Does the Japanese Financial Market Believe in Fiscal Sustainability?: Analysis of the Market for the JGB Futures Options[*1]

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Abstract

In recent years, although alarms have been sounded over an imminent fiscal crisis in Japan, yields on the Japanese Government Bond (hereafter JGB) have stayed stable at low levels. Does this mean that, in the private sector, there is no concern over fiscal sustainability? This paper analyzes prices of the JGB futures options in order to obtain information on private-sector perceptions on the future course of the JGB market. The results show that monetary policy plays a decisive role in the movements of prices of the JGB futures options. In particular, since the introduction of the yield curve control in 2016, options trading itself has remained sluggish. This paper analyzes how the market has reacted to some particular "fiscal news events," namely newsworthy incidents that may have had a significant impact on the expected future course of the fiscal deficit. We do not find any clear evidence that concerns over the deficit have been factored into asset price formation.

Keywords: government bond futures options, volatility smile, fiscal policy, monetary policy, yield curve control

JEL Classification: E44, E52

I. Introduction

I-1. Objective

This paper analyzes the market for the Japanese Government Bond (hereafter JGB) futures options, and asks if we can find any trace of a concern over fiscal sustainability. In recent years, although alarms have been sounded repeatedly over an imminent fiscal crisis in Japan, JGB yields have remained low. Does this mean that the private sector has no concern? This paper overviews the background and the idea behind my previous empirical work

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(Shioji (2020)), and gives a more intuitive account of that paper's findings, mainly through visual inspections of plots and graphs.

Private sector expectations play crucial roles in modern macroeconomic theory. In relation to the issue of fiscal sustainability, as long as market participants maintain confidence in the government's ability as well as its resolve to eventually balance the budget, they would continue to purchase JGBs. However, once the trust is lost, the yields will jump up, and that itself will make an eventual fiscal collapse more imminent.

One problem for empirical researchers is that those expectations are not directly observable. Recent studies have tried to overcome this difficulty by studying asset prices, which can be considered as a mirror which reflects what is inside the minds of those participants. This paper follows this literature and analyzes the prices of the JGB futures options. Options can be viewed as an insurance against the risk of the prices of the underlying assets, the JGB futures in this case, rising or falling unexpectedly. Their prices indicate how much those participants are willing to pay to protect themselves against such risks. Thus, by utilizing this information, we should be able to recover the shape of the subjective distribution in their minds over the future course of the JGB market.

I-2. Approach

Among existing indices, S&P/JPX JGB VIX Index, compiled by the Japan Exchange Group (JPX), is based on the JGB futures options prices. This index can be considered as the government bond version of the VIX index. Like the original VIX, it is a "model-free" measure of implied volatility. Its advantage is that it is computed without relying on a particular theoretical framework. On the other hand, its construction requires a large number of observations on the prices of options that correspond to many different levels of strike prices, in order to obtain a reliable estimate. This condition is hard to be met in reality. For this reason, I have decided to compute implied volatilities based on a particular theory. Concretely, I will be using a standard model in the field of finance for pricing options for bonds, which is called the Black (1976) model. This theory assumes that the return to a bond follows a normal distribution. Imposing this assumption enables researchers to use option prices to recover, theoretically, perceived volatility in the minds of the market participants for each and every single transaction.

Past empirical studies have repeatedly found evidence that contradict the underlying assumption of normality. That is, if the normality assumption is correct, the value of volatility computed from any option contract should be exactly the same, at whichever value of the strike price. However, in reality, there is a tendency that, as the strike price moves away from the current price of the underlying asset, volatility implied by the option price tends to increase. Imagine that we draw a graph with "strike price minus the price of the underlying asset" on the horizontal axis, and the estimated volatility on the vertical axis. Then, from the data, a U-shaped relationship emerges. This is referred to as a "volatility smile" because of its appearance. The fact that we find this shape serves as evidence that there is a discrepancy between theory and reality. That is, it indicates that the market perceives the risk of the price of the underlying asset experiencing steep declines or spectacular increases more strongly (compared to how they would be perceived under the assumption of normality).

This study utilizes minute-by-minute transactions data in the JGB futures options market to draw the smile curve on a daily (in some cases, half-daily) basis. I pay attention not only to changes in the location of the curve, which corresponds to changes in volatility, but also to other characteristics. I will pay special attention to the slope on the left side of the curve, as it is related to the market participants' perception about the downside risk, that is, chances of the price of the JGB futures falling sharply.

I will examine how the shape of the curve reacted when an important news was conveyed to the market. For example, suppose that the Bank of Japan (hereafter BOJ) just decided to accelerate purchases of the JGBs. This could not only cause a hike in the price of the JGBs, but might also make the market participants perceive that the future downside risk has been reduced. Volatility smiles allow us to examine such a possibility. Also, by comparing the responses of the curve to news about monetary policy and those related to fiscal policy, we might be able to compare the market participants' sensitivity to those two types of policies.

I-3. Overview of the results

This study reveals an overwhelming importance of the role played by monetary policy. Announcements of the BOJ's new policy initiatives, such as the Qualitative and Quantitative Monetary Easing (QQE) and the Negative Interest Rate Policy (NIRP), enhanced subjective uncertainty about the future course of the JGB futures prices felt by the market participants. On the other hand, under the recent policy regime of the Yield Curve Control (YCC), such anxieties have largely subsided. Compared to those drastic movements in the market, I could find no concrete evidence that fiscal policy-related news has had significant impacts to the market.

I-4. Related literature

In the literature of empirical studies on the impacts of macroeconomic policy changes, both the event-study approach and the asset price approach have been utilized frequently. In relation to monetary policy, Romer & Romer (1989) is an early example of a study that utilized information on monetary policy dates, namely days on which the policy deviated from its usual rule. On the other hand, Kuttner (2001) analyzes the federal funds futures market. In recent years, economists have tried to combine the two approaches and proposed ways to take advantage of the asset market's reaction to policy related news. Most of them have focused on monetary policy. This study is a rare example in which the combined approach is utilized to study fiscal policy. To the best of the author's knowledge, this is the first attempt to analyze changes in the level of private-sector confidence in fiscal sustainability through such an approach.

I-5. Structure of the paper

The rest of the paper is organized as follows. In section II, I explain the ideas behind the volatility smile curve using some examples. Section III explores how the location and the shape of the curve have evolved over time. I will also study in detail how the curve has reacted to important policy changes. Section IV utilizes regression analyses to verify the impressions we derive from the visual examinations. That is, I study if the policy effects remain significant, even after I control other factors that might influence them. Section IV concludes.

II. Market for the JGB futures options and volatility smiles

II-1. JGB futures options market

As the name suggests, this is a market for put and call options for the JGB futures. For details of this market, refer to Hattori (2020a, b). Hattori (2020c) also offers an introduction to the notion of volatility smiles, using this market as an example.

JGB futures, Long-term JGB futures to be exact, is not a derivative for a particular type of bond that exists in the real world. Rather, it is a futures contract for "standardized long-term government bonds," which is an imaginary, standardized kind of JGBs. In the actual settlement, they use ten-year coupon bonds with remaining maturity between seven and 11 years. There are four contract months, March, June, September, and December.

JGB futures options are options for these futures contract. Contract month is every month. For both JGB futures and JGB futures options, the unit of transaction is one hundred million yen (or about 1 million USD).

Major participants of the market are securities companies, banks, and overseas investors. Foreigners are the most prominent. According to Osaka Exchange (2015), in the year 2015, the share of securities companies in the total volume of transactions was 14.6%. That for commercial banks was 23.5%, while investors abroad accounted for 61.1% of the entire market.

II-2. Volatility smiles

II-2-1. Options

The basic premise of this paper (and also of preceding studies in the related literature) is that options are insurances. They are insurances against the risk of the price of the underlying asset declining below or rising above a certain threshold. A put option is an insurance against downside risk. A call option is an insurance against prices going too high. Hence, by looking at how much money people are willing to pay to protect themselves against those risks, we should be able to infer how worried they are about such possibilities.

II-2-2. Implied volatility

In Figure 1, I have chosen one day from the data set (which happens to be September 20, 2016) to illustrate the main idea behind volatility smiles. The original data is shown in Panel (A). Here, I put the difference between the strike price of an option and the price of the underlying asset (i.e., JGB futures) on the horizontal axis. The vertical axis measures the price of a JGB futures option. Each bubble represents a transaction that occurred on that day (the price on the vertical axis is the contracted price; the data set does not include transactions that were proposed but not agreed upon). The size of a bubble is proportional to the amount of transaction.

As an example, consider the bubble that is pointed by the arrow in the figure. The value along the horizontal axis that corresponds to this bubble is around -3. This means that this transaction is for an option which gives the owner the right to sell the underlying asset at a price that is three yen lower than the current price. Obviously, it does not make sense to exercise this right, if the current situation persists. However, if the price of the underlying asset decreases by more than three yen below the current level, this option will give the owner a way to contain the loss. The option price on the vertical axis tells us how much the market participants are willing to pay for an insurance that will protect them against such a downside risk. If the participants feel that the likelihood of such an event is high, they will be more willing to pay higher prices for this insurance. This means that, from the market price of this insurance, which is around 0.05 in this case, we should be able to deduce such likelihood in their minds.

Let us pretend, for a moment, that it is ok to assume that the probability distribution in the minds of the participants is normal. In such a case, the shape of the entire distribution is determined by just one parameter (besides the mean), that is, the variance. To be slightly more precise, if we assume that the participants think that the rate of change of the price of the underlying asset follows a normal distribution with a known mean and a constant standard deviation, we can infer the value of this standard deviation from the option's price. This is the so-called implied volatility (IV). This paper estimates the IVs based on the model of Black (1976). For this reason, this IV will be denoted as "BMIV" in this paper.

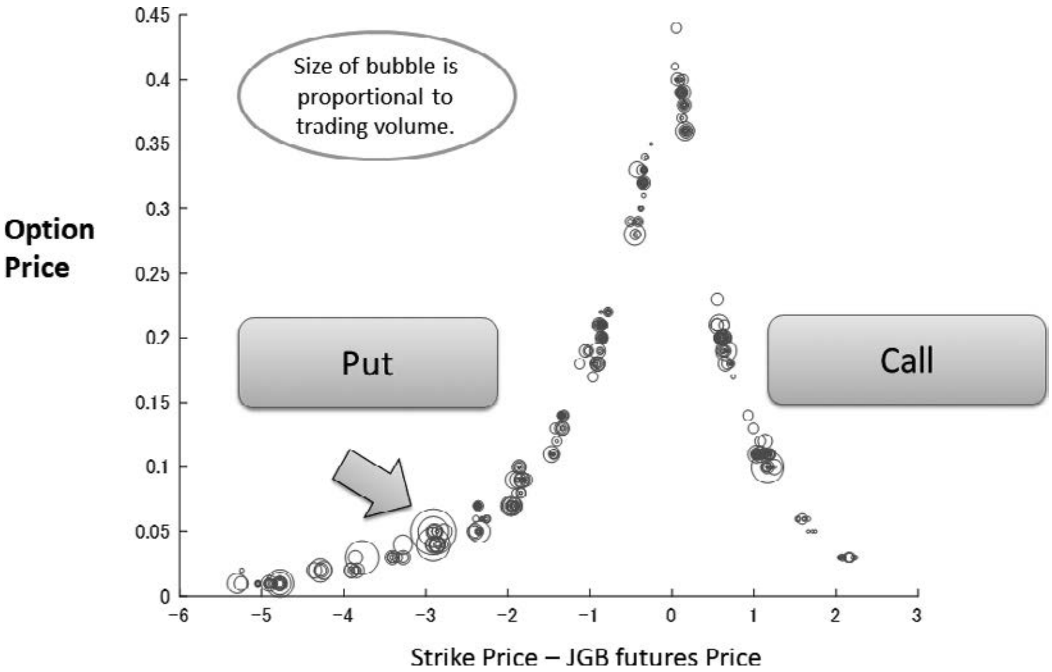
II-2-3. Volatility smile

Panel (B) of Figure 1 exhibits the BMIVs thus computed, for all the transactions that appear in Panel (A). For example, BMIV for the transaction that we discussed earlier turns out to be a little over 0.07.

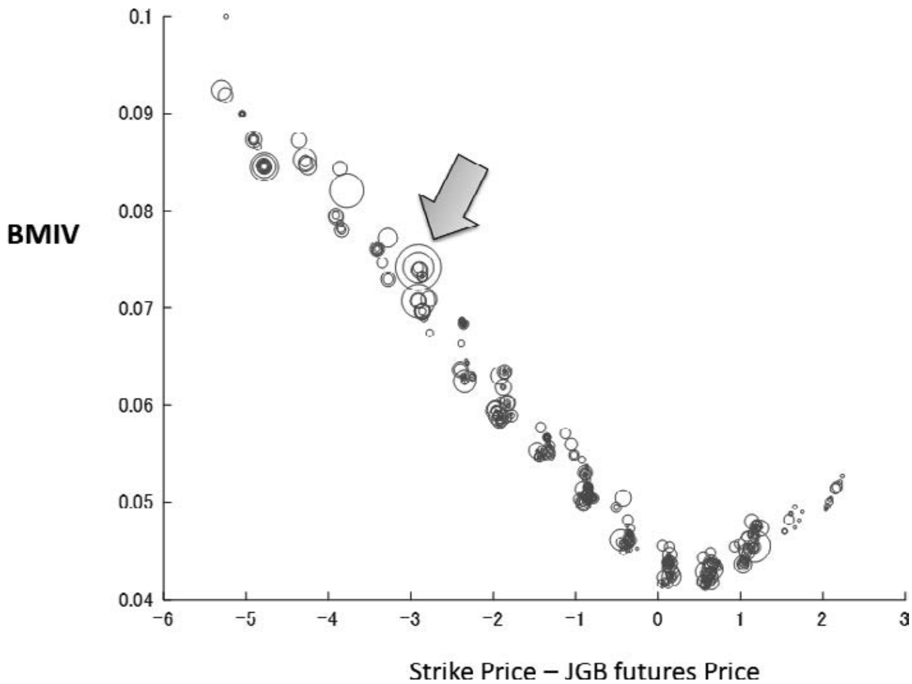
Note that, if the assumption behind the above computation of BMIV were correct, and the probability distribution in the minds of the participants were truly normal, we should be observing all the bubbles lining up along a horizontal straight line, because our theory assumes a constant volatility.

Figure 1

(A) Option Price vs Strike Price Example: Sep. 20, 2016



(B) Volatility smile Example: Sep. 20, 2016



Panel (B) contradicts this assumption. Instead of a horizontal line, we see a U-shaped curve whose bottom is near the point at which the value on the horizontal axis is zero. This is why it is called the volatility smile. It is an indication that the participants' subjective probability distribution is non-normal. A steeper slope would indicate a more serious deviation from the assumption of normality.

The fact that the curve is U shaped (rather than, for example, inverse-U shaped) implies that the participants value the risk of a larger price increase (or decrease) more heavily. For example, in panel (B), we see that BMIV that corresponds to zero on the horizontal axis is slightly higher than 0.04, while that for the value of -3 is around 0.07. This means that people perceive the chances of the JGB future's price falling by three yen to be higher (than what would be implied by the normal distribution with the standard deviation of 0.04). Hence, we can infer that the subjective probability distribution in the minds of the participants has a fatter left tail than the normal distribution. The same logic applied to the right hand side of the distribution.

II-2-4. Asymmetry in transaction amount

We can also see from Panel (B) of Figure 1 that the volatility smile on this day was longer on the left side and shorter on the right side. We would usually think of a "smile" to be symmetric between left and right, but this is not the case. I suspect this is because participants were more concerned about downside risks, and the desire to protect themselves against the risk of a price hike was weaker. Although the main interest of the paper is in the evolution of the price of the options, I will also pay attention to how the amount of transactions at different points on the smile curve evolved over time.

III. Evolution of the volatility smile

III-1. Year-by-year changes

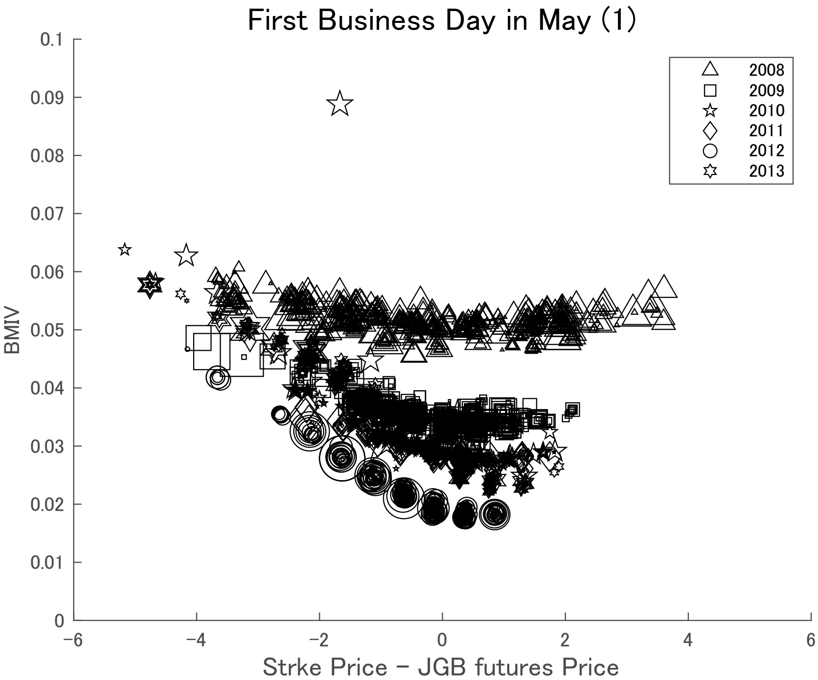
In this paper, most of the efforts will be devoted to visually inspecting the transition of the volatility smile curve over time, rather than conducting formal statistical analyses. Let me start with a long view. Figure 2 tracks long run movements in the smile curve, by picking just one day per year, and plotting the curve for that day. Panel (A) is for the years 2008-2013, and (B) corresponds to the period 2014-2019. For each year, I plot the curve for the first day of May on which the market was open.

III-1-1. Pre-QQE era

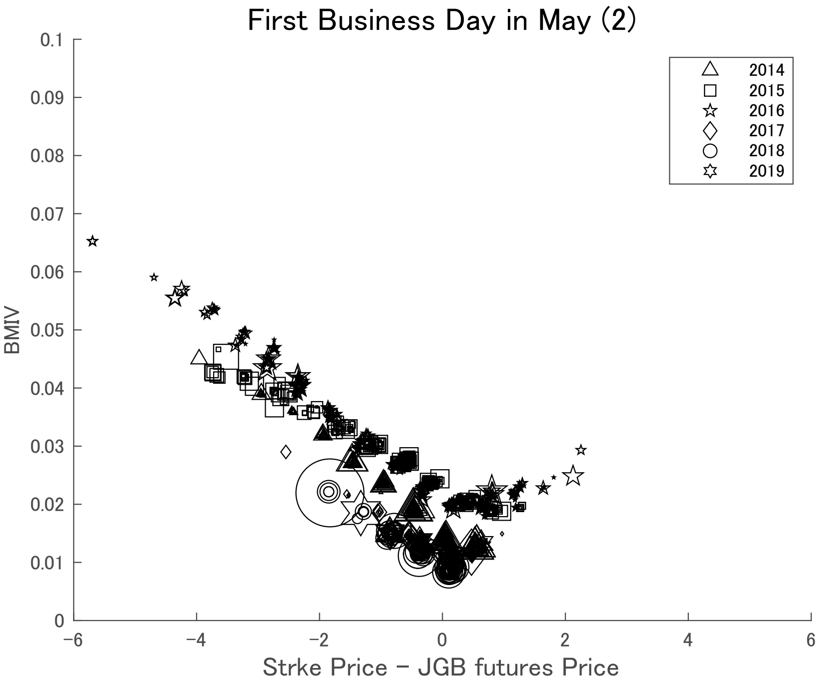
In panel (A), all the curves but the last one (for May 2013) are from the period before the BOJ's implementation of the QQE. In 2008, the curve was flatter, compared to the period afterwards. It was longer on the right side, at least in comparison to later years. The overall curve was located at a higher position, indicating that the participants' assessment of the volatility of the JGB futures price was higher. The fact that the curve was flatter implies that

Figure 2

(A) Volatility smiles for 2008-2013



(B) Volatility smiles for 2014-2019



they were not disproportionately concerned about the risks of larger price swings. The fact that the curve is longer on the right seems to indicate that they recognized the risk of price increases, at least in comparison to later years. It should also be noted that the number of the bubbles is greater, and they tend to be larger in size, comparatively speaking. This implies that the options were being traded more heavily during this period, perhaps because JGB futures were experiencing larger price swings, as we will see later in panel (A) of Figure 6.

Although it does not appear in Figure 2, the curve shoots up in reaction to the collapse of Lehman Brothers in September 2008. The slope of the curve remained flat; it indicates that the subjective probability distribution in the minds of the participants did not deviate much from the normal distribution.

Panel (A) of Figure 2 suggests that, by May 2009, the market anxiety had subsided, and the overall location of the curve was below that of the previous year. On the other hand, between this period and around 2011, the typical shape of the smile curve during much of the 2010s, which is "longer on the left and shorter on the right" and "steeper on the left," is gradually established.

Around 2011, the amount of transactions becomes smaller, and we stop witnessing transactions that are on the extreme edges of the curve, either on the left or on the right. But in 2012, just prior to the introduction of abenomics and the QQE, the curve had regained its typical shape of "longer and steeper on the left."

III-1-2. The QQE1/QQE2 periods

The BOJ announced the QQE in April 2013. To distinguish it from the later version, this original one will be denoted as "QQE1." It sent a shock wave to the financial market, as yields on the JGBs surged, while the price of the JGB futures plummeted. This is reflected in the last curve in Panel (A) of Figure 2, which is for May of 2013. It is located at a much higher position than the year before, and it is very long on the left side. This seems to indicate that the participants were taking into consideration the risk of a large decline in the price of the JGB futures. On the other hand, it should also be noted that the volume of transaction did not register a notable increase.

Moving to Panel (B) of Figure 2, a similar situation persists in May of 2014, and also in May of 2015, which is after the implementation of the QQE2 in 2014. On the other hand, trade volume decreased, making the curves look apparently thinner.

III-1-3. The NIRP period

The next crucial moment in the JGB market arrived when the BOJ announced the NIRP in January 2016, which was implemented in the following month. Under this policy, yields on long-term JGBs declined rapidly and turned negative. At that time, they were even lower than the short-term interest rates such as the call rate. On the flip side of the same coin, the JGB futures prices skyrocketed. Under such a volatile environment, in Panel (B) of Figure 2, we see that the curve for May 2016 drastically extends on the left side. This seems to indicate that the participants were acutely aware of the risk of the JGB futures prices going down.

III-1-4. The Yield Curve Control (YCC1) period

Introduction of the YCC in September of the same year caused yet another sea change in the JGB market. To distinguish it from the second, slightly modified version of the YCC that will appear later, this policy will be denoted as “YCC1.” As Panel (B) of Figure 2 indicates, in May of years 2017 and 2018, the width of the curve shrinks along the horizontal direction. Especially, the extent of the shrinkage on the left side is noticeable. This means that transactions to cover large downside risks became rare. This is probably because the BOJ now stabilizes yields on the JGBs, which are the “underlying asset of the underlying asset” of the JGB futures options, and their prices now experience little changes. The amount of transactions diminished at the same time.

III-1-5. The YCC2 period

On July 31, 2018, the BOJ announced an introduction of a new policy framework. It was featured by strengthened forward guidance and added flexibility to the YCC framework: more room was allowed for long-term bond yields to move up and down. One might have expected that this move, which would lead to larger fluctuations in the price of the JGBs, to induce more active trading of the options. However, this was not what happened. Perhaps the market interpreted this policy as an attempt to prolong the life of the YCC, through giving it a larger flexibility. As we can see in Panel (B) of Figure 2, the width of the curve for May 2019 shrinks further, especially on the left side, and very few transactions are observed that would correspond to price moves of over two yen, in either direction. As a consequence, the traditional feature of the smile curve, namely “longer on the left,” is now completely lost. The entire curve is located at a very low position, and the volume of transaction is small.

This was the situation in the market prior to the crisis of March 2020, when the market was hit by the surge of COVID-19. Given the space constraint, this crisis period (and beyond) will be left as a subject of future research.

III-2. Lessons from the long view

III-2-1. Summary of findings

The visual inspection of the previous section has revealed the importance of monetary policy regimes. Especially since the initiation of the QQE, the BOJ has become the dominant buyer in the JGB market, and the monetary authority’s policy toward JGB purchases pretty much determined the location and the shape of the smile curve. Fiscal policy does not appear to have contributed to large changes in the market.

III-2-2. Monetary policy regimes and the JGB market

It is useful to divide the evolution of Japan’s monetary policy regimes into three phases, in studying its relationship with the JGB market. Three panels in Figure 3 conceptualize those three regimes. In those panels, the vertical axis measures the long-term interest rate, and the horizontal axis is the net amount of JGBs in the hands of the private sector. That is, it is the total amount of JGBs outstanding minus the amount held by the BOJ. I am going to assume that the aggregate demand for JGBs consists of two components. One is the arbitrage demand, which comes from arbitrage transactions between the JGB market and the rest of the financial market. The other is the institutional demand, which comes from legal, institutional and regulatory reasons.

The standard theory of the term structure of interest rate, that is, the expectations hypothesis, assumes that yields on long-term bonds are determined by the arbitrage demand. According to this model, the long rate is equal to the average between today's short rate and the expected path of future short rates. In reality, we should add risk premium that comes, for example, from uncertainty regarding the eventual fiscal solvency. In either case, the fact remains that the rate that is determined from this arbitrage demand is independent of the amount of JGBs circulating in the private sector. For that reason, the demand curve is a horizontal straight line: it is flat at the level of the rate of return on private assets with similar characteristics (plus the risk premium).

To give an example of the second type of demand for the JGBs, insurance companies in Japan are required to hold at least some part of their assets in the form of safe assets such as the JGBs. I will hypothesize that this part of demand is partially elastic, and that those financial institutions would reduce their demand for the JGBs in response to a rise in their prices. In each panel of Figure 3, this demand component is represented by an upward sloping curve (note that bond yields and bond prices are negatively correlated). By combining those two parts of the demand for the JGBs, we obtain a demand curve that is upward sloping up to some level of the yield, and then becomes flat thereafter, as seen in those panels.

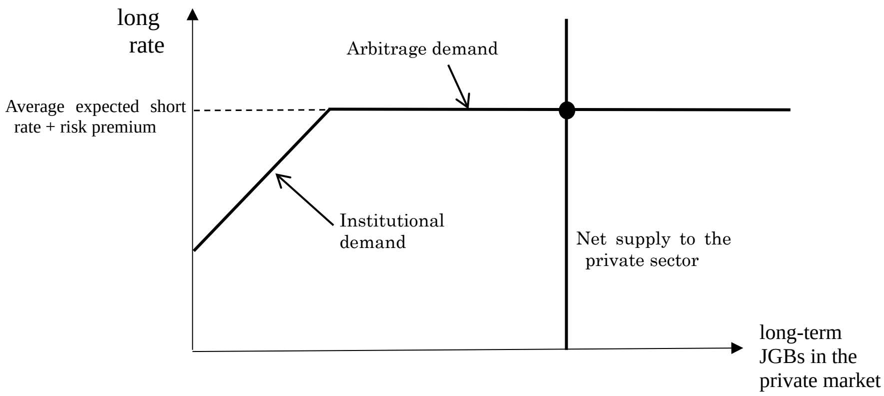
The above view of the market for government bonds is similar to the Preferred Habitat Theory developed by Greenwood and Vayanos (2014) and Vayanos and Vila (2021), among others. Fukunaga, Kato and Koeda (2015) is an empirical study of the JGB market based on this model. The above view is similar to this theory in that the demand for government bonds consists of two segments, namely the arbitrage demand and the institutional demand. On the other hand, in the Preferred Habitat Theory, the upward part of the demand curve stems from limitations of arbitrage transactions. Here, this component comes from the behavior of the institutional buyers, as they are assumed to perceive the JGBs and other types of assets as imperfect substitutes.

III-2-3. Regime N

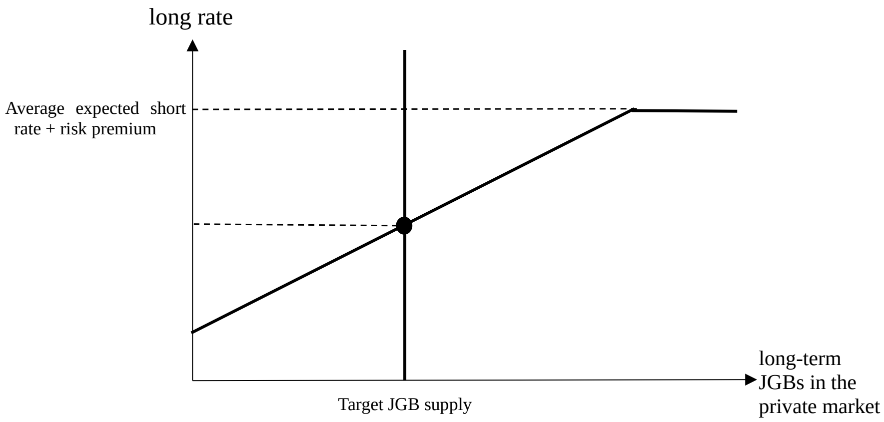
I hypothesize that the long-term JGB market before QQE1 can be represented by the first panel of Figure 3. This situation is called "Regime N" or the normal regime. The panel assumes that there is a sufficient net supply of the JGBs in the market to satisfy the institutional demand. Because of that, the supply curve intersects with the demand curve at its horizontal part. Thus, as the standard theory of finance predicts, the long rate is determined by

Figure 3 Three regimes of the long-term JGB market

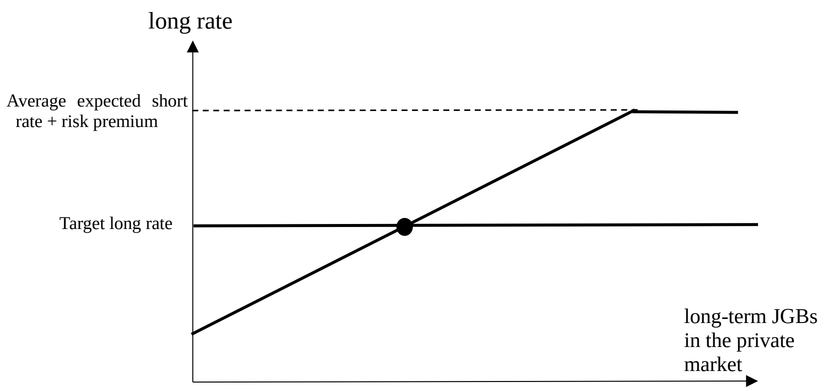
Regime N



Regime B



Regime R



Note: The vertical axis measures the interest rate. As it is negatively correlated with the bond price, the demand curve becomes upward sloping.

the arbitrage demand. If expectations regarding the future course of the short rate remains stable (because, for example, the private sector anticipates that it would be stuck at the level of the IOER (Interest on Excess Reserves) for a foreseeable future), then the long rate will stabilize. On the other hand, fluctuations in the risk premium would be reflected in the level of the long rate.

III-2-4. Regime B

Since the QQE started, the BOJ's massive purchases of the long-term JGBs reduced the net supply of those bonds to the private market. As a consequence, it is hypothesized that the market shifted to what I call "Regime B," which is depicted in the second panel of Figure 3. In this panel, as the net supply curve of the JGBs shifted leftward, making the JGBs scarce assets, the arbitrage between this market and outside breaks down. The arbitrage demand no longer determines the JGB yields, as institutional buyers such as insurance companies are willing to pay premiums to get hold of this scarce asset.

In such a circumstance, under both the QQE1 and the QQE2, the BOJ determined its target amount of JGB purchases, which in turn determined net supply of the JGBs to the private sector as a residual (taking the total stock of JGBs as approximately constant). In that sense, the net supply curve of the JGBs was vertical, as in the second panel. Then the JGB yields adjust, so as to equate the demand with this fixed amount of net supply. As the panel shows, the market equilibrium is obtained at a point where the net supply curve intersects with the upward sloping portion of the demand curve.

One of the features of this regime is that small changes in institutional demand for the JGBs could lead to volatile movements in their yields. This could explain why the demand for options that would insure the participants against the risk of falling JGB prices (which were already quite high) increased during this period.

The market under the NIRP can be understood in essentially the same manner. A slight difference is that, until then, the market considered that the level of the short rate to be virtually unchangeable. Up until then, it had been stuck at the level of the IOER, which, in turn, had been fixed at the same level for years. However, the introduction of the NIRP changed this perception. The participants now needed to worry about the possibility of the short rate moving around in near future. This destabilized the demand for the JGBs, and the demand curve started to shift up and down more frequently. This enhanced the overall level of uncertainty in the financial market in Japan. This could explain why the volume of options trading increased again.

III-2-5. Regime R

Under the YCC1/YCC2, the BOJ determines the target level of the JGB yields, and adjusts its purchases of the JGBs (and thus the net supply to the private sector) in a flexible manner to hit the target. This situation is depicted in the third panel of Figure 3 and it is called "Regime R." Now the net supply curve is horizontal, instead of being vertical. Under this regime, the JGB yields stabilize. Because of that, there is less incentive for the participants to purchase options in preparation for price changes. Changes in the risk premium are unlikely to be reflected in the yields.

III-2-6. Evaluation of the YCC1/YCC2

Looking at the bright side, the implementation of Regime B contributed to stabilize the financial market, through reducing uncertainty about the future course of the market. In addition, when there is a surge in the demand for the long-term JGBs, that is, when there is a sudden flight to safe assets, this policy framework enables the public sector to flexibly increase the net supply to meet the surging demand. On the flip side, under this regime, options trading has largely subsided. This means that we have lost a way to gauge the market's perceptions about the future as well as the degree of uncertainty in the market, especially their views on the long-run sustainability of fiscal balance.

III-3. Downward trends in transaction volume

III-3-1. Evolution of (unweighted) trading volumes

Before proceeding, it is useful to review the historical evolution of the volume of options trading over time. Its time varying nature has been hinted at by the above analysis of Figure 2. Figure 4 is an attempt to obtain a long view of this trend. Those bar graphs track transaction volumes on daily bases. Panel (A) is for put options and (B) is for call options. For put options, I exclude those options whose strike prices are above the current price of the underlying asset. For call options, those whose strike prices are below that are excluded. In this figure, the trading volumes are unweighted. That is, options whose strike prices are far from the current price of the underlying asset are treated equally with options for which those two prices are right next to each other.

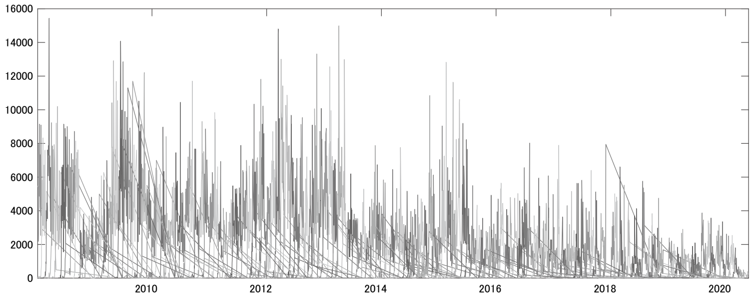
Looking at those panels, the amount of transaction is greater during the first half of the sample, for both put and call options. The volume is smaller for call options. Also, the amount starts to decline early for call options. In particular, since the QQE1 started, we see very few transactions of call options. Trading of put options starts to decline considerably since 2018.

III-3-2. Case of weighted trading volume

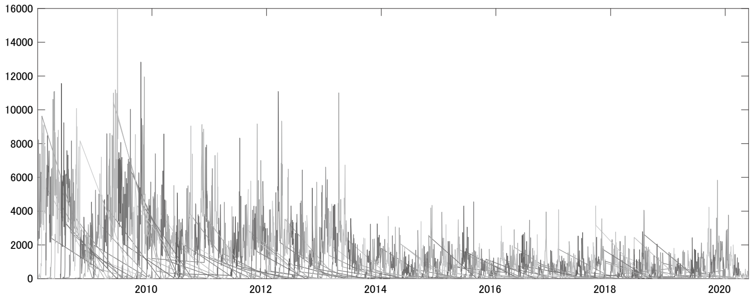
A decrease in trading volume could occur in different ways. As we have seen in Figure 2, in some cases, trading is maintained for a relatively wide range of strike prices, but the amount of transaction at each of those points declines, more or less uniformly. In other cases, the participants stop trading options whose strike prices are extremely low (or high). We may wish to distinguish between those two patterns. Thus, in panels (C) and (D) of Figure 4, I compute weighted averages of transaction volumes, giving a greater weight to an option that corresponds to a larger price movement. Concretely, for each transaction, I calculate the absolute value of the difference between the strike price and the current price of the underlying asset. I multiply this weight with the amount of trading. Then I aggregate them up.

Figure 4 Trade volume over time

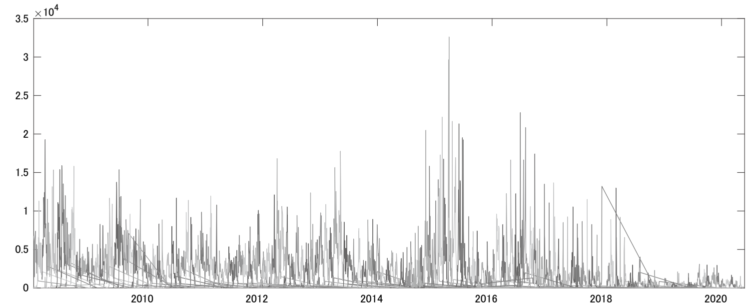
(A) Put option, unweighted



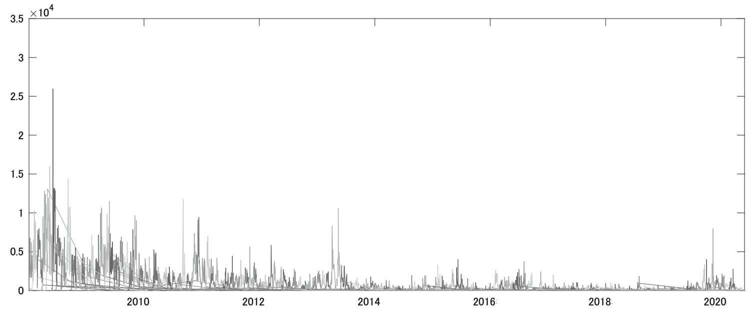
(B) Call option, unweighted



(C) Put option, weighted; weight = absolute value of ((strike price) – (current price of underlying asset))



(D) Call option, weighted; weight = absolute value of ((strike price) – (current price of underlying asset))



Comparing the weighted volume in panel (C) with the unweighted one in panel (A), we notice some interesting differences in their patterns. In panel (A), volumes tend to be higher during the first half of the sample, while in panel (C), the peak occurs after the introduction of the QQE1, especially between years 2014 and 2015, which is during the QQE2 period. We observe another, smaller peak in 2016, during the NIRP era. This indicates that there was a strong demand for options that would be useful in the event of a drastic price decrease. On the other hand, panel (D) suggests that, since the market stabilized in the aftermath of the Global Financial Crisis, demand for options that could come in handy in case of a large price increase came down considerably.

Since around 2018, transactions of both put and call options diminished. Just prior to the year 2020, we see a sign of recoveries. This tendency is slightly stronger for call options; in fact, we start to see days on which the weighted trading volume is greater for call options than put options, which has been a rare phenomenon since around 2010.

III-4. Volatility smiles at times of major policy shifts

III-4-1. QQE1/QQE2

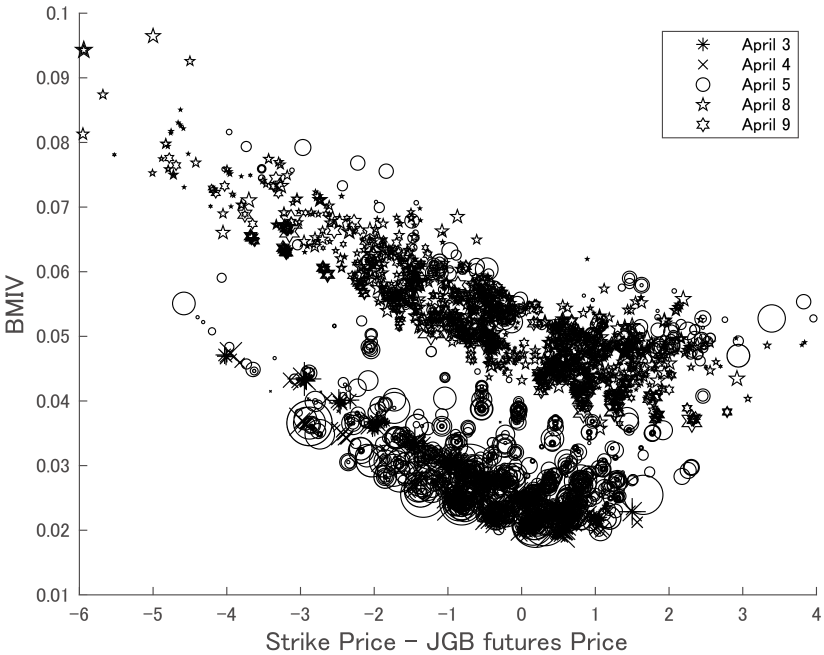
As we have seen, monetary policy regimes have major influences over the location and the shape of the volatility smile. In this section, I will focus on several instances of important policy regime changes, and examine how the curve reacted to such changes.

Consider first April 2013, at the start of the QQE1. Panel (A) of Figure 5 depicts daily shifts in the volatility curve around that time. Although the new policy was introduced on April 4, the announcement was made after the market close. Thus, the news is reflected in the market only after April 5. In this panel and the next, circle-shaped bubbles correspond to the day of the policy change. In the case of panel (A), this is defined as April 5 rather than April 4. From this panel, we can see that the location of the curve was relatively low prior to the policy announcement. Even on April 5, the curve did not shift upward immediately. It appears that the curve started low in the morning and shot up very quickly after a while. It seems to have taken some time before the market could digest the news and the prices started to reflect the new reality. After that, the curve basically stayed around the same place. Taken together, the evidence is consistent with the view that the QQE heightened volatility in the market. On the other hand, the slope of the curve on the left side did not exhibit much change.

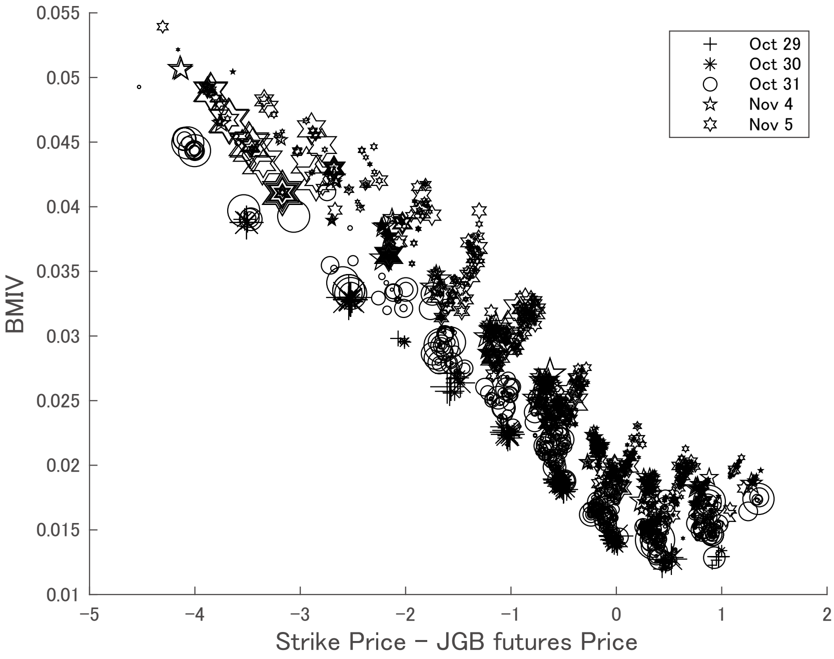
Panel (B) of Figure 5 is for when the QQE2 started. The announcement itself was made on October 31, 2014. However, perhaps because the news came in the afternoon, we do not observe much happening on that day. Still, the curve shifted up, even slightly, in comparison to the previous day and the day before. After a long weekend that included a national holiday, the curve shifts up slightly again. Taking the entire period together, we can conclude that the QQE2 also had the effect of pushing up the curve. However, compared to the case of the QQE1, the size of the effect was smaller. As in the case of the QQE1, the slope of the curve did not change much, and the entire curve shifted up vertically, in a parallel manner.

Figure 5 Responses of the smile curve at times of important monetary policy changes

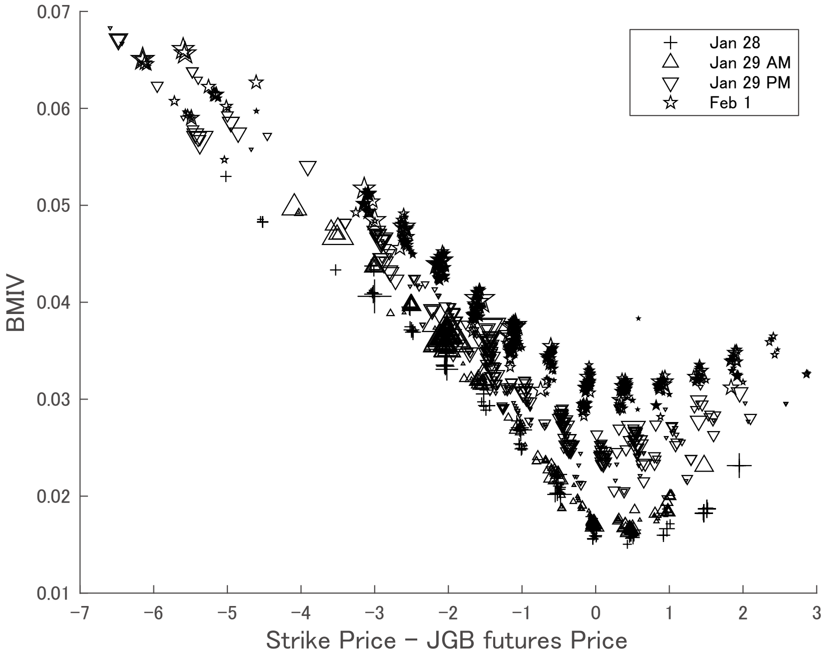
(A) Announcement of QQE1=Evening of Apr. 4, 2013



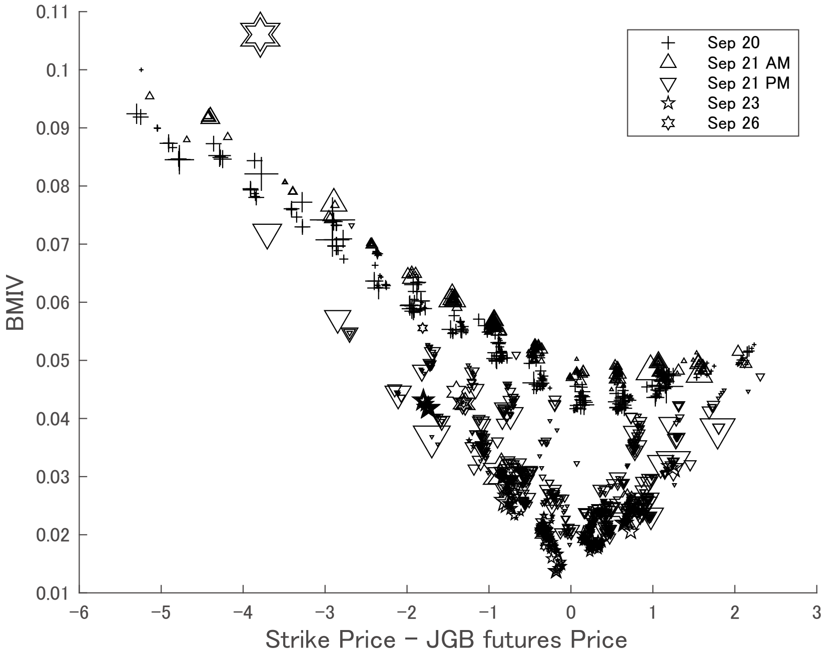
(B) Announcement of the QQE2, Oct. 31, 2014



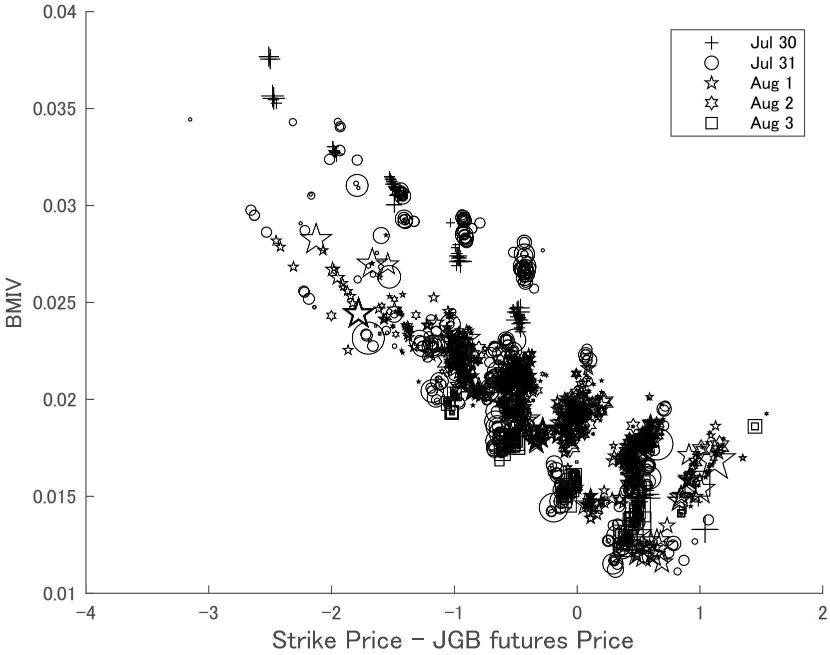
(C) Announcement of the NIRP, Jan. 29, 2016



(D) Announcement of the YCC1, Sep. 21, 2016



(E) Announcement of the YCC2, Jul. 31, 2018



III-4-2. NIRP

Panel (C) is for the days around the announcement of the NIRP. In this case, the announcement was issued during the lunch time, at 12:38, on January 29, 2016. For this reason, the panel distinguishes observations from the morning and the afternoon of that day. We clearly see an upward shift of the curve between before and after the announcement. We also start to see more transactions happening at the left tail of the curve. The curve shifts further up on Monday of the following week, namely February 1.

III-4-3. YCC1/YCC2

Panel (D) is for the case of the YCC1, which was announced on September 21, 2016, at 13:18. For this reason, the panel again distinguishes between the morning and the afternoon of that day. The curve falls dramatically between the morning and the afternoon of that day. What is noticeable is that this shift occurs mainly around the bottom of the curve. As a result, the slope of the new curve is steeper, especially on the left. However, this change in the slope turns out to be a temporary phenomenon, as we shall see later.

Panel (E) is for the YCC2. This policy was made public at 13:03 on July 31, 2018. We see that, on this day, the curve shifts further down and remains there afterwards.

III-4-4. Fiscal policy-related events

I have studied a number of events related to fiscal policy, but, in an overwhelming majority of the cases, the curve did not show any clear response. Among those, in one case, I could find a faint sign of a reaction. This was in November of 2014, when Prime Minister Abe decided to postpone the scheduled increase of the consumption tax rate. It is not clear when the prime minister made up his mind, but, based on newspaper articles, it appears that people started to sense the shifting atmosphere around November 12. Figure 6 suggests that the curve did go up slightly on that day, in comparison to November 10 or 11. However, after November 12, the curve immediately reverses course, and half of the upward shift made on that day is lost. It is thus hard to conclude that this event had a strong impact on the curve.

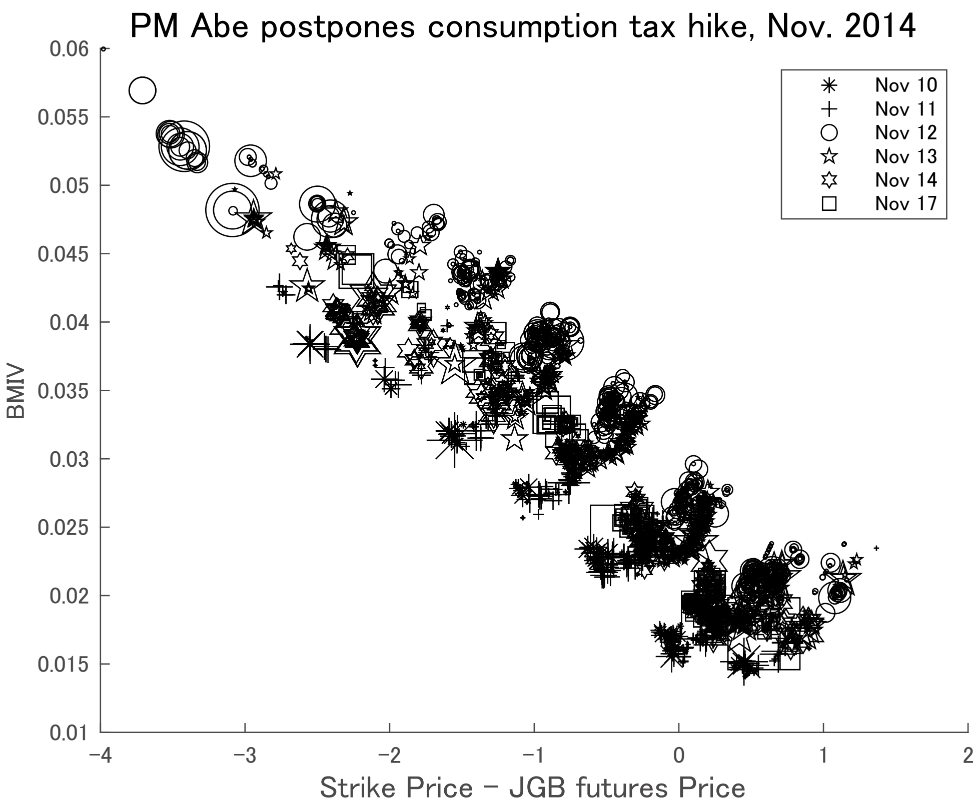
Thus, unlike the case of monetary policy, my analysis for this paper could not find evidence that fiscal policy had a strong influence on this curve.

IV. Regression analysis

IV-1. Construction of daily indices for the regression analysis

This section runs some regressions, in the hopes to reinforce the conclusions that have been derived through visual examinations. Location and shape of the smile curve are influ-

Figure 6 Smile curves at the time of a fiscal policy change



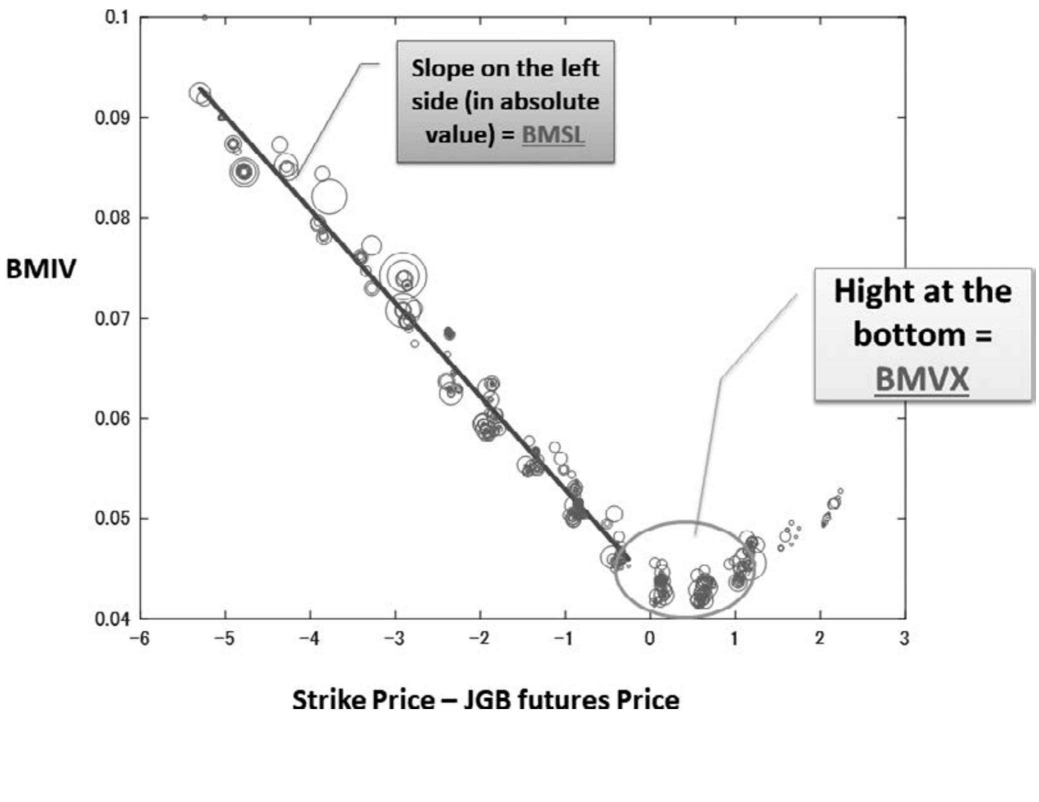
enced not only by policies but also by situations in the Japanese financial market, the Japanese economy as a whole, foreign economic policies, and the economic conditions abroad. Regressions give me a way to control for their effects. I will see if the effects of the Japanese economic policies that we found in the preceding sections survive such a scrutiny.

Here, I will create two daily indices to represent the characteristics of the smile curve. Figure 7 explains the ideas behind them. One of them measures the location (height) of the curve, and the other one gauges its slope on the left side. The former will be called BMVX, while the latter will be denoted as BMSL.

BMVX for a particular day in the sample is constructed as follows. Out of all put and call transactions (with the same contract month) on that day, I pick those that involved options whose strike prices were less than 0.5 away from the price of the underlying asset at the time (minute) of the transaction. I compute BMIV for each of them. Then I take their weighted average, where the weight attached to each transaction is the trading volume. If I could find only five transactions or fewer that fall into the above price range, BMVX for that day was treated as missing.

In constructing BMSL, I first selected transactions that involved options whose strike prices were lower than that of the underlying asset, at the time of each transaction. I compute BMIV for each of them. Using the weighted least squares approach, I regress those BMIVs on the distance between the strike price and the price of the underlying asset. The weight attached to each trade is the transaction volume. The estimated coefficient is my BMSL. If I

Figure 7 Ideas behind BMVX and BMSL



could find 15 transactions or fewer that fall into the above category, I treated BMSL for that day to be missing. This resulted in many missing observations, especially toward the end of each month. I also excluded those options whose remaining contract periods were less than five days. This also produced many missing values toward the end of each month.

IV-2. Overview of the daily indices

Figures 8 and 9 plot some of the time series data I will use in this section. Panel (A) of Figure 8 shows the historical evolution of the JGB futures prices (in logs), evaluated at the market close. I first compute daily rates of change (log differences) for futures with the same contract month. Then I use them to construct a cumulative series, starting from early January 2008 with the initial value set to be zero. I switch relevant contract month by comparing daily amounts of transactions between futures with different contract months.

Panel (B) of Figure 8 plots the JGB VIX, along with the US Government Bond VIX. Those two are positively correlated, suggesting presence of co-movement in risks across bond markets in different countries. On the other hand, the JGB VIX is also influenced by Japan-specific factors such as monetary policy changes, like the introduction of the QQEs and the NIRP.

Panel (A) in Figure 9 depicts movements in BMVX. Its evolution is broadly similar to that of the JGB VIX. As we can see, it has been on a downward trend since the Global Financial Crisis of 2008-2009. The index experiences occasional spikes, such as when the QQE1 and the NIRP were introduced.

Panel (B) of the same figure is for BMSL. The series is quite noisy, but we can at least see that its value increased under the QQE, and that it declined considerably since around 2018.

IV-3. Regression specifications

IV-3-1. Regression procedure

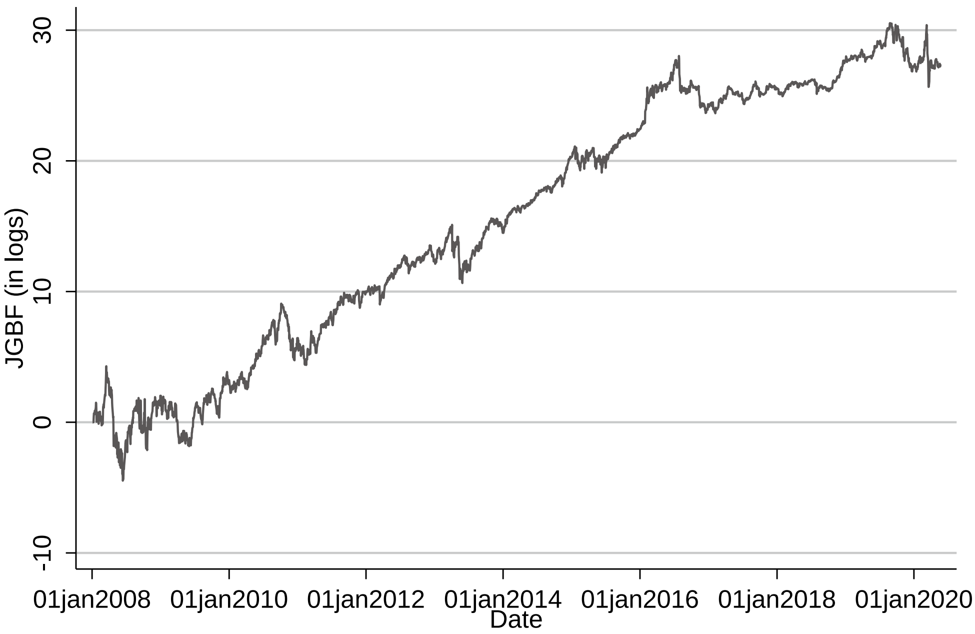
I estimate three types of regression models via the OLS, each with a different dependent variable. The first one is the log differences of the JGB futures price index (shown in panel (A) of Figure 8), denoted as JGBF. The second dependent variable is BMVX, and the third model is for BMSL. For the latter two regressions, I started with a list of many candidates of explanatory variables. I gradually removed those that turned out to be insignificant, to preserve a decent degree of freedom, and arrived at the final specifications reported below.

IV-3-2. Candidates for explanatory variables: non-policy variables

The original candidates for the regressors included the following. Lagged dependent variables turned out to be always significant, so I decided to incorporate them into the analysis. The numbers of lags were chosen based on the AIC. Among domestic non-policy variables, the candidate list included JGBF, the call rate, and VXJ (an equivalent of the VIX for Japan published by Osaka University). Among foreign non-policy variables, I tried using the

Figure 8 Evolution of financial variables

(A) JGB futures prices (in logs)



(B) JGB VIX vs US Government Bond VIX

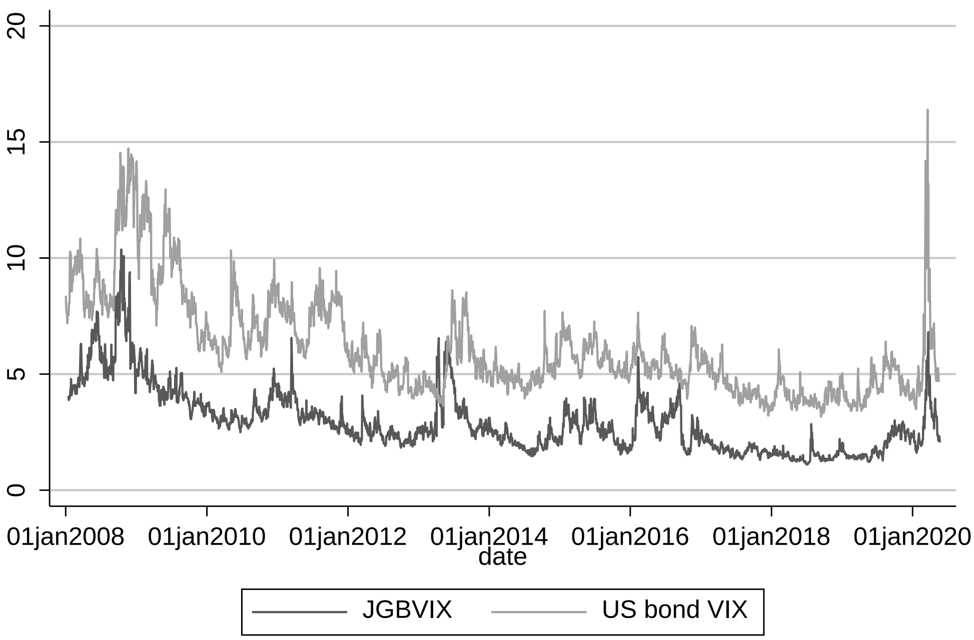
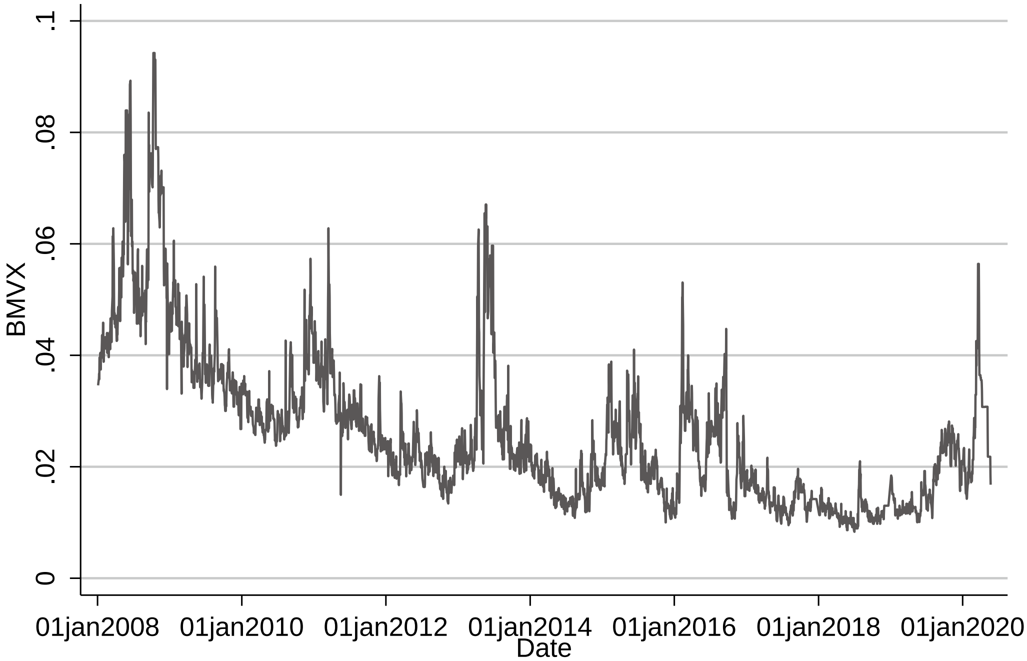
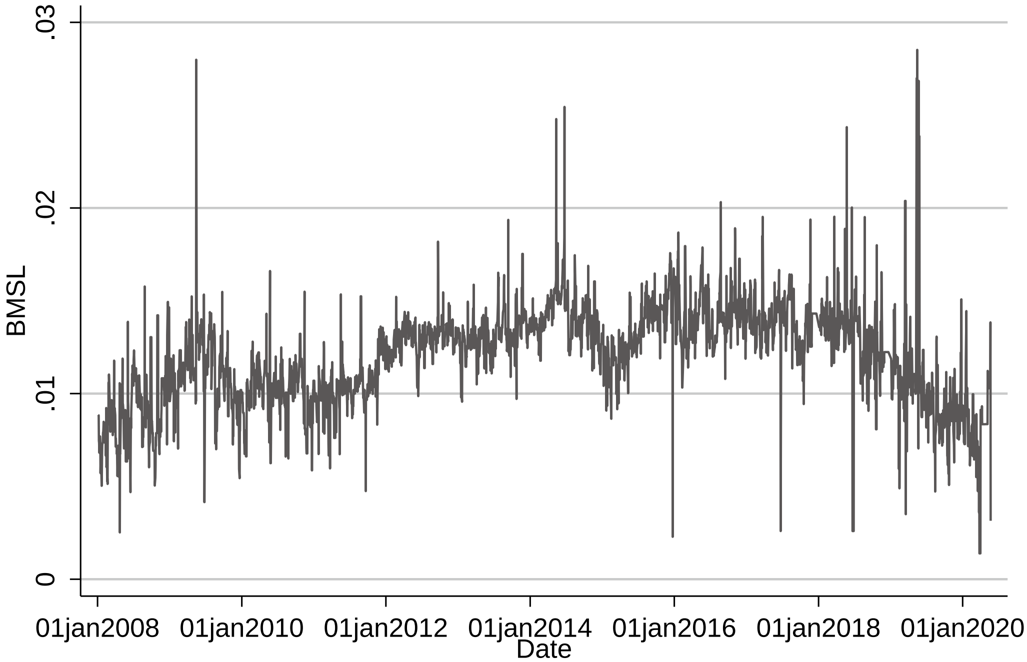


Figure 9 Evolution of BMVX and BMSL

(A) BMVX



(B) BMSL



US Treasury Bond Futures index, the European Government Bond Futures index, the VIX, VSTOXX (an equivalent of the VIX for Europe), and the US Government Bond VIX. I also tried including the rate of change in the USD-JPY exchange rate as well as its square. For the analysis of BMSL, I added BMVX to the list of the regressors. In all the cases, I tried including their contemporaneous values (for foreign variables, I take one day lag to account for the time difference) as well as their lags.

Very few of them made it to the final specifications. In the analysis of BMVX, JGBF, VXJ, US Government Bond VIX, and VIX remained. For BMSL, only BMVX survived.

IV-3-3. Candidates for explanatory variables: policy-related dummies

I created a number of dummy variables, each of which takes the value of one when there was an important news about monetary policy, and zero otherwise. I tried 38 such dummies, each corresponding to one of 38 important news. As a result, based either on the significance of the coefficient or the importance of the policy itself, I retained the following nine dummy variables in the final specification.

List of Monetary Policy Date Dummies

(1) Announcement date for the CE (Comprehensive Easing)
(2)-(5) Four business days after the announcement of the QQE1: April 4, 5, 8 and 9 of 2013.
(6) Announcement date for the QQE2
(7) Announcement date for the NIRP
(8) Announcement date for the YCC1
(9) Announcement date for the YCC2

I also created dummy variables that correspond to different monetary policy regimes. For example, the CE regime dummy is a variable which takes the value of one on all the dates between the announcement of the CE and that of the QQE1, and zero otherwise. I created the following six regime dummies.

List of Monetary Policy Regime Dummies

① CE regime
② QQE1 regime
③ QQE2 regime
④ NIRP regime
⑤ YCC1 regime
⑥ YCC2 regime (which lasts until the end of the sample)

As I will include all of them in the following regressions, the reference period would be the pre-CE period.

I also tried including Fiscal Policy Date Dummies. I tried 37 candidate dates, but few of them turned out to be significant.

I also created policy date dummies for dates on which there were important announcements concerning monetary policy by the US Fed or the ECB. Due to time differences, I take one day lags of those variables. The majority of them turned out to be insignificant.

However, the following three, all related to the Fed policies, were found to be significant, at least in some cases. And I included them in the final regression model.

List of Foreign (US Fed) Monetary Policy Date Dummies

<1> Announcement of the QE2 (August 10, 2010)

<2> Chairman Bernanke's "taper tantrum" speech (May 22, 2013)

<3> Declaration of unlimited asset purchases, in response to the COVID-19-induced financial turmoil (March 23, 2020).

In the analysis for JGBF, the list of explanatory variables included the lagged dependent variables, VXJ, JGB VIX, all Monetary Policy Date Dummies, Monetary Policy Regime Dummies, and Foreign Monetary Policy Date Dummies.

In addition, I included eight dummy variables for the Great East Japan Earthquake and the aftermath, each corresponding to each of the eight business days between March 11 and 22 of 2011. I also tried including a COVID-19 crisis dummy, which is equal to one on all days since the beginning of February (I also tried March) of 2020; it was excluded from the final specification, as its coefficient was insignificant.

IV-4. Estimation results

I estimated the three regression models using daily data. The sample starts from January 10, 2008, and ends on May 22, 2020 (this was the last day the value of the US Government Bond VIX was reported). I excluded weekends from the sample. If a certain variable was missing on other dates (due, for example, to a national holiday), I assumed that its value was unchanged from the last time it was observed.

In Table 1 (A), the dependent variable is JGBF. Focusing exclusively on monetary policy variables, a sharp decline on the day after the announcement of the QQE1 (April 5, 2013), and a sharp increase at the announcement of the NIRP are most noticeable. Monetary Policy Regime Dummies are all significant (note that they are all in comparison to the reference period, namely the pre-CE era).

In Table 1 (B), the dependent variable is BMVX. Among the Monetary Policy Date Dummies, we can see that the QQE1 had the effect of increasing the market volatility, with a few days delay. The NIRP also heightened volatility, while the announcement of the YCC1 reduced it. Moving on to the Monetary Policy Regime Dummies, the coefficient on the QQE1 regime dummy is negative. It seems that, although this policy enhanced market volatility at the outset, in the longer run, it had the effect of suppressing the anxiety. The QQE2 regime dummy is also negative. On the other hand, the coefficient on the NIRP regime dummy is insignificant. However, we should note that this means that volatility increased under this regime, if we compare it to the preceding eras of the QQE1/QQE2. Volatility diminishes drastically under the YCC1 regime. This effect weakens under the YCC2, but is still significantly negative.

Table 1 (C) is for the case of BMSL. Focusing on the Monetary Policy Regime Dummies, the slope became steeper under the QQE1, became a little less so under the QQE2, but

Table 1 OLS estimation results

(A) Dependent variable = JGBF (JGB futures prices in log differences)

	JGBF	
JGBF(-1)	0.0409*	(2.40)
JGBF(-2)	0.0574***	(3.48)
VXJ	0.0350***	(18.63)
VXJ(-1)	-0.0419***	(-16.70)
VXJ(-2)	0.00751***	(3.99)
JGBVIX	-0.258***	(-15.09)
JGBVIX(-1)	0.235***	(13.68)
Fed date 8/10/2010	0.0871	(0.39)
Fed date 5/22/2013	0.250	(1.11)
Fed date 3/23/2020	1.037***	(4.54)
MP date CE	0.182	(0.82)
MP date QQE1(4/4)	0.509*	(2.29)
MP date QQE1(4/5)	-1.287***	(-5.60)
MP date QQE1(4/8)	0.325	(1.44)
MP date QQE1(4/9)	0.348	(1.54)
MP date QQE2	-0.0473	(-0.21)
MP date NIRP	1.195***	(5.35)
MP date YCC1	-0.596**	(-2.67)
MP date YCC2	0.126	(0.57)
MP regime CE	-0.0347*	(-2.47)
MP regime QQE1	-0.0406**	(-2.58)
MP regime QQE2	-0.0435*	(-2.54)
MP regime NIRP	-0.0210	(-1.07)
MP regime YCC1	-0.0682***	(-3.83)
MP regime YCC2	-0.0657***	(-3.84)
EQ date 3/11	0.560*	(2.52)
EQ date 3/14	0.624**	(2.75)
EQ date 3/15	-0.387	(-1.66)
EQ date 3/16	-0.482*	(-2.08)
EQ date 3/17	0.0108	(0.05)
EQ date 3/18	0.584**	(2.58)
EQ date 3/21	-0.0898	(-0.40)
EQ date 3/22	0.169	(0.75)
Constant	0.0970***	(4.49)
Observations	3223	
Adjusted R-squared	0.178	

t statistics in parentheses

(Note) MP stands for Monetary policy, and EQ stands for Earthquake.

*p<0.05, ** p<0.01, ***p<0.001

(B) Dependent variable = BMVX

	BMVX	
BMVX(-1)	0.782***	(45.01)
BMVX(-2)	0.154***	(8.98)
JGBF	-0.00286***	(-14.46)
JGBF(-1)	-0.000990***	(-4.91)
JGBF(-2)	0.000351	(1.83)
JGBF(-3	0.000674***	(3.58)
JGBF(-4)	-0.000105	(-0.56)
US bond VIX(-1)	0.000285***	(5.71)
VXJ	0.000254***	(9.75)
VXJ(-1)	-0.000104**	(-3.28)
VXJ(-2)	-0.000116***	(-4.39)
VIX(-1)	-0.0000609*	(-2.17)
VIX(-2)	0.0000343	(1.11)
VIX(-3)	-0.0000221	(-0.81)
Fed date 8/10/2010	0.0163***	(6.34)
Fed date 5/22/2013	0.00285	(1.09)
Fed date 3/23/2020	0.00395	(1.49)
MP date CE	-0.000499	(-0.19)
MP date QQE1(4/4)	0.0000569	(0.02)
MP date QQE1(4/5)	-0.00148	(-0.57)
MP date QQE1(4/8)	0.0223***	(8.60)
MP date QQE1(4/9)	0.00471	(1.79)
MP date QQE2	-0.00115	(-0.45)
MP date NIRP	0.00822**	(3.19)
MP date YCC1	-0.0121***	(-4.72)
MP date YCC2	-0.000338	(-0.13)
MP regime CE	-0.000417*	(-2.51)
MP regime QQE1	-0.000719**	(-3.26)
MP regime QQE2	-0.000758***	(-3.51)
MP regime NIRP	-0.000309	(-1.13)
MP regime YCC1	-0.000899***	(-4.05)
MP regime YCC2	-0.000517*	(-2.43)
EQ date 3/11	-0.00222	(-0.87)
EQ date 3/14	0.0163***	(6.26)
EQ date 3/15	-0.00147	(-0.53)
EQ date 3/16	0.00385	(1.42)
EQ date 3/17	-0.00451	(-1.71)
EQ date 3/18	-0.0000364	(-0.01)
EQ date 3/21	0.00260	(0.99)
EQ date 3/22	0.000743	(0.29)
Constant	0.000516	(1.73)
Observations	3204	
Adjusted R-squared	0.967	

t statistics in parentheses

(Note) MP stands for Monetary policy, and EQ stands for Earthquake.
*p<0.05, ** p<0.01, ***p<0.001

(C) Dependent variable = BMSL

		BMSL	
BMSL(-1)		0.422***	(23.71)
BMSL(-2)		0.160***	(8.29)
BMSL(-3)		0.105***	(5.44)
BMSL(-4)		0.0318	(1.80)
BMVX		-0.0510***	(-5.13)
BMVX(-1)		0.00322	(0.25)
BMVX(-2)		0.0261**	(2.64)
Fed date	8/10/2010	-0.00245	(-1.61)
Fed date	5/22/2013	-0.00195	(-1.28)
Fed date	3/23/2020	-0.00376*	(-2.48)
MP date	CE	0.0000519	(0.03)
MP date	QQE1(4/4)	-0.00148	(-0.98)
MP date	QQE1(4/5)	-0.00216	(-1.43)
MP date	QQE1(4/8)	0.00214	(1.39)
MP date	QQE1(4/9)	-0.000551	(-0.36)
MP date	QQE2	0.0000424	(0.03)
MP date	NIRP	-0.000265	(-0.17)
MP date	YCC1	0.00343*	(2.25)
MP date	YCC2	-0.000180	(-0.12)
MP regime	CE	0.0000672	(0.71)
MP regime	QQE1	0.000657***	(5.70)
MP regime	QQE2	0.000438***	(3.62)
MP regime	NIRP	0.000727***	(5.03)
MP regime	YCC1	0.000421***	(3.42)
MP regime	YCC2	-0.000531***	(-4.47)
EQ date	3/11	0.000236	(0.16)
EQ date	3/14	0.00119	(0.78)
EQ date	3/15	-0.000527	(-0.35)
EQ date	3/16	-0.00155	(-1.02)
EQ date	3/17	-0.00178	(-1.17)
EQ date	3/18	0.000378	(0.25)
EQ date	3/21	0.0000389	(0.03)
EQ date	3/22	0.000620	(0.41)
Constant		0.00378***	(13.88)
Observations		3201	
Adjusted R-squared		0.674	

t statistics in parentheses

(Note) MP stands for Monetary policy, and EQ stands for Earthquake.

*p<0.05, ** p<0.01, ***p<0.001

became even steeper under the NIRP. This tendency is weakened under the YCC1 regime, and the coefficient on the YCC2 regime dummy is negative and significant.

IV-5. Visualizing the effects of monetary policy announcements and regimes

In an effort to grasp the quantitative impacts of the monetary policy variables visually, in Figure 10, I do the following exercises based on the regression results. I set the most of the coefficients in the regression models to equal zero. The exceptions are the lagged dependent variables, Monetary Policy Date Dummies, and Monetary Policy Regime Dummies. Their coefficients are set to be equal to the point estimates from the regressions. Setting the initial values of the dependent variables to be zero, I simulate how their values change over time.

Panel (A) is based on the regression results for JGBF. It falls sharply at the times of announcements of both the QQE1 and the YCC, and jumped up at the announcement of the NIRP.

In Panel (B), the dependent variable is BMVX. Volatility declines under the CE: however, this could be due to the fact that this happened to coincide with the period in which the economy was recovering from the devastating impact of the Global Financial Crisis. The QQE1, at the time of its introduction, enhanced volatility. However, after that, volatility subsides, including the period of the QQE2. Volatility increases massively due to the NIRP. The YCC1 contributes to reduce it, but it rises again under the YCC2.

Panel (C) is for BMSL. We can see that the QQE1 and the NIRP made the market participants wary of large downside risks. But this concern is reduced under the YCC1, and, under the YCC2, the left-side slope of the volatility smile curve is the smallest in our entire sample period.

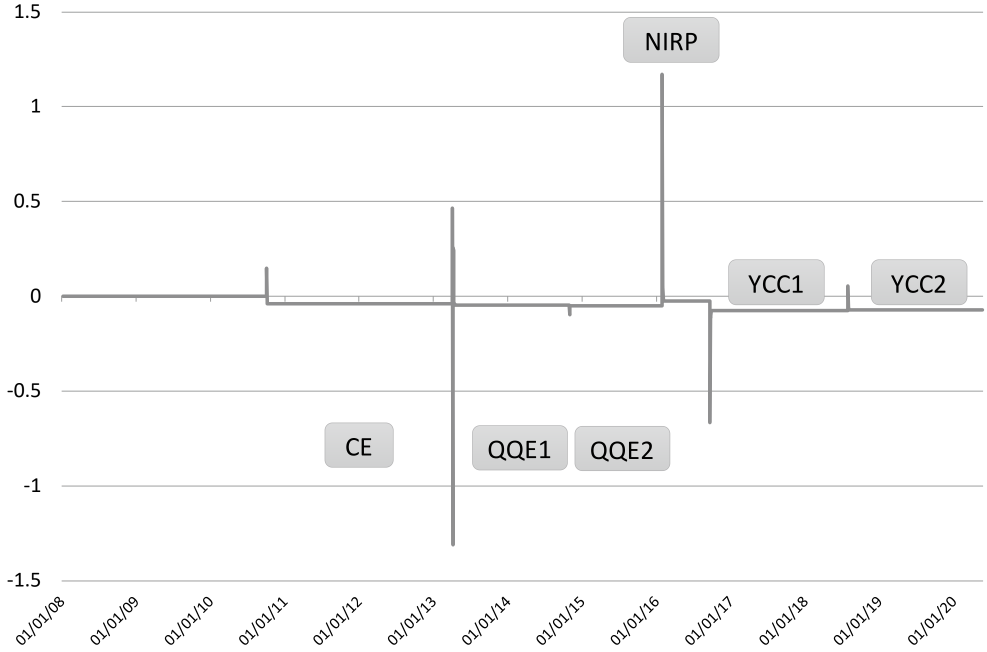
V. Conclusions

In this paper, I have studied how the Japanese monetary and fiscal policies have influenced the market participants' expectations about the future course of the JGB market. To that end, I estimated the daily (sometimes half-daily) evolution of the volatility smile curve, and examined determinants of its location and the slope, relying mainly on visual inspection of plots and graphs, but also using regression analyses. What has emerged from the study has been the overwhelming importance of monetary policy. In Japan, just prior to the COVID-19-induced crisis, thanks to the flexible implementation of the YCC, the market volatility was way down, and the market participants were apparently not much concerned for the risk of a collapse of the JGB prices. For that reason, the volume of options trading was extremely low. In such a situation, even if the market's concern for fiscal solvency had intensified, it would have been difficult to detect it from the asset market.

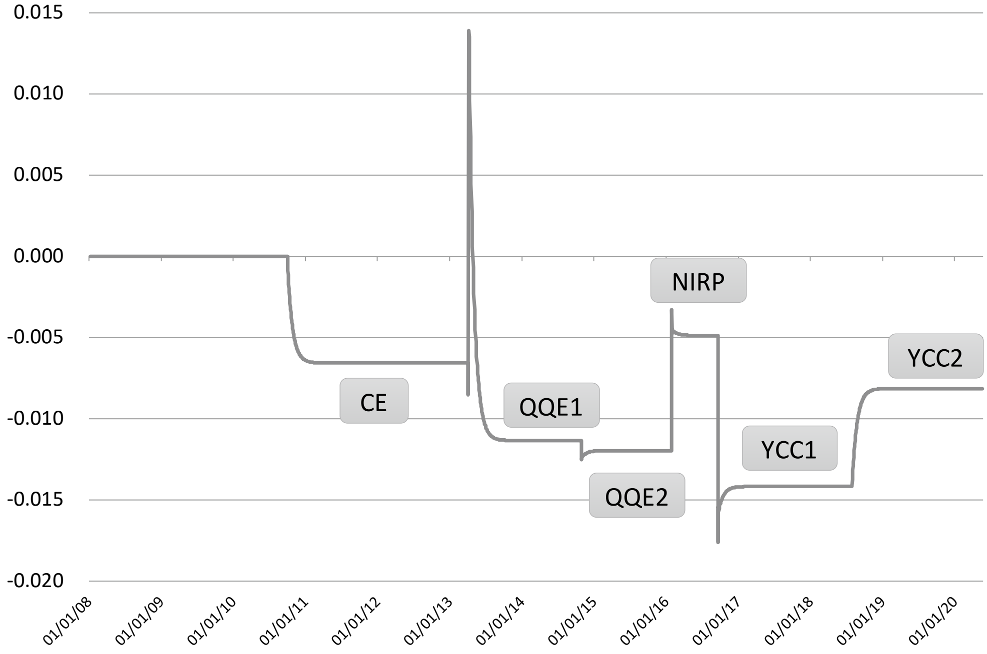
As stated in the main text, we could give a positive assessment to this policy regime, as the market anxieties were being suppressed very effectively. On the other hand, we could criticize it for rendering the asset prices' roles as signals meaningless. One would have to

Figure 10 Simulating the effects of Monetary Policy Date/Regime Dummies based on the OLS estimation results

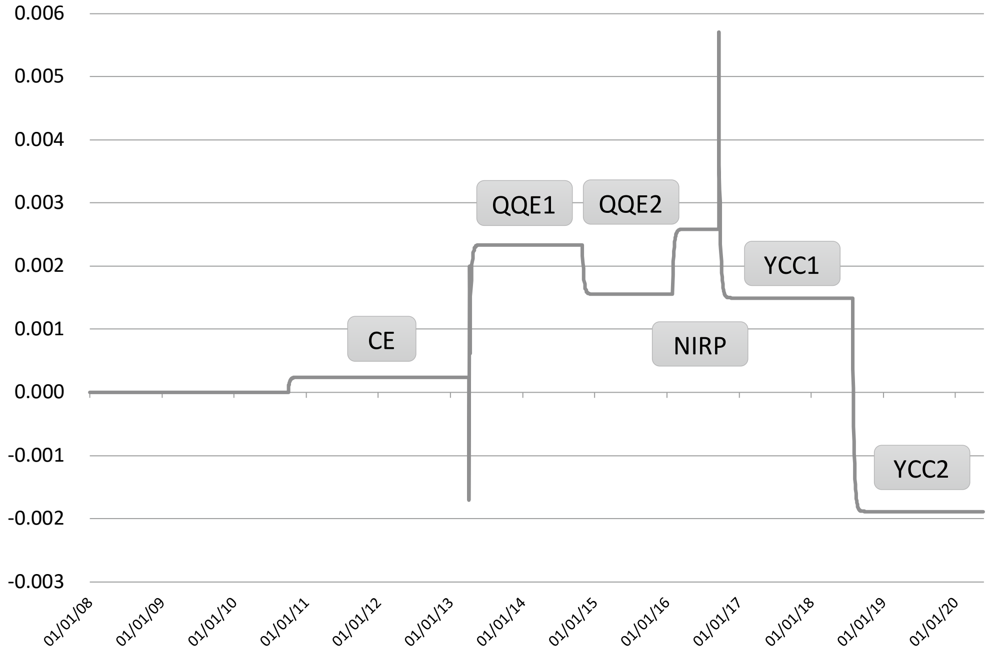
(A) Dependent variable = JGBF (in log differences)



(B) Dependent variable = BMVX



(C) Dependent variable = BMSL



have some theoretical framework to make a definitive evaluation. Developing such a framework would be an important topic for future research.

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