GPIF Working Paper

The Dot Plot and Dynamics of Financial Markets and Economy

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EXECUTIVE SUMMARY

- In investment business, much emphasis is placed on analyzing US monetary policy, which has a significant impact on global financial markets. Hence, the dot plot, which is the policy rate outlook of FOMC participants, attracts a lot of attention.
- While there have been numerous analyses of the relationship between FOMC and the markets, to the best of the author's knowledge, there have been few analyses of the relationship between the dot plot and market/economic developments based on econometric models.
- This paper takes Cochrane and Piazzesi [2002] as a starting point and analyzes the relationship between the dot plot and market/economic developments from various angles. Specifically, we analyze the causality of Granger [1969], the forecast accuracy of the median forecasts in the dot plot, and the relationship between the median forecasts in the dot plot and yield curves using the model by Nelson and Siegel [1987] and Svensson [1994].

1.Introduction

In investment business, the analysis of US monetary policy, which has a significant impact on global financial markets, is of great importance. Therefore, market participants pay close attention to the policy decisions of the Federal Open Market Committee (hereinafter referred to as “FOMC”), the decision-making body of the Federal Reserve System (hereinafter referred to as "Fed"), the central bank of the United States, and the discussions behind those decisions. In addition, they also pay great attention to the Summary of Economic Projections (hereinafter referred to as "SEP") and the monetary policy rate outlook (hereinafter referred to as "dot plot") by FOMC participants as a means of forecasting the future monetary policy.

There has been a great deal of analyses of FOMC’s monetary policy and market reactions. For example, Lunsford [2020], using the forward guidance statements by FOMC from 2000 to 2006, analyzed the market impact of the statement on the risk of the economic outlook and the statement on the direction of monetary

Note: This working paper is a compilation of research results by GPIF staff, and the contents and opinions expressed in the text do not represent the official views of GPIF.

policy, and found that the statement regarding the direction of monetary policy had a stronger impact on the market. Bauer and Swanson [2021] noted that FOMC statement had the opposite effect on market expectations regarding GDP growth, unemployment rate, and inflation from the macroeconomic model. Such an impact of FOMC statement on market expectations had been interpreted as a "Fed Information Effect." However, Bauer and Swanson [2021] show that there was no "Fed Information Effect" on market expectations because FOMC also reacted to the same information as the market. In addition, Cochrane and Piazzesi [2002] used daily market data to analyze the relationship between the Federal Funds (hereinafter referred to as "FF") rate (hereinafter referred to as "policy interest rate") target and market interest rates. They pointed out that market reactions to changes in the policy interest rate, which are recognized as monetary policy change shocks in monthly data, are not necessarily the shocks in daily data. They also analyzed the impact of monetary policy change shocks extracted based on daily data on US Treasury rates and showed that the impact of the shocks was larger than that of the analysis based on monthly data. Furthermore, they conducted an analysis using a vector autoregression model (hereinafter referred to as "VAR model") and pointed out that there was no impact of monetary policy change shocks on nonfarm employment and inflation. As used in Cochrane and Piazzesi [2002], the VAR model and causality test[1] of Granger [1969] are widely used in the analysis of spillover effects of price fluctuations among assets and causality between markets and economic indicators. For example, Yang [2005] analyzed the government bond markets of six European countries and showed that Granger causality was not confirmed across government bond markets even when short-term correlations were clear. Nomura and Miyazaki [2013] conducted Granger causality test analysis of the relationship between the volatility skew of foreign exchange options and the rate of return on the USD/JPY and confirmed the causality from the rate of return on the USD/JPY to the volatility skew.

As described above, there have been many analyses of the relationship between FOMC and markets, the spillover effects of price fluctuations among assets, and the causality between markets and economic indicators, but to the best of the author's knowledge, there has been few econometric analyses of the relationship between the dot plot and markets or economic indicators. Therefore, this paper analyzes the impact of the dot plot on them from various angles, starting from Cochrane and Piazzesi [2002]. Specifically, we use Granger causality test with a VAR model to confirm the relationship between the median forecasts in the dot plot (hereinafter referred to as "median forecasts") and market interest rates and economic indicators, and to clarify to what extent the median forecasts can predict future policy interest rates. Furthermore, we analyze the impact of the median forecasts on the term structure of US Treasury rates using models by Nelson and Siegel [1987] and Svensson [1994] that explain the shape of the yield curve. This paper makes an academic contribution by confirming the analysis by Cochrane and Piazzesi [2002] with recent data and by analyzing the relationship between the median forecasts and market interest rates and

[1] A method for testing causality proposed by Granger [1969]. It is a test to statistically determine whether another time series data is useful in predicting time series data. However, it is important to note that this test only analyzes the temporal relationship between time series data, and does not determine the "causal relationship," which indicates the relationship between cause and effect.

economic indicators.

This paper is organized as follows. Section 2 describes the data used in the analysis, and Section 3 provides an analysis using Granger causality with VAR model between the median forecasts and market interest rates and economic indicators. Section 4 analyzes the predictive power of the median forecasts, and Section 5 analyzes the impact of the median forecasts on the US yield curve. Section 6 is summary and implications.

2. The Dot Plot and Its Data Structure

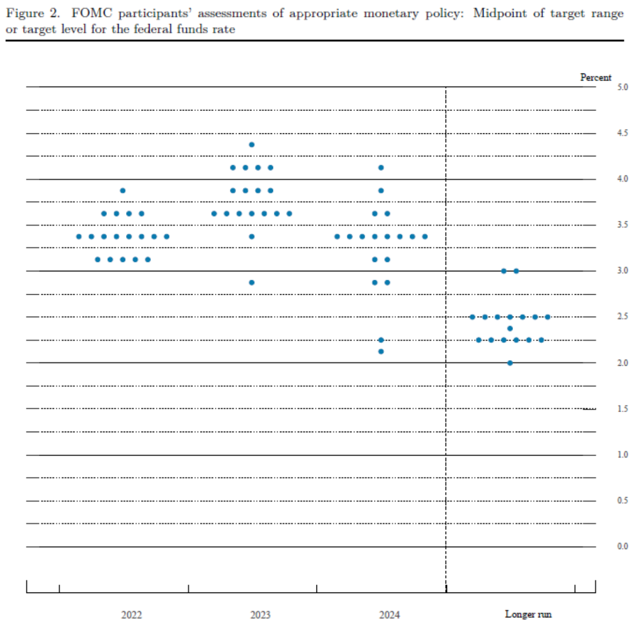
2.1 What is the Dot Plot?

The FOMC releases SEP quarterly, which provides a forecast of near-term economic indicators and policy interest rates by the seven members of the Federal Reserve Board (hereinafter referred to as "FRB") and the Governors of the twelve regional Federal Reserve Banks. Of these forecasts, each participant's forecast of the policy interest rate is published and shown as a dot in graph and therefore referred to as the "dot plot" (see Section 2.2). The dot plot attracts a great deal of attention from market participants because it shows the predicted values for all FOMC participants[2], including those who have a vote on monetary policy and those who don't. However, it has also been criticized because of the large variation in the forecast values for each FOMC participant and because anonymous forecasts do not tell us what economic outlook is being assumed when the forecasts are changed. In fact, the former Fed Chair Janet Yellen and the current Fed Chair Jerome Powell have indicated that it is not appropriate to look at the dot plot when forecasting the monetary policy (FOMC [2014], FOMC [2021], Fed [2019]).

The SEP was first published by the FRB on October 31st, 2007. The Fed Chair at that time, Ben Bernanke[3], is known for having served as Fed Chair from 2006 to 2014, which included the period of the global financial crisis. He had been researching inflation targeting (hereinafter referred to as "inflation target") before he took office at the FRB, and the SEP was introduced as an indirect inflation target. Later, amid a zero-interest-rate policy in the US in response to the global financial crisis, the FOMC decided on January 25th, 2012 to introduce PCE (Personal Consumption Expenditure, hereinafter referred to as "PCE") inflation target of around 2%, and also the dot plot was added to the SEP. The dot plot was expected to indicate that monetary policy going forward would be accommodative under a zero-interest-rate policy, and to have an easing effect by making monetary policy work against long-term interest rates. Thus, in interpreting the dot plot, it is necessary to consider it based on the comments of the FOMC participants on the dot plot.

[2] Initially, forming a consensus on the outlook among FOMC participants was considered, but since the maximum number of FOMC participants is 19 and it is difficult to reach a consensus, a form was adopted in which the outlook and forecast range for each participant is published.

[3] According to Bernanke [2015], it is necessary to cut long-term interest rates during recessions, such as mortgage rates and corporate bond yields, especially in a low interest rate environment where the room for rate cuts is limited due to the limited impact from Federal Funds rate cut. Therefore, it is necessary to demonstrate to market participants the long-term policy direction of monetary policy through an inflation target.

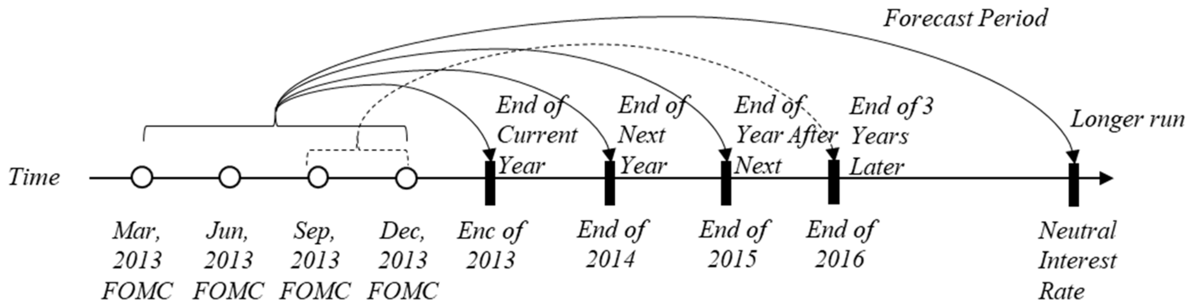


(Source: FRB Website)

Figure 1 The Dot plot published in June 2022

2.2 The Dot Plot Data Structure and Schedule for Publication

Figure 1 shows the dot plot published on June 15th, 2022 (FOMC [2022]). In Figure 1, the dots represent increments by 0.125% the policy interest rate forecasts of each of the 18 FOMC participants for the end of 2022, 2023, 2024, and the Longer run. However, one participant did not submit a forecast for the Longer run, leaving the number of dots at 17. The Longer run policy rate is referred to as the neutral interest rate. This is because the Longer run interest rate represents the level at which policy rates would converge if appropriate monetary policy were implemented and there were no additional financial or economic shocks. At the press conference after the FOMC meeting on January 25th, 2012, when the dot plot was first published, Fed Chair Ben Bernanke stated that in the dot plot they would focus on the median value for each year. Hence, the median forecast is generally used in the dot plot analysis. Therefore, we also use the median forecasts for analysis in this paper. In 2012, SEPs were released in January, April, June, September, and December, and except for March 2020, when they were not released due to the spread of the COVID-19, they have been released quarterly in March, June, September, and December since 2013. For March and June SEP, forecasts are given for "end of current year," "end of next year," "end of year after next," and "Longer run." For September and December SEP, when the end of the year approaches, forecasts are also given for "end of 3 years later." As shown in Figure 2, the outlook for the " end of current year " shows 9 months later in March, 6 months later in June, 3 months later in September, and a few weeks later in December, so it should be noted that the outlook period shortens every 3 months. As noted above, the dot plot is released in the last month of each quarter, so the forecasts are based on market and economic developments for that quarter.



(Source: Authors' compilation from the FRB website)

Figure 2: Forecast Period for the Dot Plot by Quarter of Publication (for 2013)

When checking the specific pre FOMC schedule, two weeks before the FOMC meeting, the Beige Book, an analysis of economic developments in each region by the twelve regional Federal Reserve Banks is released. Beginning on the Saturday two weeks before the FOMC meeting, the so-called "blackout period," during which no external information is disseminated by FOMC participants, begins. Then, about one week prior to the FOMC meeting, "Tealbook," the document containing an analysis of economic conditions and monetary policy options by the FRB staff are distributed to FOMC participants. Based on such information and others, FOMC participants are to submit the forecast value on the Friday immediately before the FOMC meeting, but even after that, they can revise their forecasts on the first day of the FOMC meeting. On the first day of the FOMC meeting, it seems that the staff provides a summary of financial market developments and an explanation of its analysis and forecasts of domestic and foreign economic conditions. Therefore, the dot plot forecast values are determined based on market and economic developments over a quarter period since the last dot plot, but given the above circumstances, in some cases the forecast values may reflect the discussions on the first day of the FOMC meeting.

3. Causality Between the Median Forecast and the Markets/Economy

3.1 Related Literature and the Position of this Paper

This section analyzes the causality between the dot plot and the market/economy. Cochrane and Piazzesi [2002], a previous study that is highly relevant to this analysis, analyzed the relationship between the policy interest rate and market interest rates. They used daily data on the one month Eurodollar interest rates and 1 to 10 year US Treasury rates as market interest rates against the policy interest rate to see how market interest rates had reacted to the changes in the policy interest rate in 2001. As a result, market interest rates generally moved in advance of the policy interest rate, and when market interest rates reached in advance to the level to which the policy interest rate would change, they pointed out that this as no shock from the policy interest rate change. They also pointed out that the number of shocks caused by monetary policy change in the analysis using daily data is smaller than in the analysis using monthly data.

Then, the regression analysis is conducted for the monetary policy change shocks identified in the daily data, using the change in the market interest rate from two days before the policy interest rate change day to one day after the policy interest rate change day as the dependent variable and the change in the policy interest rate as the explanatory variable. The result of this analysis indicates that a monetary policy change shock causes large changes in market interest rates (50-70 bps) and has a larger impact on long-term interest rates than on short-term interest rates. They also pointed out that the impact of a monetary policy change shock is not clear for nonfarm employment and inflation.

Cochrane and Piazzesi [2002] analyzed the relationship during 2001. The global economy after 2001 has experienced the expansion of globalization, the global financial crisis, and the subsequent zero-interest-rate policy, which may have changed the structure of financial markets and the relationship between interest rates. Therefore, this paper will check whether market interest rates continue to precede policy interest rates even after 2015, when the US first lifted its zero-interest rate policy. Furthermore, by newly adding the dot

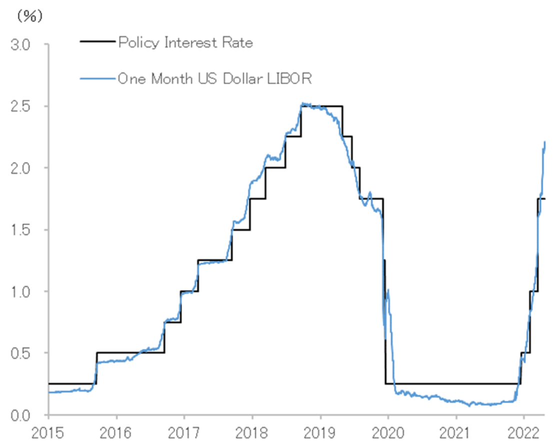


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Figure 3: Policy Interest Rate and Short-Term Interest Rates

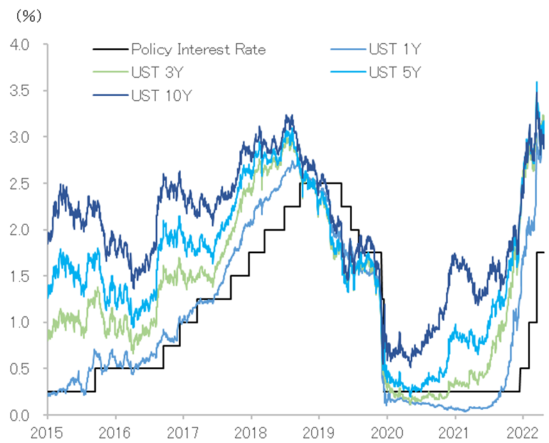

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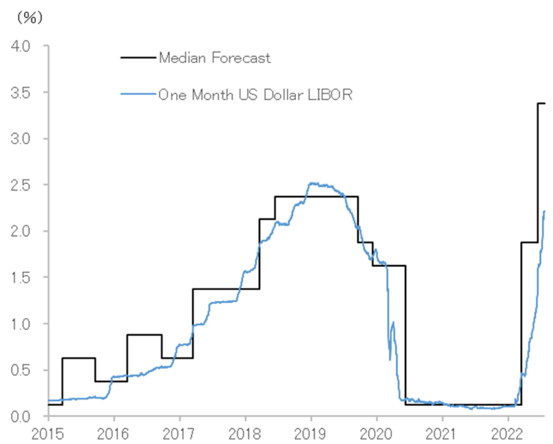
Figure 4: Policy Interest Rate and US Treasury Rate



(Source: Generated by Authors from Factset data)

Figure 5 Median Forecasts and Short-term Interest Rates

(Source: Generated by Authors from Factset data)

Figure 6 Median Forecasts and US Treasury Rates plot to the analysis, we will also analyze the relationship between market interest rates and the outlook of FOMC participants.

The trend in the one month US dollar LIBOR rate[4] and the policy interest rate in Figure 3 confirms that during the interest rate hike cycle from 2015 to 2019, short-term interest rates rose gradually ahead of the policy interest rate hike, with the one month US dollar LIBOR rates rising rapidly just before the FOMC meeting to incorporate the rate hike. In the relationship between the US Treasury rate and the policy interest rate shown in Figure 4, the US Treasury rate incorporates the policy interest rate change at an earlier stage than the short-term rate, and the policy interest rate appears to follow the US Treasury rate. This relationship is also observed in the interest rate cut cycle after 2019 and in the interest rate hike cycle after 2022, confirming a similar trend to that of Cochrane and Piazzesi [2002]. In contrast, Figures 5 and 6 show the relationship between the median forecasts (the end of current year) and market interest rates, which is the new subject of analysis in this paper. For short-term interest rates in Figure 5, compared to Figure 3, market interest rates appear to follow the median forecast, while the US Treasury rate in Figure 6 is ahead of the median forecast as in Figure 4, suggesting that the FOMC is forecasting policy interest rates in response to market interest rates. Since the relationship between the median forecasts and market interest rates is not clear, we will analyze the causality between the median forecasts and market interest rates using the VAR model.

3.2 Model and Analysis Setup

In this section, we perform Granger causality test using the VAR model. The first step is to consider the variables x_t and $y_{t.}$ These two variables are the time series data of $t = 1,2,\ldots,n$, and assumed to be stationary. For these two variables, we construct the VAR model consisting of the following equations (1) and (2). In equation (1), the variable x_t depends on the constant term, variables $X^- = \{x_{t-1}, x_{t-2}, \ldots, x_{t-p}\}$ and $Y^- = \{y_{t-1}, y_{t-2}, \ldots, y_{t-p}\}$, up to the past p periods, and the error term $\varepsilon_{x,t}$.

$$x_t = \mu_{1,t} + \alpha_1 x_{t-1} + \cdots + \alpha_p x_{t-p} + \beta_1 y_{t-1} + \cdots + \beta_p y_{t-p} + \varepsilon_{x,t} \quad (1)$$

$$y_t = \mu_{2,t} + \gamma_1 x_{t-1} + \cdots + \gamma_p x_{t-p} + \delta_1 y_{t-1} + \cdots + \delta_p y_{t-p} + \varepsilon_{y,t} \quad (2)$$

In this case, testing if the variable Y^- is useful in predicting the variable x_t is called Granger causality test (Hamilton [1994]), and the causality for variable x_t due to Y^- is tested for null hypothesis in equation (3). Similarly, the causality for variable X^- due to y_t is tested for null hypothesis in equation (4).

[4] LIBOR (London Inter-Bank Overnight Rate) was discontinued at the end of December 2021 except for some indicators for the dollar, and all indicators are scheduled to be discontinued by the end of June 2023. In this report, LIBOR is used because the period under analysis is mainly on the period prior to the end of December 2021 and because it refers to indicators for the dollar that are calculated over the entire period under analysis.

$$H_0\colon \beta_1 = \beta_2 = \cdots = \beta_p = 0 \quad (3)$$

$$H_0\colon \gamma_1 = \gamma_2 = \cdots = \gamma_p = 0 \quad (4)$$

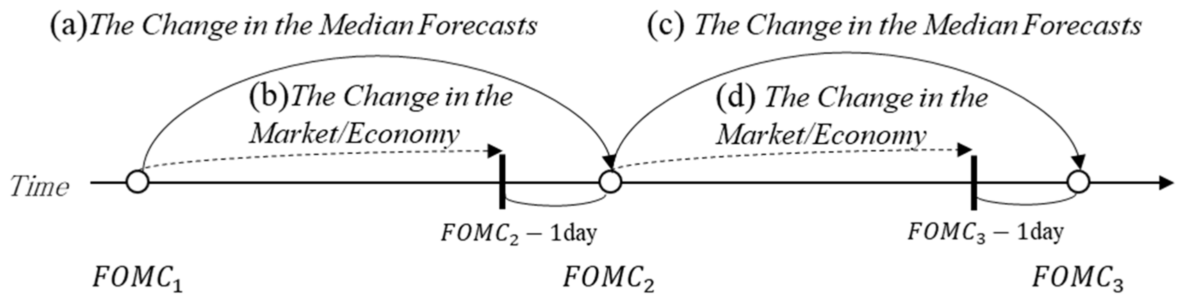
The Granger causality test for the median forecasts analyzes the causality between the median forecast and the change in the market interest rates, as shown in Figure 7. For example, when the median forecasts for 3 periods are available from $FOMC_1$ to $FOMC_3$, the analysis of the causality from the median forecast to market interest rates and economic indicators tests the impact of (a) the change in the median forecast from $FOMC_1$ to $FOMC_2$, to (d) the change in the market interest rate from $FOMC_2$ to $FOMC_3 - 1day$ and the economic indicator available at the time of $FOMC_3 - 1day$. Conversely, the analysis of the causality from market interest rates and economic indicators to the median forecast tests the effect of (b) the change in market interest rates from $FOMC_1$ to $FOMC_2 - 1day$ and the economic indicator available at the time of $FOMC_2 - 1day$ to (a) the change in the median forecast. In other words, it confirms whether the change in one value is affected by the change in the other values.

In selecting the lag p of the explanatory variables for the VAR model, it is common to use information criterion such as AIC (Akaike's Information Criterion, hereinafter referred to as "AIC"). However, as pointed out in Section 2.2, the median forecast published from March to December forecasts the same point in time, "end of current year," "end of next year," and "end of year after next." In particular, the "Longer run" has a mechanism to be updated to the outlook for the same forecast period to the most recent value in all median forecasts. Therefore, when considering causality from the median forecasts to market interest rates and economic indicators, it is appropriate to refer to the most recent median forecasts available at that point in time. In addition, in considering causality from market interest rates and economic indicators to the median forecasts, it is necessary to consider that median forecasts are published in the last month of the relevant quarters based on the quarterly market and economic developments. Therefore, in this analysis using quarterly data, market interest rates and economic indicators are set as $p = 1$, the most recent ones that are considered most likely to be referenced when setting the median forecast. The VAR models used in the estimation are equations (1') and (2') where x_t represents the median forecast, y_t represents market interest rates and economic indicators, subscript i is each of the median forecasts' projected period, and similarly j is each type of market interest rate and economic indicator.

$$x_{i,t} = \mu_{i,\,t} + \alpha_{i,\,1} x_{i,\,t-1} + \beta_{j,\,1} y_{j,\,t-1} + \varepsilon_{x,t} \quad (1')$$

$$y_{j,\,t} = \mu_{j,\,t} + \gamma_{i,\,1} x_{i,\,t-1} + \delta_{j,\,1} y_{j,\,t-1} + \varepsilon_{y,t} \quad (2')$$

The above analysis of the effect of (a) the change in the median forecasts on (d) the change in market interest rates shows that $x_{i,t-1}$ is the change in the median forecasts from $FOMC_1$ to $FOMC_2$. $y_{j,\,t}$ is the change in market interest rates from $FOMC_2$ to $FOMC_3 - 1day$, or the economic indicators available as of $FOMC_3 - 1day$ in equation (2'). In addition, the analysis of the effect of (d) the change in market interest rates on (c) the change in the median forecasts shows that $y_{j,\,t-1}$ is the change in market interest rates from $FOMC_2$ to $FOMC_3 - 1day$, or the economic indicator available as of $FOMC_3 - 1day$, and $x_{i,t}$ is the change in the median forecasts from $FOMC_2$ to $FOMC_3$. Therefore, it should be noted that data $x_{i,\,t}$ and $y_{j,\,t}$ as of time t are different between equations (1') and (2'). For the above VAR model, the impact from the median forecasts to market interest rates and economic indicators is tested by H_0: $\gamma_{i,1} = 0$, and the impact on the median forecasts is tested by H_0: $\beta_{j,1} = 0$.



(Source: Prepared by the authors)

Figure 7 Data Image of VAR model

Table 1 Descriptive Statistics of Variables Used in VAR Analysis

	Variables	Unit	N	Mean	STD	Min	0.25%	Median	0.75%	Max
Median Forecasts										
i =										
1	End of Current Year	%pt Change	41	0.08	0.48	-1.50	0.00	0.00	0.00	1.75
2	End of Next Year	%pt Change	41	0.09	0.51	-1.50	-0.25	0.00	0.25	1.88
3	End of Year After Next	%pt Change	41	0.06	0.55	-1.75	-0.25	0.00	0.44	1.50
4	Longer Run	%pt Change	41	-0.04	0.11	-0.25	-0.06	0.00	0.00	0.13
Market Rates / Economic Indicators										
j =										
1	US Treasury 2 Year Rate	%pt Change	41	0.08	0.41	-1.43	-0.02	0.02	0.13	1.44
2	US Treasury 3 Year Rate	%pt Change	41	0.07	0.40	-1.40	-0.06	0.05	0.16	1.37
3	US Treasury 5 Year Rate	%pt Change	41	0.06	0.39	-1.28	-0.11	0.04	0.22	1.34
4	US Treasury 7 Year Rate	%pt Change	41	0.05	0.39	-1.14	-0.17	0.02	0.17	1.26
5	US Treasury 10 Year Rate	%pt Change	41	0.03	0.39	-1.02	-0.21	0.00	0.18	1.19
6	US Treasury 30 Year Rate	%pt Change	41	0.01	0.35	-0.67	-0.25	-0.01	0.18	0.88
7	FF Futures End of Current Year	%pt Change	41	0.01	0.36	-1.31	-0.04	0.00	0.04	1.41
8	FF Futures End of Next Year	%pt Change	41	0.01	0.38	-1.31	-0.15	0.01	0.09	1.20
9	FF Futures End of Year After Next	%pt Change	41	0.33	0.76	-0.56	-0.11	0.08	0.57	2.58
10	CPI	YoY, %	41	2.25	1.95	-0.10	1.40	1.70	2.30	8.60
11	Core CPI	YoY, %	41	2.34	1.18	1.20	1.70	2.00	2.20	6.50
12	PCE	YoY, %	41	1.91	1.46	0.10	1.25	1.60	1.95	6.60
13	Core PCE	YoY, %	41	1.98	0.96	1.13	1.50	1.69	1.97	5.22
14	Unemployment Rate	%	41	5.65	1.92	3.60	4.10	5.10	6.90	13.00

(Source: Generated by Authors from Factset data)

3.3 Data

The data used in the analysis are the change in the dot plots published quarterly[5], the change in the US Treasury rates and in the Federal Fund futures (hereinafter referred as “FF futures”), which are expected to interact with the median forecasts. As for the economic indicators, we use the year-on-year change in the most recent monthly Consumer Price Index (hereinafter referred to as "CPI"), PCE and unemployment rate available at the time of each FOMC meeting. They are those related to the FRB dual mandate[6]. The data sample t is from April 2012 to June 2022. Table 1 shows their descriptive statistics.

Figures 8 through 11 show the trend in the median forecasts, FF futures, US Treasury rates, and economic indicators, respectively. Since 2012, when the impacts of the global financial crisis remained, the median forecasts for end of current year and end of next year forecasts have remained at 0.125%, indicating the

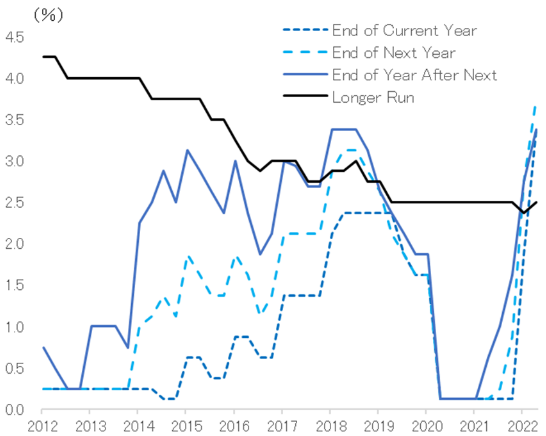


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Figure 8 Median Forecasts

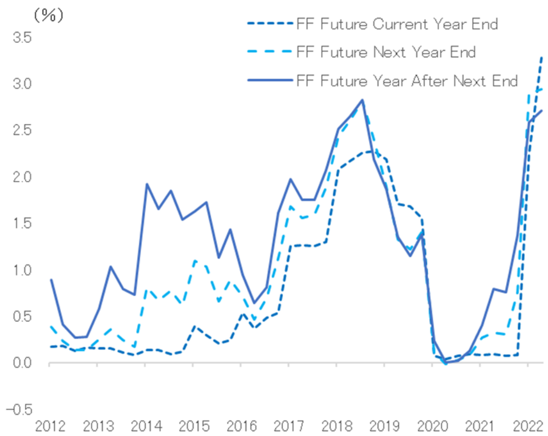

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Figure 9: FF Futures

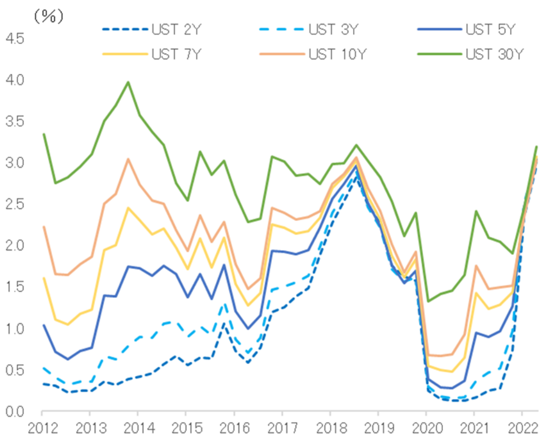

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Figure 10: US Treasury Rates

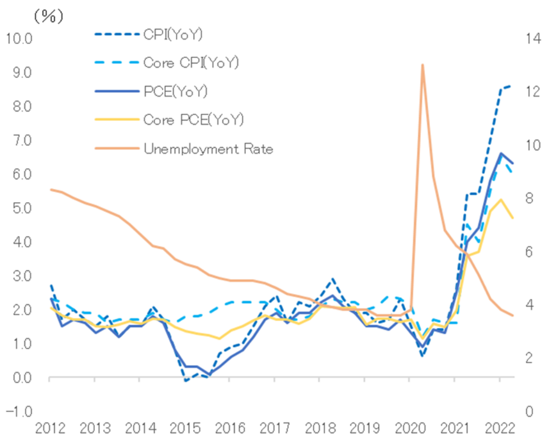

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Figure 11: Economic Indicators

5 For April 2012 to June 2012, the change is at 2-months intervals.

6 While central banks generally have a mandate for "price stability," the FRB has a similar mandate also for "maximizing employment," which is why it is called a dual mandate.

continuation of the zero-interest rate policy. However, the end of year after next forecast have been rising since the second half of 2012 and end of next year forecast have been rising since the second half of 2013, suggesting a rate hike ahead. Meanwhile, the Longer run, which indicates the destination of convergence, has been gradually declining along with the decline in the potential growth rate. Thereafter, the median forecasts have declined due to the interest rate cut cycle in 2019 and the spread of COVID-19 and rose again after 2021. FF futures in Figure 9 are moving in line with such monetary policy changes, and the US Treasury rates in Figure 10 are moving ahead of FF futures.

In addition to this, the economic indicators in Figure 11 show that the headline CPI and PCE have gradually increased, and the unemployment rate has declined since 2015, when the actual rate hike took place. Furthermore, since 2019, inflation rate has been declining and unemployment rate has been rising along with interest rate cuts. Therefore, it is difficult to say that there was the impact of FOMC's tightening (easing) by raising (lowering) policy interest rates and the median forecasts on economic indicators. As noted by Bauer and Swanson [2021], this suggests that the FOMC is making decisions in line with previous market interest rates and economic conditions.

3.4 Results and Discussion

Table 2 represents the results of Granger causality test. Each row shows the values of the end of current year, end of next year, end of year after next and Longer run median forecasts and each column shows the market interest rates and economic indicators. The top row of each column is the F value and the bottom row is the p value, with blue shadows for those statistically significant at 1% level, green shadows for those significant at 5% level, and gray shadows for those significant at 10% level.

First, regarding the impact of market interest rates and economic indicators on the median forecasts, we confirmed that all variables have a statistically significant impact on the end of current year to the end of year after next forecasts, while the 5 to 10 year US Treasury rates and FF futures for the 2 year ahead contract have a statistically significant on the Longer run median forecast. In terms of the magnitude of the impact of each variables, the F value of the FF futures for the end of current year contract is 68.5, which is the greatest compared to other variables, indicating that it has a large impact.

The next most influential variables are the US Treasury 2 year interest rate (55.71), the US Treasury 3 year interest rate (40.45), and the FF futures for the 1 year ahead contract (38.62). On the other hand, the US Treasury 30 year interest rate (8.25), the US Treasury 10 year interest rate (13.32), and the FF futures for the 2 year ahead contract (8.09) are found to be statistically significant, although their effects are relatively small. In other findings on inflation rate and employment, a greater emphasis is observed on core CPI (7.88) and core PCE (9.84) compared to headline inflation rate of CPI (4.41) and PCE (4.35). These trends are similar for the end of next year forecast in the dot plot, indicating that FOMC participants' predictions for policy interest rates in the near future are set according to market interest rates (especially for shorter terms), inflation rates and labor market conditions.

For the end of year after next forecast, the US Treasury 2 year interest rate (23.61) and the FF futures for

Table 2 Results of Granger Causality Test

	Impact of the Median Forecast in the Dot Plot on Market / Economy													
	UST2Y	UST3Y	UST5Y	UST7Y	UST10Y	UST30Y	End of Current Year FF Futures	End of Next Year FF Futures	Year After Next FF Futures	CPI	Core CPI	PCE	Core PCE	UNEMP Rate
End of Current Year	0.71	0.68	0.35	0.14	0.13	0.01	0.02	0.83	0.36	0.93	0.03	0.40	0.97	0.14
	(0.40)	(0.41)	(0.56)	(0.71)	(0.72)	(0.92)	(0.88)	(0.37)	(0.55)	(0.34)	(0.87)	(0.53)	(0.33)	(0.71)
End of Next Year	0.06	0.01	0.01	0.01	0.00	0.01	2.21	0.03	0.35	0.01	0.52	0.01	0.06	0.06
	(0.80)	(0.94)	(0.92)	(0.93)	(0.99)	(0.94)	(0.14)	(0.86)	(0.56)	(0.92)	(0.47)	(0.94)	(0.81)	(0.81)
End of Year After Next	0.03	0.03	0.04	0.01	0.02	0.06	1.23	0.03	0.05	0.00	0.51	0.02	0.08	0.02
	(0.86)	(0.87)	(0.85)	(0.94)	(0.88)	(0.81)	(0.27)	(0.86)	(0.82)	(0.97)	(0.48)	(0.89)	(0.78)	(0.90)
Longer Run	0.56	0.88	0.50	0.15	0.00	0.21	0.00	0.71	1.05	0.35	0.17	0.10	0.04	0.05
	(0.46)	(0.35)	(0.48)	(0.70)	(0.98)	(0.65)	(0.99)	(0.40)	(0.31)	(0.55)	(0.68)	(0.76)	(0.83)	(0.82)

***, ** and * indicate that the respective coefficients are statistically significant at the 1%, 5% and 10% level. Figures indicate F-values and those in parentheses indicate p-values.

	Impact of Market / Economy on the Median Forecast in the Dot Plot													
	UST2Y	UST3Y	UST5Y	UST7Y	UST10Y	UST30Y	End of Current Year FF Futures	End of Next Year FF Futures	Year After Next FF Futures	CPI	Core CPI	PCE	Core PCE	UNEMP Rate
End of Current Year	55.71***	40.45***	25.28***	17.12***	13.32***	8.25***	68.5***	38.62***	8.09***	4.41**	7.88***	4.35**	9.84***	10.84***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.04)	(0.01)	(0.04)	(0.00)	(0.00)
End of Next Year	60.45***	51.14***	29.12***	17.79***	12.32***	6.39**	54.26***	50.25***	14.33***	4.35**	7.3***	5.93**	11.23***	5.01**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.04)	(0.01)	(0.02)	(0.00)	(0.03)
End of Year After Next	23.61***	23.4***	15.62***	9.31***	6.37**	3*	22.32***	22.73***	15.19***	7.42***	7.82***	10.43***	10.62***	3.11*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.09)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.08)
Longer Run	0.70	1.58	2.82*	3.17*	3.13*	2.71	0.15	2.43	4.7**	0.00	0.00	0.21	0.34	0.31
	(0.40)	(0.21)	(0.10)	(0.08)	(0.08)	(0.10)	(0.70)	(0.12)	(0.03)	(0.96)	(0.96)	(0.65)	(0.56)	(0.58)

***, ** and * indicate that the respective coefficients are statistically significant at the 1%, 5% and 10% level. Figures indicate F-values and those in parentheses indicate p-values.

(Source: Generated by Authors from Factset data) the 1 year ahead contract (22.73) are statistically significant, which is similar to the dot plot forecast for the end of current year and next year, but the F values for market interest rates are generally lower. On the other hand, the F values for CPI (7.42), PCE (10.43), core CPI (7.82), and core PCE (10.62) are larger than those in the end of current year and next year dot plot results, indicating that FOMC participants are paying more attention to economic indicators with respect to the end of year after next policy interest rate forecast.

For the Longer run that is the neutral interest rate, the significant variables are the US Treasury 5, 7, and 10 year interest rates and the FF futures for the 2 year ahead contract, all of which have smaller F values than the results for the end of current year to year after next the median forecasts in the dot plot. Therefore, in forecasting the Longer run, we believe that the forecast values are based on different variables. It can be said that this is because the Longer run indicates where the policy interest rate would converge in the absence of additional policy changes or shocks, and the level of the interest rate being set based on the long-term equilibrium level, such as the potential growth rate of the economy, rather than on recent market and economic developments.

On the other hand, the causality from the dot plot to market interest rates and economic indicators has little impact among any of the variables. This is because, as we have already seen in Figures 5 and 6, trends in the median forecasts are incorporated into market interest rates in advance.

As above, it can be said that in the relationship between the median forecasts and market interest rates and economic indicators, the market does not incorporate in the FOMC participants' median forecasts of future policy interest rates. However, the FOMC participants consider future monetary policy based on market and economic developments. Therefore, the relationship between market interest rates and policy interest rates shown by Cochrane and Piazzesi [2002] is confirmed in the relationship between market interest rates and the median forecasts.

4. Predictive Power of the Median Forecast for Policy Interest Rates

4.1 Data and Analysis Setup

In the analysis in Section 3, Granger causality test was conducted on the quarterly changes in the median forecasts, market interest rates, and economic indicators, and it was confirmed that no influence from the median forecasts was found. In this section, we use two methods to analyze how accurately the quarterly median forecasts forecasted future policy interest rates.

In the first method of analysis (hereinafter referred to as "Method 1"), the difference between the forecast values at the end of current year, next year, and year after next in the quarterly the median forecasts and the realized values of the policy interest rate at the end of the subsequent time period (current year, next year, and year after next) is calculated. Specifically, the forecast for 1 month (or less) ahead can be obtained from the end of current year forecast value of the December FOMC, the forecast of 3 months ahead can be obtained from the end of current year forecast value of the September FOMC, and the forecast for 6 months ahead can be obtained from the end of current year forecast value of June FOMC. Furthermore, when using the end of next year forecast value, the December FOMC forecast is 12 months ahead, the September FOMC forecast is 15 months ahead, and when using the end of year after next forecast value, forecasts up to 33 months ahead can be calculated (see Appendix A for the actual calculation formula). For FF futures, the values of the end of current year, next year, and year after next contracts as of the publication date of the dot plot are used to calculate forecasts from 1 month (or less) to 33 months in the future. The difference between those median forecasts, FF futures forecasts, and the subsequently realized policy interest rate are calculated, and the difference is defined as the "quarterly forecast accuracy". Since the dot plots are published for approximately 10 years starting in 2012, a forecast accuracy of 8 to 10 samples can be calculated for each forecast period.

In the second analysis method (hereinafter referred to as " Method 2"), to increase the number of samples analyzed regarding the forecast values at the same period compared to Method 1, the median forecasts suggesting the policy interest rate 1 year ahead and 2 year ahead estimated based on certain assumptions. By using assumptions, the median forecasts themselves cannot be used, but more values for the same future point in time can be obtained than in Method 1. For example, the median forecasts that implies the policy interest rate 1 year ahead, as of March of each year, would be the sum of the value of the median forecasts at the end of current year(the forecast for 9 months going ahead) and the difference between the forecast at the end of next year and the forecast at the end of current year multiplied by 0.25 (by calculating the forecast for 3 months going ahead, starting at the end of current year). The difference between the median forecasts that suggests the policy interest rate 1 year ahead as of March and the policy interest rate realized as of March of the following year is defined as the "1 year ahead forecast accuracy." By performing similar calculation for dot plots published as of June, September, and December, "1 year ahead forecast accuracy" can be calculated for 37 samples (See Appendix B for the actual formula).

The same calculation is also performed for the 2 year ahead forecast accuracy. In other words, the median forecasts for the 2 year ahead forecast is calculated by the sum of the median forecasts for the end of the next year forecast (or the forecast for 21 months ahead in the case of the dot plot at the March FOMC meeting), and the difference between the median forecasts for the end of year after next forecast and the end of next year forecast multiplied by 0.25 (by calculating the forecast value for 3 months ahead, starting at the 1 year end ahead). In addition, the difference between the median forecasts suggesting the forecast policy interest rate for 2 year ahead, and the policy interest rate realized at the end of the 2 year later is defined as the "2 year ahead forecast accuracy." By performing similar calculation for median forecasts published as of June, September, and December, "2 year ahead forecast accuracy" is calculated for 33 samples. For FF futures, the "1 year ahead forecast accuracy" and "2 year ahead forecast accuracy" are calculated using the values of the end of current year, next year and year after next contracts on the date the dot plot is published. The number of samples is the same as that for the dot plot. The "quarterly forecast accuracy," "1 year ahead forecast accuracy," and "2 year ahead forecast accuracy" for the median forecasts and FF futures, calculated using the above two analysis methods, are discussed in the next section.

4.2 Results and Discussion

Figure 12 and 13 show the results of Method 1. Histograms are created for the "quarterly forecast accuracy" of the median forecasts and the FF futures and kernel density estimations[7] are performed. The estimation results show that the distribution is generally similar in shape between the median forecasts and the FF futures for all forecast periods, and the shorter the forecast period, the thinner the tails of the distribution, the smaller the difference between the forecast value and the realized value, and the better the forecast accuracy. The average forecast accuracy for the 3 months ahead is 0.08% pt for the median forecast and 0.19% pt for the FF futures, indicating that the median forecast in the dot plot has better forecast accuracy. This trend is confirmed over relatively short forecast periods, with forecast accuracy 6 months ahead (median forecasts: -0.04% pt; FF futures: 0.19% pt) and 9 months ahead (median forecasts: -0.03% pt; FF futures: 0.12% pt). On the other hand, the forecast accuracy for 12 months ahead (median forecasts: -0.35% pt; FF futures: -0.08% pt) confirms that the FF futures have better forecast accuracy for longer forecast periods, except for the 18 months forecast accuracy.

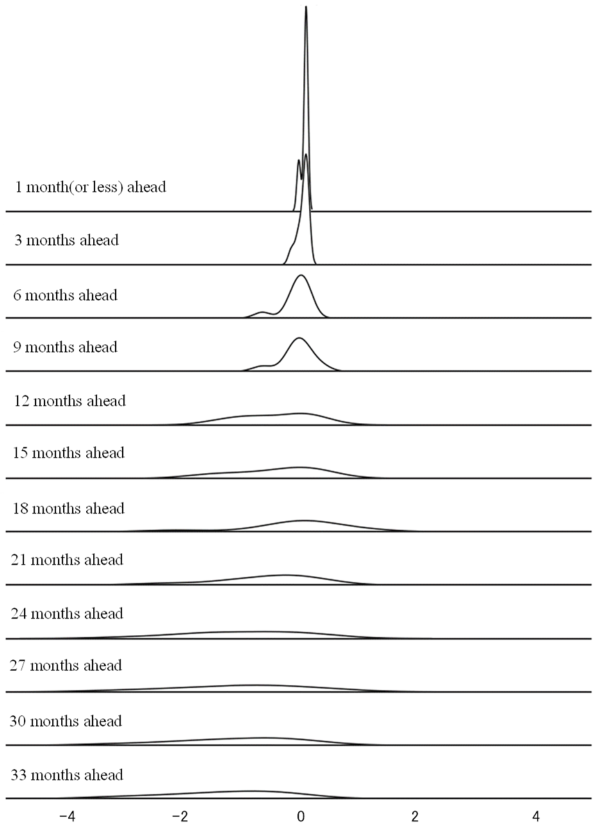
Figure 14 shows the kernel density estimation for the histogram created for the median forecasts and the FF futures calculated in Method 2, and the "1 year ahead forecast accuracy" and "2 year ahead forecast accuracy." The distribution for the shorter "1 year ahead forecast accuracy" has thinner tails, while the distribution for the "2 year ahead forecast accuracy" has fatter tails with larger variance. The average of the forecast accuracy for 1 year ahead is 0.27% pt for the median forecasts and -0.01% pt for FF futures, while for 2 year ahead, it is 0.78% pt for the median forecasts and -0.22% pt for the FF futures, confirming that the forecast accuracy for the FF futures is better, as in Method 1 in longer forecast periods.

As indicated by the above two analysis methods, the median forecasts for the near future (less than 1 year ahead) has a good forecasting accuracy. This is because FOMC participants' opinions on the policy interest rate are more likely to converge for the near term, and the actual policy interest rate will be changed accordingly. For longer horizons, on the other hand, policy interest rates follow market rates, and FF futures, which reflect forecasts by a broader range of participants than the FOMC, will have better forecasting accuracy. While it is not confirmed that the median forecasts have impact on the market with respect to changes in quarterly data for which Granger causality tests were conducted, it is thought to have predictive power in the near term for forward-looking policy interest rate forecasts.

[7] A method for estimating the distribution (density function) of the entire original data from sample data. The commonly used method of estimation and testing by assuming a distribution in econometric analysis is called the parametric method. In contrast, the method in which the distribution itself is considered unknown and inferring statistical parameters such as mean and variance is called the nonparametric method. In the approximation of the density function by the nonparametric method, given n observed variables $x_i, i = 1,2,\ldots,n$ from the same distribution, the density function estimate $\hat{f}(x)$ can be estimated by the following formula when the density function of x_i is $f(x)$. h is a parameter called bandwidth.

$$\hat{f}(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right)$$

$K(\cdot)$ is a function called kernel, so the method of estimating the density function of the original data from the data using nonparametric methods, is called kernel density estimation. Tanizaki [2005] provides more details on the nature of kernel functions and bandwidths.



(Source: Generated by Authors from Factset data)

Figure 12: "Quarterly Forecast Accuracy" for Median Forecasts

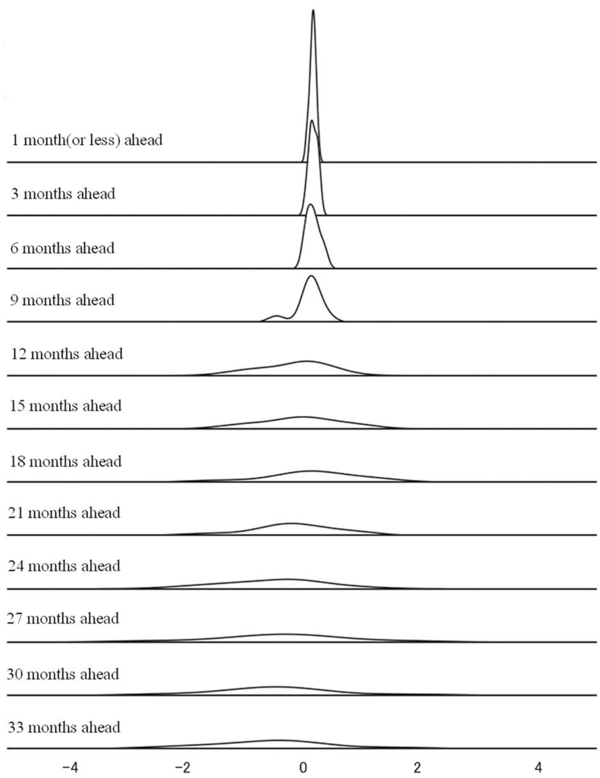


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Figure 13: "Quarterly Forecast Accuracy" for FF Futures

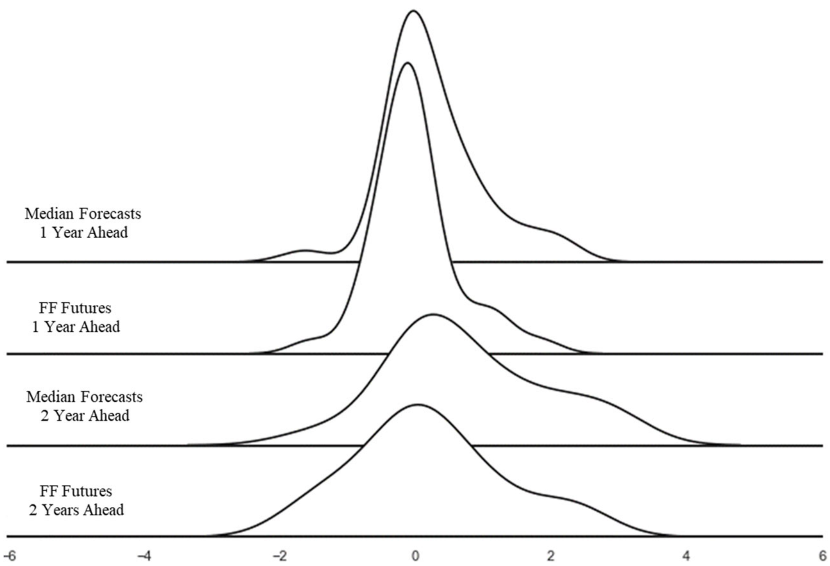

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Figure 14: "1 Year Ahead Forecast Accuracy" and "2 Year Ahead Forecast Accuracy" for Median Forecasts and FF Futures

5. The Term Structure of US Treasury Rates, Which Incorporates the Dot Plot Information

5.1 Models and Methods

As revealed by Granger causality test, market interest rates have been moving ahead of the median forecasts, and no market impact was identified from changes in the median forecasts on a quarterly basis. Therefore, the median forecasts appear to follow market interest rates, meanwhile as Lunsford [2020] points out, the market is influenced by the wording of the FOMC's forward guidance.

The FOMC normally meets eight times a year, including meetings at which the dot plot is not released, and it is possible that the next dot plot is incorporated in advance as the market reacts to the wording of the forward guidance and statements there. In such a case, at the time the dot plot is released, the shape of the yield curve, which represents the term structure of interest rates, would reflect the path of the policy interest rate indicated by the dot plot. Nelson and Siegel [1987] developed the model that explain the yield curve shape by level, slope, and curvature (hereinafter referred to as "NS model"). It was extended to a model with respect to curvature by Svensson [1994] (Nelson Siegel Svensson, hereinafter referred to as "NSS model.") We utilize the NSS model to analyze whether the US Treasury yield curve incorporates the path of the policy interest rate indicated by the median forecasts in the dot plot.

Equation (5) represents the NSS model. β_0 is the parameter of level of the yield curve, β_1 is the that of slope, and β_2 and β_3 are parameters representing the curvature. λ and κ are called the decay factor and mainly regarding at which term the peak of the curvature is located. τ denotes the term.

$$y(\tau) = \beta_0 + \beta_1\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right) + \beta_2\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right) + \beta_3\left(\frac{1-e^{-\kappa\tau}}{\kappa\tau} - e^{-\kappa\tau}\right) \quad (5)$$

To estimate the NSS model, there is a non-linear method where all parameters are estimated at once, including λ and κ, and a linear regression method where λ and κ are fixed. For example, Gürkaynak et al. [2007] estimated all six parameters of the NSS model at once by the maximum likelihood method, but also reported that the trend in parameters were unstable. On the other hand, Diebold and Li [2006] estimated $\beta_0, \beta_1, \beta_2$ by linear regression with λ as a constant value[8]. We defined $\lambda = 0.60$ and $\kappa = 0.18$ to estimate the NSS model parameters $\beta_0, \beta_1, \beta_2, \beta_3$ using the method of Diebold and Li [2006]. Note that this analysis does not regress on the yield itself, but rather on the present value basis (see Appendix C for details on the estimation method). The estimation covers 41 periods from April 2012 to June 2022, and the zero-coupon rates of US Treasuries by maturity as of the publication date of the dot plot are used for all periods. The target maturity (τ) used in the estimation is between 1 and 30 years, out of a range of 1 month

[8] Other methods have also been conducted by Wahlstrøm et al. [2022] in estimate of the NSS model, first estimating the four parameters in the NS model and based on those values, estimating the remaining two parameters in the NSS model.

to 50 years for which data are available, and illiquid maturities are excluded[9].

Figures 15 through 19 show the estimated results for the parameters of the NSS model. As reference indices for the estimated results, US Treasury 10 year rate for the level (β_0), the US Treasury 1-10 year spread for the slope (β_1), the "curvature = US Treasury 3 year rate * 2 - (US Treasury 1 year rate + US Treasury 30 year rate)" for the curvature 1 (β_2), and "curvature = US Treasury 10 year interest rate*2 – (US Treasury 1 year rate + US Treasury 30 year rate)" for the curvature 2 (β_3) are utilized. The level (β_0) rose through mid-2013 due to the market's growing view of a lifting of the zero-interest rate policy, followed by a decline in interest rates due to the emerging market shocks in early 2016 and the global spread of the COVID-19 in early 2020, and the rise in interest rates is captured in preparation for a rate hike in 2022. The slope (β_1) shows a divergence from the reference indicator in the 2017-2019 period and around 2022, but the trend of slope contraction and subsequent slope expansion from 2012 to 2014 is replicated. Furthermore, the curvature 1 (β_2) and curvature 2 (β_3) also generally follow the reference indicator when the market

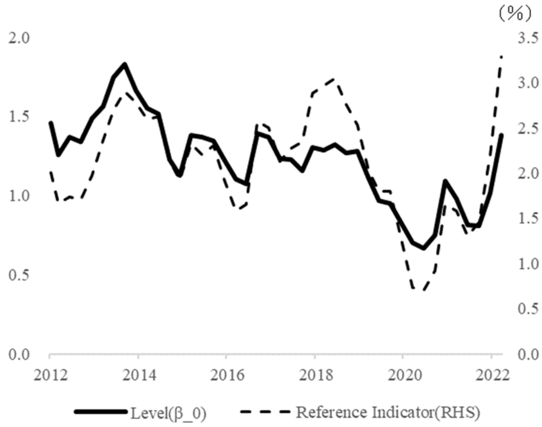

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Figure 16: Level (β_0)

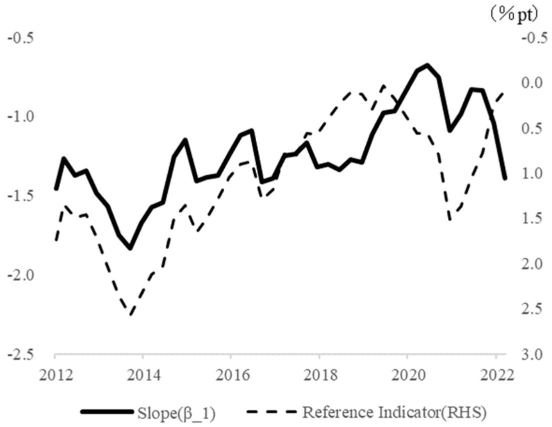

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Figure 17: Slope (β_1)

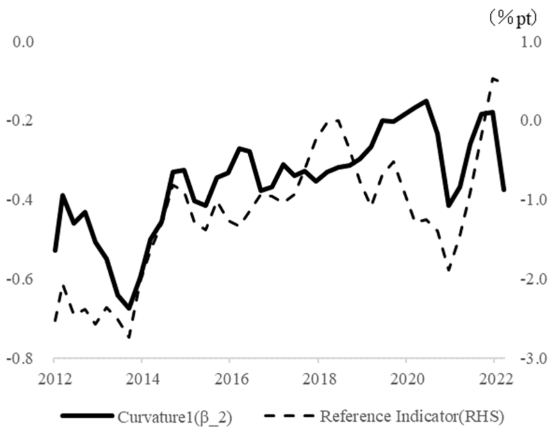

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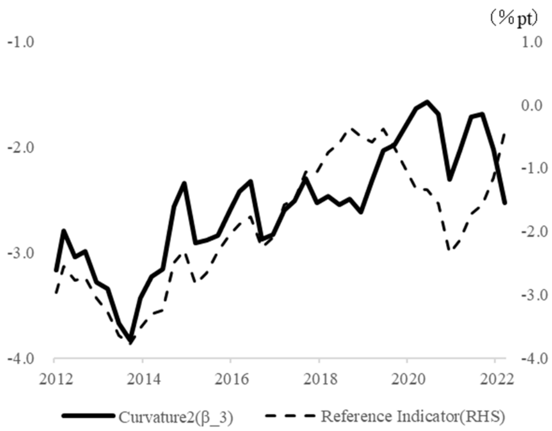
Figure 18 Curvature 1 (β_2)



(Source: Generated by Authors from Factset data)

Figure 19 Curvature 2 (β_3)

[9] Each year from 1 to 5 years and 7, 9, 10, 15, and 30 years.

fluctuates significantly, which is thought to reproduce the characteristics of the yield curve when it fluctuates[10].

Using the parameters estimated in this way ($\beta_0, \beta_1, \beta_2, \beta_3$) as explained variables, we conduct a regression analysis using the end of current year forecast median forecasts (explanatory level) and the difference between the end of year after next and next year forecasts (explanatory slope) as explanatory variables to determine to what extent the median forecasts are incorporated into the yield curve. The level and slope using FF futures are also calculated in the same manner as the median forecasts, and by using them as explanatory variables, the results of these regression analyses are compared.

5.2 Results and Discussion

Table 3 represents the result of the regression. First, regarding the coefficient value for the level (β_0), the slope of the median forecasts is 0.26 at the 1% significance level. For FF futures, both the level and the slope are shown to be significantly positive impact, with a level of 0.14 at the 5% significance level and a slope of 0.60 at the 1% significance level. Therefore, when the difference between the end of next year and year after next which is the path of the forward-looking policy interest rate according to the median forecasts and FF futures widens, the overall level of the US Treasury yield curve tends to increase. The FF futures indicated that its level at the end of current year also have an effect on yield curve. The reason why the levels of the explanatory variables are not significant for the median forecasts and low for the FF futures, despite the fact that the dependent variable is the level of the overall yield curve (β_0), is that the zero interest rate policy was in place from 2012 to 2015 during the sample period, and during that period the market was more focused on interest rates in the more distant future than on interest rates in the near future, which is the level of the median forecasts and FF futures. Therefore, it can be said that the median forecasts in the dot plot had effects on interest rates under the zero-interest-rate policy. Adjusted R^2 is 0.13 for the median forecasts and 0.31 for the FF futures, confirming that the FF futures have more than twice as much explanatory power as the median forecasts.

Second, the slope (β_1) is also confirmed that for both the median forecasts and the FF futures, the slopes have significantly negative impact. The coefficient values are -0.27 at the 1% significance level for the median forecasts and -0.61 at the 1% significance level for the FF futures. The coefficient value for the level of FF futures is -0.15 at the 1% significance level, indicating a negative impact. The adjusted R^2 is 0.15 for the median forecasts and 0.33 for the FF futures, again confirming a difference of more than two times.

The curvatures (β_2 and β_3) are also affected by both the median forecasts and the FF futures. The coefficient value of curvature 1 (β_2) is not significant for the median forecasts, and it is -0.22 at the 1% significance level for FF futures. For curvature 2 (β_3), it is -0.47 at the 5% significance level for the median forecasts, and -1.05 at the 1% significance level for the FF futures. As mentioned earlier, curvature 1 (β_2)

[10] Although the reference index calculated using market interest rates shows the same characteristics of the yield curve shape as the parameters from the NSS model, the values do not necessarily coincide due to different definitions.

Table 3: Results of Regression Analysis of Yield Curve

	Level(β_0)		Slope(β_1)		Curvature1 (β_2)		Curvature2 (β_3)	
	Median Forecasts	FF Futures	Median Forecasts	FF Futures	Median Forecasts	FF Futures	Median Forecasts	FF Futures
Constant	1.04***	0.95***	-1.04***	-0.96***	-0.35***	-0.29***	-2.32***	-2.17***
	(11.37)	(11.83)	(-11.50)	(-12.03)	(-8.05)	(-7.58)	(-12.26)	(-12.58)
End of Current Year Forecast	0.05	0.14**	-0.06	-0.15***	0.03	-0.01	0.00	-0.14
(Explanatory Variable: Level)	(1.12)	(2.68)	(-1.22)	(-2.83)	(1.23)	(-0.33)	(0.01)	(-1.24)
Diff of End of Year After Next and Next Year(Explanatory Variable: Slope)	0.26***	0.6***	-0.27***	-0.61***	-0.07	-0.22***	-0.47**	-1.05***
	(2.86)	(4.46)	(-3.03)	(-4.65)	(-1.62)	(-3.42)	(-2.50)	(-3.66)
R^2	0.18	0.34	0.19	0.36	0.16	0.32	0.17	0.29
Adjusted R^2	0.13	0.31	0.15	0.33	0.11	0.28	0.12	0.25
F value	4.09**	9.96***	4.59**	10.84***	3.56**	8.86***	3.82**	7.77***
Significance probability of F-value	0.02	0.00	0.02	0.00	0.04	0.00	0.03	0.00

***. ** and * indicate that the respective coefficients are statistically significant at the 1%, 5%, and 10% level. Parentheses indicate t-values.

(Source: Genereated by Authors from Factset data)

represents the curvature mainly on the 3 year Treasury rate, curvature 2 (β_3) represents the curvature mainly on the 10 year Treasury rate, indicating that the median forecasts and FF futures have a strong influence on the curvature 2 (β_3), in a relatively long term zone of the yield curve. This is, as suggested by the results for level (β_0), because more forward-looking information from the median forecasts and FF futures is incorporated in the market. The adjusted R^2 for the curvature 1 (β_2) is 0.11 for the median forecasts and 0.28 for FF interest rate futures. For curvature 2 (β_3), the adjusted R^2 is 0.12 for the median forecasts and 0.25 for the FF interest rate futures, and the explanatory power of the FF futures are much greater than that of the median forecasts in terms of curvature as well.

Thus, with respect to the parameters representing the characteristics of the US Treasury yield curve as estimated by the NSS model, it is confirmed that the slope is more strongly incorporated into the market than its level, for both the median forecasts and FF futures. The reason for this can be attributed by the fact that market participants are focusing on longer-term interest rate trends rather than the near future in both cases. However, both estimates indicated that the explanatory power of the FF futures is more than twice as that of the median forecasts. Therefore, although the US Treasury market has already incorporated the path of policy interest rates in the median forecasts released quarterly based on the FOMC's forward guidance, the FF futures, which are priced forward by a wide range of market participants, has the greater explanatory power than that of the median forecasts.

6. Conclusion and Implication

This paper analyzed whether changes in policy rates have been factored into market interest rates since 2015, when the zero-interest rate policy was lifted in the United States, and found that the relationship between policy rates and market rates has been maintained. In addition, three analyses were conducted. The first analysis of the relationship between the median forecasts in the dot plot and market interest rates and economic indicators using Granger causality test confirmed that the median forecasts are set to reflect market interest rates and economic indicators, and that there is no effect from the median forecasts on market interest rates and economic indicators on a quarterly basis. The second analysis of the predictive power of the future policy interest rates showed that the median forecasts have better predictive power than the FF futures for periods of less than 1 year ahead. The third analysis, using the NSS model, of how levels and slopes in the median forecasts and FF futures are incorporated into the yield curve shape, showed that while the median forecasts are incorporated into all levels, slopes, and curvatures of the yield curve at the time of publication, the level and slope of FF futures received more attention from the market. The results indicate that the market is paying more attention to the level and slope of the FF futures.

The implications of the analysis are as follows. The median forecasts have predictive power for policy interest rates in the near future, and it is useful to use its median value to predict the direction of monetary policy for about 1 year ahead. The VAR model analysis clearly shows that the median forecasts are set according to market and economic developments, and as pointed out in Section 2.1, there are doubts from successive Fed chairs as to whether the median forecasts are functioning as intended by the FOMC as a communication tool. In fact, the NSS model analysis showed that FF futures, which reflect the outlook by a broader range of market participants, are more incorporated into the yield curve than the median forecasts, which is a policy interest rate forecast by FOMC participants only. Although the dot plot has been intended to act as forward guidance of policy interest rates, its effect has been limited for the median forecasts. Based on the above, it is considered more effective to refer to market interest rates and economic indicators such as FF futures rather than the median forecasts in the dot plot in quantitative analysis of the bond market.

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Appendix A: Forecast Accuracy of the Median Forecasts and FF Futures - 1

The accuracy of the median forecasts in the dot plot forecast of the policy interest rate 1 month (or less) ahead is defined as the difference between the December median forecasts of each year (the end of current year) and the actual policy interest rate at the end of the year and is calculated for 10 samples from 2012 to 2021. The 3 months forward forecast accuracy is defined as the difference between the September median forecast (the end of current year) and the actual policy interest rate at the end of the year and is calculated for 10 samples from 2012 to 2021. The forecast accuracy for 33 months ahead will be calculated in the same way. The forecast accuracy for FF interest rate futures will be calculated using the same definition.

1 month (or less) forecast accuracy
= December FOMC median forecast (the end of current year) – December end policy interest rate

3 months forecast accuracy
= September FOMC median forecast (the end of current year) – December end policy interest rate

6 months forecast accuracy
= June FOMC median forecast (the end of current year) – December end policy interest rate

9 months forecast accuracy
= March FOMC median forecast (the end of current year) – December end policy interest rate

12 months forecast accuracy
= December FOMC median forecast (the end of next year) – policy interest rate of 1 year later at the end of December

15 months forecast accuracy
= September FOMC median forecast (the end of next year) – policy interest rate of 1 year later at the end of December

30 months forecast accuracy
= June FOMC median forecast (the end of year after next) – policy interest rate of 2 year later at the end of December

33 months forecast accuracy
= March FOMC median forecast (the end of year after next) – policy interest rate of 2 year later at the end of December

Appendix B: Forecast Accuracy of the Median Forecasts and FF Futures – 2

The "1 year ahead forecast accuracy" of the policy interest rate by the median forecasts is calculated as follows for each month the FOMC meeting was held. The "2 year ahead forecast accuracy" is calculated in the same way.

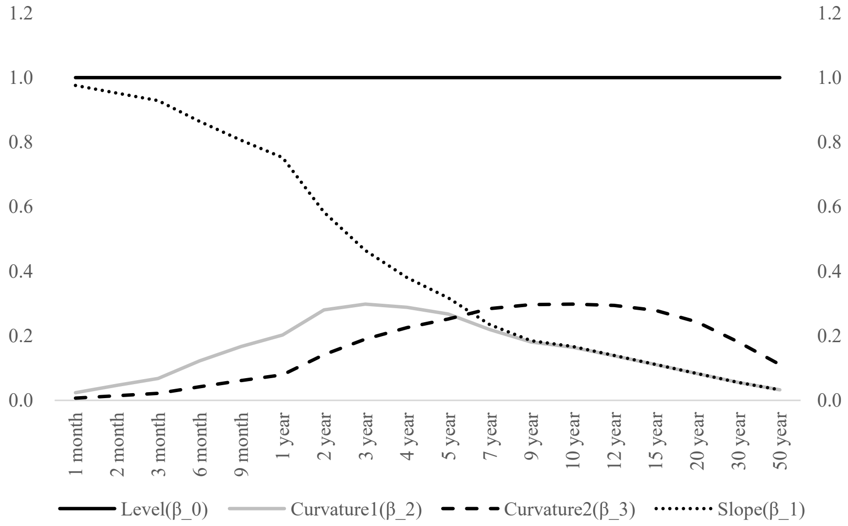
Estimated 1 year ahead median forecast as of March FOMC = current year end median forecast + 0.25*(next year end median forecast - current year end median forecast) 1 year forecast accuracy of March median forecast = Estimated 1 year ahead median forecast – policy interest rate realized in March of the following year
Estimated 1 year ahead median forecast as of June FOMC = current year end median forecast + 0.5*(next year end median forecast - current year end median forecast) 1 year forecast accuracy of June median forecast = Estimated 1 year median forecast – policy interest rate realized in June of the following year
Estimated 1 year ahead median forecast as of September FOMC = current year end median forecast + 0.75*(next year end median forecast - current year end median forecast) 1 year forecast accuracy of September median forecast = Estimated 1 year median forecast – policy interest rate realized in September of the following year
Estimated 1 year ahead median forecast as of December FOMC = end of next year median forecast 1 year forecast accuracy of December median forecast = Estimated 1 year median forecast – policy interest rate realized in December of the following year

Appendix C: Estimation of the NSS Model

Figure C1 shows the shape of differentiated level (β_0), slope (β_1) and curvature (β_2, β_3). The horizontal axis shows the term of the Treasury bond, and the vertical axis is the value of the parameters for each term.

The level (β_0) has a constant effect regardless of the term, whereas the slope (β_1) shows that the effect is greater on short term interest rates, while the effect decreases as the term increases. Each curvature (β_2, β_3), shows the convex shape of the yield curve, and according to the decay factors λ and κ, the term at which the maximum value is reached change.

Therefore, by setting λ and κ to maximize $\left(1 - e^{-\lambda\tau}/\lambda\tau - e^{-\lambda\tau}\right)$ and $\left(1 - e^{-\kappa\tau}/\kappa\tau - e^{-\kappa\tau}\right)$ in the period of years (τ) to be analyzed, it is possible to analyze the variation of curvature in the target period. (Diebold and Li [2006]).



(Source: Generated by Authors from Factset data)

Figure C1 Parameter Characteristics of the NSS model

Table C2 shows λ and κ values that maximizes the curvature in each term. For the analysis in Section 5, to consider the impact on the median forecast for 3 years, which had the greatest price volatility by terms, and 10 year as the longer period, we used $\lambda = 0.60$ and $\kappa = 0.18$.

Table C2 Decay Factor Values by Term

Term	1 year	2 year	3 year	5 year	7 year	10 year	30 year
τ	1	2	3	5	7	10	30
λ / κ	1.79	0.90	0.60	0.36	0.26	0.18	0.06

(Source: Generated by Authors from Factset data)

Note that in the estimation of the NSS model, if the yield (r) itself is estimated, for example, an estimation error of 1 basis point for a 3 year rate and 1 basis point for a 10 year rate are treated as equivalent, and errors cannot be handled according to the level of interest rates by each term. Therefore, we transformed the par value of 100 into the bond price using the yield as in equation (C3) and estimated the parameters of the NSS model for its present value.

$$y(\tau) = 100 * e(-r\tau) \tag{C3}$$