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Essays on Central Bank Projections, Credibility, and Monetary Policy

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Economics

by

Cody Allen Couture

Dissertation Committee:
Professor Eric Swanson, Chair
Professor Gary Richardson
Professor William Branch
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2021

DEDICATION

To my parents, Monty and Carole, for their unwavering love and support.

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ABSTRACT OF THE DISSERTATION

Essays on Central Bank Projections, Credibility, and Monetary Policy

By

Cody Allen Couture

Doctor of Philosophy in Economics

University of California, Irvine, 2021

Professor Eric Swanson, Chair

In Chapter 1, I examine the impact of the forecasts released by the Federal Open Market Committee (FOMC) in the Summary of Economic Projections over the period of April 2011 through March 2019. I find that changes in the median FOMC federal funds rate forecast did impact asset prices, but forecasts of output and inflation did not have any effect, which may be surprising based on the literature regarding the "Fed information effect" channel. Further, the dispersion in the federal funds rate forecast does not affect asset prices though it does impact the degree of uncertainty regarding future monetary policy. Finally, I find that most of forward guidance can be summarized through the change in the median federal funds rate forecast for the end of the following year.

In Chapter 2, I document differences in interest rate expectations between central banks and the private sector and show why such a gap is a puzzle. I then create a measure of central bank credibility by taking the absolute value of the difference in expectations, which I use in an event study across several countries to demonstrate that a decrease in credibility can reduce the efficacy of forward guidance. I also offer several possible explanations for differences in interest rate expectations. In particular, I find that some of this gap must be attributed to differences in beliefs about the central bank's reaction function.

In Chapter 3, I examine whether vacancies on the Board of Governors of the Federal Reserve

are costly. I find little evidence to suggest that this is the case: monetary policy, uncertainty about the future path of interest rates, and the Board of Governor's ability to supervise and communicate are largely unaffected by the number of absences on the committee. I also show that this low cost has important implications for the nomination process from both the perspective of the president and the Senate.

Chapter 1

Financial Market Effects of FOMC Projections

1.1 Introduction

Forward guidance, that is, communication about the future path of monetary policy, has long been one of the tools available to the Federal Open Market Committee (FOMC). However, following the financial crisis in 2008, it became more important as the federal funds rate – the typical tool for monetary policy – was rendered ineffective by the zero-lower bound (ZLB). Thus, the FOMC turned to unconventional monetary policy, which consisted primarily of forward guidance and large-scale asset purchases (LSAPs).

There is a large literature showing that forward guidance has been effective in influencing asset prices (e.g., Gürkaynak, Sack and Swanson 2005) as well as stimulating output (e.g., Bundick and Smith 2016). However, there is still much that is not understood about the channels through which forward guidance is communicated. Likewise, it is unclear precisely how various forms of FOMC communication are received by market participants. To better understand both these questions, I consider the financial market response to the Summary of Economic Projections.

Beginning in October 2007, the FOMC began to provide a Summary of Economic Projections (SEP), which summarized FOMC participants' forecasts of key economic variables – real GDP growth, the unemployment rate, personal consumer expenditures (PCE) inflation, and core PCE inflation – for the current year and the following two to three years. In 2012, forecasts of the federal funds rate, often called the dot plots, were added to the SEP. According to the FOMC, the SEP was implemented to "improve the accountability and public understanding of monetary policy making."[1] These forecasts not only provided investors with a deeper insight into policymakers' outlook on the economy, but they also allowed policymakers to communicate their anticipated path of macroeconomic variables, especially that of the federal funds rates. As such, the SEP functions as one of the channels for the FOMC's forward guidance.

Among the various forms of forward guidance, the SEP is unusual in that it is purely quantitative. As such, the communication is much less ambiguous than other forms of forward guidance such as the FOMC policy statement or speeches by FOMC members. This has led to close market scrutiny of the SEP, particularly the federal funds rate forecasts. Consequently, it appears that changes in the SEP can influence financial markets.

For instance, on March 16, 2016, the FOMC did not change the current federal funds rate and there were not any significant large-scale asset purchases or any clear verbal communication indicating forward guidance. Instead, much of the new information that day came from the SEP. In particular, the median of the dot plot for both the current year and following year dropped by 50 basis points. On that same day, the surprise change to the current federal funds rate was a 1 basis point decrease, indicating that keeping the federal funds rate unchanged was largely expected. Despite this, expectations of the federal funds rate at

[1] FOMC Press Release Nov. 14, 2007

longer horizons had a surprise decrease of 9 basis points. Treasury yields, particularly those with medium-length maturities, declined by a similar magnitude. Thus, it would appear that the expected path of interest rates and treasury yields moved almost entirely due to the SEP.

Despite this scrutiny – or perhaps because of it – James Bullard, the President of the St. Louis Federal Reserve, has suggested removing the federal funds rate forecast from the SEP due to fears that the dot plots are de-emphasizing the FOMC's continued data dependence (Bullard, 2018).[2] Despite the importance of the SEP, there are, to the best of my knowledge, no other studies examining the impact that it has on asset prices. I attempt to fill this gap by examining the relationship between SEP forecasts, private sector expectations, and asset prices between April 2011 and March 2019. Quantifying this relationship is important to understanding both how forward guidance is communicated and the effectiveness of the SEP in influencing private sector expectations.

To answer these questions, I use an event-study framework to study the financial market's response in the 30-minute window surrounding FOMC announcements. I find that a change in the FOMC's median federal funds rate forecast for the end of the current or following year had a significant impact on treasury yields. Surprisingly, a change in the median federal funds rate forecast for two years ahead did not have any impact. Further, changes in the median forecast of other variables did not have any effect on asset prices. This would suggest that the primary mechanism for the SEP is influencing beliefs regarding future monetary policy rather than providing information about the future state of the economy. I also consider the effect of unpublished projections in the years prior to the release of the SEP and find that over this period, asset prices did not respond to a change in the federal funds rate forecast, which suggests that it is the publication of the interest rate forecasts that causes the response

[2] Bullard's comments from an interview in May 2018 suggest that he is primarily concerned about the difficulty in forecasting the federal funds rate two and three years ahead and believes that the FOMC should be more 'Greenspanian' in its approach.

in asset prices rather than other variables that may be correlated.

I also consider the dispersion of the dot plots and find that this has no direct effect on asset prices. I interpret this as treasury risk premiums not responding to the distribution of the federal funds rates forecasts. However, multiple measures of dispersion are highly correlated with the uncertainty surrounding monetary policy over the next year. More importantly, changes in the dispersion can impact the degree of monetary policy uncertainty. In this sense, there may be instances in which the dot plots are creating more confusion than clarity. Finally, I find that most of forward guidance can be summarized through the forecast revision of the median federal funds rate forecast for the end of the following year.

The rest of the paper is as follows. In Section 3.3, I detail the data relating to both FOMC projections and federal funds rate futures. Section 1.3 estimates the relationship between the median federal funds rate projections and asset prices. I then show that this effect is caused by shifting investor expectations. Finally, I explore the relationship between the median forecast of the remaining variables and asset prices but find no effect. Section 1.4 explores whether there is any impact of the dispersion of the forecasts. Section 1.5 relates the FOMC projections to the more general concept of forward guidance. Section 3.8 concludes.

1.1.1 Related Literature

This paper contributes to the literature examining the effects of central bank communication; for an overview of this literature, see Blinder et al. (2008) and Eberly et al. (2019). There are a number of papers that estimate the impact of forward guidance on asset prices, including Gürkaynak et al. (2005), Campbell et al. (2012), Wright (2012), Lewis (2019), and Swanson (2020).[3] These papers find that forward guidance has generally been quite successful in

[3] Forward guidance is often identified differently across the literature. Many papers including Gürkaynak et al. (2005), Campbell et al. (2012), and Bundick and Smith (2016) measure forward guidance through unanticipated changes in futures markets, some like Del Negro et al. (2015) use anticipated shocks, and

affecting asset prices. In contrast to these papers, I focus on effects of the SEP, rather than forward guidance more broadly, though I find a similar effect on asset prices.

One strand of the literature focuses on the Fed information effect, in which asset prices respond to FOMC announcements because they convey information about non-monetary fundamentals.[4] The first paper to provide empirical evidence of this information effect is Romer and Romer (2000), who argue that the private sector updates its forecasts of inflation in response to changes in the interest rate due to the Federal Reserve's superior information. Subsequent studies such as Campbell et al. (2012), Nakamura and Steinsson (2018), Cieslak and Schrimpf (2019), and Miranda-Agrippino and Ricco (2020) have provided further evidence of the information effect.[5] Unlike these papers, I utilize the FOMC's publicly released forecasts to determine the information that is being communicated about both future interest rates and the future state of the economy. Contrary to much of this literature, though consistent with Faust et al. (2004) and Bauer and Swanson (2020), I find no evidence of any Fed information effect.

Finally, this paper also adds to the growing literature concerning the effects of FOMC announcements on monetary policy uncertainty. A number of studies have computed how the uncertainty surrounding the path of monetary policy, derived either from market-based measures (e.g., Bauer et al. 2019) or news based measures (e.g., Husted et al. 2020), responds to actions or communications from the Federal Reserve. I build on this literature by focusing on how monetary policy uncertainty responds to disagreement in the dot plots. I find that higher dispersion in the dot plots leads to greater uncertainty for market participants.

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others, such as Wright (2012) and Lewis (2019), obtain identification through heteroskedasticity.

[4]Using terminology from Campbell et al. (2012), such communications are Delphic forward guidance, as they forecast the future state of the economy. This is in contrast to Odyssean forward guidance, which commits the central bank to some future action. Examples of Odyssean forward guidance include calendar-based guidance, in which policy decisions are tied to an explicit date, and threshold-based guidance, in which policy decisions are dependent upon economic conditions reaching a given threshold.

[5]There is also evidence for the information effect outside of the United States. For example, Hubert (2015) considers central banks in Sweden, the United Kingdom, Canada, Switzerland, and Japan and finds evidence that central bank inflation forecasts have influenced private forecasts of inflation in those countries.

1.2 Data

1.2.1 Summary of Economic Projections

The first Summary of Economic Projections (SEP) was released following the October 30-31, 2007 FOMC meeting. Prior to four of the eight regularly scheduled meetings a year, the members of the FOMC, which consists of the seven members of the Board of Governors and the twelve presidents of Federal Reserve Banks, each submit individual economic projections, which are then compiled and distributed to participants. These projections consist of forecasts of real GDP growth, the unemployment rate, PCE inflation, and core PCE inflation[6] for the current year and the following two years.[7] These projections are released alongside the minutes, which are made available to the public three weeks after the press release. The SEP grew out of the biannual monetary policy reports to Congress. Also known as the Humphrey-Hawkins reports, these Monetary Policy Reports have been given every February and July since 1978. However, there are some important differences: the SEP is typically released four times per year, it forecasts on a longer horizon, and the SEP is released alongside either the meeting's policy statement or minutes.[8]

Beginning April 2011, an advanced version of the SEP was provided in conjunction with the Federal Reserve Chair's post-meeting press conference.[9] The advanced version did not contain all of the details provided in the version released alongside the minutes. Instead, it

[6]Core PCE inflation is PCE excluding food and energy. Projections of GDP and inflation are the percent changes from the fourth quarter of the previous year to the fourth quarter of the year indicated. Projections for unemployment are the average civilian unemployment rate in the fourth quarter of the year indicated.

[7]The SEP contains projections of the current year, one year ahead, and two years ahead except in the cases when the FOMC meeting is occurring in September or later; then, they also contain projections of three years ahead.

[8]While the SEP is generally released four times per year, the exception to this is 2012, during which there were five SEP releases. From 2013 onward, the SEP has been released in March, June, September, and December.

[9]Both the advanced version of the SEP and the Chair's post-meeting press conference began in April 2011 and the two events always occurred together until 2019. Beginning in January 2019, the FOMC began holding press conferences following every meeting.

summarized the range and central tendency of FOMC forecasts. The median value for these forecasts was reported beginning in September 2015. Furthermore, after a lag of five years, a more detailed version of the SEP is released, which provides the anonymous, individual forecast of each FOMC member.

In addition to the aforementioned forecasts, projections of the federal funds rate were added to the SEP beginning in January 2012. Unlike the other variables being forecasted, information on each individual FOMC member's federal funds rate was provided in the advanced version of the SEP. For simplicity, members' forecasts were rounded to the nearest quarter percent until September 2014 at which point they were rounded to the nearest eighth percent.[10] Figure 1.1 shows the median, central tendency, and range of the forecasts across the multiple horizons.[11] Unsurprisingly, there is more variation in the forecasts at longer horizons. A summary of this data can be found in Table A.1.

1.2.2 Federal Funds Futures

Although it is not possible to directly observe market expectations of monetary policy, there is a proxy: federal funds futures. The market was established in 1988 at the Chicago Board of Trade. While contracts were initially traded on one- through five-month horizons, longer horizon contracts have arisen over time. Importantly, these contracts are settled based on the average effective federal funds rate for the month specified. As shown in Kuttner (2001), the surprise change in the federal funds rate on a particular day can be computed through a scaled change in the federal funds rate futures. Let $f^0_{m,d}$ be the spot-month futures rate on day d of month m and let D be the number of days in the month. Then, the surprise

[10]The point estimates given by the SEP are rounded to the nearest tenth. However, in all calculations, I use the more precise information available in the dot plots. Though more detailed data about forecasts are released with a five-year lag, it is not considered in calculations as it was not accessible to market participants at the time of release.

[11]Similar graphs for GDP growth, unemployment, and PCE inflation can be found in Figures A.1 through A.3.

Figure 1.1: FOMC Federal Funds Rate Forecasts

change, s_t, is given by:

$$s_t = \frac{D}{D-d}\left(f^0_{m,d} - f^0_{m,d-1}\right),$$

for all but the first and last days of the month. On the first day of the month, $f_{m-1,D}$ is used instead of $f_{m,d-1}$. Given that the rescaling effect is unreasonably large towards the end of the month, I use the change in the futures contract of the following month when computing the surprise change in the last seven days of each month.

It is not only the surprise component for the current month that is of interest, but the surprise to the expected future path of federal funds rate. In particular, I consider the surprise component to the federal funds rate expectations at the end of the current and the end of the subsequent year since this is precisely what the FOMC is forecasting. While the FOMC also considers changes to the federal funds rate beyond this horizon, the corresponding futures data is not available. Let $f^{Dec,y}_{m,d}$ be the month average funds rate for December of the current year on day d of month m. Then, the surprise component for the end of the current year is:

$$s^{YE}_t = \begin{cases} f^{Dec,y}_{m,d} - f^{Dec,y}_{m,d-1} & m \neq 12 \\ \frac{D}{D-d}\left(f^{Dec,y}_{m,d} - f^{Dec,y}_{m,d-1}\right) & m = 12. \end{cases}$$

While this measure is a reasonable proxy, there are a few issues. The primary problem is that the futures price is an average of the daily prices over the month. Thus, changing expectations regarding the timing of the FOMC rate change may impact the price even though the year-end rate remains constant. For instance, suppose that markets previously anticipated a rate hike in September, but, for whatever reason, markets now anticipate a rate hike in December. Since December meetings are typically in the middle of the month, this would result in a lower rate for the first of the month, thereby lowering the average of the month while maintaining the same year-end rate. To address this problem, I also consider results using the January federal funds futures prices. While using the January federal funds futures will incorporate any rate changes enacted in the January meeting, this is mitigated for the most part due to the fact that the January meeting takes place in the last few days of the month. I find that the results are similar regardless of which month is used.

The surprise component for the end of the following year is:

$$s_t^{NY} = f_{m,d}^{Dec,y+1} - f_{m,d-1}^{Dec,y+1}$$

where $f_{m,d}^{Dec,y+1}$ is the month average funds rate for December of the following year on day d of month m. I find that over this time period, the FOMC meetings had the biggest impact on the longer horizon expectations, which is unsurprising given the ZLB constraint; see Figure A.4 for details.

1.2.3 Market Survey Data

Prior to each FOMC meeting, the New York Fed's Open Market Trading Desk conducts two surveys: the Survey of Primary Dealers (SPD) and the Survey of Market Participants (SMP). The SPD, which began in 2011, attempts to better understand the expectations of primary dealers, who are the counterparties of the Federal Reserve in its market transactions. The SMP, which consists of a subset of questions from the SPD, followed in 2014 and focuses instead on the expectations of active investment decision makers. Survey questions are released approximately two weeks prior to each FOMC meeting and results are typically published three weeks following the meeting.

In order to better understand the market's expectation of the SEP, I focus on two particular sets of questions from these surveys. The first, which has been on the SPD since it's inception in 2011, asks primary dealers to provide forecasts for the variables considered in the SEP; that is, it asks for participants' forecasts of GDP growth, unemployment, PCE inflation, and core PCE inflation for the end of the current and following two years. The second, which was added to both surveys beginning in September 2015, gauges expectations regarding the median SEP federal funds rate projection for each of the horizons that the FOMC reports. Institutions are only surveyed about their expectations regarding the SEP prior to the FOMC meetings that contain SEP releases. These survey questions are particularly useful because they enable the change in the SEP to be decomposed into an unanticipated portion and an anticipated portion. Because only the unanticipated portion of the change should matter, this provides a way to more directly measure the relationship. However, given the recency of some of the relevant questions, the sample size is rather limited.

1.3 The Effect of FOMC Projections on Asset Prices

In order to calculate the impact of FOMC projections on asset prices, I use an event-study framework and regress the change in asset prices on the change in the median forecast of the variable of interest. Let $x^i_{h|t,q}$ denote the projection of variable i released in the qth quarter of year t forecasting h years ahead. In particular, the OLS regressions are of the following form:

$$\Delta y_t = \beta_0 + \beta_1 \Delta_q x^i_{h|t,q} + \beta_2 s_t + \epsilon_t \quad \text{for } h = 0, 1, 2, \tag{1.1}$$

where $\Delta_q x^i_{h|t,q}$, the forecast revision of the FOMC projection of variable i at horizon h, is given by

$$\Delta_q x^i_{h|t,q} = \begin{cases} x^i_{h|t,q} - x^i_{h+1|t-1,4} & \text{for } q = 1 \\ x^i_{h|t,q} - x^i_{h|t,q-1} & \text{for } q = 2, 3, 4, \end{cases}$$

Δy_t is the change in asset prices in the 30 minute window surrounding the FOMC announcement, and s_t is the surprise change in the current federal funds rate.[12] Although only unanticipated changes in the FOMC's forecasts should impact asset prices, determining the unanticipated component across the entire sample period of the forecast is challenging due to a lack of data. As such, my primary analysis only considers the change in the forecast – whether it was unanticipated or not.

1.3.1 Federal Funds Rate

To begin, I consider the forecasts of the federal funds rate. Although the entire distribution of forecasts likely offers a more complete picture of future monetary policy, it is much simpler to analyze the median forecast, particularly since changes in the median forecast often indicate changes in the anticipated future path of monetary policy.[13] To find this change, I take the difference between the median forecast in the current and previous SEP at each horizon h. For the first SEP forecast of the year, I find the change by taking the difference of the current SEP forecast at horizon h and the previous SEP forecast at horizon $h+1$. For example, to find the change in the one year ahead forecast for March 2016, I take the current median one year ahead forecast and subtract the median two year ahead forecast from December 2015.

[12]For all horizons h, s_t is the surprise to the current federal funds rate in the 30 minute window surrounding FOMC announcements.

[13]Of course, the FOMC has not always made policy decisions solely based on the median preference of the committee (see, e.g., Chappell et al. 2004). Nevertheless, given that the FOMC has tended toward the committee's median preference and that the design of the SEP emphasizes the median forecast, it seems reasonable to focus on the median in this analysis.

Table 1.1: Response of Asset Prices to Changes in the Median Dot at Each Horizon

	Same Year			**One Year Ahead**			**Two Years Ahead**		
	Change in Median Dot	Target Surprise	R^2	Change in Median Dot	Target Surprise	R^2	Change in Median Dot	Target Surprise	R^2
3-Month Bill	0.019	0.372***	0.73	0.016***	0.366***	0.76	0.009***	0.409***	0.71
	(0.012)	(0.095)		(0.006)	(0.076)		(0.003)	(0.093)	
6-Month Bill	0.059***	0.614***	0.73	0.039***	0.637**	0.70	0.016**	0.761***	0.56
	(0.014)	(0.216)		(0.010)	(0.252)		(0.008)	(0.248)	
2-Year Note	0.164***	0.782*	0.50	0.150***	0.679	0.67	0.081***	1.112**	0.44
	(0.054)	(0.406)		(0.022)	(0.508)		(0.025)	(0.513)	
5-Year Note	0.206***	0.660	0.29	0.194***	0.508	0.43	0.105***	1.069	0.26
	(0.068)	(0.534)		(0.028)	(0.597)		(0.033)	(0.635)	
10-Year Note	0.165***	0.350	0.26	0.136***	0.306	0.32	0.076***	0.696	0.20
	(0.053)	(0.495)		(0.025)	(0.497)		(0.026)	(0.491)	
S&P 500	−0.812	−2.167	0.10	−0.536	−2.499	0.08	−0.329	−3.965	0.06
	(0.901)	(8.084)		(0.468)	(8.590)		(0.317)	(8.212)	

Notes: Sample contains all FOMC meetings from January 2012 through March 2019 with a Summary of Economic Projections (SEP) release (29 observations). Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively. Regressions include constant terms that are not shown in the table. See text for details.

As Table 1.1 shows, there is a clear, positive relationship between a change in the median federal funds rate forecast and treasury yields for all but the shortest maturities. The relationship appears particularly strong for medium-term treasury yields, which is consistent with the expectations hypothesis, as discussed in A.1. Interestingly, the effect appears to be stronger for forecasts at a shorter horizon. For instance, a 25 basis point increase in the median dot for the end of the current year – a forecast of one additional rate hike – results in a 4 basis point increase in the 2-year treasury yield. In contrast, the results seem to be much weaker and less significant for changes in the two year ahead forecast. The relatively high R^2 of medium-term treasury yield regressions still hold even when the surprise change, s_t, is removed. This suggests that much of the change in treasury yields on FOMC announcement dates can be explained simply through changes to the median federal funds rate forecast.

The relationship between a change in the median federal funds rate forecast and stock prices is less clear; while I find that a change in the median of the dot plots has a negative impact on the S&P 500 at all horizons, none of the relationships are statistically significant. One important consideration is that the impact of changes in the dot plot may have changed across the sampled time period, particularly given the newness of the communication. However, given the small sample size, identifying any change is not feasible.

While considering each of the forecast horizons separately is informative, the effects of the projections are likely not independent. Unfortunately, the change in the median forecasts at different horizons are highly collinear. Instead, I consider the additional information that each forecast provides relative to earlier horizons. That is, forecasts for the end of the following year provide new information about expectations from the end of the current year to the end of the following year, and forecasts for two years ahead provide new information about expectations from the end of the following year to the end of year, two years ahead. After this transformation, these estimates no longer suffer from multicollinearity.

Table 1.2: Response of Assets Prices to Changes in the Dot Plot

	3-Month Bill	6-Month Bill	2-Year Note	5-Year Note	10-Year Note	S&P 500
Change in Current Year Median Dot	0.018	0.058***	0.156***	0.195***	0.159***	-0.800
	(0.012)	(0.013)	(0.043)	(0.055)	(0.047)	(0.892)
Change in One Year Ahead Forecast	0.013*	0.016	0.143***	0.192***	0.109***	−0.219
	(0.007)	(0.015)	(0.038)	(0.044)	(0.030)	(0.578)
Surprise Change	0.362***	0.601***	0.668	0.506	0.262	−1.992
	(0.081)	(0.234)	(0.542)	(0.640)	(0.512)	(8.588)
Constant	−0.001	−0.003	−0.002	0.004	0.006	0.211**
	(0.001)	(0.002)	(0.006)	(0.013)	(0.011)	(0.100)
Observations	29	29	29	29	29	29
R^2	0.765	0.748	0.673	0.428	0.329	0.100

Notes: Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through March 2019. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent. Change in one year ahead forecast only considers the additional information provided by next year's forecast. See text for details.

More specifically, I run the regression

$$\Delta y_t = \beta_0 + \beta_1 \Delta_q x^{FFR}_{0|t,q} + \beta_2 \Delta_h \Delta_q x^{FFR}_{1|t,q} + \beta_3 s_t + \epsilon_t, \tag{1.2}$$

where $\Delta_h \Delta_q x^i_{h|t,q} = \Delta_q x^i_{h|t,q} - \Delta_q x^i_{h-1|t,q}$. This new term effectively computes the forecast revision of the annual expected change h years ahead based on the forecasts made in the qth quarter of year t. The results, which are shown in Table 1.2, appear to broadly agree with the estimates presented in Table 1.1. As before, these estimates are largely consistent with the predictions generated by the expectations hypothesis: medium-term yields respond more strongly to FOMC projection than short-term and long-term yields and the 3-month yield is the only maturity that does not have a statistically significant response.[14] Importantly, Table 1.2 only considers the forecasts for the end of the current and following year, as the inclusion of longer horizon forecasts do not impact the results, as shown in Table A.2. In other words, changes in the two-year ahead forecasts do not appear to significantly impact treasury yields.

It is natural to wonder why two year ahead forecasts appear not to matter. This may be because FOMC forecasts are conditional and at such a long horizon, the outcome is more dependent on future data than on current FOMC preferences. Another possible explanation is that these forecasts are simply not accurate enough for investors to adjust the expectations. That is, if FOMC projections are not more informative than private expectations at longer horizons, then investors do not benefit from altering their expectations. As Figure A.5 shows, the forecast error is substantially higher for forecast horizons of two years or more. Further, these forecasts have rarely been accurate, even if the margin of error is extended to 50 basis points. However, while the forecasts themselves may not be particularly accurate, they may provide an important baseline for future forecasts. This would suggest that Bullard's

[14] One potential concern about these estimates is that the forecast horizon varies across observations. Thus, the estimates are essentially an average of the effect at each horizon. However, it is not possible to consider the effect for each horizon separately, as the substantially reduced sample size results in highly inaccurate point estimates.

concerns regarding the dot plots may, at least to some extent, be unfounded.

Given the small sample size, one may be concerned that the results are driven by a few influential observations. To alleviate these concerns, I run several regression diagnostics on the specification shown in Table 1.2 in the case where the 2-year treasury yield is the dependent variable; the results can found in Figure A.6. I find that the three most influential observations correspond to meetings held on September 18, 2013, September 21, 2016, and March 15, 2017. As shown in Table A.3, even if these dates are removed from the sample, the results are largely unchanged and remain significant, suggesting that the estimates are not driven by a handful of data points.

One concern facing this analysis is that by combining the anticipated and unanticipated changes in the FOMC's forecasts, the estimates may be inaccurate, as markets should only react to the unanticipated portion. To relieve this concern, I repeat the earlier procedure but instead only consider the surprise component of the SEP. This is calculated by taking the difference between the FOMC's projections and the market expectation of these projections captured by the SMP.[15] The disadvantage of this approach is that the SMP only has data on these expectations beginning in September 2015. Table 1.3 displays the results. Overall, the results of the regression are similar to those in Table 1.1. One important difference, however, is that the impact of FOMC projections seems to be larger when only the surprise component is considered. This is consistent with the idea that only the unanticipated portion of the projection should affect future expectations. In other words, the estimates are stronger due to the use of a less noisy measure. As such, this result implies that earlier tables may be understating the true impact of changes in FOMC projections. Although the significance is not as strong as the earlier results, this is likely due to having a much smaller sample size rather than the strength of the response.

[15]These expectations are also available from the SPD. However, given the nature of this analysis, it is more natural to focus on the expectations of active market participants. If the SPD is considered instead, the results are similar.

Table 1.3: Response of Asset Prices to the Surprise Change in the Dot Plot at Each Horizon

	Same Year			**One Year Ahead**			**Two Years Ahead**		
	Surprise Change in Median Dot	Target Surprise	R^2	Surprise Change in Median Dot	Target Surprise	R^2	Surprise Change in Median Dot	Target Surprise	R^2
3-Month Bill	0.039	0.432***	0.83	0.035***	0.387***	0.89	0.018**	0.433***	0.78
	(0.029)	(0.085)		(0.008)	(0.074)		(0.007)	(0.094)	
6-Month Bill	0.104***	0.771***	0.75	0.064**	0.685**	0.69	0.012	0.763***	0.55
	(0.039)	(0.223)		(0.031)	(0.301)		(0.028)	(0.291)	
2-Year Note	0.250**	1.139***	0.59	0.192***	0.888	0.62	0.051	1.126**	0.32
	(0.102)	(0.385)		(0.059)	(0.555)		(0.071)	(0.556)	
5-Year Note	0.273**	1.078**	0.51	0.216***	0.796	0.56	0.066	1.066	0.26
	(0.134)	(0.539)		(0.071)	(0.659)		(0.083)	(0.682)	
10-Year Note	0.185**	0.710	0.45	0.144***	0.522	0.48	0.046	0.702	0.23
	(0.081)	(0.535)		(0.055)	(0.588)		(0.060)	(0.577)	
S&P 500	−1.020	−4.744	0.30	−0.670	−3.849	0.27	0.056	−4.612	0.15
	(1.799)	(4.602)		(0.472)	(4.760)		(0.407)	(4.697)	

Notes: Sample contains all 15 FOMC meetings from September 2015 through March 2019 with a Summary of Economic Projections (SEP) release and a corresponding question from the Survey of Market Participants (SMP). Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively. Regressions include surprise and constant terms that are not shown in the table.

1.3.2 Mechanism: Impacting Federal Funds Rate Expectations

The likely mechanism through which federal funds rate forecasts can impact asset prices is by influencing investor expectations of the path of the federal funds rate. Recall that federal funds rate futures are a proxy for interest rate expectations. Thus, to show that this is the mechanism at work, I show that FOMC forecasts influence federal funds rate futures, which in turn impact asset prices. Table 1.4 shows that changes in the median forecast for the end of the current and following year are strongly correlated with the surprise in the federal fund rate futures for the end of the current and following year, respectively.

Table 1.4: Impact of FOMC Forecasts on Federal Fund Rate Futures

	Year End Surprise Change	One Year Ahead Surprise Change
Change in Same Year Median Dot	0.124***	
	(0.043)	
Change in One Year Ahead Median Dot		0.179***
		(0.046)
Constant	−0.002	0.004
	(0.004)	(0.008)
Observations	29	29
R^2	0.524	0.467

Notes: Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through March 2019. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent.

Table A.4, following previous work such as Kuttner (2001) and Gürkaynak et al. (2005), captures the relationship between the surprise to federal fund rate futures and asset prices. Unsurprisingly, I find a stronger response for treasury yields than the results presented in Tables 1.1 and 1.2. The cause is likely twofold: the change in federal funds rate futures is incorporating additional information that is not present in the SEP forecasts and there is less noise given the more direct nature of the relationship. Indeed, I find evidence that the informational content of the federal funds rate futures is significantly higher than that provided by the dot plots.

1.3.3 Other Forecast Variables

Table 1.5: Response of Asset Prices to Changes in Other FOMC Forecasts

	Same Year			**Following Year**		
	GDP	UR	Core PCE	GDP	UR	Core PCE
3-Month Bill	0.000	-0.012^{**}	−0.004	0.003	−0.008	0.010
	(0.002)	(0.006)	(0.005)	(0.003)	(0.007)	(0.005)
6-Month Bill	−0.002	−0.010	0.006	0.003	−0.003	0.015
	(0.006)	(0.013)	(0.015)	(0.009)	(0.014)	(0.015)
2-Year Note	0.001	−0.019	0.008	0.008	−0.004	0.046
	(0.022)	(0.039)	(0.063)	(0.033)	(0.041)	(0.063)
5-Year Note	0.021	−0.044	−0.035	0.061	−0.030	0.005
	(0.034)	(0.053)	(0.113)	(0.066)	(0.065)	(0.113)
10-Year Note	0.027	−0.048	−0.027	0.079	−0.046	0.035
	(0.026)	(0.039)	(0.093)	(0.058)	(0.050)	(0.093)
S&P 500	−0.005	−0.154	−0.839	0.183	−0.334	−0.991
	(0.268)	(0.368)	(0.653)	(0.355)	(0.323)	(0.653)

Notes: Results are for the regression of the form $\Delta y_t = \beta_0 + \beta_1 \Delta_q x^i_{h|t,q} + \beta_2 s_t$ for $h = 0, 1$ and $i \in \{\text{GDP}, \text{UR}, \text{Core PCE}\}$. UR stands for unemployment rate. Sample is all 33 FOMC meetings with a Summary of Economic Projections (SEP) release from April 2011 through March 2019. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively. Regressions include monetary surprise and constant terms that are not shown in the table.

I repeat the procedure for the remaining variables in the SEP. In particular, I repeat the specification in (1.1) for real GDP growth, the unemployment rate, and core PCE inflation rather than the federal funds rate. However, since the median for these variables was not reported until June 2015, I impute the median prior to this date by taking the average of the central tendency.[16] As the results in Table 1.5 indicate, I find that none of the other variable forecasts appears to have an effect on asset prices. I also consider a specification in which I include multiple SEP forecast variables simultaneously; these results, which are shown in Table A.5, largely preserve the findings of the individual regressions.

Like in the case of the federal funds rate forecasts, there is some concern that the estimates may be inaccurate as they combine anticipated and unanticipated changes in the FOMC's forecasts. To address this concern, I replace the forecast revision with the difference between the FOMC's projections and market expectations obtained from the SPD. The potential problem with this approach is that, unlike the projections of the dot plots from the SMP, the survey measures market expectations about the future state of the economy rather than the median SEP forecast. Nevertheless, this should better isolate the surprise component of the SEP. The results, which are shown in Table A.6, reiterate the findings in Tables 1.5 and A.5 that the information effect does not appear to be present over this period.

These results are contrary to Romer and Romer (2000), Campbell et al. (2012), and Nakamura and Steinsson (2018), which find an information effect from Federal Reserve releases, but consistent with Faust et al. (2004) and Bauer and Swanson (2020). One possibility is that the information effect occurs in earlier samples but is not present in the period I consider, which would be consistent with Lunsford (2020). Alternatively, the effect may occur through other channels than the SEP.

[16] It is possible to obtain the actual median forecast through 2014 because the FOMC releases anonymous forecasts with a five year delay. Though it is somewhat misleading to utilize this data as it considers information that was not accessible to market participants at the time, the regression results are unchanged if the actual median is used instead of the imputed median.

Table 1.6: Response of Asset Prices to Changes in Greenbook Forecasts

	Same Year			**One Year Ahead**			**Two Years Ahead**		
	Change in Greenbook Forecast	Target Surprise	R^2	Change in Greenbook Forecast	Target Surprise	R^2	Change in Greenbook Forecast	Target Surprise	R^2
3-Month Bill	-0.019	0.076*	0.26	−0.003	0.069	0.25	−0.003*	0.073	0.33
	(0.030)	(0.045)		(0.010)	(0.055)		(0.002)	(0.049)	
6-Month Bill	0.026	0.410***	0.78	−0.003	0.418***	0.78	−0.004	0.422***	0.79
	(0.055)	(0.099)		(0.010)	(0.100)		(0.004)	(0.104)	
2-Year Note	-0.030	0.843*	0.46	-0.006	0.832*	0.46	−0.009	0.841*	0.47
	(0.229)	(0.469)		(0.044)	(0.450)		(0.018)	(0.466)	
5-Year Note	0.061	0.790	0.21	0.018	0.812	0.21	0.004	0.805	0.21
	(0.261)	(0.549)		(0.045)	(0.523)		(0.023)	(0.517)	
10-Year Note	0.050	0.588	0.06	0.003	0.604	0.06	−0.000	0.604	0.06
	(0.284)	(0.498)		(0.041)	(0.479)		(0.021)	(0.502)	
S&P 500	−0.212	−8.412*	0.31	0.036	−8.470*	0.31	0.019	−8.493**	0.31
	(2.227)	(4.774)		(0.283)	(4.388)		(0.138)	(4.312)	

Notes: Sample is all FOMC meetings from January 2008 through December 2011 excluding a few observations that were heavily influenced by significant events unrelated to the FOMC announcement (29 observations total); see text for details. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively.

There are a number of reasons why this is not surprising. First and foremost, the FOMC is actively deciding the federal funds rate. Thus, their preferred path of rates has a direct impact on the outcome. However, for the remaining variables forecasted, the FOMC cannot exert any direct influence. Further, Federal Reserve forecasts may not be superior to private forecasts for all variables. For instance, Arai (2016) shows that the FOMC forecast of some variables – namely unemployment – is inefficient. If this is indeed the case, there is no reason for the market to react.

1.3.4 Greenbook Results

Although there appears to be a clear relationship between the FOMC federal funds rate forecasts and asset prices, it is less clear that there is any causality. It is possible, for instance, that FOMC participants' forecasts are correlated with other FOMC decisions and communications, which are what are actually driving changes in asset prices. One useful exercise in testing this relationship would be to examine if changes in FOMC federal funds forecasts still impacted asset prices prior to being published. Unfortunately, such projections do not exist prior to 2012. There are, however, projections by the Federal Reserve staff available in the Greenbooks, which are published with a lag of five years. Like the FOMC forecasts, the staff forecasts the federal funds rate, real GDP growth, the unemployment rate, PCE inflation, and core PCE inflation over a horizon of several years.[17] As such, I will consider these projections as a proxy for the median FOMC member projection.[18] I repeat the specification in (1.1) but instead use the staff projections of the federal funds rate. The

[17]These projections, which were called 'The Long-Term Outlook' in the Greenbooks, first appeared as such in 2008. The Federal Reserve staff predicted year end values for these variables for the current year and following five years. Importantly, the projection of the federal funds rate and unemployment rate were the projected average over the final quarter.

[18]There are, of course, important differences between these two measures as discussed in Romer and Romer (2008) and Ellison and Sargent (2012), but, in general, the differences between them are not substantial, as shown by Ellison and Sargent (2012).

results from 2008-2011 are shown in Table 1.6.[19] Unlike the SEP forecasts, a change in the staff forecasts is not significant. This suggests that the publication of the interest rate forecasts is causing the response in asset prices rather than other variables that may be correlated.[20]

1.4 Dispersion of Forecasts

While it is clear from the previous results that the median federal funds rate forecast has a significant impact on financial markets, the effect of the dispersion of the FOMC's federal funds rate forecasts is less clear. There are two means through which it could have an impact: the risk premium and the level of uncertainty regarding monetary policy. The risk premium might be affected if the distribution is asymmetric; for instance, if the FOMC forecasts change investor beliefs so that a deviation to the upside would be more likely, then they would require a greater premium to hold longer maturity bonds. Alternatively, the dispersion may just increase the uncertainty that investors have in the forecasted path of monetary policy. In this case, the dot plots may be acting contrary to one of the primary goals of forward guidance – reducing monetary policy uncertainty (Bernanke, 2013).

[19] Two dates – March 18, 2008 and October 29, 2008 – are removed due to significant events unrelated to the FOMC announcement that occurred on the same day. On March 18, 2008, Goldman Sachs and Lehman Brothers reported earnings that beat estimates, temporarily allaying fears about liquidity (Andrews, 2008). October 29, 2008 is excluded due to the exceptionally large financial market reaction between when the Greenbook forecasts were finalized and the FOMC statement was released. In particular, the previous day saw what was, at the time, the second largest gain in the Dow Jones in history.

[20] One additional concern along these lines is that the result is primarily being driven by important forward guidance announcements that became more common during the period in which the SEP is available. As a simple check on this, I remove important FOMC forward guidance dates as indicated by the Fed at https://www.federalreserve.gov/monetarypolicy/timeline-forward-guidance-about-the-federal-funds-rate.htm. Even with these announcements removed and a much smaller sample size, the results remain statistically significant for most maturities, though the estimated response is slightly weaker; see Table A.7.

1.4.1 Range and Central Tendency

In addition to the median, the advanced SEP also reports two other statistics for each forecast: the central tendency and the range. The range is simply the largest and smallest forecast of each variable. The central tendency first removes the three largest and three smallest observations. By taking the difference between the upper and lower value of each of these statistics, it is easy to calculate two measures of dispersion. The range and central tendency for the current year are not particularly useful as the forecasts tend to converge as the year progresses. Instead, I consider the spread in the one year ahead forecasts. I find that neither the range nor the central tendency explain a change in asset prices; see Tables A.8 and A.9 for more details. This is consistent with Hubert (2014) who finds that the dispersion of FOMC forecasts of inflation has no impact on the dispersion of private forecasts of inflation. This suggests that the risk premium is not affected by changes in the FOMC's projections.

Perhaps this is unsurprising; a higher dispersion would be unlikely to influence investors' beliefs about the future path of monetary policy. Instead, it would increase the amount of uncertainty in these beliefs. To measure the uncertainty of monetary policy, I follow Swanson and Williams (2014) and combine multiple Eurodollar options with the same expiration date to calculate an implied distribution. Then, I subtract the 80th and 20th percentiles to obtain a measure of monetary policy uncertainty. I find that both measures of spread are correlated with the level of monetary policy uncertainty. This likely reflects two factors: an increased uncertainty regarding the future path of fundamental economic variables and greater disagreement from FOMC participants regarding the preferred path of the federal funds rate. However, I do not find that the range or central tendency cause any change in monetary policy uncertainty, as shown in Tables A.10 and A.11.

1.4.2 Higher Moments

Table 1.7: Impact of the Dot Plot's Higher Moments on Monetary Policy Uncertainty

	Change in Monetary Policy Uncertainty
Change in Variance of Dot Plots for Following Year	-0.090
	(0.183)
Change in Skewness of Dot Plots for Following Year	-0.107^{*}
	(0.061)
Change in Kurtosis of Dot Plots for Following Year	0.026^{*}
	(0.015)
Constant	-0.048^{**}
	(0.023)
Observations	16
R^2	0.330

Notes: Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through December 2015. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively.

Although the FOMC does not report any moments aside from the median, it is possible to calculate higher moments such as variance, skewness, and kurtosis from the dot plots. As with the range and central tendency, I find that these moments do not have a statistically significant impact on asset prices. They are, however, highly correlated with the level of monetary policy uncertainty; see Table A.12 for more information. Further, as shown in Table 1.7, I find that a change in these moments, namely the skewness and kurtosis, can impact the level of uncertainty in the economy. More specifically, I find that an increase in the kurtosis of the dot plots creates more uncertainty while an increase in the skewness does the opposite. It is intuitive that a higher kurtosis, which indicates fatter tails, would result in greater uncertainty. It is less clear, however, why a decrease in skewness would result in more uncertainty. It may be largely due to the fact that, over the period considered, the federal funds rate was already at the ZLB. Thus, the positive skewness would suggest that the FOMC would keep rates at the ZLB whereas a negative skewness would suggest an increase in the federal funds rate from the ZLB. Interestingly, it appears that the variance of the forecasts does not have any effect. Given that the distribution of the dot plots can impact the level of monetary policy uncertainty, it is possible that the federal funds rate forecasts communication can lead to negative outcomes (e.g., Bloom 2009).

1.5 Relationship to Forward Guidance

Table 1.8: Portion of Forward Guidance Explainable Through the SEP

	Forward Guidance Factor		
Change in Median Dot Plot Same Year	3.701*** (0.946)		0.462 (1.072)
Change in Median Dot Plot One Year Ahead		3.108*** (0.555)	2.868*** (0.809)
Constant	0.045 (0.156)	0.006 (0.118)	0.018 (0.127)
Observations	26	26	26
R^2	0.381	0.586	0.589

Notes: Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through December 2015. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively.

It is natural to wonder how much of forward guidance can be explained by the SEP. To calculate this, I take the estimates of the forward guidance factor calculated in Swanson (2020) and regress it on the change in the median one year ahead federal funds rate forecast. As Table 1.8 shows, I find that nearly 60% of the variability in the forward guidance factor can be explained by this single variable. Other specifications appear to do little to improve the fit. This fit is even more impressive given that the SEP is only released quarterly. The fact that much of forward guidance can be summarized in this way is particularly useful given the quantitative nature of the SEP forecasts. Unlike other forms of forward guidance, which are often qualitative in nature and difficult to assess, changes in the dot plots can be calculated easily upon their release. Further, while it is easy for policymakers to estimate the effect of a change in the median of the dot plots prior to the release of the SEP, it is much more difficult to anticipate how the market will interpret more qualitative statements.

There are, however, several major flaws of the SEP. As previously mentioned, it is not available after every FOMC meeting. As such, more frequent releases of the SEP may further facilitate communication regarding Federal Reserve forward guidance. Further, as Table 1.9 shows, the forward guidance factor is a better indicator of treasury yield responses than the change in the dot plots. This result holds even when only the unanticipated change in the dot plots is considered. This result is likely due to other channels of forward guidance that contain important information that is not summarized in the dot plots. In other words, changes in the dot plots can explain much of forward guidance and its impact on asset prices, but it is not sufficient to explain the entire effect that forward guidance has on asset prices. One potential avenue of future research is to identify the impact that other forms of forward guidance have on asset prices.

1.6 Conclusion

I examine the impact of the forecasts released by the FOMC in the SEP over the period of April 2011 through March 2019. I find that changes in FOMC members' federal fund rate forecasts have an impact on asset prices. More specifically, a change the median forecast for the end of the current or following year has an impact on all but the shortest end of the yield curve. On the other hand, I find that changes in the median forecast two years ahead do not appear to have any significant effect. This may be due to the fact that forecasts at

Table 1.9: Response of Assets Prices to Dot Plots and Forward Guidance Factor

	3-Month Bill	6-Month Bill	2-Year Note	5-Year Note	10-Year Note	S&P 500
Change in Median Dot Current Year	0.013	0.021	0.012	−0.064	−0.024	−0.150
	(0.018)	(0.025)	(0.021)	(0.109)	(0.120)	(0.976)
Change in Median Change One Year Ahead	0.006	−0.018	0.017	−0.043	−0.072	0.197
	(0.008)	(0.020)	(0.015)	(0.077)	(0.078)	(0.612)
Surprise Change	0.430***	0.642***	0.512**	0.375	0.261	5.797
	(0.113)	(0.248)	(0.201)	(0.679)	(0.854)	(7.481)
Forward Guidance Factor	0.001	0.011***	0.047***	0.084***	0.060***	−0.320***
	(0.001)	(0.004)	(0.003)	(0.022)	(0.022)	(0.138)
Constant	−0.000	−0.003	−0.004*	0.003	0.006	0.265**
	(0.001)	(0.002)	(0.002)	(0.008)	(0.009)	(0.093)
Observations	26	26	26	26	26	26
R^2	0.813	0.844	0.972	0.829	0.653	0.329

Notes: Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through December 2015. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively. See text for details.

such a long horizon are not more accurate than private forecasts. Perhaps this is unsurprising, as FOMC members have articulated the challenge in providing forecasts so far in the future. Moreover, I find that changes in the other FOMC forecasts appear to have no effect regardless of the horizon, which is contrary to the literature on the "Fed information effect."

I also consider the dispersion of the federal funds rate forecasts. I find that the dispersion does not appear to directly impact asset prices. It is, however, strongly related with the measure of uncertainty surrounding monetary policy over the next year. In fact, an increase in the dispersion of the federal funds rate forecast can increase the uncertainty about the future path of interest rates. In this sense, the dot plots may be responsible for generating confusion about expected monetary policy.

Finally, I estimate the informational content contained in the dot plots. I find that approximately 60% of forward guidance can be summarized through the forecast revision of the median federal funds rate forecast for the end of the following year. Thus, the dot plots provide a quick and objective way for investors to assess the majority of information being communicated about future monetary policy.

Overall, these results suggest that the dot plots are an important form of forward guidance. They provide a clear, explicit way for the FOMC to communicate the anticipated path of future interest rates. Perhaps more importantly, the dot plots appear to influence investors' beliefs about future interest rates. As such, it seems natural to expand the dot plots so that they are released following every FOMC meeting. While there are some concerns about the FOMC's inability to forecast meaningfully at longer horizons, such concerns are likely overblown, given that the market is not reacting to these forecasts. Further, while an increase in the dispersion of the dot plots may increase the amount of uncertainty surrounding future monetary policy, it is unclear that the path of interest rates would any less uncertain in the absence of the dot plots. It is probable that if the FOMC provided the dot plots following every meeting, it would not only facilitate a better understanding the evolution of policymaker expectations, but also facilitate a better understanding of how these expectations are formed.

Chapter 2

Differences between Central Bank and Private Sector Policy Rate Forecasts: Causes and Implications for Monetary Policy

2.1 Introduction

Central bank communication has become an increasingly important component of monetary policy. Much of this increased importance stems from the fact that communication allows the central bank to influence private sector beliefs about the future path of monetary policy, which play an important role in agents' decision-making process. Given that the central bank ultimately has significant control over the path of the policy rate, such communication is incredibly important to private agents (see, e.g., Gürkaynak et al., 2005 and Campbell et al., 2012). Despite this communication, there are often significant differences between the central bank's and private sector's expectation of future policy rates, which is quite puzzling.

Consider a general formulation of monetary policy. Interest rates can be expressed as follows

$$i_t = f_t(X_t) + \epsilon_t, \tag{2.1}$$

where i_t is the interest rate, X_t is a vector of variables describing the economy, f_t is the (potentially) time-varying reaction function of the central bank, and ϵ_t represents exogenous, random deviations from the central bank's reaction function, which are assumed to be i.i.d. Thus, expectations about future interest rates are given by

$$E_t i_{t+h} = E_t f_{t+h}(X_{t+h}). \tag{2.2}$$

In the special case where the reaction function is linear and independent of the current state of the economy, expectations of the future interest rate can be expressed even more simply as

$$E_t i_{t+h} = E_t \beta_{t+h} E_t X_{t+h}, \tag{2.3}$$

where β_t is a vector of responses to the variables describing the economy. This generalization encompasses all linear Taylor-type rules with or without time-varying parameters.

In many standard macroeconomic models, these expectations are the same for the private sector (PS) and the central bank (CB). Indeed, if the reaction function is known and agents have identical information about the future state of the economy, expectations of future interest rates should be identical. However, in practice, this is usually not the case, as the private sector and central bank often expect the economy to evolve in different ways. Further, the reaction function of the central bank is generally not known – in fact, it is likely too complicated to be fully communicated by the central bank – and instead must be inferred from central bank communication and past policy (see Rudebusch and Williams, 2008). In this way, it is more appropriate to express the expected interest rate as

$$E_{j,t} i_{t+h} = E_t[f_{t+h}(X_{t+h})|\mathcal{I}_j], \tag{2.4}$$

where $\mathcal{I}_j$ represents the information set of agent j for $j \in \{PS, CB\}$.

It is often assumed that $\mathcal{I}_{PS} \subseteq \mathcal{I}_{CB}$. That is, the central bank has at least as much information about the future state of the economy and the policy reaction function as the private sector (see, e.g., Romer and Romer, 2000; Eusepi and Preston, 2010; Andrade et al., 2019). Thus, the central bank's expectation of the future path of the policy rate should be at least as good as the private sector's expectation. As such, differences in policy rate expectations should only arise when the private sector is unaware of the central bank's expectations. If the private sector is informed of the central bank's policy rate expectation for any horizon h, then agents should adopt this expectation as their own, even if they do not fully understand how the expectations are being formed.

Although central banks regularly communicate their expectations of the future policy rate, these communications are difficult to interpret precisely. In fact, many studies attempt to do exactly this (e.g., Boukus and Rosenberg, 2006; Hendry and Madeley, 2010; Hansen et al., 2018). As such, it is not surprising that differences in interpretation can arise in real time. However, several central banks avoid much of this problem by publishing explicit quantitative projections of the policy rate. Thus, at least on the date of publication, policy rate expectations should synchronize.

However, this is not what we find empirically: instead, there is frequently a substantial gap in interest rate expectations (e.g., Svensson, 2015). The gap exists in a variety of countries and is largely robust to assumptions about risk premia. The origin of such a gap is not obvious. There are several explanations for why such a gap could rationally exist. First, the central bank's projections may, for a variety of reasons, not be representative of their true expectations. Second, the private sector might have, in at least one dimension, better information than the central bank about the future state of the economy, which drives the differences in expected policy. Third, the private sector could have, at least partially, better information than the central bank about the future policy reaction function. Fourth, the private sector's expectation formation process may result in superior estimates despite possessing less information than the central bank. All of these explanations have important implications for the role of central bank communication and, potentially, the formation of expectations more generally. I consider each of these scenarios and discuss their implications.

I find that neither the representativeness of central bank projections nor differences in expectations about the future state of the economy are sufficient to fully explain the difference in policy rate expectations between the central bank and private sector. As such, some portion of the gap must be a result of differences in beliefs about the central bank's reaction function. Since I find that the private sector, at least for the most part, appears to have more accurate forecasts, monetary policy may have been improved given the information available at time t. Moreover, this may suggest that the private sector has sufficiently learned the central bank reaction function such that it can predict future policy better than the central bank.

Further, I consider the implications of such a gap on the effectiveness of forward guidance. One intuitive way to think about this is from a credibility standpoint. As the gap in expectations rises, central banks' interest rate projections can be thought of as less credible. I define the credibility gap to be the absolute value of the difference in policy rate expectations. I then use this measure to assess what effect, if any, credibility has on the effectiveness of forward guidance in the United States. I find that a loss in credibility can significantly reduce the impact that forward guidance has on medium- and long-term Treasuries, corporate bond yields, and consumer borrowing rates. In fact, if the difference in expectations is above 100 basis points, the effect of forward guidance is almost completely eliminated. Further, I find evidence in both New Zealand and Sweden that also supports the idea that credibility can dampen the effects of forward guidance.

These results have several important implications for monetary policy. First, credibility is important in determining a central bank's optimal choice of monetary policy instrument, particularly when the policy rate is constrained. In particular, LSAPs are likely less impacted by credibility and may be more effective than forward guidance if a central bank is not considered to be credible. Another important implication of these results is that much of the forward guidance puzzle (see, e.g., Del Negro et al., 2015; McKay et al., 2016) can be explained by a lack of credibility, especially at longer horizons. Indeed, if the impact of forward guidance is so heavily influenced by a central bank's credibility, any model omitting this will drastically overstate its impact. This finding is consistent with Cole and Martínez-García (2020), which considers the impact of an alternative measure of credibility on forward guidance in a New Keynesian framework.

The rest of the paper is as follows. Section 2.2 documents the gap in interest rate expectations across several countries and shows that it is robust to a variety of assumptions. Section 2.3 utilizes a simple model to show why credibility should impact forward guidance. Section 2.4 estimates the effect that the gap in expectations can have on the effectiveness of forward guidance. Section 2.5 explores the possibles causes of such a gap. Section 2.6 discusses the implications of these results. Section 3.8 concludes.

2.2 Differing Policy Rate Expectations

2.2.1 Measuring Central Bank Expectations

To measure policymakers' expectations of future interest rates, I use explicit quantitative projections released by the central bank, typically following one of its regularly scheduled meetings. The Reserve Bank of New Zealand (RBNZ) has provided quantitative interest rate forecasts since 1997 alongside its quarterly Monetary Policy Report.[1] The RBNZ provides forecasts for each quarter, typically for a horizon of at least eight quarters. For most of the sample, the RBNZ has provided forecasts of the 90-day interest rate rather than forecasts of the policy rate, the official cash rate (OCR). However, this changed beginning in November 2016, when the RBNZ began to provide forecasts of the OCR instead. Although the 90-day interest rate is closely related to the OCR, it is typically higher and does not perfectly track the OCR one-to-one. Thus for most of the sample period, the analysis is not directly considering the policymaker's plans but a rate heavily influenced by them.

Like the RBNZ, the Riksbank, the central bank of Sweden, provides quarterly forecasts of its policy rate, the repo rate, and has done so since 2007. The Riksbank provides these forecasts six times per year in conjunction with the release of its Monetary Policy Report.[2] These projections typically provide forecasts for the following 13-16 quarters.

To measure expectations in the United States, I consider the Summary of Economic Projections (SEP), which has been released since 2012 following four of the eight annual meetings held by the Federal Open Market Committee (FOMC).[3] The SEP contains the so-called "dot plots", which show the interest rate forecast of each member of the FOMC for the end of

[1] Although the RBNZ began releasing projections in 1997, the data has only been in its current format since December 2000.

[2] Prior to 2015, every other release was a Monetary Policy Update but still included revised quantitative forecasts.

[3] The exception to this is in 2012, when SEP was released after five of the eight annual FOMC meetings.

the current year as well as the following two to three years. Importantly, unlike the forecasts by the RBNZ or Riksbank, the FOMC's forecast is always for the end of the year, so the forecast horizon varies depending on which meeting the forecasts are released.

It is important to note that all of these reports also provide forecasts of other key economic variables, namely unemployment, inflation, and GDP growth. Further, the releases by the RBNZ and Riksbank, particularly later in the sample, also provide forecasts of a multitude of other economic variables such as housing prices and trade volumes. Thus, markets not only have access to the policy rate forecasts, but also forecasts of the future state of the economy to provide context.

2.2.2 Measuring Private Sector Expectations

To approximate the private sector's expectation of future interest rates, I use the market close of policy rate futures from the day of the policy announcement.[4] For the United States, I use federal funds futures. More specifically, I use the settlement price for the year-end contract of the horizon being considered.[5] To measure market expectations in Sweden, I use RIBA futures, which measure the Riksbank's repo rate, and have traded since April 2009. Likewise, I use New Zealand 90-Day bank bill futures to measure market expectations of the policy rate in New Zealand. Since this is the rate that the central bank projected through 2016, it

[4] One minor concern is that there may be important macroeconomic news released between when the forecasts were finalized and the time that they are released. One possible fix would be to use market expectations corresponding to the date that forecasts were finalized. However, doing so would fail to account for changes in private sector expectations in response to the central bank's announcement. However, given the size and persistence of the gap in interest rate expectations, this is unlikely to be the driving factor. Indeed, the change in the current and year ahead federal funds rate futures from a week prior to the FOMC meeting to the day before is small over this period.

[5] There are two possible choices for contract month: December and January. Throughout the analysis, I consider January, as it should better reflect the year-end interest rate since the first Federal Reserve meeting of the year has typically been held toward the end of January or beginning of February. Further, as discussed in Boguth et al. (2019), rates are less likely to be changed in January since these meetings lacked a press conference for most of the sample. If the December contract is used instead, the results are similar.

allows for direct comparison. For consistency, I ignore the period from 2017 onward.[6]

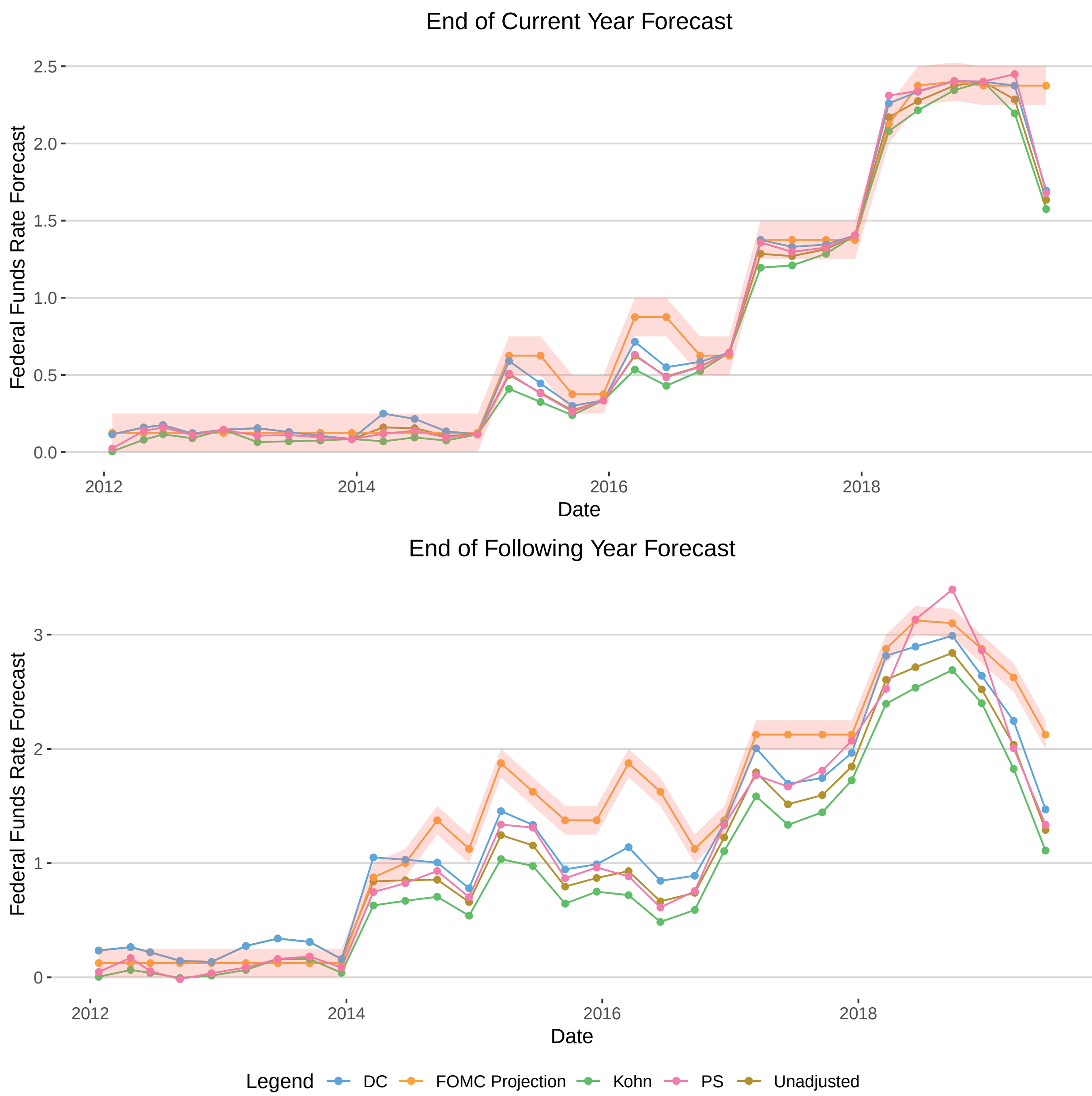
Without adjustment, however, futures prices may inaccurately measure expectations as they do not take into account the risk premium. Unfortunately, accounting for the risk premium is not simple. In the case of the United States, I consider several approaches to calculating the risk premium, which provides a reasonable range for private sector expectations. First, I follow the former Federal Reserve Board's rule of thumb described in Piazzesi and Swanson (2008) and Diercks and Carl (2019) and consider a constant risk premium of one basis point per month (henceforth called Kohn's rule). Second, I follow Piazzesi and Swanson (2008) by estimating a time-varying risk premium in which I account for changes in the business cycle. Further, I consider the estimates obtained in Diercks and Carl (2019), which looks at federal funds futures with 3 to 9 month maturities and finds roughly a 0bp per month difference during the zero lower bound (ZLB) period and a 1-2bp per month negative risk premium in the post-ZLB period. Finally, I consider the difference between the federal funds rate indicated in the Summary of Market Participants (SMP) and the rate implied by federal funds futures. A more detailed accounting of these risk premia can be found in Appendix B.1.

To adjust the RIBA futures for the risk premium, I consider a similar spread of assumptions. In the baseline case, I follow the rule of thumb employed by the Riksbank and consider a constant risk premium of one bp per month (Sveriges Rikbank, 2013). I also consider the time-varying risk premium implied by the difference between the repo rate forecasts from survey data and those implied by RIBA futures. However, the survey is limited, as it only covers a handful of horizons.[7] Finally, I consider a negative risk premium of one basis point per month. The justification for this is two-fold. First, this corresponds to the average risk premium implied by the difference between the survey and futures data. Second, it provides

[6] It would be possible to consider the period from 2017 onward, but it would require adjusting for the difference between the 90-day interest rate and the OCR, which is likely time-varying.

[7] On behalf of the Riksbank, TNS Sifo Prospera surveys approximately 50 market participants each month to obtain expectations of the repo rate at horizons of 3, 12, 24, and 60 months.

Figure 2.1: Difference in Interest Rate Expectations – United States



an analogue to the measure obtained from Diercks and Carl (2019).

Unlike the case in the United States and Sweden, there does not appear to be a rule of thumb adjustment employed by the Reserve Bank of New Zealand. Ferrero and Secchi (2009) use survey data from 1999-2007 and find the 3-month futures risk premium to be about 6.5bp and the 12-month futures risk premium to be 28bp, which suggest that the average risk premium over this period is approximately 2bp per month. Unfortunately, there are few ways of obtaining a time-varying risk premium across the entire sample.

2.2.3 Gap in Interest Rate Expectations

Figure 2.2: Difference in Interest Rate Expectations – Sweden and New Zealand

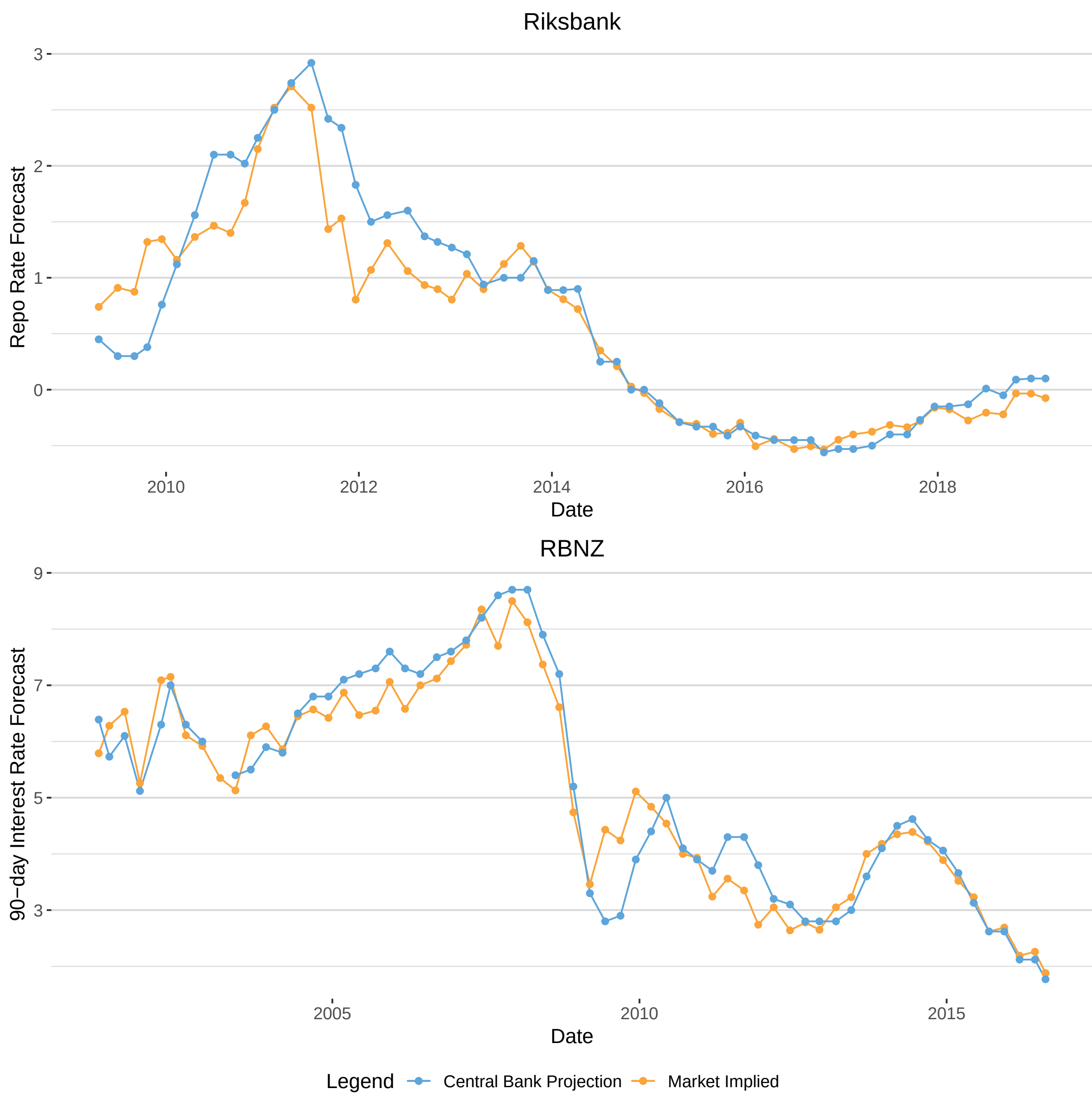


Figure 2.1 shows the expectations for the central bank and private sector in the United States under varying assumptions regarding the risk premium. The 'market implied' rate denotes the unadjusted market forecast, 'Kohn' denotes a risk premium of 1bp per month, 'DC' denotes the risk premium calculated in Diercks and Carl (2019), and 'PS' denotes the risk premium obtained by following Piazzesi and Swanson (2008). As Figure 2.1 shows, the FOMC's forecast has been consistently and substantially above the private sector's following the ZLB period. I also find large gaps in interest rate expectations in Sweden and New Zealand, as shown in Figure 2.2. Figure 2.2 considers expectations five quarters ahead to best match the horizon in the United States, but the gap exists regardless of the choice of horizon.

Given that the central bank's interest rate forecast in these countries is public, it is somewhat surprising that this gap exists. It is natural to expect that the central bank has more information than the private sector about the path of the policy rate since the central bank is responsible for setting the policy rate. If this was the case, however, the private sector should adopt the central bank's forecast as its own. The existence of such a gap may cast doubt on the assumption that the expected value of central bank projections is reflected in futures contracts.[8]

2.2.4 Interest Rate Forecast Accuracy

Given that the private sector and central bank have different views about the future path of the policy rate, it is natural to compare the accuracy of the forecasts. Table 2.1 shows the root-mean-squared error (RMSE) for New Zealand, Sweden, and the United States at various horizons under the assumption of a 1bp per month risk premium. Results for the United States under alternative risk premium assumptions can be found in Table B.3.

[8]See, for example, Moessner and Nelson (2008) and Demters and Nautz (2012).

Table 2.1: Policy Rate Forecast RMSE

Horizon (Quarters Ahead)	PS	CB	$H_0 : PS = CB$
	RMSE		
New Zealand			
1	0.42	0.37	0.751
2	0.57	0.75	0.179
3	0.91	1.10	0.196
4	1.22	1.43	0.204
5	1.52	1.72	0.262
Sweden			
0	0.02	0.02	0.516
1	0.10	0.12	0.186
2	0.19	0.24	0.098
3	0.29	0.37	0.026
4	0.40	0.55	0.118
United States: Greenbook Data			
0-3	0.45	0.41	
4-7	1.52	1.51	
United States: SEP Data			
0-3	0.16	0.22	
4-7	0.57	0.70	

New Zealand forecasts are from 2000-2016 (64 observations), Sweden forecasts are from 2009-2019 (59 observations), United States Greenbook forecasts are from 2005-2014 (80 observations), and United States SEP forecasts are from 2012-2019 (31 observations). The rightmost column reports the p-value from the Diebold-Marino test.

I find that private sector forecasts in New Zealand and Sweden are more accurate than those of the central bank at predicting policy rates several quarters ahead. Table 2.1 also shows the results of the Diebold and Mariano (1995) test for forecast accuracy. The p-values are obtained from the small sample adjustment suggested in Harvey et al. (1997). The only results that are significant are the 2- and 3-quarter ahead forecasts in Sweden, which both indicate that the private sector is more accurate than the Riksbank. The lack of significance elsewhere may be due to the relatively small sample sizes and long horizons being considered.

These results are consistent with an internal evaluation from the Riksbank that compared the repo rate forecasts of the Riksbank to those of five private forecasters and found that the Riksbank was the least accurate forecaster over the period from 2007 to 2018 (Sveriges Rikbank, 2019). Perhaps even more striking is that there was not a single year over the sample in which the Riksbank was above average at forecasting the repo rate. This also corresponds with Natvik et al. (2020), who find that the publication of interest rate forecasts by the central bank has not improved private sector forecast accuracy in Sweden and Norway.

In the United States, the results are less clear. When comparing Greenbook and private sector forecasts from 2005 to 2014, the Federal Reserve's forecasts appear to be more accurate than those of the private sector, though this is dependent upon the assumption of risk premium.[9] However, when comparing private sector forecasts to the median projection in the SEP, private sector forecasts appear to perform much better for all risk premia considered.[10] There is no p-value reported for the United States because the forecast horizon varies across observations. These results seem to indicate that the Federal Reserve was more accurate prior to the ZLB but that the private sector has been more accurate following the ZLB.

2.3 A Simple Model of Credibility and Forward Guidance

To help motivate the empirical analysis in Section 2.4 and provide intuition for the results, I consider a simple theoretical model similar to Morris and Shin (2002). In particular, I

[9]Even disregarding the differences across the assumption of risk premium, the superior accuracy of the Greenbook forecasts over this period should be treated with some skepticism. As previously mentioned, the central bank is predicting the average target rate for the fourth quarter while the private sector is predicting the average effective rate. While this difference is generally negligible, the effects in the fourth quarter of 2008 are actually quite large and make the central bank's forecasts appear more accurate relative to the private sector for purely technical reasons.

[10]It is important to note that the forecasts in the SEP represent FOMC members' view of appropriate policy, which many be different from their view of the most likely outcome. For a more complete discussion of this distinction, see Section 2.5.1.

intend to illustrate the mechanism through which a central bank's credibility can impact the effectiveness of its forward guidance. As such, the model is kept intentionally simple.

Let there be a continuum of agents, indexed by the unit interval [0,1]. Agent j forms expectations of next period's interest rate $i_j \in \mathbb{R}$. The payoff for agent j is given by

$$u_j(i, \theta) = -(1-r)(i_j - \theta)^2 - r(L_j - \bar{L}),$$

where $0 \leq r \leq 1$ is a constant that measures the externality in which individuals try to second-guess the decisions of other individuals in the economy, θ is next period's interest rate, and

$$L_j \equiv \int_0^1 (i_k - i_j)^2 dk$$
$$\bar{L} \equiv \int_0^1 L_k dk.$$

The payoff increases as the agent's expectations of next period's interest rate become more accurate and as the agent's forecast becomes more in line with other agents' forecasts. This secondary component can be thought of as a penalty for failing to coordinate. Let us consider the case where there is both the public and private information regarding the future path of interest rates. In particular, the central bank communicates a public signal

$$y = \theta + \eta,$$

where η is normally distributed with mean zero and variance σ_η^2. It is natural to interpret the signal from the central bank as forward guidance, as it contains information regarding the expected future path of interest rates. Note that η can be thought of as the error in the central bank's expectations or as transmission noise associated with the inability of the central bank to communicate their expectations perfectly. Further, each agent j receives a private signal

$$x_j = \theta + \epsilon_j,$$

where ϵ_j is white noise with variance σ_ϵ^2 such that $E(\epsilon_j \epsilon_k) = 0$ for $k \neq j$. Unlike in Section 2.5, I take no stand on how the signals are being communicated or why the disagreement arises. It may be that agents have different signals about the future state of the economy and thus expect different interest rates. Alternatively, agents may agree on the future state of the economy but disagree on the central bank's reaction function. Morris and Shin then show that the unique equilibrium interest rate forecast i_j is given by

$$i_j = \frac{\alpha y + \beta(1-r)x_j}{\alpha + \beta(1-r)},$$

where $\alpha = \frac{1}{\sigma_\eta^2}$ and $\beta = \frac{1}{\sigma_\epsilon^2}$ are the precision of the public and private signal, respectively. If we define $\kappa \equiv \frac{\alpha}{\alpha+\beta(1-r)}$, then the equilibrium action reduces to

$$i_j = \kappa y + (1-\kappa)x_j.$$

It is natural to think of κ as denoting the credibility of the central bank's signal since it is a measure of the precision of the central bank's signal relative to the precision of the private market's signal. In the limiting case as $\kappa \to 1$, the central bank is completely credible and the market perfectly aligns its interest rate expectations to agree with the central bank. In the limiting case as $\kappa \to 0$, the central bank has no credibility and the market completely ignores any information from the central bank regarding the future path of interest rates. In this sense, the credibility of a central bank is a direct determinant of the efficacy of the central bank's forward guidance. As κ increases, forward guidance has more of an impact on interest rates, and therefore, a greater impact on the economy.

2.4 Implications of Differences in Policy Rate Forecasts for Forward Guidance

In this section, I estimate the impact that the credibility of a central bank's communication can have on the effectiveness of its forward guidance. First, I create a measure of credibility based on the difference in interest rate expectations detailed in Section 2.2. I then use this measure in an event-study framework on FOMC announcement days to quantify how the effect of forward guidance on Treasury yields, corporate bond yields, and consumer borrowing rates is influenced by credibility. I then repeat this analysis for government bond yields in both New Zealand and Sweden.

2.4.1 Defining the Credibility Gap

As in Cukierman and Meltzer (1986), I define credibility as "the absolute value of the difference between the policymaker's plans and the public's beliefs about those plans." In particular, I will focus on the anticipated path of the policy rate, which is the primary tool of most policymakers. Thus, I define the credibility gap, $c_{t,h}$, as the absolute value of the gap in interest rate expectations at horizon h, which can be written as

$$c_{t,h} \equiv |E_t^{CB} i_{t+h} - E_t^{PS} i_{t+h}|, \tag{2.5}$$

where E_t^{CB} denotes the expectations of the central bank at time t, E_t^{PS} denotes the expectations of the private sector at time t, and i_{t+h} denotes the policy rate h periods ahead. Accordingly, a smaller gap in expectations of the interest rate implies greater credibility by the central bank.

2.4.2 United States

Now, I provide empirical evidence that the expectations gap dampens the impact of forward guidance in the United States. I consider a regression of the form

$$\Delta y_t = \alpha + \beta_0 \Delta s_t + \beta_1 f_t + \beta_2 c_t + \beta_3 f_t * c_t + \epsilon_t \tag{2.6}$$

where t indexes FOMC announcements containing SEP releases, Δy_t is the day-to-day change in the financial asset y, Δs_t is the surprise change in the federal funds rate as in Kuttner (2001), f_t is a measure of forward guidance as in Swanson (2020), and c_t is the credibility gap as defined in (2.5). The measure of forward guidance, f_t, is obtained by principal component analysis on the 30-minute asset price responses to each FOMC announcement, which are then rotated to economically meaningful factors.[11] I then scale this measure to correspond to a 25 basis point change in the one-year-ahead Eurodollar futures rate. Of particular interest is β_3.

For the following analysis, I will define the Fed's credibility gap as the difference in expectations at the end of the following year. This is done for several reasons. First, the interest rates for the end of the current year will naturally converge as the forecast announcements approach the end of the year. As such, the gap depends heavily on the timing of the forecast as well as the difference in expectations. While this feature may also be present in longer horizon forecasts, it is mostly mitigated. Second, at horizons longer than the end of the following year, it is difficult to obtain accurate measures of market expectations. Further, as discussed in Chapter 1 of the dissertation, the market does not appear to respond to the FOMC's forecasts at these horizons, suggesting that the informational value is much lower.

[11] The principal component analysis is performed on matrix containing the first and third federal funds futures contracts, the second, third, and fourth Eurodollar futures contracts, and the 2-, 5-, and 10-year Treasury yields. Importantly, no data from the SEP is included.

Table 2.2: Credibility and Treasury Yield Response to FOMC Announcements

	3-Month	2-Year	5-Year	10-Year	30-Year
Surprise	60.1***	20.7	38.3	34.4	25.6
Change	(22.1)	(34.6)	(54.0)	(44.2)	(38.8)
Forward	1.06	10.8**	32.1***	25.4***	13.7***
Guidance	(2.31)	(4.3)	(9.0)	(7.3)	(5.1)
Credibility	−0.09	−1.05	−2.08	−2.74	−4.22
Gap	(1.45)	(2.22)	(3.57)	(2.97)	(2.57)
Cred*FG	2.12	4.08	−24.4**	−23.1***	−15.1**
	(3.54)	(5.9)	(10.0)	(8.6)	(6.9)
Constant	−0.81	0.34	−0.30	−0.06	0.89
	(0.7)	(1.1)	(1.7)	(1.5)	(1.3)
Observations	31	31	31	31	31
R^2	0.31	0.70	0.63	0.57	0.35

Notes: Estimated coefficients from $\Delta y_t = \alpha + \beta_0 \Delta s_t + \beta_1 f_t + \beta_2 c_t + \beta_3 f_t * c_t + \epsilon_t$, where t indexes FOMC announcements containing SEP releases, Δy_t is the daily change in the financial asset y, Δs_t is the surprise change in the federal funds rate , f_t is a measure of forward guidance, and c_t is the credibility gap. Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through June 2019. Coefficients are in basis points. Bootstrapped standard errors are reported in parentheses. Superscripts *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent. See text for details.

Treasury Yields

Table 2.2 reports the responses of 3-month and 2-, 5-, 10-, and 30-year Treasury yields to changes in forward guidance and credibility from January 2012 to June 2019. Bootstrapped standard errors are given in parentheses.[12] As expected, the surprise change in the federal funds rate has a positive and significant effect on short-term yields. In particular, a 100bp

[12]Due to the fact that several of the covariates from the regressions in Section 2.4 are generated from an estimated procedure rather than being directly observed, more traditional measures of standard error likely fail to capture the additional uncertainty surrounding the estimates (see, for example, Pagan, 1984). To account for this additional uncertainty, I follow a similar procedure to Swanson (2020) and bootstrap the standard errors. More specifically, for each bootstrap sample, I sample the 213×8 matrix X of responses on FOMC announcement days with replacement and generate a matrix of synthetic factors. To respect any potential differences between SEP dates and non-SEP dates, I draw samples from each group separately. I then sample the residuals of the dependent variable in the same way and rerun the specified regression. I repeat this procedure 5,000 times and then compute the standard errors from the empirical distribution.

surprise change in the federal funds rate results in 60bp change in the 3-month Treasury yield, which is fairly consistent with estimates in the literature, such as Kuttner (2001) and Gürkaynak et al. (2005). Forward guidance has a positive and significant impact on medium- and longer-term treasuries. For example, forward guidance indicating a 25bp increase in the federal funds rate one year ahead results in a 32bp increase in the 5-year Treasury yield. It might be surprising that the 5-year yield increases by more than 25bp, but this is likely due to the fact that the forward guidance is indicative of other future rate hikes, particularly given that the sample begins in the ZLB period. The effects of forward guidance are somewhat larger than those found in Gürkaynak et al. (2005), Campbell et al. (2012), and Swanson (2020), which is likely due to the introduction of the credibility term. Credibility has no direct impact on Treasury yields, as expected: the gap in interest rate expectations in the future should not directly determine the change in the Treasury yields. The parameter of particular interest is β_3, the coefficient on the interaction term. For the 5-, 10-, and 30-year yields, the impact is negative and significant. This indicates that the less credible the central bank's indicated path of future interest rates, the smaller the impact that forward guidance will have. In fact, in the case of an expectations gap of around 100bp, the estimated effect of forward guidance is almost completely counteracted. However, in the data, the gap is about 40bp on average, which suggests that forward guidance was only 60% as effective as it would have been if the central bank was completely credible over this period. To ensure that these results are robust to concerns of background noise like those raised in Nakamura and Steinsson (2018), I also consider the corresponding high-frequency responses, which can be found in Table B.4. These results are also robust to the choice of risk premium, as shown in Table B.5.

One potential concern is that these results do not incorporate LSAPs, which may be an important omitted variable (see, e.g., Gagnon et al., 2011; Lewis, 2019; Swanson, 2020). To account for this, I add the measure of LSAP from Swanson (2020) into the specification in equation (2.6). The results can be found in Table B.6. The results are similar to those without the inclusion of the LSAP factor, with the exception that credibility no longer appears to have an effect on the 30-year Treasury yield.

Corporate and Consumer Borrowing Rates

Table 2.3 reports analogous results for corporate bond yields as well as mortgage and auto loan rates. To measure corporate bond yields, I use Moody's seasoned Aaa and Baa long-term corporate bond yield indices. Both Aaa and Baa corporate bond yields are positively impacted by forward guidance and negatively impacted by the interaction term. More specifically, a 25bp increase in forward guidance results in a 12.5bp increase in both Aaa and Baa yields, which is about half of the impact on the 10-year Treasury yield. These results suggest that if the central bank is less credible, forward guidance is less effective in reducing corporate borrowing rates, and therefore, should be less effective in stimulating corporate investment.

To measure mortgage rates, I use the 15- and 30-year national average fixed home mortgage rate provided at a daily frequency by Bankrate.com; for auto loan rates, I consider the 60-month national average rate for new cars, which is also provided at a daily frequency by Bankrate.com. At both mortgage maturities, the effect of forward guidance is positive and significant while the impact of the interaction term is negative and significant. The 30-year mortgage rate increases approximately 11bp in response to a 25bp increase in forward guidance and, as with corporate and Treasury yields, the effect of forward guidance is almost completely dampened when the credibility gap is 100bp. The effect on automobile rates appears to be similar, if weaker. The response of the 60-month rate is significant and follows the same pattern as previous assets, though the effect of forward guidance is only 8bp, which is slightly less than the other assets considered.

Given these results, it seems clear that the impact of forward guidance on consumer borrow-

Table 2.3: Credibility and Corporate and Consumer Borrowing Rate Responses to FOMC Announcements

	Corporate Yields		Mortgage Rate		Auto Loan Rate
	Aaa	Baa	15-Year	30-Year	5-Year
Surprise Change	40.4 (37.9)	29.8 (38.2)	-20.2 (27.9)	-7.2 (30.9)	-0.90 (22.4)
Forward Guidance	12.3^{**} (4.81)	12.6^{***} (4.87)	7.83^{**} (3.43)	11.5^{***} (4.13)	8.53^{***} (2.98)
Credibility Gap	-5.04^{**} (2.48)	-3.82 (2.53)	-0.75 (1.88)	0.09 (2.01)	2.09 (1.47)
Cred*FG	-15.7^{**} (6.9)	-14.0^{**} (6.8)	-9.10^{*} (4.9)	-10.9^{**} (5.4)	-9.02^{**} (4.0)
Constant	0.90 (1.22)	0.84 (1.24)	0.11 (0.90)	-0.44 (0.98)	-1.53^{**} (0.71)
Observations	31	31	31	31	31
R^2	0.34	0.32	0.18	0.32	0.34

Notes: Estimated coefficients from $\Delta y_t = \alpha + \beta_0 \Delta s_t + \beta_1 f_t + \beta_2 c_t + \beta_3 f_t * c_t + \epsilon_t$, where t indexes FOMC announcements containing SEP releases, Δy_t is the daily change in the financial asset y, Δs_t is the surprise change in the federal funds rate , f_t is a measure of forward guidance, and c_t is the credibility gap. Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through June 2019. Coefficients are in basis points. Bootstrapped standard errors are reported in parentheses. Superscripts *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent. See text for details.

ing rates is dependent on the central bank's credibility. As such, a central bank's credibility has a clear channel to impacting the real economy. Table B.7 considers the reduced-form relationship between the number of new homes sold and 30-year mortgage rates and finds the mortgage rate has strong, negative correlation with the number of homes sold. If we interpret the reduced-form estimates as causal, then it suggests that if the 30-year mortgage rate is 100 basis points higher, then there would be approximately 50,000 fewer new single family homes sold each month. Thus, if forward guidance is rendered less effective in reducing mortgage rates due to a lack of credibility, then forward guidance may be less effective in stimulating the real economy.

I also consider the impact on the stock market, which is shown in Table B.8. To measure the change in the stock market, I consider the daily percentage change in the S&P 500. The impact of forward guidance on the stock market is negative and significant, as in Lakdawala and Schaffer (2019) and Swanson (2020). An increase in forward guidance results in approximately a 2.3% decline in the S&P 500. Though the sign on the interaction term is positive, as expected, it is not significant. It is likely that the effect is present but not sufficiently strong enough to be detected by a relatively small sample size, especially given the volatility of the stock market.

2.4.3 New Zealand

Measuring credibility in New Zealand is similar to the case in the United States, but there are a few important differences. Namely, the RBNZ provides quarterly forecasts of the 90-day interest rate rather than year end forecasts. Another advantage of the New Zealand data is that it dates back to 2000, which provides a larger sample and allows consideration of the economy across a wider variety of states.

To obtain estimates of forward guidance in New Zealand, I follow the methods in Gürkaynak et al. (2005); see Appendix B.2 for details.[13] The forward guidance measure is then scaled to correspond to a 25bp change in the one-year-ahead 90-day bank bill futures rate. To measure credibility, I consider the difference in the 5-quarter ahead estimates of the policy rate, as this is the best analogue to the horizon chosen in the United States.[14] Figure 2.2 shows the comparison between the market and central bank forecasts 5-quarters ahead.

I consider the same specification as in equation (2.6). The response of the 3-month and 2-,

[13]For robustness, I also consider an alternative measure of forward guidance obtained by taking the residuals from regressing the change in 2-year bond yield on the surprise change in the policy rate (see Rogers et al., 2018). The results are similar to the baseline case.

[14]Unlike in the case of the U.S., there is no obvious choice of horizon in measuring credibility. Although I only show results for the 5-quarter ahead estimates, the results are robust to the choice of horizon.

Table 2.4: Credibility and New Zealand Government Bond Yield Responses to RBNZ Announcements

	3-Month	2-Year	5-Year	10-Year
Surprise Change	32.4***	29.4***	17.2***	7.4**
	(4.72)	(4.20)	(2.87)	(2.76)
Forward Guidance	13.6***	16.3***	14.7***	12.8***
	(2.85)	(2.27)	(1.71)	(1.61)
Credibility Gap	1.44	3.12	2.40	0.42
	(2.44)	(2.00)	(1.47)	(1.40)
Cred*FG	−7.6***	−7.2***	−5.8***	−4.6***
	(2.86)	(2.25)	(1.71)	(1.59)
Constant	0.10	−0.21	−0.53	0.47
	(1.17)	(0.99)	(0.71)	(0.68)
Observations	62	57	62	62
R^2	0.52	0.67	0.69	0.60

Notes: Estimated coefficients from $\Delta y_t = \alpha + \beta_0 \Delta s_t + \beta_1 f_t + \beta_2 c_t + \beta_3 f_t * c_t + \epsilon_t$, where t indexes RBNZ Monetary Policy Statement releases, Δy_t is the daily change in the financial asset y, Δs_t is the surprise change in the 90-day interest rate, f_t is a measure of forward guidance, and c_t is the credibility gap. Sample is all Monetary Policy Statements from from March 2001 through August 2016. Superscripts *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent. Coefficients are in basis points. Bootstrapped standard errors are reported in parentheses.

5-, and 10-year government yields are shown in Table 2.4. The overall results are similar to those in the United States. Both forward guidance and surprise changes to the policy rate have a positive and significant effect on government yields at all maturities. For instance, an announcement of 25bp of forward guidance one year ahead results in 16bp increase in the 2-year yield. Further, the sign on the interaction term is negative and significant at all horizons.

Despite these similarities, the effects of forward guidance differ in a few important ways. In New Zealand, forward guidance appears to peak at the 2-year horizon while forward guidance in the United States has a much greater impact at the 5- and 10-year horizons. More specifically, forward guidance in the U.S. is approximately twice as effective at the 5- and 10-year horizons. Further, it appears that the credibility of the RBNZ may have had less of an impact on its forward guidance. These differences could be due to the fact that as the policy rate was less constrained, the RBNZ did not need to be as explicit with its forward guidance.

Overall, these results reinforce the findings in the United States that credibility has a significant impact on the effectiveness of forward guidance. Further, they show that the results are not specific to the Federal Reserve but appear to hold for central banks more generally.

2.4.4 Sweden

The Riksbank, like the RBNZ, provides quarterly forecasts of its policy rate, the repo rate. As such, I define the credibility gap for Sweden as the absolute difference in the 5-quarter ahead expectations of the policy rate. Likewise, I also obtain estimates of forward guidance by following Gürkaynak et al. (2005). The comparison of market and Rikbsank expectations, which are shown in Figure 2.2, match up to well-known episodes in the Swedish experience, most notably the difficulties of September 2011 (Svensson, 2015).[15]

The response of the 3-month and 2- and 5-year government bond yields are shown in Table 2.5.[16] The impact of forward guidance is stronger than in the United States or New Zealand. For instance, forward guidance indicating a 25bp increase in the repo rate one year ahead results in a 35bp increase in the 2-year bond yield. Further, as in the other countries considered, the interaction term is negative for all horizons, though only the results on the

[15]In September 2011, the Riksbank announced that it would postpone additional increases in the policy rate. The Riksbank's corresponding forecasts indicated that they expected to increase the policy rate approximately 75bp over the next six quarters. However, this communication was almost completely incredible as the market – both before and after the announcement – expected a 75bp decrease over the same horizon.

[16]The results under alternative assumptions regarding the risk premium are displayed in Table B.9.

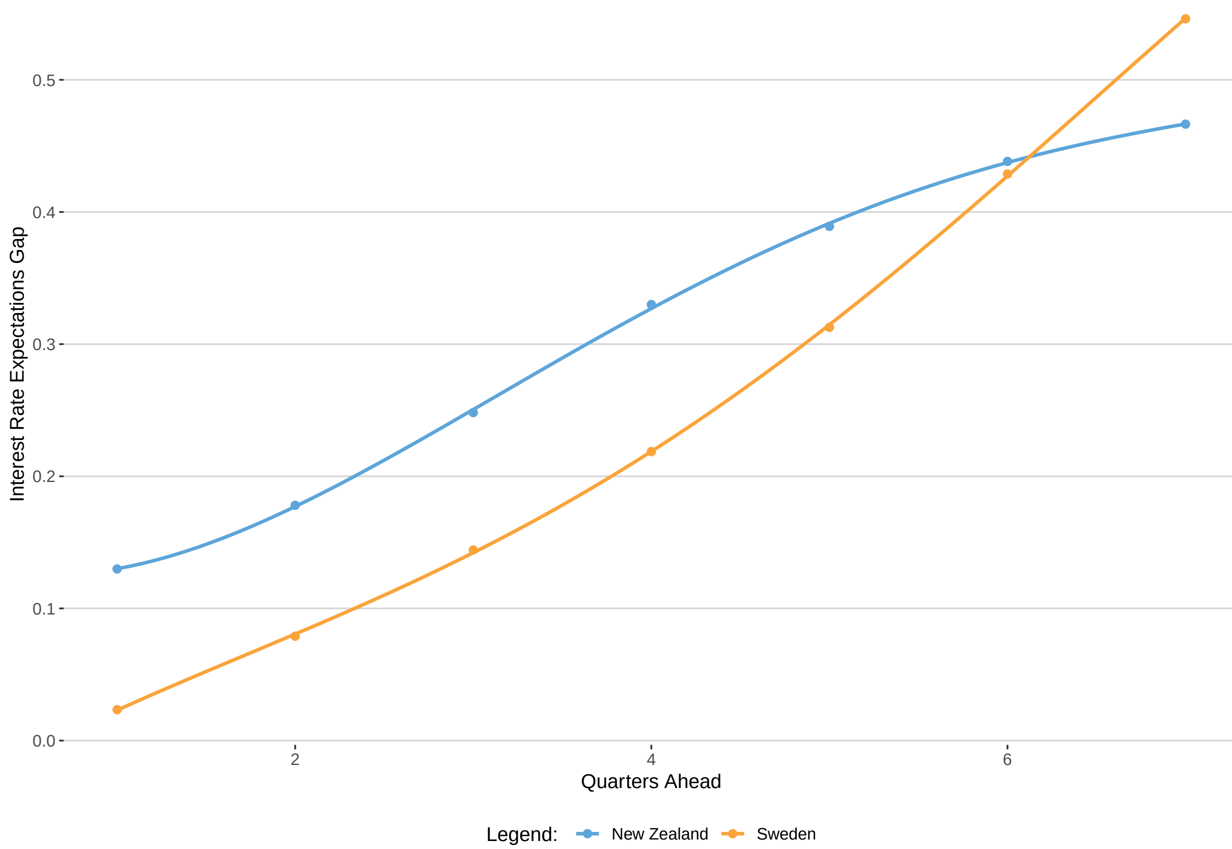
Table 2.5: Credibility and Swedish Government Bond Yield Responses to Riksbank Announcements

	3-Month	2-Year	5-Year
Surprise	82.3***	58.7***	42.4***
Change	(7.4)	(2.3)	(8.3)
Forward	5.7	35.0***	38.5***
Guidance	(4.1)	(1.3)	(4.6)
Credibility	−2.8	0.5	2.9
Gap	(1.7)	(0.5)	(1.8)
Cred*FG	−7.8	−5.8*	−9.2
	(10.6)	(3.2)	(11.8)
Constant	−0.58	−1.29***	−1.76***
	(0.53)	(0.17)	(0.58)
Observations	54	55	55
R^2	0.71	0.98	0.76

Notes: Estimated coefficients from $\Delta y_t = \alpha + \beta_0 \Delta s_t + \beta_1 f_t + \beta_2 c_t + \beta_3 f_t * c_t + \epsilon_t$, where t indexes Riksbank Monetary Report announcements, Δy_t is the daily change in the financial asset y, Δs_t is the surprise change in the repo rate, f_t is a measure of forward guidance, and c_t is the credibility gap. Sample is all Riksbank Monetary Policy Reports from February 2010 through February 2019. Superscripts *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent. Coefficients are in basis points. Bootstrapped standard errors are reported in parentheses.

2-year government bond yield are marginally significant. It is unclear why this is the case. One possible explanation is that the market expectations, particularly in the beginning of the sample, were imprecise due to the newness of the futures contracts. Another option is that the Riksbank's prolonged history of negative interest rates has mitigated the effect.

Figure 2.3: Interest Rate Expectations Gap by Horizon



2.4.5 Credibility Curve

One advantage of the Sweden and New Zealand forecasts is that they are quarterly. As such, it possible to examine how the gap in interest rate expectations varies across horizons. Figure 2.3 shows the average gap in interest rate expectations in Sweden and New Zealand at varying horizon lengths. Unsurprisingly, the average gap increases as the number of quarters increases. On average, it appears that the gap in interest rate expectations increases by about 6 basis points per quarter though this may change at longer horizons. The gap in New Zealand is approximately 10 basis points higher than in Sweden at shorter horizons, but as the forecast horizon increases, the gap in Sweden appears to grow more quickly. One interpretation of this is that the Riksbank is better at managing expectations in the short-term while the RBNZ is better at managing expectations in the long-term.

2.5 Causes of Differences in Policy Rate Forecasts

As Figures 2.1 and 2.2 show, there exists a frequent and sizable difference in interest rate expectations. However, it is not obvious why such a gap would exist. Explaining the causes of this difference in expectations is important not only in understanding how agents form expectations, but also because these differences in expectations can have important implications for the economy, as discussed in Section 2.4.

In this section, I consider several possible explanations for the gap in expectations. First I consider whether the gap in expectations can be explained by the fact that the central bank's forecasts may not be representative. Second, I explore the possibility that the gap is due to differences in expectations regarding the future state of the economy. Finally, I examine whether the difference is due to contrasting beliefs about the central bank's future reaction function.

2.5.1 Unrepresentative Central Bank Forecasts

One natural explanation for the difference in policy rate expectations is that a central bank's published forecasts are not representative of its true expectations. There are several ways in which this could happen. First, the central bank could be projecting something that is similar to, but distinct from, the expected path of policy rate. Second, the central bank might not spend sufficient time and energy to ensure that its projections reflect its full information set. Finally, the central bank may strategically misrepresent its expectations in order to influence private sector beliefs. I show below that none of these explanations are very convincing in fully explaining the gap in expectations.

Measuring Different Outcomes

It may be that much of the difference arises due to technical reasons. In fact, there are several complications in comparing expectations in the United States. First, the SEP provides forecasts of what participants think the federal funds rate would be under optimal policy, not what they think is the most likely outcome. For example, if a FOMC member thought that the committee would lower rates but that the best course of action was to raise rates, the SEP would reflect the latter. Of course, if the FOMC voted by a simple majority of all its members, the median SEP forecast would also represent the most likely path of policy. In reality, the FOMC does not always vote by a simple majority and not all members of the FOMC vote every meeting, which may distort the median as a measure of accuracy. Despite this, the median dot plot is generally similar to the FOMC staff forecast as presented in the Tealbook.[17] Further, the FOMC's median rate preference has historically been a good indicator of the committee's policy decision (Chappell et al., 2004). More importantly, there are several instances in which all FOMC members prefer a higher rate path than expected by the market. Thus, even if it is difficult to exactly measure the expectations of the FOMC, there clearly exist instances when the committee's expectations exceed those of the private sector.

Second, FOMC members are providing their modal expectation while futures measure probability-weighted expectations (Bernanke, 2016). As such, it is possible that the difference in interest rate expectations is due to the fact that the dot plots are ignoring downside risk to the federal funds rate. However, this does not appear to be the case. If we focus on survey expectations from the Summary of Market Participants (SMP), which measure the modal expectation

[17]The comparison of the median dot plot and FOMC staff forecast is shown in Figure B.1. The slight difference between the forecasts in 2014 is likely due to the fact that the Tealbook is forecasting the average rate in the fourth quarter while the FOMC is forecasting the year end rate. Thus, any rate hikes in the fourth quarter would not be fully incorporated into the Tealbook forecasts. More generally, the difference between the forecasts of the FOMC and those of the staff presented in the Greenbook/Tealbook are quite similar (Ellison and Sargent, 2012).

of private sector agents, the gap in interest rate forecasts is still present, though perhaps somewhat smaller than indicated through futures markets.

Third, the FOMC is forecasting the federal funds rate target at the end of the year while the private sector is forecasting the average effective federal funds rate for a given month. As such, it would not be surprising if there were minor differences between the two forecasts, particularly if there was a reason to expect that federal funds rate would tend toward one end of the target range. However, as shown in Figure 2.1, even accounting for this potential variation, there is still a large gap in interest rate expectations. One might also be concerned about the RBNZ, as the central bank forecasts the 90-day interest rate rather than the policy rate. However, given that the private sector is forecasting the 90-day interest rate as well, there is no problem.

Private Sector Forecasts Involve More Effort

Another possible explanation for why the private sector does not fully adopt the central bank's forecast is that the private sector believes, at least in some ways, it has more accurate forecasts than the central bank due to additional time and energy spent generating their forecasts. This is not unreasonable, as private agents can profit greatly from correct predictions. However, central banks also benefit from accurate projections. Not only do central banks need to forecast future policy to make optimal policy decisions in the short term, but central bank projections also can influence market expectations of future rates and thus improve economics outcomes today. Moreover, the central bank's reputation may suffer if forecasts are consistently inaccurate. The RBNZ has greatly emphasized its forecasts for over two decades. Similarly, in the United States, the forecasts draw significant attention and were implemented to help the public better understand the determination of monetary policy. It would be foolish for central banks to include these forecasts if they did not believe that they were as accurate as possible.

Strategic Central Bank Projections

An alternative explanation is that central banks strategically publish misleading projections in order to strategically influence the private sector's expectations. More specifically, central banks can potentially reduce the private sector's inflation expectations by communicating that interest rates will be higher than they actually expect them to be. In this manner, the central bank suggests that it is more hawkish than it is in reality.

To see this, let's consider a three-equation New Keynesian Model along the lines of Gali (2015). The central bank has the following loss function.

$$E_0 \sum_{t=0}^{\infty} \pi_t^2 + \lambda x_t^2. \tag{2.7}$$

As is standard, the New Keynesian Phillips Curve is given by

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t, \tag{2.8}$$

where the shock u_t is assumed to follow an AR(1) process,

$$u_t = \rho u_{t-1} + \nu_t. \tag{2.9}$$

The IS Curve is given by

$$x_t = E_t x_{t+1} - (i_t - E_t \pi_{t+1} - r_t^*). \tag{2.10}$$

Combining the first order conditions yields the solution under discretion

$$x_t = -\frac{\kappa}{\lambda} \pi_t.$$

As in Rudebusch and Williams (2008), I append a transitory policy shock, ω_t to the central bank's policy, so that the solution will be given as

$$x_t = -\frac{\kappa}{\lambda}\pi_t + \omega_t, \tag{2.11}$$

where ω_t is assumed to be an i.i.d normally distributed shock. Further, I assume that ω_t and u_t are uncorrelated. Substituting (2.11) into (2.8) yields the following difference equation for inflation:

$$\pi_t = \frac{\lambda}{\lambda + \kappa^2}\left(\beta E_t \pi_{t+1} + \kappa\omega_t + u_t\right). \tag{2.12}$$

Solving (2.12) forward, inflation under full information is given by

$$\pi_t = \frac{\lambda}{\kappa^2 + \lambda(1 - \beta\rho)} u_t + \frac{\lambda\kappa}{\lambda + \kappa^2}\omega_t. \tag{2.13}$$

However, in reality, agents do not know perfectly understand the process through which monetary policy is set. Instead, they infer this process through central bank actions and communications. In particular, I assume that agents do not know λ, the preferences of the central bank. As such, agents will estimate $\hat{\lambda}_t$ each period.[18]

If agents do not know the preferences of the central bank, then the difference equation for inflation is given by (2.12) where the expectations of inflation are formed under the assumption that $\lambda = \hat{\lambda}_t$. Let $\hat{a}_t = \frac{\hat{\lambda}_t}{\hat{\lambda}_t + \kappa^2}$. Then, expectations of next period's inflation are given by

$$E_t \pi_{t+1} = \frac{\rho \hat{a}_t}{1 - \rho\beta\hat{a}_t} u_t.$$

[18] Agents behave within an anticipated utility framework; that is, they do not consider that they may update $\hat{\lambda}_t$ in the future. Cogley and Sargent (2008) show that the anticipated utility approach provides a good approximation to the Bayesian approach.

Thus, inflation is given by

$$\pi_t = \frac{\lambda}{\lambda + \kappa^2} \left(\frac{1}{1 - \rho\beta\hat{a}_t} u_t + \kappa\omega_t \right).$$

Then the estimated loss without communication is given by

$$\begin{aligned} L_a &= E_0 \sum_{t=0}^{\infty} \beta^t (\pi_t^2 + \lambda x_t^2) \\ &= \sum_{t=0}^{\infty} \beta^t E_0 \left((\lambda + a\kappa^2)\omega_t^2 + \frac{a}{(1 - \rho\beta\hat{a}_t)^2} u_t^2 \right). \end{aligned}$$

The first question that arises from this is there a role for central bank communication. Assuming that the central bank's preferences are estimated in an unbiased manner – that is, $E[\hat{a}] = a$ – then central bank communication reduces central bank loss. In particular, the loss if the central bank clearly communicates its preferences is given by

$$\begin{aligned} L_c &= \sum_{t=0}^{\infty} \beta^t E_0 \left((\lambda + a\kappa^2)\omega_t^2 + \frac{a}{(1 - \rho\beta a)^2} u_t^2 \right) \\ &\leq \sum_{t=0}^{\infty} \beta^t E_0 \left((\lambda + a\kappa^2)\omega_t^2 + \frac{a}{(1 - \rho\beta\hat{a}_t)^2} u_t^2 \right) = L_a, \end{aligned}$$

which is true by Jensen's inequality. However, it is natural to wonder if the central bank can do better if it inaccurately communicates its preferences. The central bank faces the following problem

$$\min_{\hat{a}_t} \sum_{t=0}^{\infty} \beta^t E_0 \left((\lambda + a\kappa^2)\omega_t^2 + \frac{a}{(1 - \rho\beta\hat{a}_t)^2} u_t^2 \right),$$

to minimize its loss subject to the public's beliefs.[19] Taking derivatives yields

$$\frac{2\beta\rho a}{(1-\beta\rho\hat{a}_t)^3}u_t^2,$$

which is strictly positive if $\beta \in (0,1)$, $\rho \in (0,1)$, $\hat{a} \in (0,1)$. As such, the central bank's loss is increasing in the public's belief of λ. Thus, if the central bank is able to completely influence market beliefs about policy preferences (for instance, $sd_\omega = \infty$), it should indicate that $\lambda = 0$. In other words, the central bank wants markets to believe that it is entirely focused on stopping inflation in order to lower inflation expectations. Of course, it is unlikely that the central bank is completely able to influence market beliefs about λ. However, even if that is true, central banks still have an incentive to communicate a lower λ than they actually experience to try convince agents that they have a stronger preference for fighting inflation than is true.

However, despite the potential reduction in the central bank's loss, such an explanation is unlikely in practice. Central banks often have political requirements of accountability and transparency. The Federal Reserve, for instance, is required to submit a semiannual report to Congress. In this report, they explain recent economic developments, monetary policy, and provide a summary of projections about the future state of the economy. Because this summary of projections is the same that is given to markets, it is unlikely that the Federal Reserve would be able to strategically mislead the private sector through its communications. Further, as discussed in Vissing-Jorgensen (2019), there are regular leaks of information from central banks. Thus, even if a central bank wanted to communicate strategically, these leaks would likely render such communication ineffective.

[19]This minimization abstracts away from the fact that a central bank would, in practice, also want to consider the effects of its policy actions on the public's perception of its preferences. This simplifies the problem greatly and retains much of the qualitative results of more complicated formulations.

2.5.2 Differing Expectations of the Future State of the Economy

Perhaps the most obvious explanation for a difference in policy expectations is that private sector participants have superior information, in at least one dimension, relative to the central bank about the future state of the economy. That is, $E_t(X_{t+n}|\mathcal{I}_{\mathcal{PS}})$ is more accurate than $E_t(X_{t+n}|\mathcal{I}_{\mathcal{CB}})$, where $\mathcal{I}_j$ represents the information set of agent j for $j \in \{PS, CB\}$. If true, then they could incorporate the central bank projections into their information set and update accordingly. Given this additional information, their expectations would likely differ from those of the central bank. Indeed, Caballero and Simsek (2020) consider a model in which the difference in interest rate expectations is driven by an assumed disagreement regarding aggregate demand. There are however, several reasons to be doubtful that this can fully explain the gap.

First, this is contrary to the "Fed information effect" literature, which attributes some of the market reaction in response to FOMC announcements to the fact that the FOMC is also providing additional information about the future state of the economy to the private sector (see Romer and Romer, 2000; Campbell et al., 2012; Nakamura and Steinsson, 2018; Cieslak and Schrimpf, 2019; Jarociński and Karadi, 2020; and Miranda-Agrippino and Ricco, 2020). If the market is responding to the macroeconomic content of FOMC announcements, then this suggests that the Federal Reserve has superior information to communicate.

Even if one is skeptical of the Fed information effect, there is still evidence that the central bank is at least as accurate as the private sector at predicting the future state of the economy. Gamber and Smith (2009) compares the forecasts of the Fed to those of the private sector as measured by the Survey of Professional Forecasters (SPF) and Blue Chip forecasts. They find that over the period from 1964-2001, the Fed was substantially more accurate. Gamber and Smith also examined how the forecast accuracy changed across the sample. They find that even in the later part of the sample, the Fed was more accurate, though the difference in accuracy had been reduced. Bauer and Swanson (2020) consider a more recent sample and find that the RMSE of the Federal Reserve and Blue Chip forecasts of unemployment, output, and inflation are remarkably similar over the period 1990-2013, with the exception of inflation in the current quarter, which the Fed was more accurate at predicting.

Further, if the private sector was truly better at forecasting the future state of the economy, central banks could simply adopt their forecasts because they have access to the aggregated market opinions through the prices of various assets such as TIPS, surveys like the Blue Chip Economic Indicators, and informal conversations with market participants.

Even if the central bank is better at predicting the future state of the economy on average, private agents might think that they can forecast the state of the economy better in particular instances. However, even this is insufficient to fully explain the gap in interest rate expectations. For instance, consider the case in Sweden for much of 2009. Following the release of the April 2009 monetary policy report, the market implied rate was higher than the Riksbank's projection at almost all horizons. In fact, the market prediction for the fourth quarter of 2010 was almost 100bp higher than the central bank's forecast. Further, this difference in expectations persisted for several quarters. However, this gap cannot be explained by perceptions about the future state of the economy as the market expected lower inflation and GDP growth over this period (Svensson, 2010). Thus, if anything, the gap should have been in the opposite direction.

Such instances are not restricted to Sweden. For instance, in June 2019, the median SEP federal funds rate forecast was 2.4 for the end of the current year and the 2.1 for the end of the following year. The minimum forecast for both periods was 1.9. However, the respective unadjusted market implied rates were 1.6 and 1.3, much lower than the those of the central bank; even if an alternative risk premium is considered, it is still insufficient to explain the difference. Further, expectations about the future state of the economy do not appear to be driving this difference. As shown in Table 2.6, the market was more optimistic about

Table 2.6: Differences in Future State of the Economy: June 2019

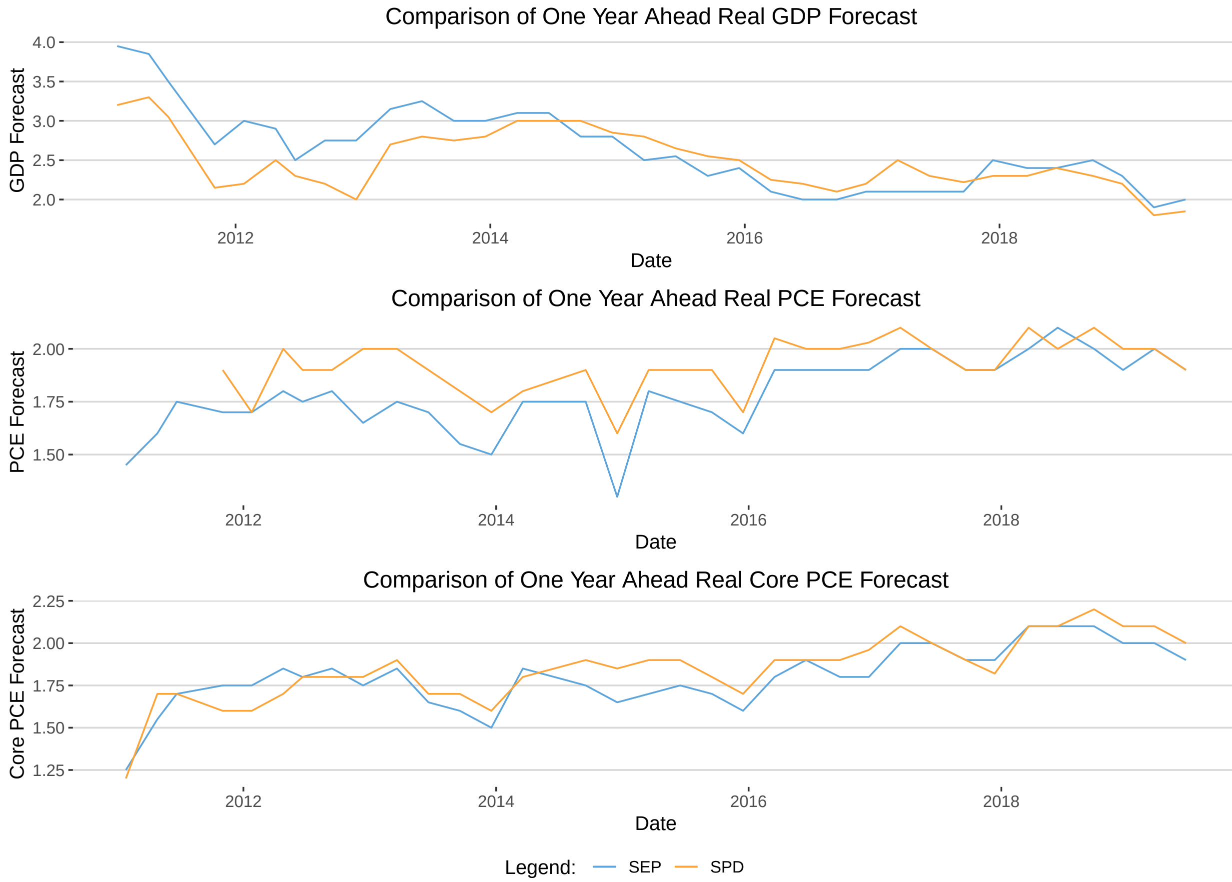
Horizon (Years Ahead)	GDP	Unemp.	PCE Inflation	Core PCE Inflation
FOMC June				
0	2.1	3.6	1.5	1.8
1	2.0	3.7	1.9	1.9
SPD June				
0	2.1	3.6	1.8	1.8
1	1.9	3.7	1.9	2.0
SPF Q2				
0	2.6	3.7	1.7	1.7
1	2.0	3.6	1.9	2.0
SPF Q3				
0	2.3	3.7	1.6	1.7
1	1.9	3.6	1.9	2.0

FOMC June denotes the estimates from the SEP release accompanying the June 18-19, 2019 FOMC meeting, SPD June denotes estimates from the SPD with a deadline on June 10, 2019, SPF Q2 denotes estimates from the SPF with a deadline on May 7, 2019, and SPF Q3 denotes estimate from the SPF with a deadline of August 6, 2019.

PCE inflation and quite similar to the FOMC estimates of GDP growth, unemployment and Core PCE inflation. In fact, based on Table 2.6 alone, it would not be unreasonable for the private sector to have higher interest rate expectations.

In fact, this appears to be the case for much of the post-ZLB period in the United States. Figure 2.4 compares the median forecasts of GDP, PCE inflation, and Core PCE inflation from the SEP and Summary of Primary Dealers (SPD) for the following year. As Figure 2.4 shows, primary dealers' forecasts of output and inflation have been higher for most of the ZLB period. This also appears true based on results from other survey data. As Figure B.2 shows, since 2014, the SEP forecast for real GDP growth has been at or below the SPF forecast. Likewise, the SEP forecast for PCE inflation has been at or below the SPF forecast for almost the entire period since 2012. The relationship between the forecasts for Core PCE inflation are less striking, but the trend still holds; since 2012, the SEP forecasts has

Figure 2.4: SPD vs. FOMC: Economic Variables



generally been at or below the SPF forecasts. Given that the FOMC was projecting lower growth and inflation, it would be natural to expect that the FOMC would be forecasting more accomodative policy rates than the private sector. Instead, the opposite was true.[20]

Forecast Error Correlation

One alternative explanation for the gap is that, even though the central bank's forecasts of the state of the economy are superior, the forecast errors of the private sector are correlated in such a way that the policy rate forecasts are more accurate. For instance, consider monetary

[20] Of course, such results are only suggestive, as the timing and therefore information sets, of the forecasts differ.

policy decided by a simple Taylor-type rule,

$$i_t = \beta_\pi \pi_t + \beta_x x_t,$$

where π_t is inflation, x_t is the output gap, and β_π and β_x are policy parameters, which are assumed to be positive. Then the expectation of future interest rates is given by

$$E_t i_{t+n} = \beta_\pi E_t \pi_{t+n} + \beta_x E_t x_{t+n}.$$

Thus, if we define the forecast error of variable j as $\eta_{j,t+n} = E_t j_{t+n} - j_{t+n}$, then the forecast of the interest rate is given by

$$\eta_{i,t+n} = \beta_\pi \eta_{\pi,t+n} + \beta_x \eta_{x,t+n}.$$

If the forecast errors of inflation and the output gap are positively correlated, interest rate forecasts will, on average, be less accurate. On the other hand, if the forecast errors are negatively correlated, the forecasts of the interest rate will tend to be more accurate.[21] If the process through which private sector agents form expectations makes it more likely that the forecast errors are negatively correlated, then it is possible that aggregate forecasts will be more reliable. However, this is not supported by the data. Table B.10 compares the correlation of forecast errors of inflation and output from the SEP and SPD. As Table B.10 shows, if the correlation of forecasts was an important determinant of accuracy, one would expect, if anything, the FOMC's forecasts to be better.

[21] If unemployment is used instead of the output gap, these relationships will be reversed.

2.5.3 Differing Expectations of the Central Bank Reaction Function

If the difference in interest rate projections cannot solely be explained by beliefs about the future state of the economy, then it is likely due to differences in expectations about how the central bank will set the policy rate. This would be surprising, however, since much of the literature around central bank communication is predicated upon the question of whether communication allows markets to better understand the reaction function of the central bank, which presupposes that the central bank has a better understanding of how policy is set.

Regime Changes

One simple explanation is that the difference in expectations largely arises from regime changes. If central banks are predicting the path of policy rate beyond the current regime, their estimates of future interest rates are unlikely to be credible. For instance, current regimes cannot necessarily commit future regimes to any particular policy. Furthermore, the future regime may have significantly different preferences, which could lead to different monetary policy. Although regime changes most likely correspond to changes in the chair or governor of the central bank, they could also correspond to large political changes within a country or changes to the structure of the central bank.[22]

If this explanation was true, we would expect to see gaps in expectations arise predominantly near possible regime changes and for expectations to otherwise be relatively similar. This does not, however, appear to be the case, at least in the United States. The largest gaps in expectations for the FOMC occurred for monetary policy outcomes that were completely

[22]For instance, in 2019, the RBNZ moved from having policy solely decided by its governor to having policy determined by a committee.

encompassed by Janet Yellen's appointment.[23] On the other hand, this explanation may provide some explanation in the case of the Riksbank. Some of the largest gaps in policy expectations in Sweden arose in late 2011, with two of the six members of the executive board intending to retire at the end of the year. To the extent that policy would change along with a change in the composition of the executive board, such differences are understandable.

Misestimating Policy Parameters

Another option is that central banks incorrectly estimate how they will react to the state of the economy. In other words, $E_t\beta_{t+n}$ from equation (2.3) is not very accurate. This is not unreasonable as central banks appear to have changed their policy response not only over longer periods (e.g., Clarida et al., 2000) but also across shorter periods as well (e.g., Kim and Nelson, 2006). As such, it is possible that central banks could fail to anticipate changes in their response to economic variables or anticipate a change that failed to materialize. For instance, it is easy to imagine a central bank anticipating that it will respond to inflation in the future more strongly than it actually does.

As a simple check on whether the central bank and private sector have different expectations for policy parameters, I estimate a Taylor-type rule using projections from the SEP and SPD. More specifically, I consider a specification of the form

$$i_t = r^* + \pi_t + \gamma_\pi(\pi_t - \pi^*) + \gamma_u \hat{u}_t + \epsilon_t, \tag{2.14}$$

where i_t denotes the federal funds rate, r^* denotes the natural rate of interest, π_t denotes inflation, π^* denotes the inflation target of 2%, and $\hat{u}_t$ denotes the unemployment gap, the difference between current and long-run unemployment. To avoid problems with the ZLB, I remove any meeting date where either of the interest rate forecasts is at the lower

[23] Yellen was Chair from February 3, 2014 to February 3, 2018

bound. The estimates, which are shown in Table B.11, suggest that the FOMC anticipated a stronger response to inflation while the private sector anticipated a stronger response to unemployment.

A similar but distinct possibility is that central banks omit variables from their expectations but ultimately respond to them. One potential omitted variable is the state of the financial sector, as it is not explicitly mentioned in many central banks' mandates and directly responding to financial instability runs the risk of moral hazard. Indeed, Bernanke and Gertler (1999, 2001) argue that although the Federal Reserve responds to the stock market, this response is driven entirely by its effect on inflation and output. However, there is evidence to the contrary. Rigobon and Sack (2003) finds that the Federal Reserve responds to stock market fluctuations. In fact, as Ravn (2012) shows, this response has been asymmetric. If the Fed is responding by lowering rates when the stock market faces losses, but does not anticipate that it will act this way, then they will predict a higher federal funds rate than will prevail on average.

However, it is more difficult to assign this as the cause in Sweden and New Zealand. The financial markets in both countries are smaller and more subject to global trends. Of course, an asymmetric response function more generally could lead to central banks overestimating the future path of the policy rate. If central banks forecast as though their response is symmetric, but in practice, they respond more strongly to negative shocks than positive shocks, policy will tend to be more accommodative than predicted. Unfortunately, accurately testing these hypotheses is difficult as it requires information not only about the current reaction function of the central bank, but also about the central bank's anticipated reaction function.

The Natural Rate of Interest

It is also possible that central banks have tended to incorrectly estimate the value of the future natural rate of interest.[24] This would not be particularly difficult given the large decline in the natural rate (r^*) across the globe (see Laubach and Williams (2003) and Cúrdia (2015) for the United States, Armelius et al. (2018) for Sweden, Plantier and Scrimgeour (2002) and Richardson and Williams (2015) for New Zealand, and Holston et al. (2017) for a multi-country overview). In addition to estimating the past natural rate of interest, Cúrdia (2015) – work published at the Federal Reserve Bank of San Francisco – projects r^* from 2015 through 2020 and anticipates a large increase in the natural rate over this horizon. If this was representative of the Federal Reserve's view more broadly, it would appear likely that they overestimated the path of the natural rate.[25] Perhaps more importantly, the Federal Reserve's estimates of r^* also appear to be higher than those of the private sector. For instance, Figure B.3 shows that the private sector's estimate of a related measure, the long run interest rate, was lower than the central bank's for most of the sample period. Similarly, the estimates of r^* shown in Table B.11 indicate that private sector anticipated a lower natural rate than the central bank.[26]

If central bankers incorporate the natural rate into their formulation of the policy rate, then overestimating the value of the natural rate means overestimating the future path of the policy rate. In particular, if we think about the natural rate entering the policy rule linearly,

[24]Technically, since the natural rate is unobservable, especially in real time, the explanation would be that the central bank's projection of the future natural rate at time t, $E_t r^*_{t+n}$, has been substantially different that the central bank's estimation at time $t+n$, $E_{t+n} r^*_{t+n}$.

[25]Likewise, in Laubach and Williams (2003) and Holston et al. (2017) the natural rate of interest is the sum of two variables that follow a random walk. Thus, the best estimate of future values is the current estimate. As such, it is not unreasonable to think that the natural rate was systematically overestimated. The Laubach and Williams (2003) measure in particular seems likely to be believed by the FOMC given that one of its long-time members, John Williams, coauthored the paper and it has been mentioned by former Chair Janet Yellen in a speech explaining her rationale for forward guidance (Yellen, 2015)

[26]Of course, such results are only suggestive due to the difficulty in accurately assessing beliefs about the natural rate of interest. Estimates of the private sector's beliefs of r^* are sporadically available in the SMP, but there is no central bank equivalent with which to compare them.

as in a Taylor-type rule, it is clear to see how this difference in expectations of the natural rate could lead to the observed gap in interest rate expectations.

Effective Lower Bound Uncertainty

Finally, it is possible that there is disagreement about how central banks will react when constrained by the effective lower bound (ELB). First, disagreements may occur over the exact level of the bound. Swanson and Williams (2014) find that a rate of 1% was the effective lower bound in the early 2000s in the US. However, it is unclear if such a sentiment was shared by all participants, particularly if the economy was faced with a negative shock. Further, at least one member of the FOMC advocated for a federal funds rate below zero in 2015 despite a general consensus that the federal funds rate was constrained at zero. Such concerns might be even more important in Sweden given that the central bank lowered the repo rate to 50bp points below zero and the deposit rate to 125bp below zero. Second, there may be disagreement about the cost of being at the effective lower bound. Although one would imagine that the central bank has a better idea about how these costs would affect future policy, this may not be true, especially as this constraint was new to most central banks during the Great Recession. As such, it is not surprising that there was substantial variation in expectations of future rates, especially concerning the speed of "liftoff".

2.6 Discussion: Implications for Monetary Policy

The existence of the gap in interest rate expectations has a number of important implications for monetary policy. Of course, these implications are dependent on the nature and origin of the gap. Because the primary cause of the gap in expectations may vary across time and across countries, I separately discuss the implications of each potential cause outlined in Section 2.5.

In the case that the difference in expectations is primarily due to difficulties in finding an accurate and comparable measure of policy rate expectations, rather than any actual difference then there should be little real effect.[27] If the gap is primarily caused by differences in beliefs about the future state of the economy, communication about future monetary policy will not be entirely successful. However, to the extent that the central bank is communicating its reaction function rather than communicating about the economy, the private sector should still respond. Further, to the degree that differences in beliefs about the future state of the economy arise due to informational differences, the gap could likely be reduced by an increase in transparency from the central bank or by a greater effort in surveying the private sector.

If the gap is instead caused by differences in beliefs about the central bank's reaction function, then it is possible that communication from central banks will primarily have an effect through the fed information effect channel. If such a channel does not exist, then communication might have no effect on market beliefs. The interpretation of these effects will differ based upon whether such differences are justified. In the case that the central bank's expected path is accurate, then policy will be tighter (or looser) than the central bank desired, depending on the direction of the gap. If we assume that the central bank chose the optimal path of interest rates, this deviation is strictly worse for the economy. Further, resources have likely been inefficiently allocated as a result of decisions that agents may have made under their faulty interest rate expectations.

On the other hand, if the private sector is correct about the future path of interest rates, it seems inaccurate to suggest that policy deviated from the central bank's desired path, as the expectations that agents acted upon matched reality.[28] Instead, it seems more appropriate

[27] That said, the belief that such a gap exists, even if untrue, could have important consequences, particularly if the central bank responds to these perceived policy differences.

[28] Of course, it is possible that the private sector's expectations became a self-fulfilling prophecy, which would suggest that market expectations are more important in determining policy than previously believed.

to claim that the central bank unnecessarily increased the amount of uncertainty regarding the future path of policy. If the central bank's communication simply matched private sector expectations, the anticipated path of future policy would have been much clearer. Furthermore, it suggests that the central bank may not understand its policy reaction function particularly well. Indeed, if the private sector is able to accurately predict the path of the policy rate, the central bank certainly should have been able to as well. Additionally, large differences in interest rate expectations, particularly in the case when the central bank and private sector expect the policy rate to move in opposite directions could indicate suboptimal policy decisions by the central bank. For example, consider a case in which the central bank began to move interest rates up as part of a longer-term plan but quickly reversed course and ultimately moved interest rates down to the level that the private sector had originally anticipated. This suggests that not only was the initial rate hike a poor decision, but also that policymakers should have been able to make a better decision with the information set available at the time. In the event that the central bank may be constrained, such policy decisions could be even more costly.

As shown in Section 2.4, I find evidence that the difference in interest rate expectations – also referred to as the credibility gap – diminishes the impact that forward guidance has on market participants in the United States, New Zealand, and Sweden. Thus, the credibility of the central bank's communications can have important consequences for the real economy. This relates to the literature on the effect of uncertainty on the transmission of monetary policy (see, for instance, Baker et al., 2016; Scotti, 2016; and Bauer et al., 2019), as a larger gap likely indicates more uncertainty about the future path of monetary policy.

One implication of these results is that a central bank's choice of monetary policy instrument may depend on its credibility. While the efficacy of forward guidance is dampened by low credibility, the impact of LSAPs are likely less affected by credibility since they can be implemented in the present. Thus, a central bank with relatively low credibility would likely find LSAPs more effective than forward guidance.

Another implication is providing insight on the forward guidance puzzle. Indeed, if the impact of forward guidance is so heavily influenced by a central bank's credibility, any model omitting this will drastically overstate its impact. Furthermore, forward guidance at even short horizons can have relatively low credibility. At very long horizons, forward guidance may be inherently much less credible. For example, the leader of the central bank typically serves for a term of only a few years, so any promises after this horizon are beyond their ability to keep.

This finding provides empirical evidence that supports other papers emphasizing the role of credibility in explaining the forward guidance puzzle (e.g., Haberis et al., 2019; Goy et al., 2020; Cole and Martínez-García, 2020). In addition to credibility, there are a number of alternative explanations for explaining the forward guidance puzzle. Some, such as Andrade et al. (2019), emphasize the role of heterogeneous expectations, which could, at least in part, be explained by the credibility of the central bank's communications. Others instead focus on explanations that are distinct from, but potentially complementary to, the role of credibility. For instance, some papers consider an explanation of bounded rationality such as limited attention (Gabaix, 2020) or a lack of common knowledge about higher order beliefs (Angeletos and Lian, 2018). Del Negro et al. (2015) introduce a probability that agents die each period, which makes them discount the future more and thereby reduces the forward guidance puzzle. McKay et al. (2016) find that heterogeneous agents with borrowing constraints mitigates the future effect. Even if these explanations are correct, it remains likely that credibility plays at least some role in ameliorating the puzzle.

In a larger sense, there appears to be a trade-off between inaccurate central bank communication and credibility, though this trade-off may be unimportant to the extent that central banks are able to effectively substitute other policy tools for forward guidance. One potential avenue for future research is to better understand the factors that reduce a central bank's credibility and estimate the impact of such factors. Another possibility may be to further examine how the relationship between credibility and the efficacy of forward guidance varies across countries. In particular, one could imagine that less established central banks would be more heavily impacted by a loss in credibility.

2.7 Conclusion

I show that there is a sizable and persistent gap in interest rate expectations between the central bank and private sector. This gap is present in New Zealand, Sweden, and the United States and is robust to a range of assumptions regarding risk premia. Some portion of the gap is likely explained through technical differences, but this appears largely insufficient to explain the majority of the gap. Likewise, differences in the expected future state of the economy are also insufficient to fully explain the gap. In fact, in several cases, differences in beliefs about the future state of the economy only exacerbate the puzzle. Instead, much of the gap appears to be largely driven by differences in the expected policy reaction function, though the precise nature of these differences is difficult to determine with certainty.

To quantify the impact of the gap in interest rate expectations, which can also be thought of as the credibility of a central bank's communications, I consider an event study of the financial market response on announcement dates. I find that credibility can have significant effects on the impact that forward guidance can have on Treasury yields, corporate yields, and consumer borrowing rates. Thus, the credibility of a central bank can have important consequences for the real economy. This empirical evidence supports the idea that credibility plays a role in explaining the forward guidance puzzle.

Chapter 3

Vacancies on the FOMC: What is the Cost?

3.1 Introduction

The Federal Reserve Open Market Committee (FOMC) consists of the twelve Reserve Bank presidents and the seven members of the Board of Governors. Unlike Reserve Bank presidents, who are nominated through a process within the Federal Reserve, members of the Board of Governors are appointed by the President of the United States and must be confirmed by the Senate. Difficulty in obtaining Senate approval can lead to extended vacancies on the Board of Governors. This has become more frequent and pronounced as political polarization has increased the difficulty of obtaining Senate approval. This raises an important question: what is the cost of vacancies on the FOMC?

If the cost of vacancies is high, presidents should prioritize appointing individuals who are more likely to make it through the confirmation process. Likewise, members of Senate should be less discerning about the characteristics of appointees if the cost of a vacancy is high. On the other hand, if vacancies are relatively costless, then presidents should nominate individuals whose policy preferences are more aligned with their own, even if such individuals may not make it through the nomination process, and members of Senate should be more willing to reject nominations to the Board of Governors who are undesirable.

Furthermore, the cost of vacancies may provide insight into the importance of a single member of the Board of Governors. In other words, the lower the cost of a vacancy, the lower the marginal benefit of an additional member to the Board of Governors. Of course, this does not provide information about the overall contribution of Board of Governors or the FOMC, merely the impact on the margin.

Why might vacancies be costly? First, monetary policy might be set differently if several seats of the Board of Governors are empty. One possible explanation for this is the difference in policy preferences between Governors and Reserve Bank Presidents. Historically, Governors have tended to be more dovish (see, e.g. Puckett, 1984; Chappell et al., 1993; Istrefi 2018; Malmendier et al. 2020) and have put greater emphasis on national rather than regional data (see, e.g. Gildea, 1992; Hayo and Neuenkirch, 2013). To the extent that these changes are suboptimal, vacancies on the Board of Governors would be costly by reducing the effectiveness of monetary policy.

Second, vacancies may increase the uncertainty surrounding the future path of monetary policy. If market participants believe that future FOMC decisions are contingent upon who, if anyone, fills the vacant FOMC seats, then vacancies may make market participants less confident in the future path of monetary policy.[1] This higher uncertainty about policy rates could have significant costs for the broader economy (e.g., Bloom, 2009; **?**).

Third, members of the FOMC, particularly those on the Board of Governors, may have to

[1]Kuttner and Posen (2010) find that markets respond significantly to changes in the leader of a central bank, but it is less clear that markets care as strongly about the appointment other members. Rosa (2016) shows that markets react to speeches by the chair but not to those of other Governors or Presidents, including the Vice Chair.

increase their workload in response to these vacancies, which may reduce their overall effectiveness. In addition to setting and communicating monetary policy, members of the Board of Governors have a number of other responsibilities including supervision of the Reserve Banks, supervision of the private banking sector, and the publication and communication of important economic information. It may be that even if monetary policy is unaffected, these other responsibilities may suffer.[2] Related to this point is the increased difficulty of operating under procedures that are designed under the assumption that the board would have seven members. For instance, until recently, when a quorum of members of the Board were present, federal law required that there should be advanced notice and record-keeping. If the Board of Governors is sufficiently empty, as it was in 2018, the meeting of a quorum becomes rather difficult to avoid and costly to implement.

I empirically investigate each of these potential causes and find that there appears to be little cost associated with prolonged vacancies on the FOMC. Policy does not appear to be set differently as a result of the missing members of the Board of Governors; instead the policy reaction function in the event of vacancies is remarkably similar to the reaction function when the committee is full. Further, uncertainty about monetary policy when there are vacancies does not appear to be noticeably different than uncertainty when the committee is full. Finally, although it is difficult to precisely assess whether committee members' efficiency is reduced, I do find some evidence suggesting that this do not occur.

These results have two important sets of implications. The first is in regards to the nomination process. Given that the the cost of vacancies is low, both the president and members of the Senate should be more willing to allow vacancies in order to ensure the candidate is closer to their preferences. Second, the marginal benefit of an additional board member appears to be relatively low. There are several possible explanations for this. Perhaps most likely is that monetary policy is largely decided by the chair, especially during the Greenspan

[2]For instance, Mishra and Reshef (2019) shows that central bank leaders have significant impact on financial regulation.

era. Thus, other opinions, especially those of other members of the Board of Governors, do not strongly impact monetary policy, which would be largely consistent with Chappell et al. (2004), Blinder and Reis (2005), and Blinder (2007). An alternative possibility is that the FOMC staff is a major factor in policy decisions (see, e.g. Romer and Romer, 2008; Ellison and Sargent, 2012). Thus, since the value added by each FOMC members tends to be relatively low, policy is largely unaffected by vacancies.

Of course, these results are primarily focused on the case in which the Board of Governors has two or fewer vacancies. In the event that the Board of Governors has additional vacancies, such as the four vacancies that needed to be filled following the retirement of Janet Yellen in February 2018, the cost is likely much higher. Indeed, it is probable that the cost of vacancies increases non-linearly. If so, the incentive to fill vacancies would increase if future vacancies were anticipated. However, the historical lack of a high number of vacancies makes this cost difficult to estimate.

This paper contributes to a large literature which investigates the influence of politicians on the Federal Reserve. In general, this influence can take two forms: direct, in which politicians exert pressure on the central bank through public or private actions, and indirect, in which politicians affect central bank actions through the appointment process. Chappell et al. (1993) and McGregor (1996) find that the primary channel of political pressure is indirect influence. There are, however, numerous examples of direct influence. Federal Reserve policy in the 1970's appears to have responded to changes in the presidency (Beck, 1982) as well as to threats from Congress (Hess and Shelton, 2016). Similarly, Bianchi et al. (2020) finds that the market's expectation of the federal funds rate changed in response to President Trump's tweets.

The structure of the paper is as follows. Section 3.2 explains the structure of the FOMC. Section 3.3 discusses the sources of data used throughout the paper. I find that vacancies have increased over time. Correspondingly, the time required to obtain Senate approval has lengthened and the number of votes in favor of nominees has decreased. Section 3.4 estimates the response of monetary policy in periods with and without vacancies. Section 3.5 considers the impact that vacancies on the Board of Governors has on monetary policy uncertainty. Section 3.6 explores how vacancies impact the effectiveness of the remaining members of the Board of Governors. Section 3.7 considers a game-theoretical model of the Board of Governors nomination process. Section 3.8 concludes.

3.2 FOMC Structure

The Federal Reserve Open Market Committee consists of nineteen members: twelve regional presidents and seven members on the Board of Governors. However, only 12 of the 19 members of the FOMC are able to vote in a given year. The seven members of the Board of Governors are always able to vote, as is the President of the Federal Reserve Bank of New York. The final four votes are rotated among remaining 11 regional presidents, who alternate serving one year terms.[3] This structure is important for several reasons. First, under a full FOMC, the Board of Governors always has more votes than the regional presidents despite the fact that there are more Reserve Bank Presidents than Governors. This structure was implemented intentionally to keep much of the power of the Federal Reserve centralized. Moreover, the chair of the Board of Governors also serves as the chair of the FOMC, which has historically been a position of considerable influence (see, e.g., Chappell et al., 2004; Romer and Romer, 2008). Second, it shows how even if the composition of the FOMC is stable across multiple years, the individuals who are voting on policy in a given year are fluctuating.

Unlike regional presidents, who are nominated through a process within the Federal Reserve,

[3]For the most part, the Reserve Banks are grouped in trios that alternate voting privileges. These trios are San Francisco, Kansas City, and Minneapolis; Atlanta, St. Louis, and Dallas; and Richmond, Boston, and Philadelphia. Chicago and Cleveland form a duo that vote every other year rather that every third year.

members of the Board of Governors are appointed by the president and must be confirmed by the Senate.[4] More specifically, after being nominated by the president, a candidate must first be approved by the United States Senate Committee on Banking, Housing, and Urban Affairs. Once approval has been granted, then the candidate may seek approval from the entire Senate.[5] In principle, Governors are appointed to staggered 14 year terms, but in practice, members do not typically serve an entire term. They either resign before their term is completed or they are appointed to a term that is already in progress. In fact, as Table A.1 shows, the average appointment to the Board of Governors only lasts approximately 6.5 years.

Important positions on the FOMC, like the chair, require additional Senate approval. From 1936 through 1977, the chair and vice-chair were appointed by the president without the need for Senate approval. This changed with the Federal Reserve Reform Act of 1977, which required Senate approval for the appointment of both positions and limited the position to four-year terms.[6] The Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 added the position of vice chair for supervision, which also requires Senate approval. Any members appointed to these positions are required to be permanent members of the FOMC – members of the Board of Governors or the President of the Reserve Bank of New York.

[4]One minor exception to this setup is that if vacancies occur when the Senate is in recess, the president may temporarily appoint a candidate until the Senate resumes its session. Such appointments are rare. Since 1980, only one member of the Board of Govenors – Martha Seger – has been appointed in this manner.

[5]Prior to 1970, the Committee on Banking, Housing, and Urban Affairs was instead called the Committee on Banking and Currency. It largely appears that the preferences of the Senate Banking Committee are similar to those of the Senate overall (Krehbiel, 1990). However, the smaller number of votes – typically been between 20 and 25 over the past few decades – may result in a different outcome if the vote is close.

[6]The Federal Reserve Reform Act of 1977 and Full Employment and Balanced Growth Act, which followed in 1978, had other important implications for the FOMC and Board of Governors, more specifically. First, it codified what is now called the dual mandate. Second, it prohibited discrimination in the selection of members of the Board of Governors; shortly thereafter, Nancy Teeters became the first woman on the Board of Governors. Third, it mandated that the Board of Governors make a semiannual report to Congress. Fourth, the act changed the selection process for Federal Reserve Bank directors, who are critical in choosing regional bank presidents.

Table 3.1: Summary Statistics

	Obs.	Mean	Median	St. Dev	Min	Max
Appointment Length	92	6.59	5.27	4.55	0.19	21.21
Vacancy Length	44	0.97	0.31	2.02	0.003	10.61
Senate Approval Duration	36	100.0	92	92.3	7	408
Senate Approval Votes	17	82.2	90	16.4	57	100

Notes: Data is from March 1936 through July 2020. Statistics for the duration of appointments and vacancies are in years while length of Senate confirmation is in days. Vacancy length describes periods in which the Board of Governors had at least one vacancy. The membership statistics ignore Governors whose term is in progress as of 7/15/2020. The vacancy statistics consider the recent period of vacancies through 7/15/2020.

3.3 Data

3.3.1 Vacancies

Data on FOMC vacancies can be obtained directly from the Federal Reserve's website. In particular, I obtain the names of all individuals who have served on the Board of Governors, the district that they are associated with, the date of their initial oath of office, information regarding reappointments, and the date they left the Board of Governors. From this data, I am able to construct the number of vacancies on the Board of Governors since its inception in 1936, which can be seen in Figure 3.1. Another way of viewing the data is to examine the average number of vacancies in a given year, which is shown in Figure 3.2. As Figures 3.1 and 3.2 show, the number of vacancies on the Board of Governors has, on average, risen over the past several decades.

3.3.2 FOMC Votes

For much of the analysis regarding the impact of absences on how monetary policy is set, I use missing FOMC votes, which is obtained from Thornton et al. (2014), rather than the number

Figure 3.1: Board of Governors Vacancies Across Time

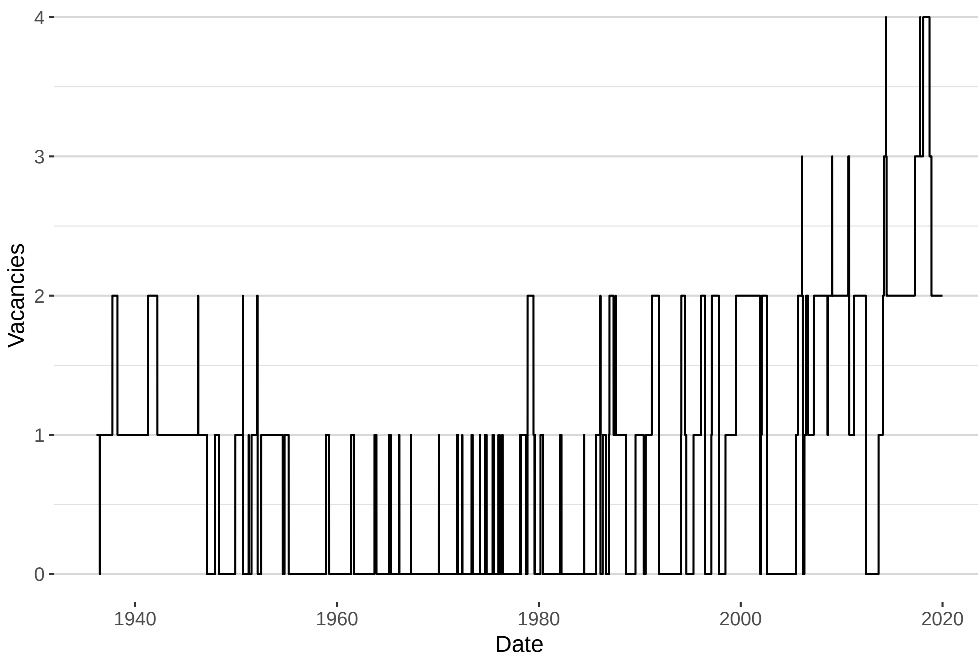
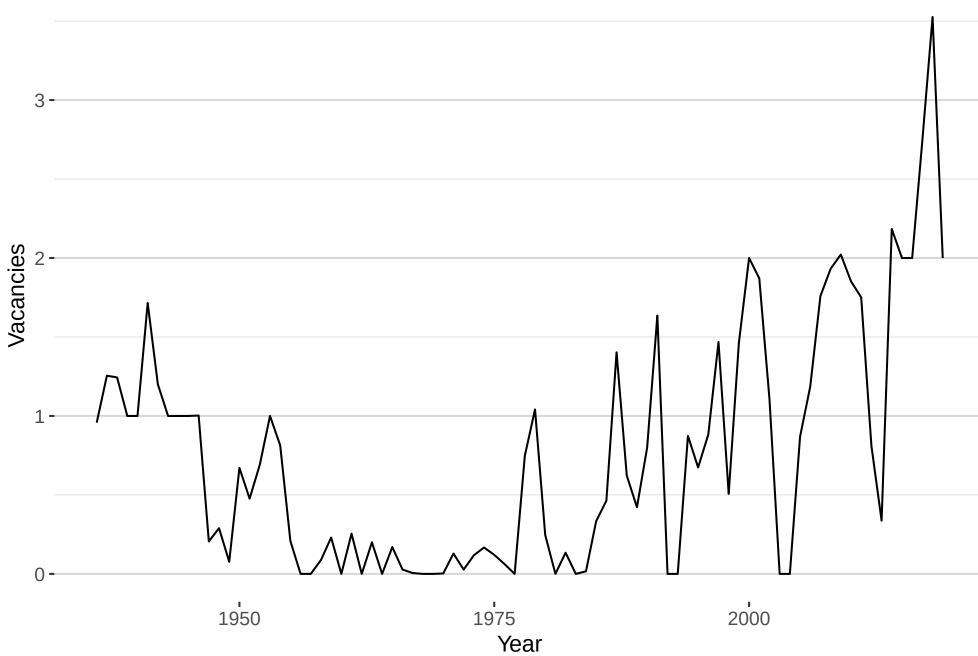
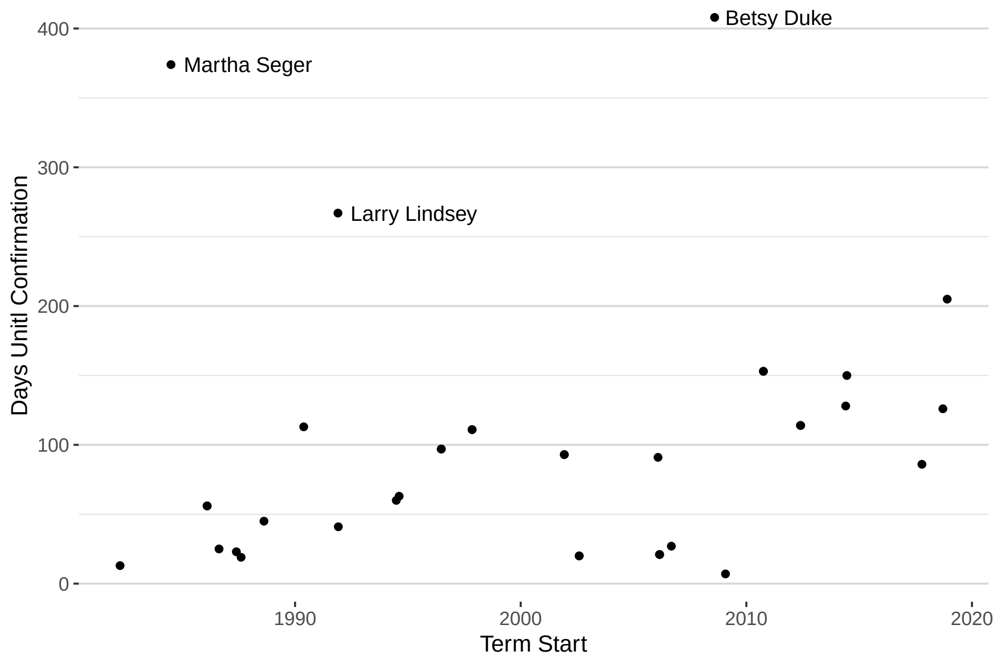


Figure 3.2: Average Board of Governors Vacancies by Year



of vacancies. In general, missing votes are most commonly attributed to vacancies. However, they are not the sole reason. Many of the remaining missing votes can be attributed to

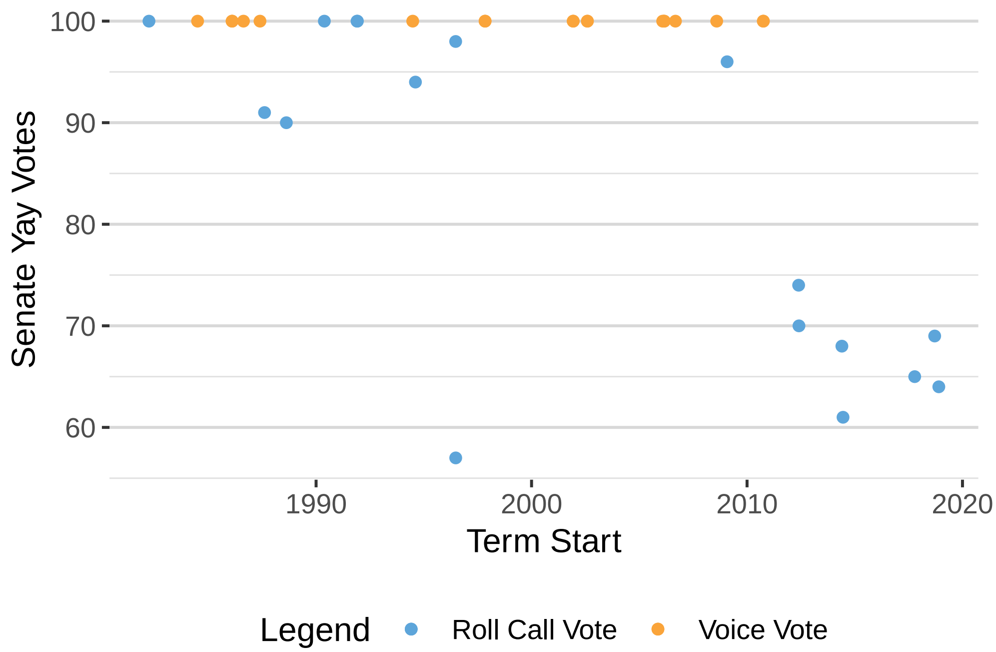
Figure 3.3: Board of Governors Time Until Senate Confirmation



upcoming resignations. The standard procedure within the FOMC is that when an member of the Board of Governors is going to resign their position, they do not vote in the meeting (or two) prior to their departure. This is done primarily to keep the impartiality of the board. Missing votes can also occur due to more general problems of availability, particularly if the meeting is unscheduled.[7] Importantly, only members of the Board of Governors are likely to be responsible for these missing votes. If a regional president is absent or their position vacant, then a designated alternate – one of the presidents who would otherwise not have a vote at the meeting – votes in their place. The singular exception to this is the Federal Reserve Bank of New York, in which the vice president of the New York Fed acts as the alternate.

[7]For instance, Governor Minshkin was absent for the January 21, 2008 meeting. The minutes for that meeting state that “He is aware of this meeting, but he is on the slopes—I think in Idaho somewhere.”

Figure 3.4: Board of Governors Votes on Approval from Senate



Notes: Voice votes do not have yay votes recorded. As such, the location of the orange dots on the y-axis does not represent a nominee's actual favorability. Anecdotally, however, many of voice votes were unanimous or nearly unanimous.

3.3.3 Senate Approval

In addition to the information about the timing of vacancies, I also obtain information regarding the Senate confirmation process. Data regarding nominations requiring Senate approval is available online from the Congressional Record dating back to 1981. Further, information dating back to 1947 is available through photocopied congressional documents. In particular, I am able to obtain the date that request was received from the president, the date of the Senate approval, and – if the vote was recorded – how many Senators voted for and against each nominee. This data is particularly useful in understanding why the rate of vacancies has increased over time. Figure 3.3, which plots the number of days between when the president formally nominated a candidate and when the candidate was approved, shows the increase in the average time until confirmation over the past four decades.[8] One striking feature of the figure is how long several of the candidates needed to wait. Martha Seger and Betsy Duke, for example, both required over a year before they were confirmed.[9] Figure 3.4 shows the number of votes of approval for a candidate in the event of a roll call vote. Since 2010, the proportion of votes in favor of a candidate has noticeably decreased. Unfortunately, votes are not recorded for all candidates. In a number of instances, a voice vote occurred instead of a roll call vote. Typically, voice votes are less contentious and unofficial records indicate that many of these voice votes were nearly unanimous. The absence of voice votes in the past decade is of itself telling.

I am also able to obtain data about nominees to the Board of Governors who were not approved; these individuals are shown in Table 3.2. As Table 3.2 indicates, rejections have become much more frequent over the past few decades, presenting one major reason for the increase in vacancies. Indeed, there are no rejections from Congress prior to 1997. Table 3.2 only includes candidates that were officially nominated to the Board of Governors. As such, it excludes candidates that presidents considered nominating who were informally rejected. Examples of such candidates include Felix Rohatyn and Alicia Munnell under Bill Clinton and Steve Moore and Herman Cain under Donald Trump. Alicia Munnell's case is particularly illustrative. Clinton announced his intention to nominate Munnell in 1995, but 10 Republican Senators indicated that her candidacy was unacceptable due to a perceived lack of emphasis on price stability (New York Times, 1995). As a result, Clinton did not officially nominate Munnell to the Board of Governors, but instead appointed her to the President's Council of Economic Advisers. To the extent that such actions speed up the

[8]The analysis focuses on initial appointments rather than reappointments. This is primarily due to the fact that the timing for reappointments is different, as there tends to be less urgency since the individual in question is already serving on the Board of Governors.

[9]Both candidates were heavily criticized, particularly Duke. Seger's case is complicated by the fact that Reagan made her a recess appointment approximately a month after announcing her nomination. Thus, the urgency of her confirmation was relatively low relative to other appointments, much like in the case of reappointments. Nevertheless, Democrats largely opposed her nomination and were hoping the upcoming elections would change control of the Senate (New York Times, 1985).

Table 3.2: Rejected Board of Governors Nominations

Candidate	President	Initial Nomination Date	Nomination Type
Carol Parry	Bill Clinton	August 5, 1999	Appointment
Larry Klane	George W. Bush	May 16, 2007	Appointment
Randall Kroszner	George W. Bush	May 16, 2007	Reappointment
Peter Diamond	Barack Obama	April 29, 2010	Appointment
Alland Landon	Barack Obama	January 7, 2015	Appointment
Kathryn Dominguez	Barack Obama	July 21, 2015	Appointment
Marvin Goodfriend	Donald Trump	January 28, 2018	Appointment
Nellie Liang	Donald Trump	September 28, 2018	Appointment
Judy Shelton	Donald Trump	January 28, 2020	Appointment

Notes: This list only includes candidates that were formally nominated to the Board of Governors. Initial Nomination Date is the date on which the Senate received the nomination from the president, which may differ from the date that the president announces an intention to nominate.

rejection process, this type of communication may be desirable.

3.4 Impact of FOMC Vacancies on Monetary Policy

The most obvious way that a vacancy on the Board of Governors can be costly is by directly impacting the way that the FOMC sets monetary policy. Indeed, there are a number of reasons why the vacancy might affect policy in important and systematic ways. One possible reason for this difference in policy is that Governors and Reserve Bank Presidents appear to have different policy preferences. Indeed, there is a large body of literature finding that Governors have tended to be more dovish than Reserve Bank Presidents. Puckett (1984) and Chappell et al. (1993) show that Governors are substantially more likely to dissent in a dovish manner while Reserve Bank Presidents are substantially more likely to dissent in a hawkish manner. Malmendier et al. (2020) shows that the degree to which an FOMC member is hawkish or dovish depends largely on their life experience. In addition to the difference in voting behavior, they analyze inflation forecasts and speeches to, among other things, show that regional presidents exhibit more hawkish behavior. Moreover, past inflation experiences have a stronger impact on Reserve Bank Presidents than Governors. Istrefi (2018) estimates the market's perception of the FOMC rather than assessing differences in policy preferences though monetary policy actions. Istrefi finds that Governors are perceived to be more dovish over the majority of the sample. If such analyses are correct, then it would not be unreasonable to expect that the FOMC would favor more hawkish policy in the absence of Governors, who are typically dovish.

Another possible reason for differences between Reserve Bank Presidents and Governors is that Reserve Bank Presidents may tend to place greater weight on economic outcomes in their region while Governors tend to focus on national data. Indeed, both Gildea (1992) and Hayo and Neuenkirch (2013) find evidence of such behavior. Meade and Sheets (2005) also provide evidence that Reserve Bank Presidents respond to regional outcomes, but argue that Governors appear to be more responsive to these disparities. Jung and Latsos (2015), on the other hand, show that only a fraction of Reserve Bank Presidents displayed a regional bias and that even in those instances, the bias was not particularly large. To the extent that the regional response between Reserve Bank Presidents and Governors is different, vacancies may impact the degree to which policy responds to regional economic conditions.

Although it is impossible to truly know what policy would be set under the counterfactual of a full Board of Governors, it is possible to estimate whether policy differed as a result of vacancies. I estimate the relative response to inflation and output through a simple Taylor-type rule. In particular, I consider the specification:

$$i_t = c + \phi_\pi E_t \pi_{t+2} + \phi_x E_t x_t + \phi_g E_t g_t + \epsilon_t, \tag{3.1}$$

where i_t is the interest rate, $E_t \pi_{t+2}$ is the expectation of the average rate of inflation over the next two quarters, $E_t x_t$ is the expectation of output gap, and $E_t g_t$ is the expectation of the growth in output.[10] The specification expands the original rule proposed in Taylor

[10]This choice of horizon for expectations is the specification that Coibion and Gorodnichenko (2011) find

Table 3.3: Taylor Rule Coefficients: Full vs Vacancies

	Entire Sample				Pre-1979				Post-1982			
	Full	Vac.	Full	Vac.	Full	Vac.	Full	Vac.	Full	Vac.	Full	Vac.
ϕ_π	1.27	1.20	1.26	1.21	0.99	1.00	0.83	0.91	2.62	1.57	2.55	1.62
	(0.12)	(0.08)	(0.12)	(0.08)	(0.14)	(0.14)	(0.12)	(0.12)	(0.16)	(0.12)	(0.15)	(0.12)
ϕ_x	0.24	0.29	0.24	0.29	0.40	0.32	0.38	0.35	0.03	0.17	0.07	0.15
	(0.06)	(0.03)	(0.06)	(0.03)	(0.05)	(0.05)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)
ϕ_g			−0.03	−0.08			−0.21	−0.22			0.31	0.21
			(0.06)	(0.04)			(0.04)	(0.05)			(0.10)	(0.06)
c	2.03	2.66	2.14	2.84	3.98	3.88	5.24	5.36	−1.64	1.71	−2.39	1.08
	(0.405)	(0.25)	(0.47)	(0.27)	(0.63)	(0.79)	(0.58)	(0.77)	(0.40)	(0.32)	(0.45)	(0.36)
Obs.	155	157	155	157	74	46	74	46	81	111	81	111
R^2	0.44	0.61	0.44	0.61	0.51	0.64	0.66	0.74	0.81	0.62	0.83	0.65

Notes: Specification for the regression is of the form $i_t = c + \phi_\pi E_t\pi_{t+2} + \phi_x E_t x_t + \phi_g E_t g_t$. The entire sample contains data from Greenbook forecasts from 1969-1978 and 1983-2006. Full contains the subset of observations that occurred when the maximum of 12 FOMC members voted. Vacancies contains the subset of data in which at least one member was absent.

(1993) with the growth in the output rate as advocated by Ireland (2004) and Coibion and Gorodnichenko (2011). To estimate the rule, I follow Orphanides (2004) and use real time data from Greenbook forecasts. I also follow the literature by separating the results prior to 1979 from those after 1982 to account for a large shift in policy following the appointment of Chairman Paul Volcker; the results are show in Table 3.3.[11]

The estimates are split by whether the entire committee voted or if there was at least one missing vote. It is possible that the missing vote is not due to a vacancy, current or impending, but such cases are rare and should exhibit much of the same behavior. As such, they are treated equally. The estimates are quite similar regardless of vacancies, particularly prior to 1979. To the extent that a difference exists, the estimates suggest policy is more dovish in the case of vacancies, which is the opposite of what the literature suggests. Therefore, it does not appear that vacancies impact the accomodativeness of monetary policy.

best fits the data, but the results are not sensitive to the choice of horizon.

[11] The period 1979 through 1982 is removed as the FOMC pursued a policy of targeting monetary aggregates rather than targeting the interest rate. If this period is included, the results are largely the same.

Table 3.4: Taylor Rule Coefficients: Paired Vacancies

	Entire Sample				Pre-1979				Post-1982			
	Full	Vac.	Full	Vac.	Full	Vac.	Full	Vac.	Full	Vac.	Full	Vac.
ϕ_π	1.34	1.25	1.31	1.23	1.20	1.14	1.11	1.04	2.26	2.14	2.20	2.05
	(0.20)	(0.17)	(0.20)	(0.17)	(0.17)	(0.19)	(0.16)	(0.19)	(0.47)	(0.37)	(0.47)	(0.38)
ϕ_x	0.41	0.35	0.41	0.34	0.45	0.36	0.44	0.36	0.04	0.13	0.08	0.17
	(0.07)	(0.06)	(0.07)	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)	(0.17)	(0.13)	(0.17)	(0.14)
ϕ_g			−0.05	−0.06			−0.12	−0.11			0.26	0.39
			(0.07)	(0.07)			(0.05)	(0.07)			(0.26)	(0.39)
c	2.92	3.07	3.14	3.32	3.75	3.61	4.46	4.48	−0.11	0.55	−0.74	−0.25
	(0.68)	(0.62)	(0.76)	(0.71)	(0.70)	(0.92)	(0.70)	(1.03)	(1.27)	(0.99)	(1.42)	(1.26)
Obs.	50	41	50	41	34	27	34	27	16	14	16	14
R^2	0.51	0.61	0.51	0.62	0.71	0.70	0.76	0.74	0.69	0.77	0.71	0.79

Notes: Specification for the regression is of the form $i_t = c + \phi_\pi E_t \pi_{t+2} + \phi_x E_t x_t + \phi_g E_t g_t$. The entire sample contains data from Greenbook forecasts from 1969-1978 and 1983-2006 in which the committee is identical with the exception of vacancies in the Board of Governors. Full contains the subset of observations that occurred when the maximum of 12 FOMC members voted. Vacancies contains the subset of data in which at least one member was absent.

There is one major problem with the analysis presented above: it does not isolate the impact of a vacancy. Put another way, it is unlikely that the above analysis is solely comparing the difference in policy resulting from vacancies. First, the composition of the FOMC changes across time. Thus, the two samples are not comparing the same group of individuals. In particular, the FOMC presidents are regularly alternating voting privileges, which may impact the setting of policy. Second, policy preferences have changed over time (e.g, Kim and Nelson, 2006). Thus, unless vacancies are evenly distributed across time, this may bias the results. To address this issue, I restrict the sample to pairs of meetings before and after the number of votes change. Further, I remove any pairs that are in different years to avoid complications regarding the rotation of Reserve Bank Presidents. I then repeat the estimation in (3.1); the results are shown in Table 3.4. The results are broadly consistent with those in Table 3.3 despite the reduction in the sample.

There are two likely explanations for this result. First, forecasts from FOMC members, especially members on the Board of Governors, are strongly influenced by the estimates produced by the staff at the Board of Governors. As Ellison and Sargent (2012) shows, the difference between staff and FOMC forecasts is generally quite small. Thus, changing the composition of the Board of Governors through vacancies has relatively little impact because the staff is the basis for most of the forecasts and are largely unaffected by vacancies. The second explanation is that the chair has a disproportionate influence on the committee's decision. For instance, Chappell et al. (2004) find that the voting weight of the chair is between 40% and 50%. One illustrative instance of this is the meeting in May 1973, when the committee decided to adopt Chairman Arthur Burns's preference of a target interest rate of 7.56% despite every other member of the committee preferring a higher interest rate.

3.5 FOMC Vacancies and Uncertainty

Even if vacancies on the Board of Governors do not directly impact the way that the central bank sets monetary policy, it is possible that vacancies, particularly multiple vacancies, increase the level of uncertainty surrounding the future path of monetary policy. In particular, it is easy to think that market participants might imagine that policy, especially interest rates one to two years in the future, is less certain when some of the individuals deciding the policy are unknown. Couture (2021) finds that the greater the dispersion of FOMC preferences regarding the interest rate, the greater the uncertainty of future monetary policy. Given this, it would not be surprising if unknown preferences also generated uncertainty.

3.5.1 Uncertainty and the Level of Vacancies

To test whether vacancies have a impact on uncertainty, I estimate a regression with a similar specification to that in **?**. In particular, it is of the form

$$MPU_t = \alpha + v_t + \chi_{t-1} + \zeta_t + \epsilon_t, \tag{3.2}$$

Table 3.5: Vacancies and Monetary Policy Uncertainty

	HRS	BBD	Surprise
Vacancies	0.60	−4.47	−0.25
	(3.1)	(3.3)	(0.65)
Financial	32.4*	122.5***	−3.75
Uncertainty	(17.0)	(17.7)	(3.84)
Macroeconomic	−94.5**	−89.7**	−2.95
Uncertainty	(38.8)	(40.4)	(8.21)
Geopolitical	0.30***	0.20***	−0.01
Risk	(0.04)	(0.04)	(0.01)
Constant	104.7***	70.4***	5.06
	(21.1)	(22.0)	(4.13)
Observations	396	396	262
R^2	0.22	0.28	0.03

Notes: Data is from January 1985 through December 2019. HRS indicates the measure from **?**; BBD indicates the measure from Baker et al. (2016). The regression includes dummy variables for each FOMC chair.

where MPU_t represents the monetary policy uncertainty, v_t represent the number of vacancies, χ_{t-1} captures institutional values of the FOMC, namely dummies variables for the chair, ζ_t represents the value of control variables for macroeconomic, financial, and geopolitical uncertainty, and t indexes by month.[12] I use two separate measures to calculate uncertainty: the measure of monetary policy uncertainty from **?** and the measure from Baker et al. (2016). The results, which are shown in Table 3.5, suggest that vacancies do not have an impact on the level of monetary policy uncertainty.

Table 3.6: Uncertainty and Changes in the Board of Governors

	Change in Monetary Policy Uncertainty			
	(1)	(2)	(3)	(4)
Term Starting	−0.044 (0.029)			
Term Starting or Ending		−0.008 (0.021)		
Nomination Announcement			−0.019 (0.033)	
Senate Confirmation				0.022 (0.031)
Constant	−0.001 (0.002)	−0.001 (0.002)	−0.001 (0.002)	−0.001 (0.002)

Notes: There are a total of 6,362 observations from January 1990 to February 2015. There are 22, 42, 16, and 18 observations that are true, respectively.

3.5.2 Uncertainty and Changes in Vacancies

Another possibility is that although vacancies themselves do not impact monetary policy uncertainty, changes in vacancies are important. In other words, uncertainty is only affected when members join or leave the Board of Governors. If this was the case, then it may be important for policymakers to prioritize individuals who would serve as long as possible, particularly given the infrequency with which the full 14-year term is served. To test whether changes in vacancies matter, I estimate the impact changes in vacancies on the measure of monetary policy uncertainty obtained by following Swanson and Williams (2014), which, unlike the measures of uncertainty in Section 3.5.1, has the advantage of being available at the daily frequency. Swanson and Williams (2014) uses one year ahead Eurodollar options to

[12]The measure of macroeconomic uncertainty is obtained from Jurado et al. (2015), the measure of financial uncertainty is obtained from Ludvigson et al. (2015), and the measure of geopolitical risk is obtained from Caldara and Iacoviello (2018).

calculate an implied distribution and then subtracts the 80th and 20th percentiles to obtain a measure of monetary policy uncertainty. The two disadvantages of this approach are that the data is only available beginning in 1990, greatly restricting the sample size, and that the data is not available at the intraday frequency, which reduces the ability to precisely identify the effect. The regression is of the form

$$\Delta MPU_t = \alpha + \Delta v_t, \tag{3.3}$$

where ΔMPU_t is the change in monetary policy uncertainty on day t and Δv_t is a dummy variable on days in which there is a change in vacancies.[13] The one problem with this approach is that it is unclear which dates are important from the viewpoint of market participants. The simplest method would be to use the dates at which individuals are sworn into office. However, if agents are forward-looking, nothing should happen on this date as it is already known that the Governors will soon be sworn in. There are two possible alternatives: the date on which the president announces nominations and the date on which the Senate gives approval. As such, I consider both. The results are shown in Table 3.6. Regardless of the timing considered, it does not appear that there is a large change in uncertainty. However, it should be noted that the sample size is relatively small and the data is relatively noisy, which may influence the results.

3.5.3 Vacancies and the Surprise of FOMC Announcments

It is also possible that vacancies impact the ability of the market to anticipate the central bank's policy decisions. To calculate the unanticipated portion of FOMC rate changes, s_t, I

[13] One potential concern is that the change in uncertainty is asymmetric. For instance, it might matter more that vacancies are filled than that it did that they opened. Unfortunately, it is more difficult to obtain data on when resignations were announced and in the case of an expiring term, there is no announcement date.

follow Kuttner (2001). I then consider a similar regression of the form:

$$s_t = \alpha + \upsilon_t + \chi_{t-1} + \zeta_t + \epsilon_t. \tag{3.4}$$

The results, which are displayed in Table 3.5, indicate that monetary policy decisions are not more unexpected than usual when there are vacancies.

3.6 Do Vacancies Impact Regulation, Supervision, and Communication?

The members of the Board of Governors have a number of additional responsibilities beyond setting monetary policy. Thus, even if monetary policy is unaffected, members of the Board may have less time for other important tasks, which could have an adverse impact on the economy. Unfortunately, assessing any impact on these other activities is more difficult than assessing the impact on monetary policy. Although I will be unable to directly identify any differences, there are a number of ways to proxy for the variables of interest.

3.6.1 Board of Governors Responsibilities

Aside from setting monetary policy, the primary task of the Board of Governors is supervision. The Board of Governors, along with Reserve Banks, is responsible for supervising the compliance and financial soundness of most large domestic banking institutions. Further, they are responsible for monitoring domestic branches of international banks. In additional to playing a major role in supervision the banking sector overall, the Board of Governors also supervises the Reserve Banks. This supervision is extensive and includes approving annual budgets as well as any major expenditures, approving Reserve Bank president nominations, and appointing three of the nine directors at each Reserve Bank.

In addition to supervision, the Board also has a responsibility to communicate. Some of this comes through speeches, which explain Board members' views on monetary policy and supervision, and therefore allow individuals beyond the central bank to anticipate future policy. This also includes listening to consumers in order to ensure that financial activity is largely equitable. Further, the Board of Governors publishes a variety of important economics statistics including data on industrial production and banking activity that are widely used.

These operations are, in their own way, as important to the functioning on the economy as the setting of monetary policy. However, unlike the setting of monetary policy, these tasks can, at least in most cases, be completed either partially or fully, without direct intervention from the Board of Governors. The Board of Governors employs approximately 2,850 employees with over 400 economists. Further, the Reserve Banks also have a large number of employees and the Board of Governors has access to a number of advisory and working committees. Accordingly, many tasks are completed primarily by these individuals. In fact, although the Board of Governors are in charge of directing supervisory policy, the actual supervision is done by the Reserve Banks. Likewise, there is little reason why Board members need to be involved in the publishing of statistics. The data can be collected and communicated without any oversight, particularly once it has become established. Moreover, many of the supervisory tasks can done primarily by the Board of Governors staff, rather than the members of the Board. Indeed, the staff is highly competent, evidenced by the fact that several staff members – Donald Kohn for instance – have later become members of the Board themselves. In this sense, vacancies, particularly a single vacancy, need not be excessively costly.

Of course, there are a number of tasks that can only be completed by members of the Board of Governors or, in some cases, other members of the FOMC. One of these tasks is communication, both to the public through speeches and to Congress through semiannual

Table 3.7: Relationship between Vacancies and FOMC Speeches

	Full Sample			Low Vacancy		
	All	Gov.	Pres.	All	Gov.	Pres.
Vacancies	-0.30	-0.40^{***}	0.15	0.87	-0.41^{**}	1.25
	(0.94)	(0.15)	(0.83)	(1.19)	(0.19)	(1.05)
Constant	27.7^{***}	3.3^{***}	20.6^{***}	26.0^{***}	3.3^{***}	19.0^{***}
	(2.1)	(0.33)	(1.8)	(2.3)	(0.36)	(2.0)
Observations	108	108	108	98	98	98
R^2	0.00	0.06	0.00	0.01	0.05	0.01

Notes: The data covers 2907 speeches or other forms of remarks from FOMC members from January 2011 through December 2019. Low vacancy restricts the sample to months in which the average vacancy rate was three or fewer.

hearings. In order to estimate the impact of the vacancies on the FOMC's communications, I consider a regression of the form

$$c_t = v_t + \epsilon_t, \tag{3.5}$$

where c_t represents the number of speeches or communications in month t and v_t represents the average number of vacancies in month t. As shown in Table 3.7, I find that although the Board of Governors gives fewer speeches when there are vacancies, the communications of the FOMC as a whole do not appear affected.[14] This is partially because Reserve Bank Presidents appear to communicate more, perhaps to compensate for the vacancies, and partially because Governors tend to make speeches less frequently than Reserve Bank Presidents. As such, vacancies do not appear to significantly impact the FOMC's ability to communicate to the public.

Of course, the impact may not be constant. The stress on Governors may be most acute in periods when there is greater turmoil in the banking sector such as the 2008 Financial

[14] This is somewhat less true in the case of months with four vacancies, though it is harder to identify if this is a consequence of a historically high number of vacancies or due to period-specific characteristics.

Crisis. Under such conditions, committee members need to put in more time and effort to ensure adequate regulation, which becomes more difficult with fewer members.

Also, the cost of vacancies likely is dependent on the total number of vacancies. A single vacancy is likely relatively low cost, but four or five vacancies would likely be substantially more costly.

3.7 Board of Governors Nomination Process Model

One important implication of the cost of vacancies on the Board of Governors is the optimal response from policymakers, namely the president and Senate. The Board of Governor's appointment process has been modeled before, as in Chang (2001). However, previous studies did not consider the potential cost of vacancies, thus missing an important element of the dynamics. For one, it may be in either player's best interest to have no candidate nominated than a candidate acceptable to the other player. Further, if the players face asymmetric costs, the player with the lower cost will have more leverage in negotiations than it would appear otherwise.

To understand how their responses change according the costs and their preferences, I consider a simple sequential game model. In it, there are two players: the president (p) and the Senate (s). Each player has policy preferences $\rho \in [0, 1]$, where the respective preferences are given by ρ_p and ρ_s. Perhaps the simplest interpretation of the preferences are that the represent how dovish or hawkish a candidate would prefer to set policy, with a lower number representing more dovish policy preferences. Further, both players experience a cost $c > 0$ for each period that the vacancy is unfilled, which are given by c_p and c_s, respectively. These costs may be the same for both players, but this framework allows for the possibility that the vacancy is more costly for one of the parties than the other. In particular, it is not unreasonable to believe that a failed nomination is more costly for the president than for individual members of the Senate. In the event of a vacancy, the president nominates a candidate with policy preferences denoted by ρ_n. Then the Senate has the choice of either accepting or rejecting the nominated candidate. If the Senate does not approve the candidate, the president will then nominate another candidate in the following period. This process continues until a candidate is selected or a president's tenure in office ends. The payoffs are given by $-|\rho_i - \rho_n| - tc_i$ for $i \in \{p, s\}$, where $t \in 1, 2, \ldots, T$ indicates the number of additional periods in the nomination process.

In the case of full information, the nominee will be accepted if and only if $|\rho_p - \rho_s| < T(c_p + c_s)$. In other words, the nomination will only go through if the costs of delaying the nomination are greater than the differences in preferences between players. If policy preferences are sufficiently close, the president will nominate a candidate with preferences ρ_n^* given by

$$\rho_n^* = \begin{cases} \rho_p & \text{if } \rho_s - Tc_s \leq \rho_p \leq p_s + Tc_s \\ \rho_s + Tc_s & \text{if } \rho_p > \rho_s + Tc_s \\ \rho_s - Tc_s & \text{if } \rho_p < \rho_s - Tc_s. \end{cases}$$

This has several important but unsurprising implications. First, by being the player who makes the nomination, the preferences of candidates are closer to those of the president than those of the Senate. Indeed, this result is largely supported by historical performance. Chappell et al. (1993) shows that behavior of appointed FOMC members can largely be explained by the political party holding the presidential office during their initial appointment. Second, the more time that a president has left in office, the greater the first-player advantage. The intuition here is that if the president is close to leaving office, the Senate can respond to any unfavorable nomination through rejection and instead wait for the incoming president.

Under full information, nominations should generally be approved quickly by the Senate.

Both parties only are worse off by delaying a nomination that will later be accepted. However, this is not what we observe in the data. For instance, the Senate took over 400 days before accepting Betsy Duke's nomination. One possible explanation for this is that the assumption of full information is violated. Perhaps the simplest way to model incomplete information in this setting is by assuming that the president does not have complete information about the preferences of the Senate. Instead, the president can learn the preferences through the nomination process. In particular, if a candidate is rejected, then the president would have to select a more moderate candidate. Alternatively, it may be that the Senate does not fully know the preferences of a nominee. Then, the drawn out nomination process of candidates like Betsy Duke can be viewed through the lens of the Senate attempting to learn the candidate's preferences.

3.8 Conclusion

I examine the cost of vacancies on the Board of Governors of the Federal Reserve in three dimensions. I find that the cost of a vacancy is relatively low in that it does not appear to impact how monetary policy is set or uncertainty regarding the future path of monetary policy. Although it is less clear, it also appears that vacancies do not have a significant impact on the Board of Directors regulatory or communication abilities.

I then show that this cost has important implications for the nomination process from both the perspective of the president and the Senate. In particular, the model indicates that presidents have more control over the nomination process than the Senate, particularly if the nomination occurs toward the beginning of their tenure. The model also suggests that one possible reason for the increase in vacancies is that the rise in political polarization has lowered the political costs of vacancies, which, when combined with a relative low economic cost, has resulted in a stalemate between the president and the Senate. However, it remains unclear how the costs of vacancies changes when the number of vacancies accumulate.

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Appendix A

Appendix to Chapter 1

A.1 Expectations Hypothesis

The expectations hypothesis of the term structure can be written as

$$i_{n|t,q} = \frac{1}{n}\sum_{j=0}^{n-1} E_{t,q}(i_{1|t,q+j}) + \phi_n,$$

where $i_{n|t,q}$ is the yield of an n-period bond in quarter q of year t and ϕ_n is the constant risk premium associated with n periods. While the expectations hypothesis has been rejected by a large number of studies (see, for example, Fama 1984, Mankiw and Summers 1984, and Campbell and Shiller 1991), it still is useful to elucidate how FOMC projections can impact asset prices. In the following, I will drop the risk premium term for simplicity, which seems reasonable given the results in Section 1.4. Boguth et al. (2019) shows that the market typically does not anticipate any major rate change on FOMC meetings without press conferences. Therefore, the federal funds rate should remain constant between the four meetings with a press conference and SEP release. Further, for simplicity, I will denote $i_{1|t,q} \equiv i_{t,q}$. Accordingly, the FOMC's federal funds rate projections can be thought of as

$E_{t,q}^{FOMC}(i_{t+j,4})$ for $j = 0, 1, 2, 3$, where $E_{t,q}^{FOMC}$ is the expectation of the FOMC, which may differ from market expectations.

If the FOMC's expectations contain information that is absent in market expectations, their publication should impact $E_{t,q}(i_{t+j,4})$ for $j = 0, 1, 2, 3$ beyond the announcement of current interest rate. With this framework in place, it is now possible to consider which bond maturities will be affected the most. The 3-month bond is only affected by $i_{t,q}$ and therefore should be unaffected by a change in the projections. The 6-month bond can be written as

$$i_{2|t,q} = \frac{i_{t,q} + E_{t,q}(i_{t,q+1})}{2},$$

where $E_{t,q}(i_{t,q+1})$ is the expected federal funds rate at the FOMC meeting three months ahead. As before, $i_{t,q}$ will be unaffected by the FOMC projections. The impact on $E_{t,q}(i_{t,q+1})$ is less clear. Recall that the FOMC is forecasting the year-end interest rate. Thus, in most cases, the effect of $E_{t,q}^{FOMC}(i_{t,4})$ will depend on investors' expectations on the timing of rate hikes. For instance, if the March FOMC same-year forecast indicates one rate hike and investors believe that it will come in December, there should be no effect on the 6-month yield. On the other hand, if investors instead believe that the rate hike will come in June, the projection should impact next period's expectations and thus raise the 6-month yield. Under other circumstances, the effects may be less reliant on the expectations of the timing. For example, if the FOMC September same-year forecast indicates a future rate hike, there is little ambiguity about timing; it will likely occur in December, and therefore should impact next period's expectations. More generally, it is most natural to consider the case when investors do not have any beliefs about the timing of the hike and assign each period an equal probability of a rate hike. Under this assumption, a change in the FOMC projections should have an impact, but one that is much smaller than the case in which the rate hike is expected to occur next period.

For medium-term yields, forecasted rate changes are more likely to occur before the bond matures. Further, the rate change may affect the bond for a larger portion of its maturity, particularly when rates are at or near the ZLB. Thus, the impact on medium-term yields should be greater than the impact on short-term yields. For long-term bonds, the impact on expectations should be moderated, at least to some extent, by the horizons beyond which the FOMC is forecasting. For instance, investors may expect the interest rate to revert to the target rate in the long-run regardless of short-term projections. Thus, the majority of expected future interest rates would remain unchanged, which would result in a smaller impact on the long-term yield.

A.2 Supplemental Tables and Figures

Figure A.1: FOMC GDP Growth Forecasts

Figure A.2: FOMC Unemployment Rate Forecasts

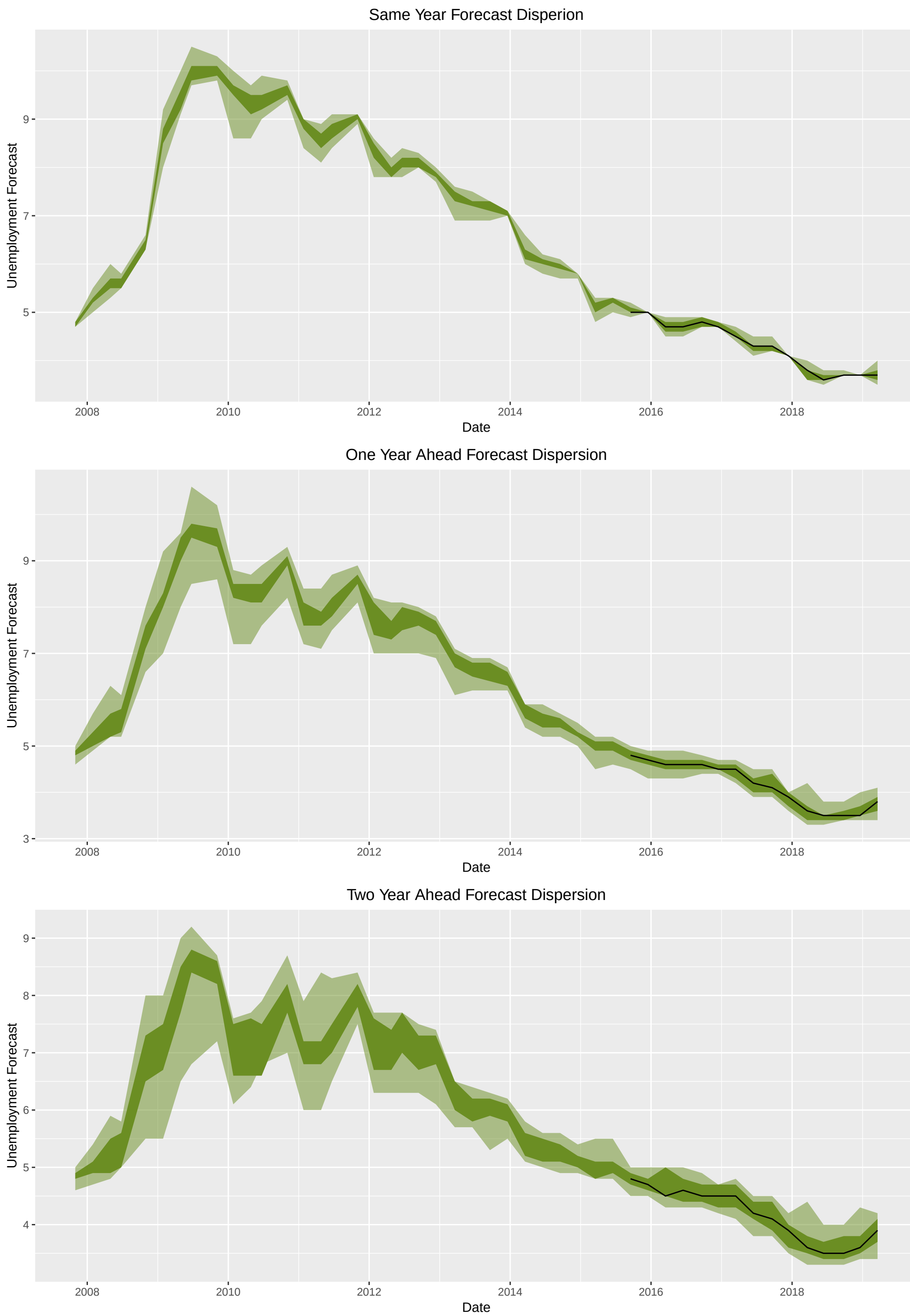


Figure A.3: FOMC Core PCE Inflation Forecasts

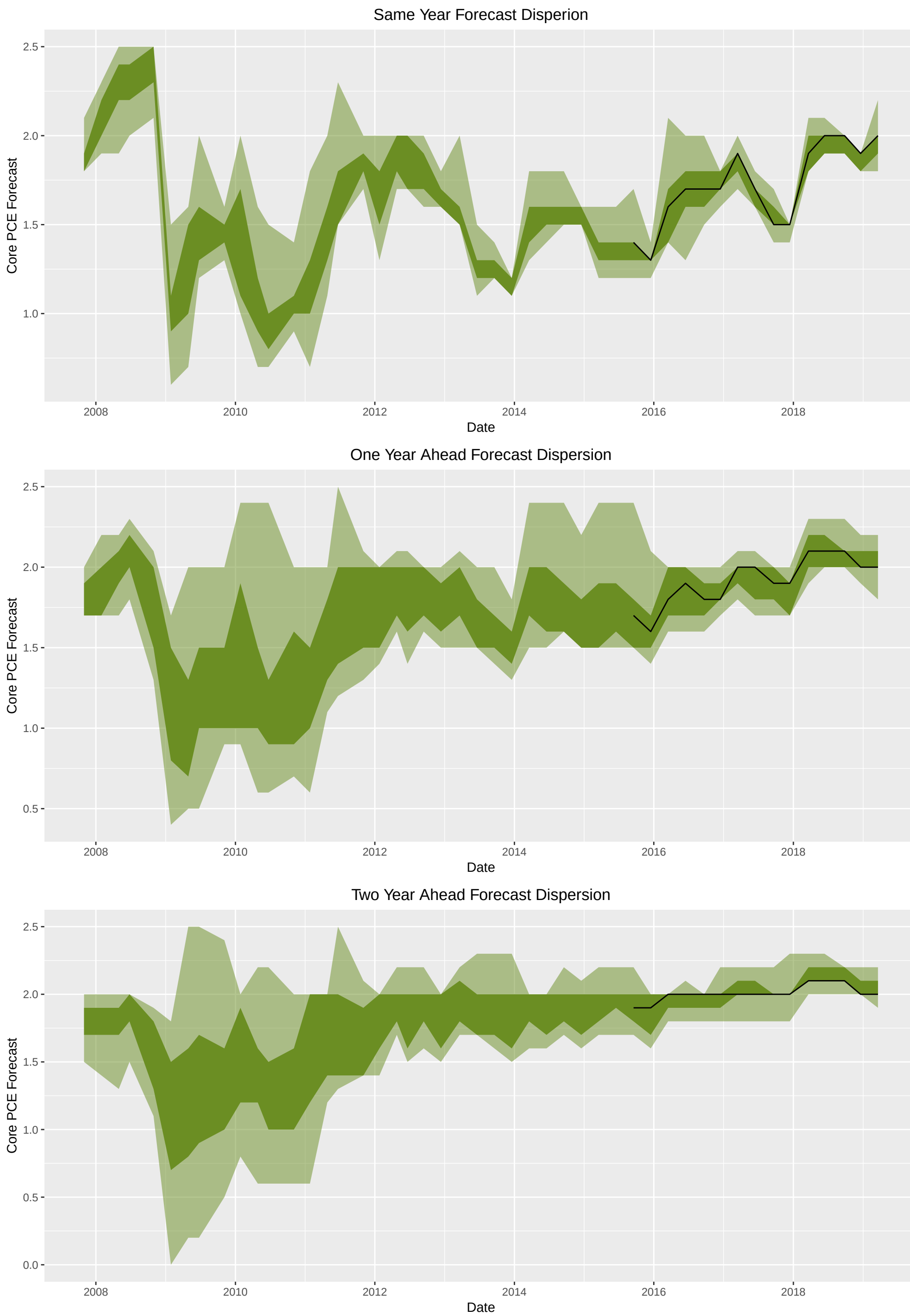
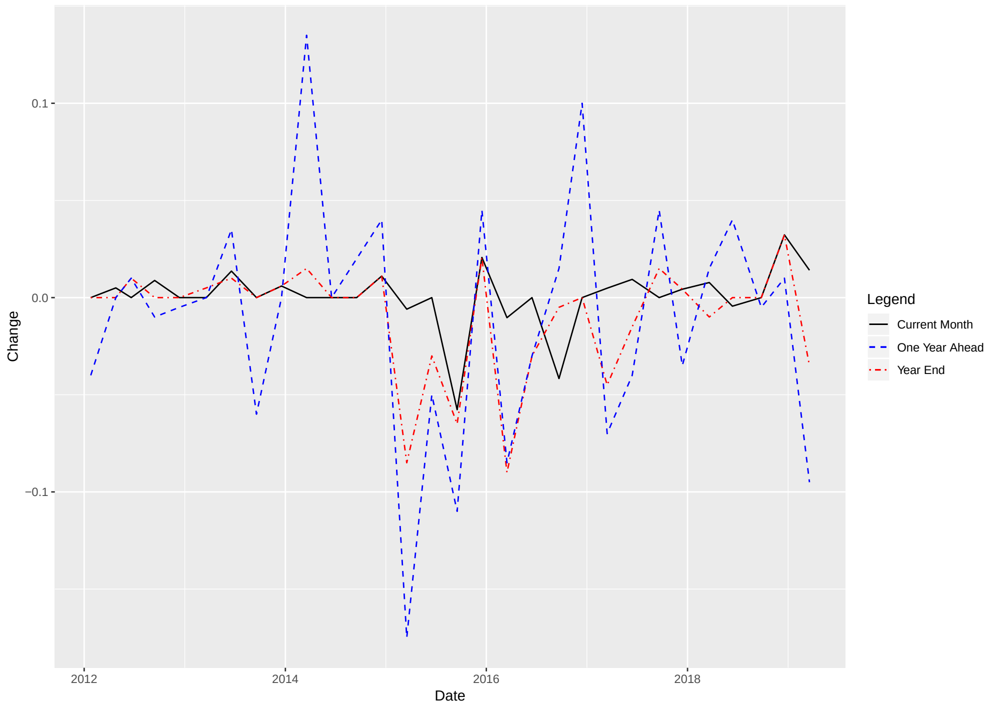


Figure A.4: Surprise Change in Federal Funds Rate Futures at Various Horizons



Notes: The figure displays the daily surprise change in the federal funds rate on FOMC announcement days.

Figure A.5: Forecast Error by Forecast Horizon

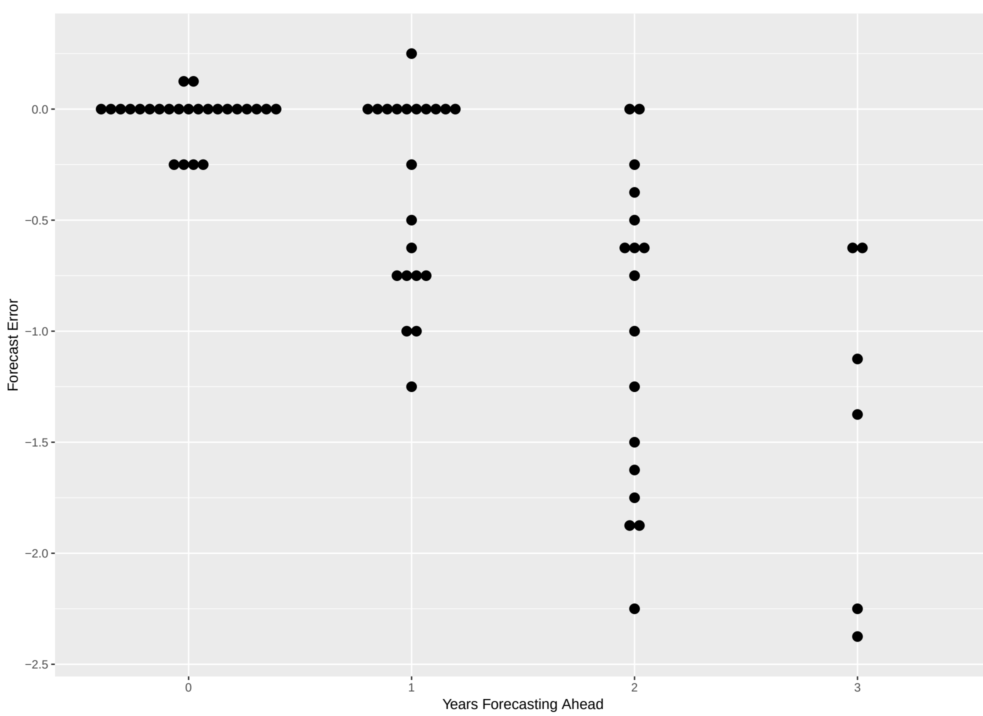
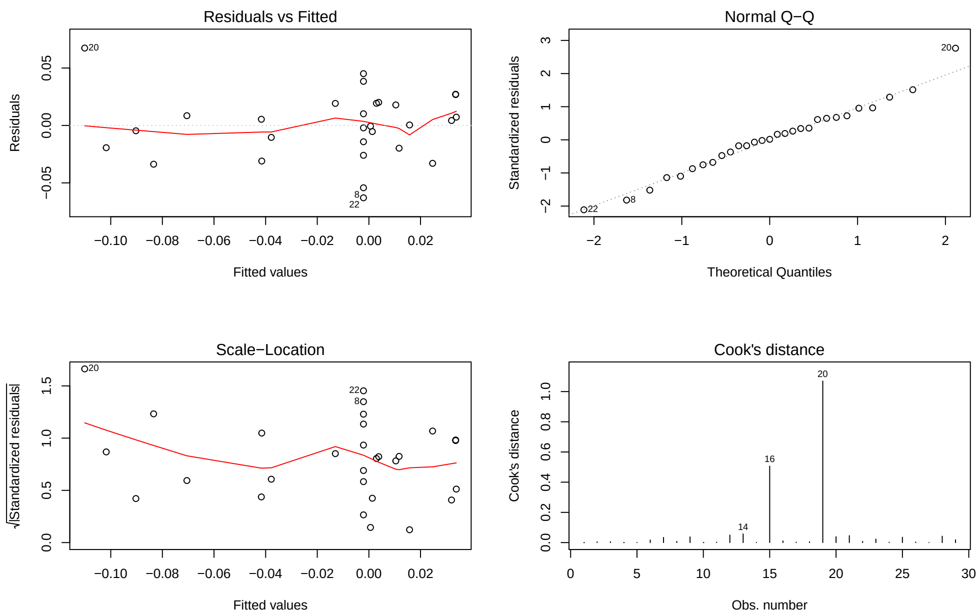


Table A.1: Summary Statistics

	Obs	Mean	St. Dev	Min	Max
Change in SEP					
Same Year FFR Forecast	29	-0.06	0.17	-0.50	0.25
Next Year FFR Forecast	29	-0.07	0.24	-0.62	0.25
Two Year Ahead Year FFR Forecast	29	-0.10	0.29	-0.62	0.50
Same Year GDP Forecast	33	-0.14	0.31	-1.15	0.30
Next Year GDP Forecast	33	-0.07	0.22	-0.80	0.40
Same Year Unemployment Rate Forecast	33	-0.07	0.17	-0.45	0.30
Next Year UR Forecast	33	-0.07	0.18	-0.30	0.60
Same Year PCE Forecast	33	-0.03	0.30	-0.60	0.95
Next Year PCE Forecast	33	-0.03	0.10	-0.45	0.15
Same Year Core PCE Forecast	33	-0.01	0.14	-0.30	0.30
Next Year Core PCE Forecast	33	-0.01	0.10	-0.20	0.30
Change in Asset Prices					
Target Surprise	30	-0.00	0.02	-0.06	0.03
3-Month Bill	30	-0.00	0.01	-0.03	0.01
6-Month Bill	30	-0.01	0.02	-0.08	0.01
2-Year Note	30	-0.01	0.05	-0.12	0.06
5-Year Note	30	-0.01	0.08	-0.20	0.17
10-Year Note	30	-0.01	0.06	-0.17	0.14
S&P 500	30	0.27	0.50	-0.79	1.66

Notes: UR denotes the Unemployment Rate. The summary statistics for federal funds rate forecasts and asset prices shown above cover the period from January 2012 through March 2019. Those for other forecasts cover the period from April 2011 through March 2019.

Figure A.6: Regression Diagnostics



Notes: The figure displays various regression diagnostics for the specification shown in Table 1.2 in the case where the 2-year treasury yield is the dependent variable.

Table A.2: Response of Assets Prices to Dot Plots Including Two Year Ahead Forecasts

	3-Month Bill	6-Month Bill	2-Year Note	5-Year Note	10-Year Note	S&P 500
Change in Current Year Median Dot	0.018	0.053***	0.145***	0.178***	0.158**	−0.894
	(0.012)	(0.016)	(0.051)	(0.060)	(0.062)	(1.091)
Change in One Year Ahead Forecast	0.013	0.022	0.156***	0.213***	0.111**	−0.104
	(0.008)	(0.017)	(0.045)	(0.054)	(0.044)	(0.711)
Change in Two Year Ahead Forecast	0.001	−0.012	−0.028	−0.043	−0.004	−0.242
	(0.005)	(0.013)	(0.033)	(0.050)	(0.055)	(0.669)
Surprise Change	0.363***	0.587**	0.635	0.456	0.258	−2.273
	(0.086)	(0.262)	(0.578)	(0.696)	(0.531)	(9.203)
Constant	−0.001	−0.004*	−0.004	0.4002	0.006	0.197**
	(0.001)	(0.002)	(0.006)	(0.014)	(0.012)	(0.095)
Observations	29	29	29	29	29	29
R^2	0.766	0.757	0.681	0.436	0.329	0.105

Notes: Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through March 2019. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent. Change in one and two year ahead forecast only considers the additional information provided at each horizon. See text for details.

Table A.3: Response of Asset Prices to Changes in the Dot Plots Excluding Most Influential Observations

	3-Month Bill	6-Month Bill	2-Year Note	5-Year Note	10-Year Note	S&P 500
Change in Current Year Median Dot	0.018	0.060***	0.168***	0.222***	0.180***	−0.901
	(0.014)	(0.015)	(0.045)	(0.055)	(0.058)	(1.126)
Change in One Year Ahead Forecast	0.011	0.029***	0.175***	0.227***	0.128**	−0.349
	(0.007)	(0.010)	(0.026)	(0.034)	(0.026)	(0.546)
Surprise Change	0.334***	0.800***	1.150***	0.995*	0.505	−3.842
	(0.110)	(0.206)	(0.266)	(0.535)	(0.708)	(10.536)
Constant	−0.000	−0.003*	0.000	0.013	0.014	0.177*
	(0.001)	(0.002)	(0.004)	(0.009)	(0.009)	(0.103)
Observations	26	26	26	26	26	26
R^2	0.69	0.88	0.86	0.69	0.55	0.15

Notes: Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through March 2019 excluding the meetings held on 03/19/2014, 09/17/2015, and 09/21/2016 . Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively.

Table A.4: Response of Asset Prices to Changes in Federal Fund Rate Expectations

	3-Month Bill	6-Month Bill	2-Year Note	5-Year Note	10-Year Note	S&P 500
One Year Ahead Surprise Change	0.031	0.164***	0.605***	0.883***	0.632***	−3.642***
	(0.024)	(0.043)	(0.078)	(0.137)	(0.123)	(1.338)
Surprise Change	0.434***	0.678***	0.582	0.610	0.520	0.166
	(0.128)	(0.219)	(0.431)	(0.689)	(0.622)	(7.873)
Constant	−0.002**	−0.006***	−0.008	−0.003	−0.001	0.232***
	(0.001)	(0.002)	(0.006)	(0.009)	(0.008)	(0.082)
Observations	30	30	30	30	30	30
R^2	0.647	0.713	0.681	0.585	0.479	0.200

Notes: Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through March 2019. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively.

Table A.5: Response of Asset Prices to Changes in All FOMC Forecasts

	Same Year				**Following Year**			
	FFR	GDP	UR	Core PCE	FFR	GDP	UR	Core PCE
3-Month Bill	0.018***	−0.003	−0.014*	−0.015*	0.013***	0.001	−0.011	−0.003
	(0.006)	(0.004)	(0.007)	(0.008)	(0.005)	(0.006)	(0.008)	(0.013)
6-Month Bill	0.065***	−0.005	0.001	−0.021	0.045***	0.012	0.018	−0.041
	(0.014)	(0.009)	(0.016)	(0.018)	(0.011)	(0.014)	(0.019)	(0.030)
2-Year Note	0.174***	−0.012	−0.018	−0.061	0.165***	0.016	0.051	−0.064
	(0.048)	(0.032)	(0.055)	(0.063)	(0.029)	(0.037)	(0.052)	(0.082)
5-Year Note	0.218**	0.009	−0.050	−0.160	0.202***	0.098	0.029	−0.180
	(0.085)	(0.055)	(0.097)	(0.111)	(0.057)	(0.071)	(0.100)	(0.159)
10-Year Note	0.170**	0.020	−0.040	−0.127	0.122**	0.119*	−0.010	−0.083
	(0.069)	(0.045)	(0.079)	(0.091)	(0.048)	(0.060)	(0.085)	(0.134)
S&P	−0.718	−0.237	−0.368	−0.606	−0.530	0.078	−0.381	−0.999
	(0.660)	(0.430)	(0.754)	(0.863)	(0.499)	(0.627)	(0.881)	(1.395)

Notes: UR stands for unemployment rate. Sample is all 30 FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through March 2019. Standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively. Regressions include monetary surprise and constant terms that are not shown in the table. More specifically, the regression is of the form $\Delta y_t = \beta_0 + \beta_1 \Delta_q x^{FFR}_{h|t,q} + \beta_2 \Delta_q x^{GDP}_{h|t,q} + \beta_3 \Delta_q x^{UR}_{h|t,q} + \beta_4 \Delta_q x^{CorePCE}_{h|t,q} + \beta_5 s_t$ for $h = 0, 1$.

Table A.6: Response of Asset Prices to Surprise Change in Other FOMC Forecasts

	Same Year			**Following Year**		
	GDP	UR	PCE	GDP	UR	PCE
3-Month Bill	−0.001	−0.013	−0.002	0.003	−0.009	0.004
	(0.005)	(0.010)	(0.008)	(0.003)	(0.008)	(0.008)
6-Month Bill	0.013	−0.035	0.005	0.016***	−0.023	0.005
	(0.011)	(0.025)	(0.022)	(0.006)	(0.019)	(0.022)
2-Year Note	0.031	−0.039	0.040	0.035	−0.045	0.080
	(0.037)	(0.087)	(0.059)	(0.023)	(0.072)	(0.059)
5-Year Note	0.031	−0.020	0.084	0.048	-0.055	0.066
	(0.064)	(0.152)	(0.089)	(0.039)	(0.153)	(0.089)
10-Year Note	0.028	−0.010	0.063	0.048	−0.052	−0.005
	(0.053)	(0.125)	(0.072)	(0.032)	(0.135)	(0.072)
S&P 500	−0.494	−0.633	−0.360	0.013	−0.226	−1.403*
	(0.383)	(0.841)	(0.617)	(0.239)	(0.615)	(0.617)

Notes: UR stands for unemployment rate. Sample is all 33 FOMC meetings with a Summary of Economic Projections (SEP) release from April 2011 through March 2019. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively. Regressions include monetary surprise and constant terms that are not shown in the table.

Table A.7: Response of Asset Prices to Changes in the Dot Plots Excluding Important FOMC Forward Guidance Announcements

	3-Month Bill	6-Month Bill	2-Year Note	5-Year Note	10-Year Note	S&P 500
Change in Current Year Median Dot	0.03	0.07	0.15	0.18	0.12	−0.29
	(0.036)	(0.055)	(0.103)	(0.230)	(0.422)	(1.658)
Change in One Year Ahead Forecast	0.018***	0.018	0.106**	0.150**	0.090*	0.467
	(0.007)	(0.022)	(0.048)	(0.060)	(0.048)	(0.540)
Surprise Change	0.343***	0.594*	0.767	0.618	0.369	−4.733
	(0.106)	(0.310)	(0.607)	(0.785)	(0.816)	(8.109)
Constant	−0.000	−0.002	0.003	0.007	0.004	0.092
	(0.001)	(0.002)	(0.008)	(0.021)	(0.018)	(0.110)
Observations	19	19	19	19	19	19
R^2	0.91	0.78	0.67	0.32	0.21	0.14

Notes: Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through March 2019 excluding the meetings with important FOMC foward guidance announcements as indicated by the Fed at https://www.federalreserve.gov/monetarypolicy/timeline-forward-guidance-about-the-federal-funds-rate.htm. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively.

Table A.8: Response of Assets Prices to the Range of the Dot Plots

	Level				**Difference**			
	Current Year		**Next Year**		**Current Year**		**Next Year**	
	Range	Median	Range	Median	Range	Median	Range	Median
3-Month Bill	0.002	0.020*	0.003	0.014**	−0.005	0.019**	−0.002	0.016**
	(0.003)	(0.012)	(0.002)	(0.006)	(0.003)	(0.012)	(0.002)	(0.007)
6-Month Bill	−0.008	0.054***	−0.006	0.042***	−0.002	0.059***	−0.008*	0.041***
	(0.006)	(0.016)	(0.004)	(0.011)	(0.007)	(0.014)	(0.004)	(0.009)
2-Year Note	-0.006	0.160*	−0.009	0.154***	0.001	0.164***	−0.013	0.154***
	(0.025)	(0.085)	(0.010)	(0.022)	(0.028)	(0.052)	(0.014)	(0.021)
5-Year Note	−0.006	0.202***	−0.011	0.199***	0.000	0.206***	−0.026	0.202***
	(0.044)	(0.065)	(0.021)	(0.038)	(0.039)	(0.071)	(0.031)	(0.033)
10-Year Note	−0.010	0.159***	−0.011	0.142***	−0.007	0.166***	−0.024	0.144***
	(0.036)	(0.051)	(0.018)	(0.032)	(0.028)	(0.054)	(0.027)	(0.28)
S&P500	−0.253	−0.968	0.072	−0.571	−0.096	−0.809	0.112	−0.568
	(0.352)	(0.995)	(0.206)	(0.582)	(0.337)	(0.852)	(0.196)	(0.482)

Notes: Sample is all 30 FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through March 2019. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively. Regressions include monetary surprise and constant terms that are not shown in the table.

Table A.9: Response of Assets Prices to the Central Tendency of the Dot Plots

	Level				**Difference**			
	Current Year		**Next Year**		**Current Year**		**Next Year**	
	CT	Median	CT	Median	CT	Median	CT	Median
3-Month Bill	−0.001	0.018	0.004	0.016***	0.007	0.024*	−0.000	0.016**
	(0.006)	(0.012)	(0.003)	(0.006)	(0.006)	(0.012)	(0.002)	(0.006)
6-Month Bill	−0.029**	0.046***	−0.009	0.039***	−0.011	0.051***	−0.005	0.039***
	(0.012)	(0.016)	(0.006)	(0.010)	(0.014)	(0.017)	(0.005)	(0.010)
2-Year Note	−0.054	0.140***	0.007	0.150***	−0.026	0.145***	0.015	0.148***
	(0.045)	(0.051)	(0.019)	(0.023)	(0.043)	(0.055)	(0.019)	(0.022)
5-Year Note	−0.094	0.164***	0.029	0.195***	−0.024	0.189**	0.053	0.188***
	(0.069)	(0.064)	(0.053)	(0.034)	(0.057)	(0.081)	(0.050)	(0.032)
10-Year Note	−0.055	0.141**	0.009	0.137***	0.004	0.168**	0.042	0.132***
	(0.058)	(0.063)	(0.048)	(0.028)	(0.045)	(0.066)	(0.046)	(0.030)
S&P 500	−0.316	−0.953	−0.467	−0.551	0.850*	−0.206	−0.389	−0.493
	(0.470)	(0.904)	(0.447)	(0.542)	(0.451)	(0.824)	(0.244)	(0.483)

Notes: Sample is all 30 FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through March 2019. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively. Regressions include monetary surprise and constant terms that are not shown in the table.

Table A.10: Relationship between Range, Central Tendency, and Monetary Policy Uncertainty

	Monetary Policy Uncertainty	
Range of One Year Ahead Dot Plot	0.188***	
	(0.054)	
Central Tendency of One Year Ahead Dot Plot		0.395***
		(0.115)
Constant	0.176	0.274**
	(0.111)	(0.076)
Observations	17	17
R^2	0.336	0.362

Notes: Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through December 2015. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively.

Table A.11: Relationship between Changes in the Range, Central Tendency, and Monetary Policy Uncertainty

	Change in Monetary Policy Uncertainty	
Change in Range of Dot Plots	0.008	
	(0.037)	
Change in Central Tendency of Dot Plots		0.049
		(0.035)
Constant	−0.029	−0.032**
	(0.019)	(0.015)
Observations	16	16
R^2	0.005	0.115

Notes: Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through December 2015. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively.

Table A.12: Relationship between Higher Moments of the Dot Plot and Monetary Policy Uncertainty

	Monetary Policy Uncertainty
Variance of Dot	-0.086
Plots for Following Year	(0.159)
Skewness of Dot	-0.424^{***}
Plots for Following Year	(0.043)
Kurtosis of Dot	0.074^{***}
Plots for Following Year	(0.014)
Constant	0.750^{***}
	(0.075)
Observations	17
R^2	0.936

Notes: Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through December 2015. Bootstrapped standard errors are reported in parenthesis. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively.

Appendix B

Appendix for Chapter 2

B.1 Calculating Risk Premium

It is difficult to precisely calculate the risk premium of the policy rate futures. As such, I calculate a variety of measures and show that the expectations gap is robust to the choice of risk premium. The risk premium is given by

$$f_t^{(n)} = E_t[i_{t+n}] + \mu_t^{(n)},$$

where $f_t^{(n)}$ is the n period ahead policy rate futures price, $E_t[i_{t+n}]$ is the expectation at time t of the average policy rate in period $t+n$, and $\mu_t^{(n)}$ is a potentially time-varying risk premium for the n period ahead futures rate.

B.1.1 United States

First, I consider the simple rule-of-thumb employed by the Federal Reserve Board of 1bp per month, which I will call the Kohn rule. Second, I consider the approach of excess return in Piazzesi and Swanson (2008). Define the excess return, $rx_{t+n}^{(n)}$, as

$$rx_{t+n}^{(n)} = f_t^{(n)} - i_{t+n}.$$

Then, I consider the regression

$$rx_{t+n}^{(n)} = \psi_0 + \psi_1 f_t^{(n)} + \psi_2 \Delta NFP_{t-1},$$

where ΔNFP_{t-1} is the lagged year-to-year change in log non-farm payrolls. I then use the fitted values of this equation as the measure of risk premium at each time t. Third, I follow Diercks and Carl (2019), who estimate the risk premium through the context of the no arbitrage condition. In particular, they regress the difference between the implied federal funds futures rate and survey data on the covariance of real activity and the interest rate. Finally, I use the survey data from the New York Fed in the Survey of Market Participants. Each month, the New York Fed asks, among other things, about the expected path of the target rate path. I consider the risk premium to be the difference between the midpoint/target rate provided for the end of each year and the futures implied rate on the date the survey was received by.[1]

[1] Between September 2014 and January 2016, the New York Fed separated respondents that report a target range and target rate; I focus on the midpoint of the target range as most respondents provided a range rather than a target rate.

B.1.2 Sweden

As in the case of the United States, I consider a simple rule-of-thumb employed by the Riksbank of 1bp per month. I also consider the risk premium implied by the survey conducted by Prospera about market expectations of the repo rate. Unfortunately, this survey only provides expectations for 3, 12, and 24 months ahead, so any intermediate horizon is linearly interpolated. To calculate the risk premium, I subtract the survey expectations from the corresponding futures implied repo rate on the day that the survey is conducted. The disadvantage of this method is that it assumes that the risk premium found on survey days is the same as the risk premium on Riksbank announcement days. In addition, I consider a risk premium of negative 1bp per month, which corresponds to the average premium implied by the survey data at the horizon of 12 months and corresponds to the estimates that Diercks and Carl (2019) find for the United States following the ZLB period.

B.2 Calculating Forward Guidance

Let X denote a $T \times n$ matrix of data generated by a factor model:

$$X = F\Lambda + \eta,$$

where F is a $T \times k$ matrix of unobserved factors, Λ is a $k \times n$ matrix of factor loadings, and η is a $T \times n$ matrix of white noise disturbances.

B.2.1 New Zealand

In the case of New Zealand, let X contain the changes in the first through sixth New Zealand 90-day bank bill futures contracts and the 5-year government bond yield from December 2000 through November 2018 on RBNZ Monetary Policy Statement release dates. Thus, X is a 72×7 matrix. In order to determine how many factors characterize the data, I apply the rank test of Cragg and Donald (1997). As the results in Table B.1 show, the hypotheses that the data can be explained with either zero or one factor are strongly rejected. With two factors, however, I fail to reject the hypothesis. Thus, two factors appear to be sufficient. This is largely consistent with communication by the RBNZ, who state that their tested tools consist of the OCR and forward guidance.

Table B.1: Test for Underlying Factors of RBNZ Monetary Policy Reports

H_0	Degrees of Freedom	p-value
0	21	3.62×10^{-7}
1	14	0.0018
2	8	0.073

Notes: Results from the Cragg and Donald (1997) rank test for the number of factors k underlying the asset price responses to RBNZ Monetary Policy announcements from December 2000 through November 2018. The testis for $H_0 : k = k_0$ vs. $H_1 : k > k_0$.

B.2.2 Sweden

For Sweden, let X contain the changes in the first through fourth RIBA futures contracts and the 2- and 5-year government bond yields from April 2009 through December 2018 on Riksbank Monetary Policy Report release dates, including any Monetary Policy Updates for years prior to 2015. As in the case of New Zealand, I apply a rank test. As Table B.2 shows, the data suggests that two factors are sufficient, which is consistent with Brubakk et al. (2017).

B.3 Supplemental Figures and Tables

Table B.2: Test for Underlying Factors of Riksbank Monetary Policy Reports

H_0	Degrees of Freedom	p-value
0	15	1.46×10^{-7}
1	9	0.0075
2	4	0.094

Notes: Results from the Cragg and Donald (1997) rank test for the number of factors k underlying the asset price responses to Riksbank Monetary Policy reports from April 2009 through December 2018. The testis for $H_0 : k = k_0$ vs. $H_1 : k > k_0$.

Table B.3: Federal Funds Rate Forecast RMSE – Risk Premia Robustness

Horizon (Quarters)	FOMC	Kohn	RMSE Unadjusted	DC	PS
Greenbook Forecasts					
0-3	0.41	0.45	0.48	0.49	0.57
4-7	1.51	1.52	1.61	1.64	1.41
SEP Forecasts					
0-3	0.22	0.16	0.16	0.17	0.18
4-7	0.70	0.58	0.59	0.64	0.67

United States Greenbook forecasts are from 2005-2014 (80 observations) and United States SEP forecasts are from 2012-2019 (31 observations). The third to sixth columns present the RMSE of private sector forecasts under a variety of risk premia assumptions. Details can be found in Appendix B.1.

Table B.4: Credibility and High-Frequency Treasury Yield Response to FOMC Announcements

	3-Month	2-Year	5-Year	10-Year	30-Year
Surprise	36.4***	13.3	7.8	6.0	−6.4
Change	(5.4)	(14.3)	(20.3)	(22.8)	(23.8)
Credibility	−0.30	−0.11	0.28	−0.20	−1.01
Gap	(0.35)	(0.89)	(1.31)	(1.53)	(1.63)
Forward	0.35	10.0***	22.8***	16.8***	7.1**
Guidance	(0.6)	(2.6)	(5.4)	(4.4)	(3.1)
Cred*FG	1.10	2.29	−12.1***	−10.9**	−5.8
	(0.9)	(2.9)	(4.2)	(4.4)	(4.2)
Constant	−0.06	−0.21	−0.70	−0.41	0.17
	(0.17)	(0.43)	(0.64)	(0.74)	(0.79)
Observations	31	31	31	31	31
R^2	0.72	0.91	0.89	0.74	0.29

Notes: Same as Table 2.2, except that the financial market response is measured in the 30-minute window surrounding FOMC announcements rather than at the market close.

Table B.5: Forward Guidance Dampening Effects – Risk Premia Robustness

	3-Month	2-Year	5-Year	10-Year	30-Year
Kohn					
Forward Guidance	1.06	10.8**	32.1***	25.4***	13.7***
	(2.62)	(4.0)	(6.4)	(5.3)	(4.6)
Cred*FG	2.12	4.08	−24.4**	−23.1***	−15.1**
	(3.91)	(6.00)	(9.6)	(7.9)	(6.9)
Unadjusted					
Forward Guidance	1.57	11.97***	31.13***	24.00***	12.99**
	(2.67)	(4.11)	(6.66)	(5.57)	(4.78)
Cred*FG	2.11	2.23	−28.64**	−25.76**	−17.30*
	(5.07)	(7.80)	(12.65)	(10.59)	(9.10)
SMP					
Forward Guidance	0.65	13.91***	26.11***	19.15***	9.67***
	(1.76)	(2.79)	(4.32)	(3.70)	(3.30)
Cred*FG	9.79	4.46	−34.77*	−30.56**	−14.55
	(7.00)	(11.11)	(17.22)	(14.73)	(13.16)
DC					
Forward Guidance	1.06	10.77**	32.12***	25.40***	13.670***
	(2.62)	(4.03)	(6.44)	(5.30)	(4.60)
Cred*FG	2.12	4.1	−24.4**	−23.1***	−15.1**
	(3.908)	(6.002)	(9.589)	(7.890)	(6.860)
PS					
Forward Guidance	2.15	12.3***	27.7***	21.4***	11.2**
	(2.20)	(3.41)	(5.54)	(4.59)	(4.04)
Cred*FG	−0.46	2.18	−25.8*	−24.2**	−14.0
	(5.12)	(7.94)	(12.9)	(10.7)	(9.41)

Notes: Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through June 2019. Coefficients are in basis points. Bootstrapped standard errors are reported in parentheses. Superscripts *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent. See Section 2.4.2 for details.

Table B.6: Credibility and Treasury Yield Response including LSAPs

	3-Month	2-Year	5-Year	10-Year	30-Year
Surprise	36.5***	22.4*	−2.4	−16.4	−27.2
Change	(5.4)	(12.3)	(19.4)	(17.5)	(19.5)
Forward	0.29	14.4***	19.3***	8.9***	0.34
Guidance	(0.72)	(4.1)	(5.7)	(3.3)	(2.7)
Credibility	−0.52	−1.48	−0.75	−0.61	−1.37
Gap	(0.45)	(1.0)	(1.6)	(1.5)	(1.6)
LSAP	0.004	1.16*	−1.30	−2.74***	−2.48***
	(0.16)	(0.67)	(0.91)	(0.64)	(0.61)
Cred*FG	1.36	−4.90	−11.3**	−2.63	2.19
	(1.30)	(3.12)	(5.3)	(4.3)	(4.8)
Constant	−0.01	0.04	−0.32	−0.12	0.34
	(0.16)	(0.37)	(0.58)	(0.53)	(0.61)
Observations	31	31	31	31	31
R^2	0.72	0.93	0.91	0.86	0.56

Notes: Estimated coefficients from $\Delta y_t = \alpha + \beta_0 \Delta s_t + \beta_1 f_t + \beta_2 c_t + \beta_3 l_t + \beta_4 f_t * c_t + \epsilon_t$, where t indexes FOMC announcements containing SEP releases, Δy_t is the daily change in the financial asset y, Δs_t is the surprise change in the federal funds rate , f_t is a measure of forward guidance, c_t is the credibility gap, and l_t is a measure of LSAPs. Sample is all FOMC meetings with a Summary of Economic Projections (SEP) release from January 2012 through June 2019. Coefficients are in basis points. Bootstrapped standard errors are reported in parentheses. Superscripts *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent. See text for details.

Table B.7: Effects of Mortgage Rate on Home Sales

	New One-Family Home Sales
30-Year Mortgage Rate	-49.4***
	(0.05)
Constant	1035.3***
	(4.19)
Observations	577
R^2	0.96

Notes: Model contains year fixed effects. Data is monthly from April 1971 through April 2019. Units are in thousands. Superscripts *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent.

Table B.8: Credibility and Stock Market Response to FOMC Announcements

	S&P 500
Surprise	−1.33
Change	(7.7)
Forward	−2.34**
Guidance	(0.97)
Credibility	−0.71
Gap	(0.51)
Cred*FG	1.61
	(1.3)
Constant	0.62**
	(0.25)
Observations	31
R^2	0.29

Notes: Superscripts *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent. Coefficients are in percentage points. Bootstrapped standard errors are reported in parentheses. See notes to Table 2.2 for details.

Table B.9: Riksbank Forward Guidance Dampening Effects – Risk Premia Robustness

	3-Month	6-Month	2-Year	5-Year
Rule of Thumb				
Forward Guidance	5.7 (4.1)	10.6 (6.4)	35.0*** (1.3)	38.5*** (4.6)
Cred*FG	−7.8 (10.6)	−16.8 (16.1)	−5.8* (3.2)	−9.2 (11.8)
Unadjusted				
Forward Guidance	6.0 (3.7)	10.4* (5.9)	34.6*** (1.2)	37.651*** (4.3)
Cred*FG	−11.0 (11.2)	−20.9 (17.6)	−5.8 (3.5)	−8.4 (12.9)
Negative Rule of Thumb				
Forward Guidance	7.8* (4.0)	11.8* (6.4)	34.3*** (1.3)	36.9*** (4.6)
Cred*FG	−20.5 (14.0)	−27.2 (22.0)	−4.9 (4.5)	−6.1 (16.2)
Prospera				
Forward Guidance	12.5** (4.5)	21.6*** (7.4)	33.4*** (1.1)	35.8*** (5.3)
Cred*FG	−47.8** (18.6)	−78.4** (29.7)	−1.04 (6.3)	0.29 (21.5)

Notes: Sample is all Riksbank Monetary Policy Reports from February 2010 through February 2019. Coefficients are in basis points. Bootstrapped standard errors are reported in parentheses. Superscripts *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent. See Section 2.4.4 for details.

Table B.10: Forecast Error Correlation

	GDP Growth				Unemployment			
	Current Year		Next Year		Current Year		Next Year	
	SEP	SPD	SEP	SPD	SEP	SPD	SEP	SPD
PCE	-0.48	0.09	0.04	0.51	0.07	0.27	0.34	0.25
Core PCE	-0.38	0.09	-0.26	-0.17	-0.06	-0.03	0.35	0.05

Sample contains data from the SEP and SPD from 2011 through 2019 (35 observations). The displayed values are the correlation of the forecast errors of inflation and output.

Table B.11: Taylor Rule Estimates

	PCE Inflation		Core PCE Inflation	
	SEP	SPD	SEP	SPD
γ_π	0.64	0.30	2.66	1.61
	(0.24)	(0.23)	(0.38)	(0.40)
γ_u	-0.44	-1.39	-0.29	-1.21
	(0.13)	(0.19)	(0.12)	(0.19)
r^*	0.25	-0.42	0.44	-0.29
	(0.10)	(0.10)	(0.09)	(0.10)
R^2	0.54	0.63	0.44	0.61

Sample contains data from the SEP and SPD from March 2013 through March 2019 for projections in which neither median forecast was constrained by the ZLB (71 observations). The displayed values are the coefficients obtained from estimating a Taylor-type rule using projections from the SEP and SPD of the specification $i_t = r^* + \pi_t + \gamma_\pi(\pi_t - \pi^*) + \gamma_u \hat{u}_t + \epsilon_t$, where π_t denotes inflation π^* denotes the inflation target, and $\hat{u}_t$ denotes the gap between current and long-run unemployment.

Figure B.1: Comparison of FOMC and Tealbook FFR Forecast

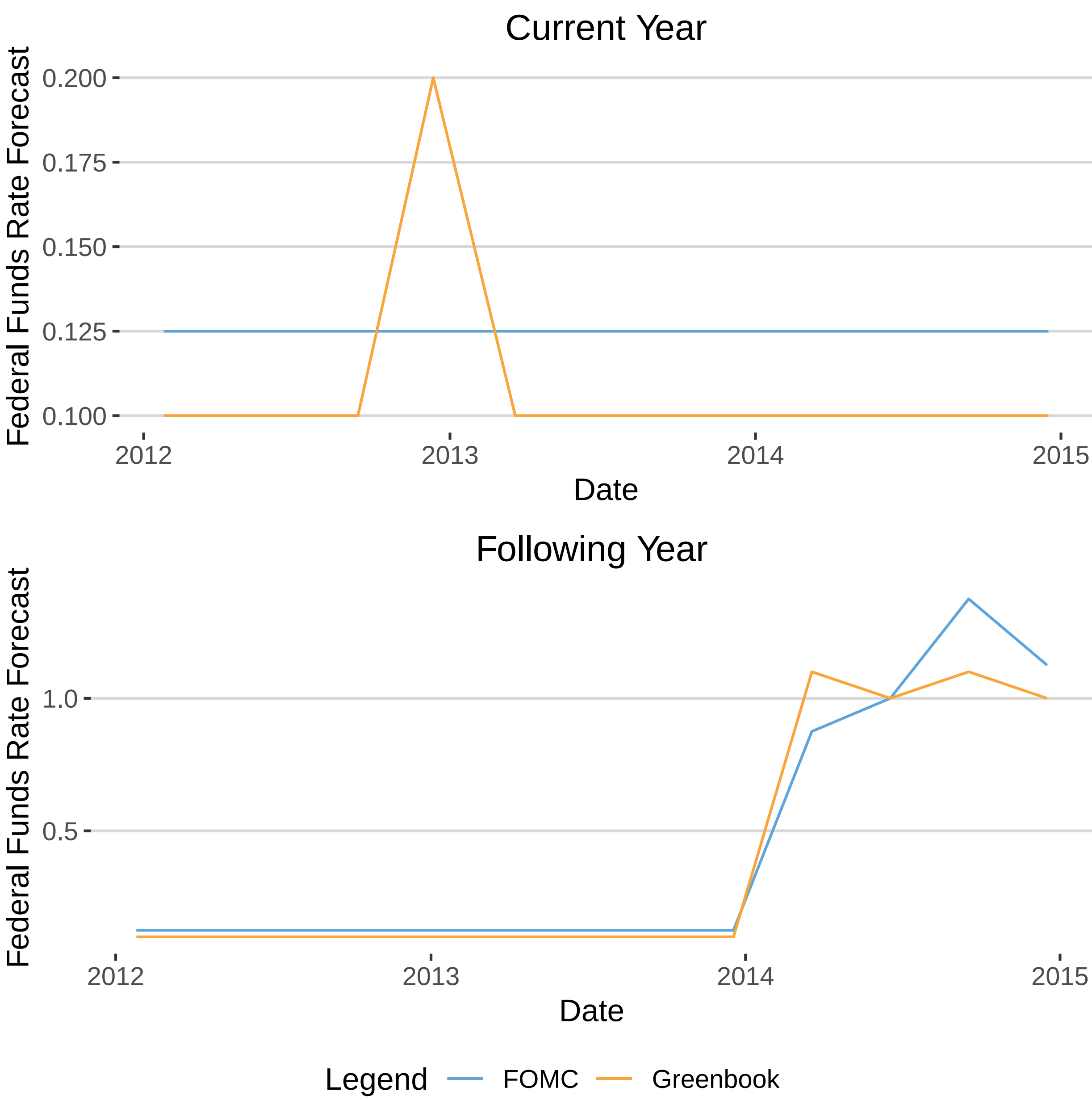


Figure B.2: SPF vs. FOMC: Economic Variables

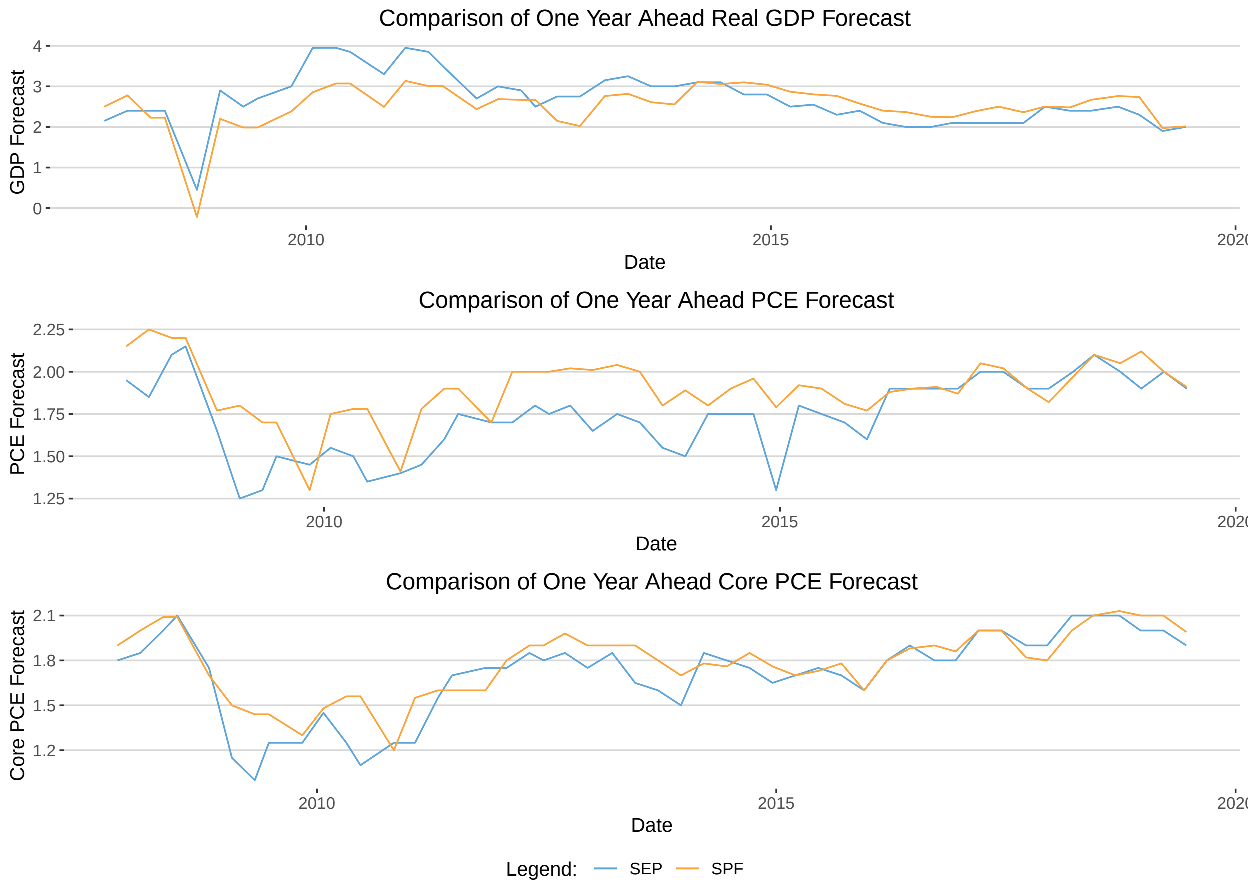


Figure B.3: SEP: Long-Run Real Federal Funds Rate Forecast