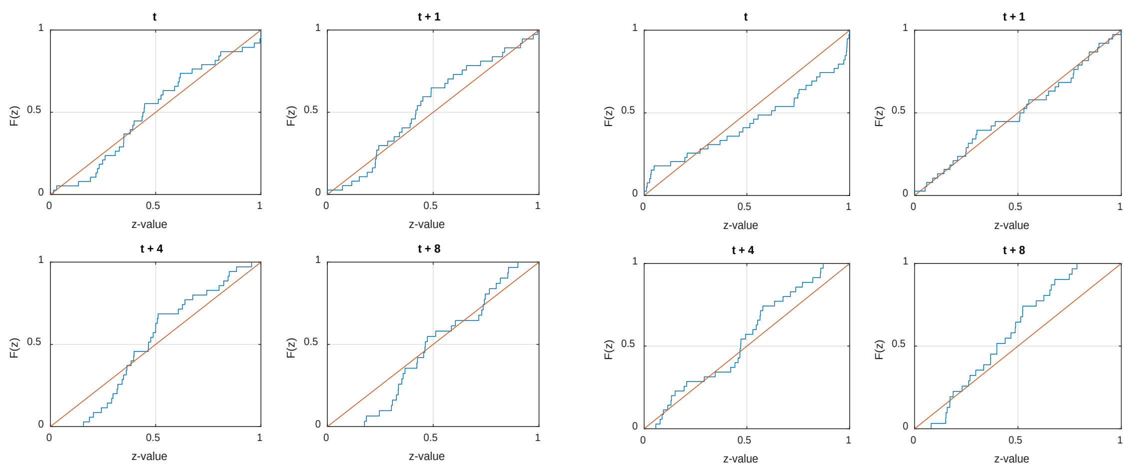


Note: Authors' elaboration. Source: Monetary Policy Reports.

Figure A2: z-value distribution vs uniform distribution

(Sample: 2009 IV – 2019 II)

Inflation **GDP growth**



Note: Authors' elaboration. Source: Monetary Policy Reports.

Table A.1. RMSFE of GDP growth

(Percentage, y-o-y, annual frequency)

		Current year		*Following year*	
		2008-18	2010-18	2008-18	2010-18
MPR	March	1.5	0.9	--	--
	June	0.8	0.7	--	--
	September	0.5	0.3	2.1	1.2
	December	0.3	0.3	1.8	1.1

Source: Monetary Policy Reports.

Note: Authors' elaboration. It uses the center of the range of GDP growth published, MPRs issued from 2008 to 2018. MPRs for January, May and September in 2008, whereas from 2009 onwards issued quarterly.

For next year projections, we do no report RMSFE for MPRs of the first semester due to few forecasting errors to calculate averages accurately (since March 2018 three-year forecasts are reported).

Annex B. Risks communicated to baseline forecasts (MPRs issued by CBoC)

Table B.1. Risks to baseline scenarios in MPRs

MPR	Risks to the baleline projection: GDP growth	Risks to the baleline projection: Inflation
may-00	Downward risk	IPCX equil. (hor. 24m), inflation with upward risk (oil price shock).
sep-00	Balanced	Balanced
jan-01	Downward risk	Downward risk
may-01	Small downward risk	Balanced
sep-01	Downward risk	Upward risk
jan-02	Balanced	Balanced
may-02	Balanced	Balanced
sep-02	Downward risk	Balanced
jan-03	Downward risk	Upward risk
may-03	Balanced	Balanced
sep-03	Balanced	Balanced
jan-04	Balanced	Balanced
may-04	Balanced	Small upward risk
sep-04	Balanced	Upward risk
jan-05	Balanced	Upward risk
may-05	Downward risk	Balanced
sep-05	Balanced	Balanced
jan-06	Balanced	Balanced
may-06	Upward risk	Balanced
sep-06	Downward risk, only in the current year	Balanced
jan-07	Balanced	Balanced
may-07	Upward risk	Balanced
sep-07	Downward risk	Balanced
jan-08	Downward risk	Balanced
may-08	Downward risk	Balanced
sep-08	Downward risk	Small upward risk (current year)
nov-08	(*)	(*)
jan-09	Downward risk	Balanced (not explicit)
may-09	Downward risk	Balanced
sep-09	Balanced	Balanced
dec-09	Balanced	Balanced
mar-10	Balanced, in the short run donward risk	Balanced
jun-10	Balanced	Balanced
sep-10	Balanced	Balanced
dec-10	Downward risk	Balanced
mar-11	Upward risk	Upward risk
jun-11	Balanced	Balanced
sep-11	Downward risk	Balanced
dec-11	Downward risk	Balanced
mar-12	Balanced	Balanced
jun-12	Balanced	Balanced
sep-12	Balanced	Balanced
dec-12	Balanced	Balanced
mar-13	Upward risk	Balanced
jun-13	Balanced	Balanced
sep-13	Downward risk	Balanced
dec-13	Balanced	Balanced
mar-14	Downward risk	Balanced
jun-14	Balanced	Balanced
sep-14	Balanced current year, downward risk next	Balanced
dec-14	Downward risk	Balanced
mar-15	Downward risk	Balanced
jun-15	Balanced	Balanced
sep-15	Downward risk	Balanced, upward risk in short run
dec-15	Balanced	Balanced
mar-16	Balanced	Balanced
jun-16	Balanced	Balanced
sep-16	Balanced	Balanced
dec-16	Balanced	Balanced
mar-17	Balanced	Balanced
jun-17	Balanced	Balanced
sep-17	Balanced	Balanced, downward risk in the short run
dec-17	Balanced	Balanced
mar-18	Upward risk	Balanced
jun-18	Upward risk	Balanced
sep-18	Balanced	Balanced
dec-18	Balanced	Balanced
mar-19	Upward risk	Balanced
jun-19	Downward risk	Balanced
sep-19	Downward risk	Balanced
dec-19	Downward risk	Balanced

Note: Authors' elaboration. The area marked in grey refers to MPRs analyzed in Figure 6. (*) refers to a forecast update delivered in form of presentation in November 2008. From December 2009 onwards MPRs are issued quarterly.
Source: Monetary Policy Reports.

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