HONG KONG MONETARY AUTHORITY

Research Memorandum 01/2019

24 January 2019

INTERPRETING SURVEY-BASED FEDERAL FUNDS RATE FORECASTS: HOW ACCURATE ARE THEY IN REFLECTING MARKET EXPECTATIONS?

Key Points:

- *What the market thinks is most likely to occur is not necessarily what the market expects to occur. This note explains why most of the surveys of federal funds rate outlook deviate substantially from the true market expectation, especially as the forecast horizon increases.*

- *Surveys often ask participants for their forecast of the "most likely outcome", which differs from the expected outcome. The latter has to take into account not only the most likely outcome but also those less likely to occur, that is, weighing all the possible outcomes by their probabilities.*

- *In a tightening (easing) cycle, the most likely outcome tends to be higher (lower) than the expected outcome, leading to a false impression that the Fed will tighten (ease) more than what the market expects. For instance, the latest surveys suggest market participants believe there will most likely be another two to three rate hikes by the end of 2020, but in fact they expect the rate to stay basically unchanged.*

- *As the probability distribution gets more skewed to the left in progressive surveys, the "most likely outcome" forecast is increasingly subject to a greater downside risk. This, coupled with the relatively small increase in the probability at the high end of the forecasting range, means that market participants can progressively see the light at the end of the tunnel, that is, the end of the tightening cycle.*

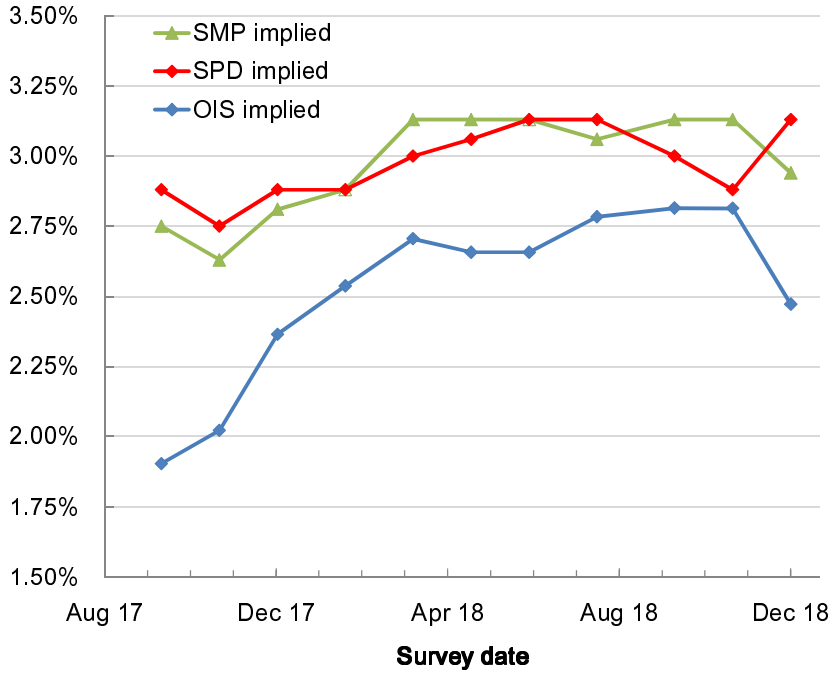
Prepared by : *Max Kwong, David Leung, Alfred Wong and Jiayue Zhang*
Hong Kong Monetary Authority

* The authors would like to thank Cho-hoi Hui, Estelle Liu and Jason Wu for invaluable comments and discussions, and Peter Lau for research assistance.

I. INTRODUCTION

The US interest rate outlook drawn from recent surveys of market participants tends to portray a more hawkish Fed than what the market actually expects. For example, the results of the Survey of Market Participants (SMP) and the Survey of Primary Dealers (SPD) in December 2018 suggest that the effective federal funds rate (EFFR) is most likely to fall in the target ranges of 2.75-3% and 3-3.25% by the end of 2020 respectively, that is, another two or three rate hikes from the current range (Chart 1).[1] However, this is far from where market participants are betting their money with. The overnight indexed swap (OIS) rate, a market-based measure of expected EFFR, implies that the EFFR would stay in the current range. So, who is right, and why is there such a difference?

Chart 1: Outlook for end-2020 federal funds rate at different survey dates



Sources: Federal Reserve Bank of New York, FOMC and Bloomberg.

To answer these questions it is important to understand that what these surveys are trying to predict does not necessarily equate to market expectations, the reason being that survey respondents are asked to provide their forecast of the "most likely outcome". This means they only need to predict the outcome with the highest probability. There is no need for them to consider those with lower probabilities. Hence, it is not the outcome they actually expect which, theoretically, is one of all possible outcomes weighted by their respective probabilities. Put another way, what

[1] See Appendix A for additional historical forecasts of SMP, SPD and OIS.

they actually expect is a probability-weighted average of all outcomes.

During a monetary tightening cycle, the probabilities of higher rate outcomes are almost certainly greater. As a result, the most likely outcome tends to exceed the expected outcome. By the same token, during a monetary easing cycle, survey findings tend to understate what the market expects. It is only when the chances of rate hikes and rate cuts are roughly balanced that survey findings come close to reflecting the true market expectation.

The objective of this note is to explain the popular misconception and provide an idea of the extent of the current bias. The remainder of this note is arranged as follows. In the next section we discuss survey-based measures, highlighting their major advantages and disadvantages. In Section III we do the same for two of the most popular market-based measures and evaluate their differences and past performances. Section IV compares survey-based and market-based forecasts. Section V concludes.

II. SURVEY-BASED FEDERAL FUNDS RATE FORECASTS

In this section, we review the advantages and disadvantages of survey findings in indicating the market-expected future US monetary policy stance. The key features of two major surveys are as follows:

Survey of Primary Dealers (SPD): The SPD is conducted by the Federal Reserve Bank of New York on primary dealers, usually two to three weeks before the FOMC meeting. The primary dealers are asked to give the "most likely outcome" of the target range they perceive. The median, the 25th and 75th percentiles of their answers are reported to the public. They are also asked to give the probability distribution of various policy rate target ranges conditional on certain scenarios.

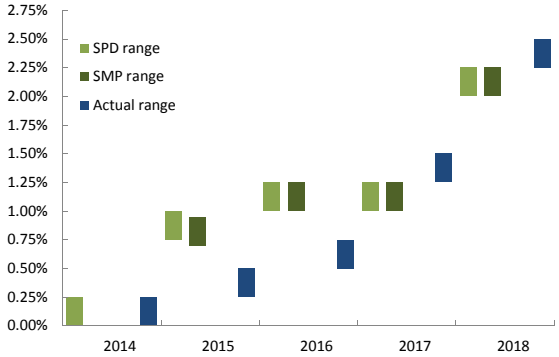
Survey of Market Participants (SMP): The SMP is similar to the SPD in terms of objective and methodology, but covers broader respondents including buy-side firms associated with four of the Federal Reserve Bank of New York advisory and sponsored groups who represent active

investment decision makers beyond primary dealers.[2] The SMP survey results are publicly available in conjunction with the SPD. The SMP also asks respondents their modal expectation for the path of the policy rate, as well as the probability distribution for certain dates.

Compared with market-based forecasts, these survey-based gauges have the advantage of being free of risk premium, with uncertainties captured by the disagreement among survey participants, which is reflected in the statistical distribution of their forecasts. Their main drawbacks are low frequency and limited number of forecast dates due to the time-consuming process of conducting the survey. In addition, they have a relatively short history: the SPD was first conducted in 2011 and the SMP in 2014.

Chart 2 presents the one-year-ahead forecasts from the two surveys and the FOMC's target ranges determined subsequently. As mentioned above, the survey forecasts are the modal expectations of the respondents, which tend to be higher than the probability-weighted mean expectations during a rate hike cycle. The mean-mode difference makes the survey forecast a biased estimator of the expected federal funds rate, as reflected in the sizeable gap between the one-year-ahead survey forecasts and the actual target ranges in 2015-16. It should also be noted that such bias may vary over time, depending on the skewness of the probability distribution function of the respondents at the time the surveys are taken. A more in-depth comparison between the modal and mean expectations of the two surveys can be found under Section V.

Chart 2: One-year-ahead survey forecasts and realised federal funds targets



Sources: Federal Reserve Bank of New York and Bloomberg.

[2] The four groups are the Investor Advisory Committee on Financial Markets, the Foreign Exchange Committee, the Treasury Market Practices Group, and the Buyside General Counsel Committee.

III. MARKET-BASED FEDERAL FUNDS RATE FORECASTS

Alternatively, monetary policy expectations can also be extracted from interest rate derivatives. Unlike surveys, market data are available continuously during trading hours, allowing close monitoring of the market's view. Arguably, they are also more credible than surveys since market participants "put their money where their mouths are". If we assume market participants are risk-neutral (that is, they only care about expected returns and are indifferent to the risks involved), then the prices of these instruments reflect only a probability-weighted expectation of the EFFR. In reality, however, market participants are usually risk-averse and hence demand a compensation for the risk they take. Therefore, a risk premium is built into the market price. Consequently, market-based forecasts are also generally higher than the true market expectations, particularly during periods of market stress where the risk premium tends to be higher than in normal times. In any case, if the risk premium is high, it will only reinforce the argument that survey-based measures overstate market expectations, as even market-based measures, which are much lower, are also likely to exceed market expectations. In this note, we focus on two most popular instruments, the Fed funds futures and the OIS.

a. Fed funds futures

Fed funds futures are commonly employed to hedge interest rate risk or speculate on interest rate movements. Conceptually, a buyer (seller) of Fed funds futures agrees to lend (borrow) at a predetermined interest rate (as reflected in the price of Fed funds futures).[3] The buyer will sell (buy) Fed funds futures if the implied EFFR is lower (higher) than the buyer's expected rate. Therefore, the price of Fed funds futures should reflect the perceived probability-weighted average of the EFFR.[4] Appendix B shows details of how EFFR expectations can be extracted. However, there are three drawbacks of using Fed funds futures to gauge monetary policy expectations:

Bias of risk premium: As investors are generally risk-averse and willing to pay a premium to avoid uncertainty, the price of Fed funds futures is generally higher than the probability-weighted average of the EFFR. Appendix C gives a hypothetical example to illustrate how the risk premium overstates the

[3] In practice, only the difference between the market and settlement rates would be paid by one party to another on settlement and there is no actual provision of loan involved. The settlement date is on the final business day of the delivery month.

[4] Please refer to Appendix B for the equations related to the pricing of Fed funds futures.

risk-neutral expectation of the EFFR.

Low liquidity at the long end: While Fed funds futures traded on the Chicago Board of Trade are available for 36 calendar months, liquidity (as measured by open interest) tends to concentrate on the first nine months. Hence, there are doubts as to how well the futures prices can reflect market expectations at the longer end.

Lack of opinions dispersion: As a point forecast, the futures-implied EFFR does not indicate the dispersion of opinions. A 25bps increase in the implied EFFR may mean many possibilities, such as (i) market participants are 100% certain about a 25bps hike, or (ii) market participants expect a 50% chance of a 50bps rate hike and another 50% chance of no rate hike at all. Unless we restrict the outcomes of an FOMC meeting to two (either no action or a 25bps move), we cannot tell the chance of a rate hike or rate cut.[5]

b. *Overnight indexed swaps (OIS)*

The OIS is a floating-for-fixed interest rate swap, whose floating leg is the geometric mean of an overnight index rate (the EFFR for the US dollar), and the fixed leg (the OIS rate) is calculated by traders such that an OIS contract has zero initial cost. Therefore, the OIS rate, which can be regarded as the expected average policy rate throughout the term of maturity, is widely used to hedge against changes in the policy rate. Unlike Fed funds futures, which mature at month-ends, the OIS can be constructed flexibly to provide expectations over a variety of dates. Indeed, it is possible to construct a "meeting-to-meeting" OIS contract covering the exact period between two FOMC meetings, in order to express views on the anticipated rate decision of the policy meeting.[6] Under certain assumptions, the implied probability of FOMC rate decisions can be extracted.[7]

However, like Fed funds futures, the OIS-implied policy rate is also subject to distortion by risk premium. For example, Chang and Feunou (2013) show that the Canadian dollar OIS rate includes a time-varying risk premium

[5] For details on the methodology, see http://www.cmegroup.com/education/fed-funds-futures-probability-tree-calculator.html.

[6] The fixed rate for a meeting-to-meeting OIS should be close to the expected target range mid-point, assuming no anticipation of inter-meeting rate changes (Cheng et al., 2010). In the following section, however, we use standardised instead of meeting-to-meeting OIS to estimate the expectation for EFFR after FOMC meetings, since OIS with standardised maturities are much more liquid than meeting-to-meeting OIS. For details, see Appendix C.

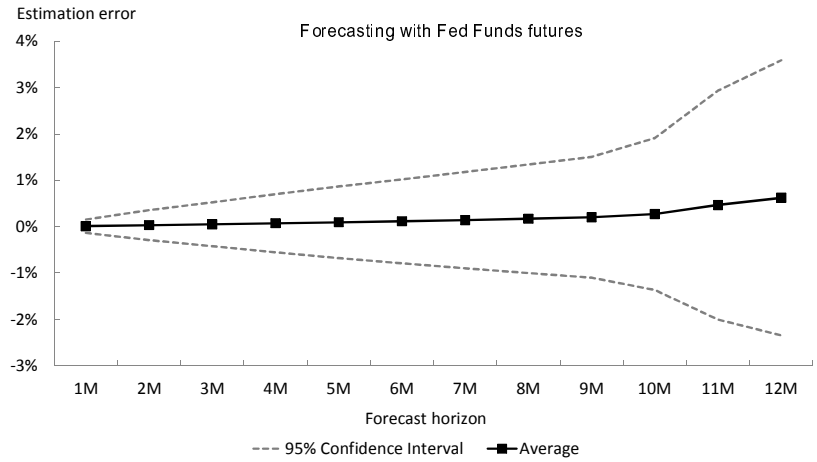
[7] For example, Bloomberg's World Interest Rate Probability (WIRP) function provides FOMC decision probability derived from OIS by assuming i) the outcome of future FOMC is either no change or a fixed hike/cut, ii) the EFFR after a rate change is the mid-point of the target range, and iii) linear interpolation.

ranging from -0.4% to 0.6% for the 3-month tenor and -0.5% to 1.6% for the 9-month tenor. Similarly, Sundaresan et al. (2017) decompose the OIS term spread into expectation and risk premium components using a Fed-CIR model adapted to the Fed's open market operations, and find that the risk premium in the six-month-one-week US dollar OIS term spread is always positive (around 0.1 percentage point depending on the model specification). Therefore, one should caution that a higher OIS rate may be driven by increased risk premium rather than expectation of a higher policy rate.

c. *Fed funds futures vs OIS: Which performs better?*

The difference between the implied EFFRs of Fed funds futures and the OIS is fairly small, which is understandable as any large differences presumably would invite arbitrage to a considerable extent (although it is important to bear in mind that it is not always possible to perfectly replicate the payoff structure using the other instrument).[8] In terms of forecasting performance, both instruments work equally well for the shorter term (nine months or less), with the average estimation errors close to zero. However, beyond nine months, the performance of the Fed fund futures-based forecasts deteriorates significantly. This is attributable to the lack of active trading on longer-term Fed funds futures.[9] Charts 3 and 4 compare the forecasting performance of Fed funds futures and OIS for the period between May 2003 and March 2018 when both instruments are available.

Chart 3: Performance of Fed funds futures in forecasting EFFR

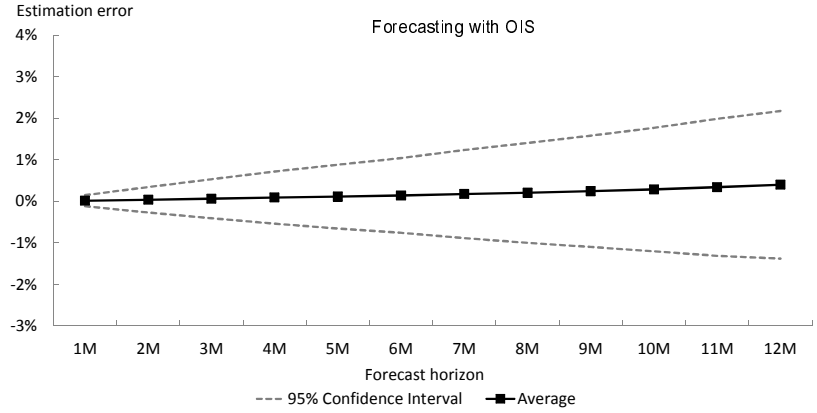


Sources: Bloomberg and HKMA staff estimates.

[8] While the payoffs of Fed funds futures and OIS are determined by the arithmetic mean and geometric mean of EFFR respectively, their implied rates are comparable after adjustment. For example, the average difference (in absolute value) between the two is approximately 2.5bps (ranging from -5.8 bps to 6.8 bps) across an 11-month horizon that covers eight FOMC meetings at 23 July 2018.

[9] We also compare the root-mean-squared errors (RMSE) of the two forecasts and the results are similar.

Chart 4: Performance of OIS in forecasting EFFR



Sources: Bloomberg and HKMA staff estimates.

In the next section, let's focus on the OIS-implied rate when compared with survey-based forecasts given the more favourable forecasting performance of OIS, since there is little difference between the implied EFFRs of the two instruments.

IV. COMPARING SURVEY-BASED AND MARKET-BASED FORECASTS

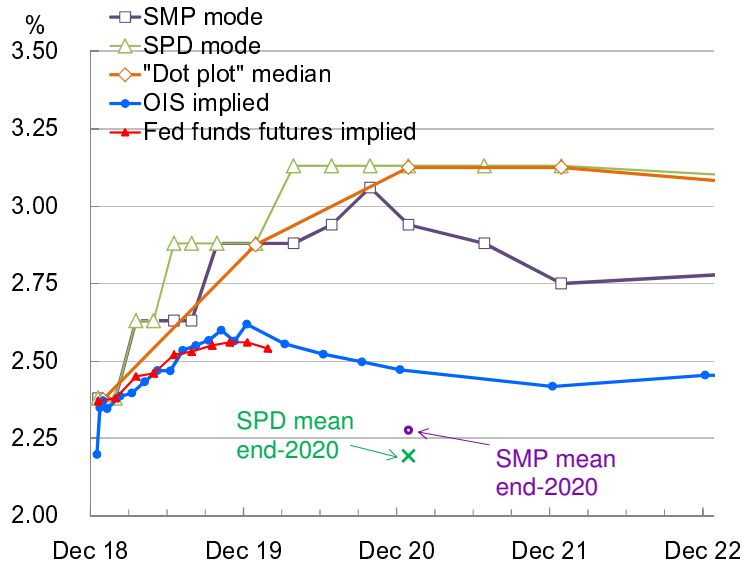
Chart 5 shows the forecasts of the US federal funds rate target range according to survey-based measures (with hollow markers) and market-based measures (with solid markers) at 10 December 2018. As can be seen, those survey-based forecasts are significantly higher than the market-based ones over the medium to longer horizons. As discussed earlier, this is due to the fact that the survey-based forecasts are actually modal expectations whereas the market-based measures are mean expectations plus a risk premium. Given the current market outlook where a rate hike is much more likely than a rate cut, the probability distribution for future rates is skewed to the left, causing modal expectations to be higher than mean expectations.

Without the risk premium, the bias is even larger. To show this, we extract the probability-weighted mean expectation from SMP and SPD (dots in Chart 5) based on the probability distributions.[10] Since the SPD and SMP means are weighted by the probabilities perceived by survey participants, rather than the probabilities consistent with the price of the market instrument, they do not contain a risk premium component. Therefore, the survey-based means are lower than the

[10] The surveys only report probability distributions on 2-3 dates (compared with modal expectations reported on 14-15 dates). As a result, the probability-weighted mean is only available on a few dates based on each survey. Therefore, we can only plot two data points in Chart 5. For details about obtaining the mean expectation from surveys, see Appendix D.

means implied from market-based measures due to the risk premium.[11]

Chart 5: Survey-based and market-based expectations of US federal funds rate at 10 December 2018



Notes:
1. "SMP mode" and "SPD mode" are the median of all respondents' modal expectations of federal funds target. "SMP mean" and "SPD mean" are based on the average probability of all responses. "'Dot plot' median" is the median of all FOMC participants' appropriate federal funds target.
2. "OIS implied" is the risk-neutral probability weighted average of EFFR immediately after FOMC meetings before end-2018, and the geometric average of expected EFFR over the quarter (or the year) after 2019. "Fed funds futures implied" is the risk-neutral probability weighted average of EFFR immediately after FOMC meetings.

Sources: Federal Reserve Bank of New York, FOMC, Bloomberg, CME Group and HKMA staff estimates.

V. COMPARING SURVEY-BASED MEAN AND MODAL FORECASTS

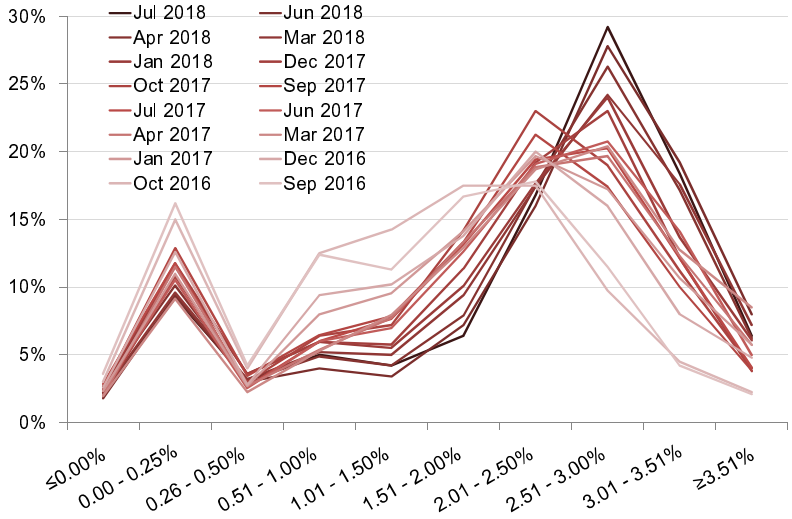
In this section we repeat the above exercise for the surveys prior to June 2018 to analyse how market views have changed in recent years in regard to the current process of monetary normalisation.

First, we observe that the mean forecast has increased considerably in the surveys over the past few years. This suggests that expectations for a faster pace of monetary tightening have been on the rise. However, it is useful to note that the increase in the mean forecast is not principally a result of the whole distribution proportionally shifting to the right, as can be seen in Charts 6 and 7, which plot the probability distribution of the end-2019 policy rate forecasts as an example. Rather, it is more of a result of the mean being pulled up by the increase in the mode, as the probability distribution gets increasingly skewed to the left. In general, at the high

[11] A similar exercise by the Federal Reserve Bank of New York in 2016 shows that the risk premium can be negative. See "Reconciling survey- and market-based expectations for the policy rate" for more information.

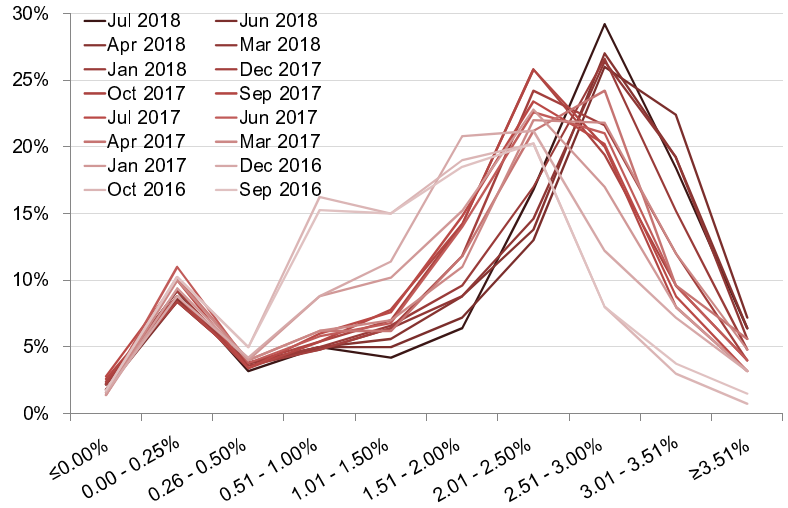
end of the forecasting range the probability has increased only at a gradual pace, especially since the beginning of 2017.

Chart 6: Probability distribution of expected target range at end-2019 (SMP)



Sources: Federal Reserve Bank of New York and HKMA staff estimates.

Chart 7: Probability distribution of expected target range at end-2019 (SPD)



Sources: Federal Reserve Bank of New York and HKMA staff estimates.

As the distribution gets more skewed, the mode increases at a faster rate than does the mean. Tables 1 and 2 show the gap between the mean and the mode in the surveys prior to December 2018, where the right-most column represents the average gap for ten of the approximately three-year-ahead forecasts (framed in black) for ease of comparison. The gap emerged just before the Fed increased its policy rate for the first time in this cycle at the end of 2015, but has since risen considerably. The gap averaged 0.08% in the SPD and 0.04% in the SMP prior to the first rate hike, but rose to 0.87% in SPD and 0.88% in SMP more recently. In Charts 8 and 9, the black dotted lines denote the mean-mode gap in its

three-survey moving average for the same yearend. To show the general upward trend of the gap, the red line connects the black dotted lines, with the simple average taken of any two overlapping moving average mean-mode gaps in the same survey despite the fact that these gaps actually refer to the forecasts for different yearends.

The widening mean-mode gap implies that the bias or exaggeration of how much the Fed is going to tighten has also increased. With the distribution becoming more skewed, the probabilities of the future policy rate falling below the mode increasingly outweighed the probabilities falling above. This means market participants have increasingly priced in a greater downside risk to the policy rate forecast.

Table 1: Difference between mode and mean expectations in SPD

	Projection date							
Survey date	end-2014	end-2015	end-2016	end-2017	end-2018	end-2019	end-2020	Average
22/04/2014	-0.01%	0.16%	0.16%					
21/07/2014	-0.01%	0.05%	0.20%					
20/10/2014	0.00%	0.15%	0.27%	0.12%				0.08%
08/12/2014		0.19%	0.30%	0.12%				
20/01/2015		0.13%	0.30%	0.17%				
09/03/2015		-0.05%	0.03%	0.24%				
20/04/2015		0.06%	0.24%	0.10%				
08/06/2015		0.12%	0.12%	0.04%				
20/07/2015		0.18%	0.15%	-0.10%				
08/09/2015		0.04%	0.01%	-0.27%				
19/10/2015		0.18%	0.14%	0.17%	0.43%			0.50%
07/12/2015			0.08%	0.17%	0.43%			
19/01/2016				0.58%	0.81%			
07/03/2016				0.21%	0.86%			
18/04/2016				0.26%	0.74%			
06/06/2016				0.35%	0.59%			
18/07/2016				0.09%	0.34%			
12/09/2016				0.07%	0.28%	0.62%		
24/10/2016					0.29%	0.53%		0.59%
05/12/2016					0.28%	0.62%		
23/01/2017					0.26%	0.54%		
06/03/2017					0.37%	0.62%		
24/04/2017					0.33%	0.61%		
05/06/2017					0.43%	0.74%		
17/07/2017					0.42%	0.59%		
11/09/2017					0.40%	0.46%	0.91%	
23/10/2017						0.59%	0.78%	0.87%
04/12/2017						0.61%	0.88%	
22/01/2018						0.53%	0.80%	
12/03/2018						0.70%	0.88%	
23/04/2018						0.68%	0.90%	
04/06/2018						0.63%	0.98%	
23/07/2018						0.64%	1.00%	
17/09/2018						0.61%	0.82%	
29/10/2018							0.69%	
10/12/2018							0.94%	

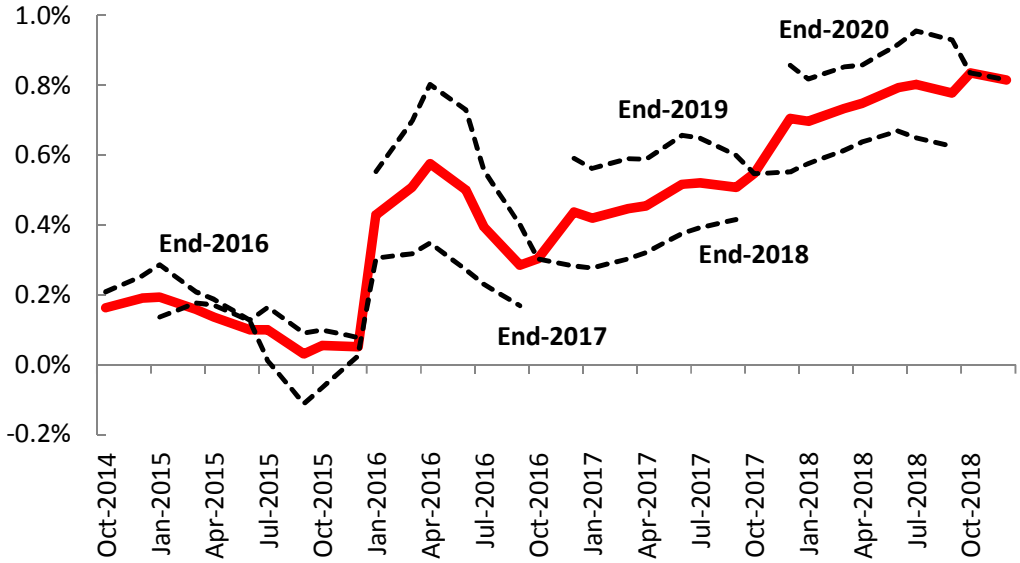
Sources: Federal Reserve Bank of New York and HKMA staff estimates.

Table 2: Difference between mode and mean expectations in SMP

	Projection date							
Survey date	end-2014	end-2015	end-2016	end-2017	end-2018	end-2019	end-2020	Average
22/04/2014	-0.01%	0.33%	0.13%					
21/07/2014	-0.01%	0.20%	0.15%					
20/10/2014	0.00%	0.00%	0.16%	0.38%				0.04%
08/12/2014		0.10%	0.14%	0.38%				
20/01/2015		0.00%	0.26%	0.19%				
09/03/2015		0.13%	0.24%	0.33%				
20/04/2015		0.07%	0.11%	-0.04%				
08/06/2015		0.11%	0.18%	-0.24%				
20/07/2015		0.15%	0.18%	-0.41%				
08/09/2015		0.01%	0.05%	-0.40%				
19/10/2015		0.18%	-0.01%	0.16%	0.09%			0.37%
07/12/2015			0.10%	0.04%	0.13%			
19/01/2016				0.53%	0.76%			
07/03/2016				0.36%	0.90%			
18/04/2016				0.13%	0.40%			
06/06/2016				0.22%	0.38%			
18/07/2016				0.04%	0.22%			
12/09/2016				0.23%	0.29%	0.64%		
24/10/2016					0.31%	0.63%		0.70%
05/12/2016					0.23%	0.59%		
23/01/2017					0.45%	0.63%		
06/03/2017					0.28%	0.71%		
24/04/2017					0.35%	0.66%		
05/06/2017					0.34%	0.79%		
17/07/2017					0.43%	0.76%		
11/09/2017					0.36%	0.80%	0.91%	
23/10/2017						0.67%	0.70%	0.88%
04/12/2017						0.81%	0.93%	
22/01/2018						0.84%	0.89%	
12/03/2018						0.69%	1.03%	
23/04/2018						0.72%	1.07%	
04/06/2018						0.61%	0.93%	
23/07/2018						0.64%	0.84%	
17/09/2018						0.77%	0.89%	
29/10/2018							0.81%	
10/12/2018							0.66%	

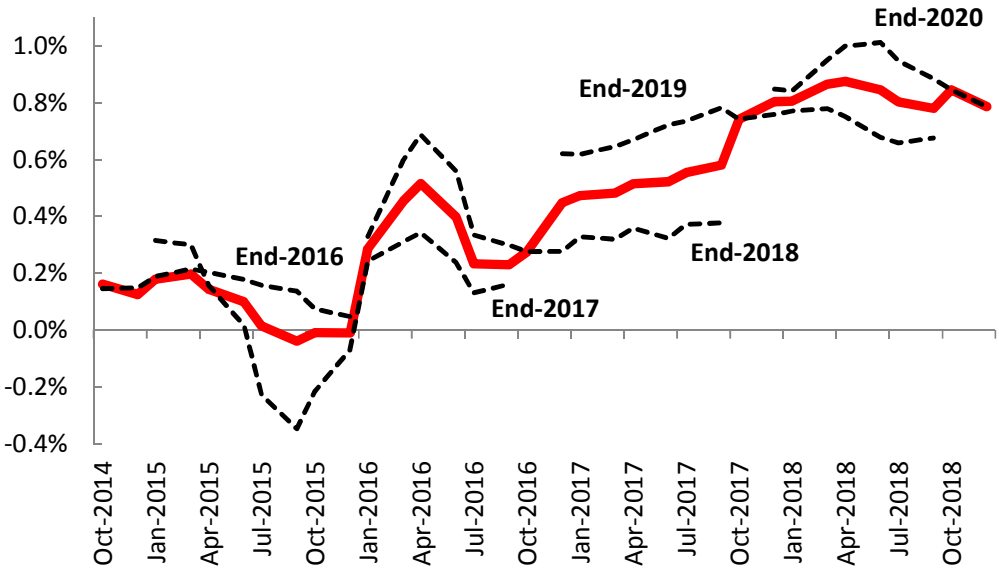
Sources: Federal Reserve Bank of New York and HKMA staff estimates.

Chart 8: Mean-mode gap in SPD (3-survey moving average)



Sources: Federal Reserve Bank of New York and HKMA staff estimates.

Chart 9: Mean-mode gap in SMP (3-survey moving average)



Sources: Federal Reserve Bank of New York and HKMA staff estimates.

Notwithstanding the rising mean and mode, the overall forecasting range has registered relatively little change. At the high end of the range (above 3.5%) the probability has increased at a much more gradual pace than at around the mode. Hence, as the distribution becomes increasingly skewed and the mode moves higher, the slope of the distribution at the higher end (e.g., from the mode) gets steeper. In other words, the probability of the higher rate outcomes reduces at a faster pace survey after survey, reflecting that market participants are more able to see the light at the end of the tunnel, i.e., the market believes the tightening cycle is getting increasingly nearer to its end as the Fed tightens.

VI. CONCLUDING REMARKS

In sum, surveys grossly overstate how much the Fed is going to tighten monetary policy in the coming years. The problem is that they focus on the most likely outcome which, in light of the prevailing market conditions, is highly misleading. The bias is caused by the modal expectation exceeding the probability-weighted expectation by a wide margin, reflecting the distribution of forecasts being significantly skewed away from higher-rate outcomes in a tightening cycle. For example, while the latest SMP and SPD suggest that the federal funds rate will most likely reach the 2.75-3.25% range by the end of 2020, the OIS shows that the rate will fall within 2.25-2.50%, a range that is much closer to the true market expectation. As the distribution becomes increasingly skewed in progressive surveys, the bias has increased markedly over recent years. This, combined with a fairly stable overall forecasting range, suggests that the downside

risk to the survey forecast has increased considerably as market participants see the current tightening cycle move closer to an end.

REFERENCES

Brodsky, B., Del Negro, M., Fiorica, J., LeSueur, E., Morse, A., & Rodrigues, A. (2016). Reconciling survey- and market-based expectations for the policy rate. *Liberty Street Economics,* *http://libertystreeteconomics.newyorkfed.org/2016/04/reconciling-survey-and-market-basedexpectations-for-the-policy-rate.html* .

Chang, B. Y., & Feunou, B. (2013). Measuring uncertainty in monetary policy using implied volatility and realized volatility. *Bank of Canada Working Paper,* No. 2013-37.

Cheng, M., Dorji, S. L., & Lantz, C. (2010). A guide to the front-end and basis swap markets. *Basis points, Credit Suisse, Fixed Income Research.*

Nosal, E. (2001). How well does the Fed funds futures rate predict the future federal funds rate? *Federal Reserve Bank of Cleveland, Economic Commentary, October*, 1-4.

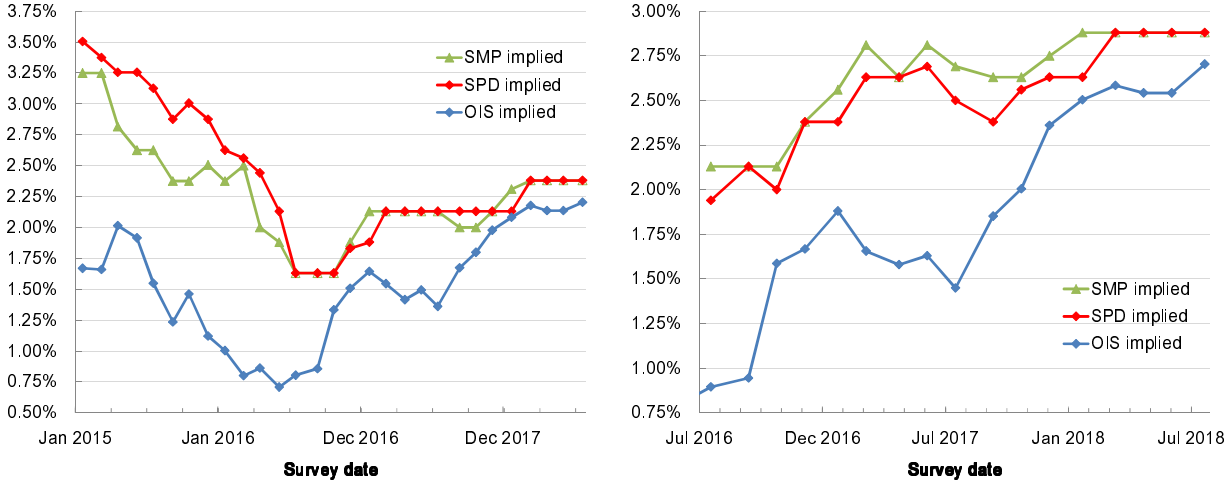
Piazzesi, M., & Swanson, E. T. (2008). Futures prices as risk-adjusted forecasts of monetary policy. *Journal of Monetary Economics*, *55*(4), 677-691.

Sundaresan, S. M., Wang, Z., & Yang, W. (2017). Dynamics of the expectation and risk premium in the OIS term structure. *Kelley School of Business Research Paper*, No. 17-41.

APPENDIX A: FORECAST HISTORY OF FEDERAL FUNDS RATES

As can be seen in Chart A1, the end-2018 and end-2019 forecasts over the past few years show the trend of a quickening pace of rate hikes since September 2017, which is similar to the trend shown in the end-2020 forecast in Chart 1. Over the same period, the OIS-implied federal funds rate increases at a faster pace than that in the surveys, reducing the differences between these two types of measures.

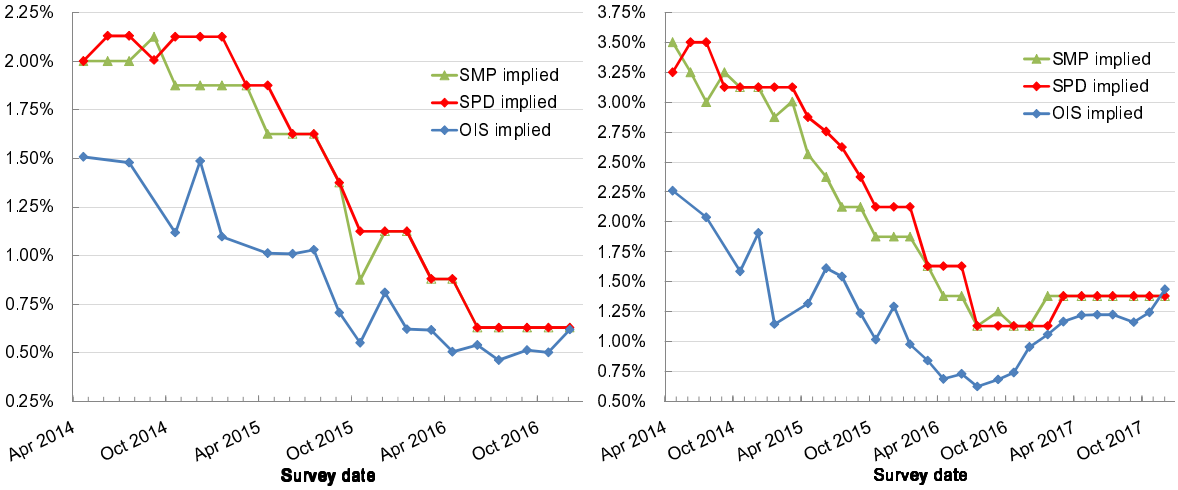
Chart A1: Outlook for the federal funds rate at the end of 2018 (left panel) and 2019 (right panel)



Sources: Federal Reserve Bank of New York, FOMC and Bloomberg.

Regardless of the level of the expected rate, however, the spread between survey-implied and OIS-implied federal funds targets continues to shrink as the forecast date is drawing close. This is even more evident for earlier forecast dates where we can evaluate the forecast history against the realised outcome (Chart A2).

Chart A2: Outlook for the federal funds rate at the end of 2016 (left panel) and 2017 (right panel)



Sources: Federal Reserve Bank of New York, FOMC and Bloomberg.

Chart A2 shows that survey-implied and OIS-implied rates only converge to the same 0.25% band as the realised rate two to three months ahead of the realisation, before which the gap between these two measures remains sizable. Therefore, it is crucial to understand this tangible spread between survey- and market-based measures.

APPENDIX B: PRICING MECHANISM

B1 FED FUNDS FUTURES

The settlement price of Fed funds futures is calculated as 100 minus the arithmetic average of the daily EFFR over the month.

$$Fed\ funds\ futures\ settlement\ price = 100 - \frac{\sum_{i=1}^{n} Realised\ (EFFR_i)}{Days_n}$$

where n = the total number of days in the contract month.

The expected EFFR embedded in the prices of Fed funds futures can be extracted as follows:

$$Current\ Month\ Futures\ Price = 100 - \left[\frac{\sum_{i=1}^{j} realised\ (EFFR_i)}{Days_n} + \frac{\sum_{i=j+1}^{n} expected\ (EFFR_i)}{Days_n}\right]$$

$$Deferred\ Month\ Futures\ Price = 100 - \frac{\sum_{i=1}^{n} expected\ (EFFR_i)}{Days_n}$$

$$Expected(EFFR) = \sum_{k=1}^{m} EFFR_k\ P(EFFR_k)$$

where j = number of days passed to date;
m = number of possible outcomes.

B2 OIS

An n-day OIS can be calculated as below.[12]

$$OIS_{0,n} = \left(\prod_{i=0}^{n}\left(1 + \frac{expected(FER_i)}{360}\right) - 1\right) * \frac{360}{n}$$

If we suppose two consecutive FOMC meetings happen on day *m* and day *n*, the OIS rate between these two meetings can be expressed as

[12] The day-count convention in the OIS market is 360 days per annum.

$$OIS_{m,n} = \left(\prod_{i=m}^{n} \left(1 + \frac{expected(FER_i)}{360} \right) - 1 \right) * \frac{360}{n-m}$$

or

$$OIS_{m,n} = \left(\frac{OIS_{0,n} * \frac{n}{360} + 1}{OIS_{0,m} * \frac{m}{360} + 1} - 1 \right) * \frac{360}{n-m}$$

APPENDIX C: DISTORTION OF MARKET-BASED FORECAST BY RISK PREMIUM

Consider a scenario where individual A is risk-averse and has a *concave* utility function as follows:

$$Utility = Log\ (Asset - Liability)$$

Individual A pays an interest rate equivalent to the average EFFR on his $5mn outstanding loan and he considers that there is a 50-50 chance for the average EFFR to be at either 2% or 4% in the next 12 months. Assuming the only asset he holds is a fixed-rate time deposit which provides him with a guaranteed payment of $5,300,000 in a year, his expected utility is 5.151 if he chooses to do nothing to hedge against the interest rate risk (Table C1).

Table C1: Calculation of expected utility of individual A (without hedging)

EFFR	Probability	Asset	Liability = $5,000,000 x (1+EFFR)	Asset - Liability	Probability x (Asset - Liability)	Utility = Log(Asset - Liability)	Expected Utility
2.00%	50%	$5,300,000	$5,100,000	$200,000	$100,000	5.301	2.651
4.00%	50%	$5,300,000	$5,200,000	$100,000	$50,000	5.000	2.500
							5.151

Alternatively, he can lock in his interest expense by taking a short position on Fed funds futures.[13] If the realised EFFR is above the implied rate, he would make a profit from the contract, covering the extra interest expense on his loan. If the realised EFFR ends up below the implied rate, the saved interest expense from his loan could be used to settle his short position on the futures. Assuming that the Fed funds futures are traded at the probability-weighted rate of 3% (= 2% x 50% + 4% x 50%), individual A's wealth would be at $150,000 regardless of the actual EFFR realised in a year's time (Table C2).

Table C2: Calculation of expected utility of individual A (with hedging)

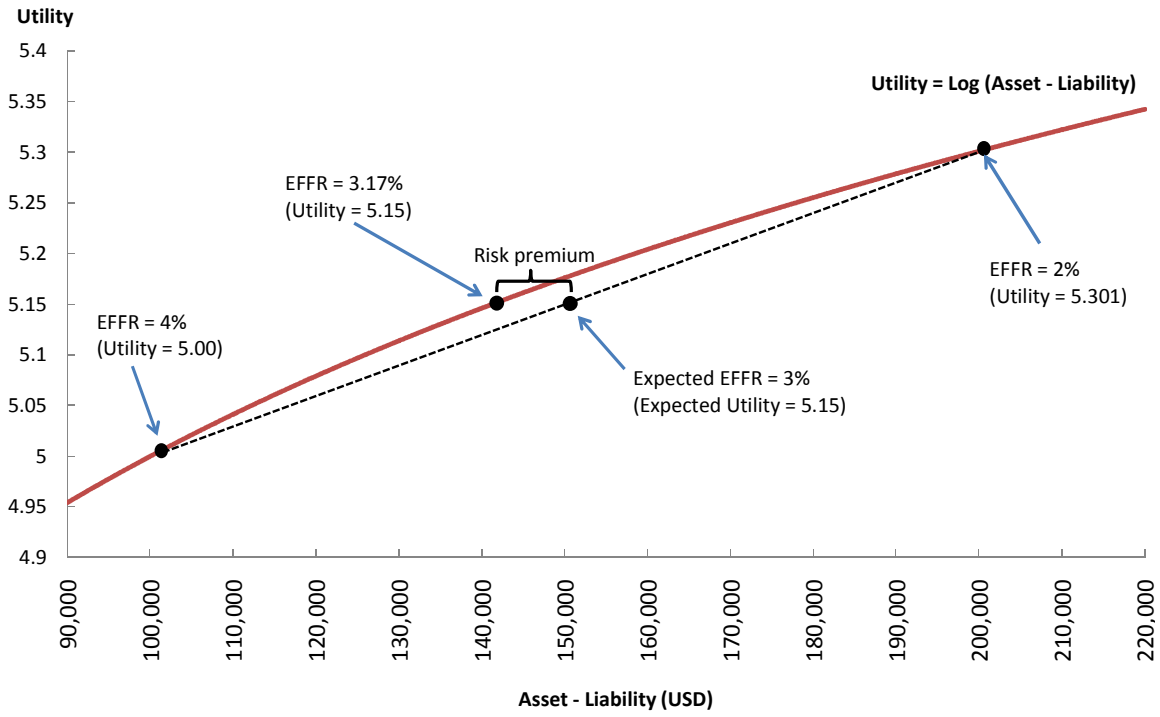
EFFR	Probability	Asset	Liability = $5,000,000 x (1+EFFR)	Increase in asset / (liability) due to Fed Funds futures	Asset - Liability	Probability x (Asset - Liability)	Utility = Log(Asset - Liability)	Expected Utility
2.00%	50%	$5,300,000	$5,100,000	($50,000)	$150,000	$75,000	5.176	2.588
4.00%	50%	$5,300,000	$5,200,000	$50,000	$150,000	$75,000	5.176	2.588
								5.176

The higher expected utility in Table 3B suggests that individual A is

[13] For illustration purpose, the settlement price of the Fed funds future in this example is assumed to be determined using EFFR over a 12-month period. In reality, the settlement price of a standard Fed funds future is determined using average EFFR over a 1-month period.

actually willing to accept a lower price (i.e., a higher implied rate) on the Fed funds future he sells. Based on his utility function, the maximum interest rate he will accept to maintain the same level of expected utility without the hedging is 3.17% (Chart C1). From this example, we can see that risk aversion of Fed funds futures participants could cause the market-implied EFFR (3.17%) to differ from the probability-weighted average of EFFR (3%). The difference is known as risk premium. From this example, we can see that the level of the risk premium depends on the difference between each outcomes and the degree of uncertainty involved.

Chart C1. Utility function of individual A



An empirical study by Nosal (2001) estimates that the risk premium was 0.187% on average in the period from April 1989 to October 2001. A subsequent study by Piazzesi and Swanson (2008) using data from October 1988 to December 2005 finds that the risk premium was time-varying and had a strong correlation with macroeconomic factors and corporate yield spreads. Based on their model, it is estimated that the annualised risk premium on 4-month-ahead Fed funds futures could vary from about -40 bps to 260 bps, depending on the economic conditions.[14] As discussed in Brodsky et al. (2016), the direction and magnitude of the risk premium also depend on the market's relative aversion to each possible outcome at the time the instruments are traded. If an increase (decrease) in interest rate is considered to be an unfavourable outcome, additional

[14] Piazzesi and Swanson (2008) found that the risk premium is countercyclical and inversely related to the employment growth.

compensation would be required by the buyer (seller) of Fed funds futures when he determines his bid (ask) price. This would in turn lead to an overstatement (understatement) of the probability-weighted federal funds rate. As such, proper calibrations are required before the estimates can measure interest rate expectation.

APPENDIX D: ESTIMATING THE PROBABILITY-WEIGHTED MEAN FROM SURVEYS

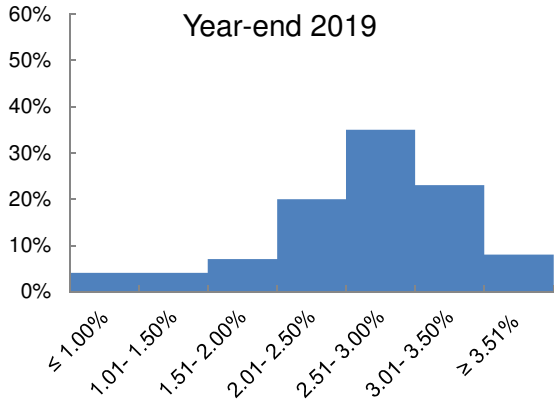
To compare the expectation from survey- and market-based measures, we construct the mean expectation from SMP and SPD, following a similar methodology adopted by Brodsky et al. (2016). The idea is to obtain the probability distribution function (PDF) from the survey and, based on certain assumptions, calculate the probability weighted mean expectation.

Among the questions in SMP and SPD, one particularly asks the "percentage chance" attached to a number of federal funds rate target ranges at the end of the coming two to three years. Based on the responses to this question, we can infer the PDF of an average survey respondent. Since 2016, the question is further expanded to three parts, asking the PDFs conditional on two scenarios, and the probability of each scenario. Based on the PDF(s) and some regular assumptions, we can calculate the probability-weighted mean expectation.

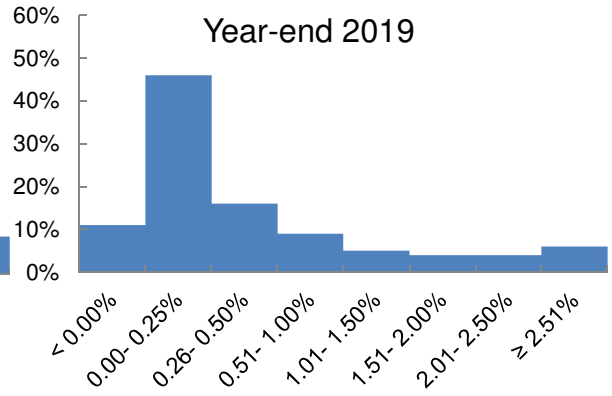
Take the SMP in March 2018 as an example. The PDF conditional on the first scenario (not moving to zero lower bound (ZLB)) shows the average percentage chance attached to seven interest rate bands from below 1.00% to above 3.51% (Chart D1). The PDF conditional on the second scenario (moving to ZLB) reports the average percentage chance attached to 8 interest rate bands from below 0.00% to above 2.51% (Chart D2).

Chart D1. Conditional PDF of federal funds rate target at end-2019 from SMP

Conditional on not moving to ZLB:



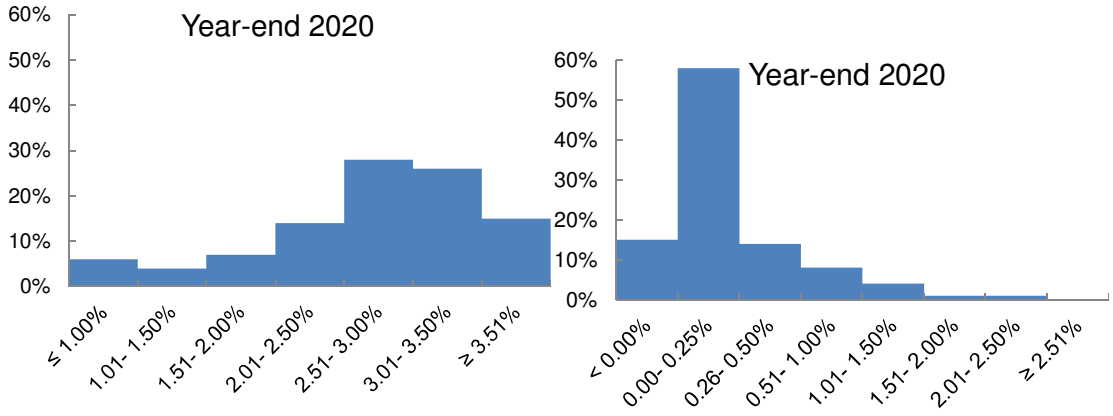
Conditional on moving to ZLB:



Source: Federal Reserve Bank of New York

Chart D2. Conditional PDF of federal funds rate target at end-2020 from SMP

Conditional on not moving to ZLB: Conditional on moving to ZLB:



Source: Federal Reserve Bank of New York

Next, we aggregate the information above to generate the unconditional PDF based on two assumptions:

I. The median probability of moving to ZLB is equal to an average respondent's estimate.

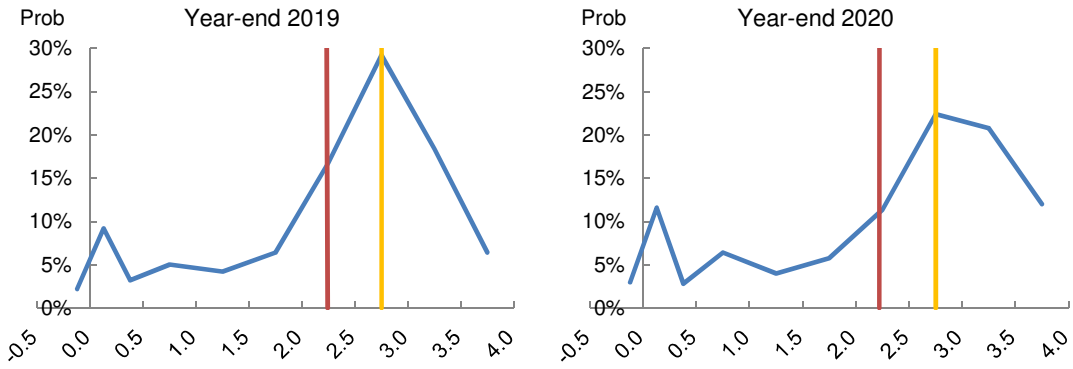
II. The percentage chance attached to the "below 1.00%" rate band is wholly attached to the "0.51 – 1.00%" band in the first scenario, and likewise, the percentage chance attached to the "above 2.51%" rate band is wholly attached to the "2.51 – 3.00%" rate band in the second scenario.

In the March 2018 surveys, the median probability is 20% in SMP. According to the Kolmogorov definition of conditional probability that

$$P(A \cap B) = P(A|B)P(B)$$

We can calculate the unconditional probability in each target rate band. Aggregating the two scenarios, we have nine interest rate bands to describe the PDF. The blue lines in Chart C3 represent the unconditional PDFs. As can be seen, the primary dealers and market participants share very similar views on the federal funds target range in the coming two to three years.

Chart D3. Unconditional PDFs from SMP



Source: Federal Reserve Bank of New York

Finally, based on the unconditional PDF, we can easily calculate the probability weighted mean expectation by multiplying the probability and the mid-point of each rate band. Here we made a third assumption:

III. The percentage chance attached to the "below 0.00%" rate band is wholly attached to the "-0.25 - 0.00%" band, and likewise, the percentage chance attached to the "above 3.51%" rate band is wholly attached to the "3.51 – 4.00%" rate band.

The red lines in Chart D3 represent the calculated means whereas the yellow lines represent the modes. It is not surprising to find that under the market condition in March 2018, the means are lower than the modes as the PDFs are negatively skewed.