Communicating uncertainty - a fan chart for HICP projections

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Economists use models and judgement to produce macroeconomic forecasts. In many institutions forecasts for variables such as inflation and gross domestic product (GDP) growth tend to be a single figure for a specific year or quarter (a "point" forecast), with a focus on the story behind the point forecasts.[1] However, the model generating projections is always an incomplete approximation of true economic behaviour. The model's parameters estimated from a sample are subject to an element of uncertainty. Furthermore, and perhaps more important, an economy is always hit by random shocks, so "surprises" occur from time to time. These factors introduce considerable uncertainty around any forecaster's outlook. Thus, it is normal to comment on the possibility that the future will not turn out as expected owing, for example, to unforeseen forces, such as higher than expected oil prices or a sudden episode of sub-par growth in trading partners' economies.[2]

The origin and use of the fan chart

An increasingly popular way to communicate risks to the central projection is to use a fan chart, a tool pioneered by the Bank of England.[3] A fan chart is a diagram which shows both the history and forecast of a variable, such as inflation, and the region in which future values of that variable are expected to fall. The fan chart embodies a density

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[1] In this article the terms *forecasts* and *projections* are used interchangeably.

[2] In a speech given at the University of London titled "Forecast errors" in May 2013, Ben Broadbent, external member of the Bank of Englands Monetary Policy Committee, gives a detailed description of the context in which forecasts are made. Available at:
http://www.bankofengland.co.uk/publications/Pages/speeches/2013/653.aspx

[3] The objective behind the Bank of England's creation of the fan chart was "to convey to the reader a more accurate representation of the Bank's subjective assessment of medium-term inflationary pressures, without suggesting a degree of precision that would be spurious." See Britton, E., P. Fisher and J. Whitley, "The Inflation Report projections: understanding the fan chart", *Quarterly Bulletin*, Bank of England, February 1998.

forecast, i.e. a forecast of the distribution of the projection, and not just the most likely path. A fan chart usually shows 90% of the probability distribution of the forecast. This means that if "economic circumstances at the start of the fan chart were to prevail on 100 occasions inflation [would be] expected to lie somewhere within the entire fan chart on 90 out of 100 occasions".[4]

The bands of the fan chart can either be constructed using stochastic simulation or by applying the average dispersion (variance) of historical forecast errors.[5] For instance, the initial calibration of the probability distribution of the Bank of England's projections is based on the history of forecast errors.[6] The distribution is initially assumed to follow the Normal distribution (the familiar bell-shaped curve) and may then be allowed to be skewed along one of the tails.[7] The central projection is represented by the mode, while the mean and median are used to assess the relative risks to the central forecast. If the mode, mean and median are identical, then the fan chart is symmetric. A symmetric fan chart implies that the outturns are expected to be either above or below the central forecast with equal probability, and inversely an asymmetric chart displays an unequal balance of risks.[8]

Thus, the fan chart can be seen as an *ex ante* expectation of uncertainty around a forecast, which is based on a set of conditioning assumptions. In this sense, the fan chart does not summarise all that can be expected to happen it characterises uncertainty around the central projection, which is only one out of possibly many scenarios.[9]

A number of central banks use fan charts in their communication of their projections to the public. A recent study lists 20 central banks which produce and publish fan charts, eight of which are in Europe, including, apart from the Bank of England, those of the Czech Republic, Poland, Hungary and Norway.[10] Indeed, the European Central Bank (ECB) started using fan charts to communicate uncertainty in its December 2013 projections.[11] The distribution used by the ECB is based on an estimate of mean absolute difference

[4] Elder, R., G. Kapetanios, T. Taylor and T. Yates, "Assessing the MPC's fan charts", *Quarterly Bulletin*, Autumn 45(3), Bank of England, 2005, p. 326.

[5] A forecast error is defined here as the actual inflation outturn less the projected year-on-year inflation rate.

[6] See Blake, A.P. "Forecast Error Bounds By Stochastic Simulation" *National Institute Economic Review* May 1996, for an illustration of generating uncertainty bounds using a model simulation. Typically, however, a number of models, as well as expert judgement, are used to construct the forecast. Hence the distribution tends to be based on the history of forecast errors and judgement rather than on pure model simulation.

[7] For this purpose, the Bank of England uses a "two-piece Normal" distribution. See footnote 4

[8] For a more complete treatment on density forecasting, see Tay, A.S. and K. Wallis, "Density Forecasting: A Survey", *Journal of Forecasting*, Vol. 19, 2000, pp. 235-254.

[9] For example, in its *Inflation Report* of May 2014, the Bank of England published two fan charts for inflation, one under a scenario in which future interest rates evolve according to market expectations, and another under the assumption of constant nominal interest rates in the future.

[10] Franta, M., J. Baruník, R. Horváth and K. Šmídková, "Are Bayesian fan charts useful for central banks? Uncertainty, forecasting, and financial stability stress tests", *Czech National Bank Working Paper Series* No. 10, Czech National Bank, 2011.

[11] See "Eurosystem Staff Macroeconomic Projections for the Euro Area", European Central Bank, December 2013.

between historical forecasts and the outturns, and the resulting fan chart displays a 57.5% confidence interval.[12]

Application: a fan chart for inflation projections for Malta

In this section a fan chart for the Central Bank of Malta's 12-month-ahead inflation projections, based on the Harmonised Index of Consumer Price (HICP), is constructed.[13] As the HICP is rarely revised, this is an ideal variable on which to apply this technique as any uncertainty in the forecast relates only to the future. Twelve months fall within the horizon considered in the Bank's short-term inflation forecast exercise. The latter is mainly based on time-series methods.[14]

All the vintages of inflation projections from December 2007 were collected and the one to the 12-month-ahead forecast errors for each vintage were calculated. Separate vectors for one-month ahead errors, two-month ahead errors, up to 12-month ahead errors were computed, along with a standard deviation for each vector.[15]

The vector of standard deviations of the forecast errors was then filtered to obtain a smooth series.[16] In turn, this was used to simulate the empirical probability distribution around the central projection.[17] In this way a probability distribution around the Banks inflation projections was built based on historical information about the projection errors. Chart 1 shows a recent HICP projection in the form of a fan chart, in which successive bands around the central projection capture an additional 15% of the probability distribution. This means that based solely on historical patterns of forecast errors, by 2015Q1 there would be:

- a 30% chance that inflation will be between 0.7% and 1.2%;
- a 60% chance of it being between 0.4% and 1.4%;
- a 90% chance that it will be between -0.1% and 1.8%.

We notice that the bands start off very narrow and then "fan out" over time. This is because as the forecast horizon extends into the future, the data reveal that uncertainty about the range of possible values for the indicator of interest increases. In other words, variables in the future become progressively harder to predict. Hence, as the Chart

[12] For more information, see "New Procedure for Constructing Eurosystem and ECB Staff Projection Ranges", European Central Bank, 2009. It is worth bearing in mind that the ECB forecast ranges represent a confidence interval of 57.5%, compared with an interval of 90% presented in this article.

[13] See Gatt, W. "Being vaguely right A fan chart for Maltese HICP inflation projections", forthcoming, for a technical explanation of the method used.

[14] See "Box 4: Forecasting inflation at the Central Bank of Malta", *Quarterly Review* 2012:4, p.68.

[15] An estimate for the one-month ahead standard deviation was computed using all one-month ahead forecast errors across all the forecast vintages, the two-month ahead standard deviation using all two-month ahead forecast errors across all vintages, and so on.

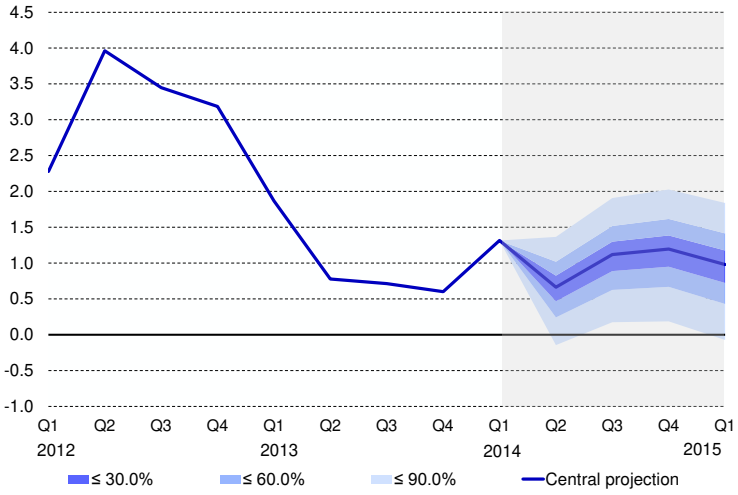
[16] This follows the method found in Oparty, T. and M. Gavura, "Estimating the probability distribution of an inflation forecast", *BIATEC* Volume XIII 5, National Bank of Slovakia, 2005.

[17] For the purpose of constructing a density forecast and hence a fan chart, the central projection is also considered as the mode, or peak, of the distribution.

shows, although each band above and below the central projection represents 15% of the distribution, the thickness of each band is not the same in each and every period, but increases as the band is stretched farther from the central projection.

Furthermore, because historically negative forecast errors (episodes in which inflation was overestimated) tended to be more dispersed (volatile) than positive forecast errors, following the approach used by the Bank of England the fan chart in Chart 1 is constructed such that the distribution is asymmetric, or skewed.[18]

Chart 1
A FAN CHART FOR HICP INFLATION PROJECTIONS
(annual percentage changes)



Sources: Central Bank of Malta; author's calculations.

In other words, there is slightly more uncertainty about the lower range (values below the central projection) than about the upper range (values above).

Generally speaking, it may well be that during a particular forecasting round risks to the central projection are judged to be balanced, resulting in symmetrical bands. In other instances, however, the forecaster may judge the balance of risks to be skewed to one side. For example, the forecaster may believe that there is a higher likelihood of oil prices being above rather than below the level incorporated in the baseline technical assumptions. This would result in the upper bands being wider than the lower bands.

In sum, although the starting point of a density forecast is historical information on forecast errors, through effective use of incoming information about the future the forecaster can always adjust the distribution to better fit the prevailing views about the economic environment and the associated risks to the projections.

Concluding remarks

This article has introduced the fan chart as an effective way of communicating the inherent uncertainty that surrounds a future outlook. This technique was applied to HICP inflation projections.

This article also presented a hypothetical fan chart, which offers a foundation for gauging the uncertainty that surrounds the Bank's forecasts. Such a fan chart can also form part of the forecast exercise, so that judgement about the outlook is also incorporated in the

[18] See footnote 4.

width of the bands. This means that the width of the bands can sometimes be narrower than historical errors would suggest, and sometimes wider, depending on the forecaster's best assessment of uncertainty given all available information.

It is a forecaster's job to form an opinion about a likely occurrence, subject to some assumptions about other driving forces, such as international oil prices. Therefore, a forecast is conditional on both technical assumptions and a particular scenario. Fan charts should neither be too wide, nor too narrow, but should be based on an *ex post* assessment of forecast accuracy. Furthermore, the width of the bands in the fan chart may vary between different forecasts; this would reflect the fact that the degree of uncertainty around the forecasts may vary over time, depending on the economic environment that prevails. Fan charts, therefore, are a useful tool to increase transparency surrounding projection exercises and to raise awareness of risk. "Public discussion of macroeconomic point forecasts too often treats them as exact, and to acknowledge explicitly that they are not, perhaps by publishing a density forecast, can only improve the policy debate."[19]

[19] Tay, A.S. and K. Wallis, "Density Forecasting: A Survey", *Journal of Forecasting*, Vol. 19, 2000, pp. 235-254.