Term Structure of Japanese Treasury Bills under Different Regimes of non-Traditional Monetary Policy

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Abstract

When the BOJ (Bank of Japan) adapted a quantitative and qualitative easing policy, zero bound restriction existed. The notion of market practitioners that the BOJ would not adapt a negative interest rate policy gave a less volatilities in the TB (Treasury Bill) market in comparison with a regime of a negative interest rate policy. After the BOJ decided to adapt a negative interest rate policy, zero bound restriction was lifted. The market practitioners expected that the policy rate decided by the BOJ might be lowered. The expectation gave a room for TB yields to be moving more than before. This expectation caused more volatilities in the TB market under the regime of a negative interest rate policy than a quantitative and qualitative easing policy. This is why TB yield curve under a negative interest rate policy is driven by a single common trend with mutual causalities in all maturities. In other words, normal transmission function of TB yield curve recovered by the introduction of "a negative interest rate policy".

Keywords: Negative Interest Rate, Quantitative and Qualitative Easing, Treasury Bill, Yield Curve

JEL Classifications:E43, G12

1.Introdcution

The BOJ (Bank of Japan) adopted a quantitative and qualitative easing policy during the period from April 4, 2013 to January 28, 2016, as mentioned in BOJ (2013). The pillars of a quantitative and qualitative easing policy are as follows: "(1) The adoption of the monetary base control, (2) An increase in JGB (Japanese Government Bond purchases and their maturity, (3) An increase in

ETF (Exchange Traded Fund) and J-REIT (Real estate Investment Fund) purchases, (4) A continuation of quantitative and qualitative monetary easing to achieve the price stability target of 2 percent".

The BOJ adopted a negative interest rate policy from January 29, 2016. This policy is not included in the classification proposed by Bernanke and Reinhart (2004). The Danish central bank introduced the first negative interest rate policy in the world in July 5, 2012. According to the BOJ (2016a), "they apply a negative interest rate of minus 0.1 percent to the policy-rate balances in current accounts held by financial institutions at the Bank. They purchase JGBs so that 10-year JGB yield remains more or less at the current level (around zero percent)".

This paper analyzes the yield curve of TB (Treasury Bills) under different regimes of non-traditional monetary policy in Japan. It refers to a quantitative and qualitative easing policy and a negative interest rate policy. This paper is the first one to analyze the term structure of Treasury Bills under a quantitative and qualitative easing policy and a negative interest rate policy in Japan. In addition to that, it makes comparative analyses between two regimes. This paper has great originalities over related studies mentioned below.

Related studies, such as Andresen (2015), Jackson (2015), Arteta et al. (2016), Bech and Malkhozov (2016), Turk (2016), Ito (2017), and Ito(2019) analyze short- term markets under non-traditional monetary policies such as negative interest rate policy.

Andresen (2015) concludes that "the reduction of the certificate of deposit (CD) rate has increased the spread between the current account rate and the CD rate and thus the scope for fluctuations in overnight money market rates in Denmark". Jackson (2015) outlines "the concerns associated with negative interest rates, provides an overview of the international experience with negative policy rates so far, and sets out some general observations based on this experience".

Arteta et al. (2016) report that "monetary transmission channels under a negative interest rate policy are conceptually analogous to those under a conventional monetary policy, but a negative interest rate policy presents complications that could limit policy effectiveness". Bech and Malkhozov (2016) conclude that, "for the most part, modestly negative policy rates transmit through to money markets and other interest rates in the same way as positive rates do". Turk (2016) analyzes the profitability of Danish and Swedish banks under a negative interest rate policy. Ito (2017) concludes that "in Denmark, monetary policy expectations have some impact on the interbank interest rates in the maturities of one, three, and six months".

Ito (2019) analyzes the yield curve of interbank interest rates in the maturities of three, six, nine, and twelve months under different regimes of non-traditional monetary policy. It concludes that "monetary policy expectations are not fully transmitted to the yield curve end of the short-term money market under a quantitative and qualitative easing policy or a negative interest rate policy".

2. Data

Daily data of TBs with maturities of three, six and twelve months provided by a major Japanese security company are used for the analyses. The entire sample period is from April 4, 2013 to January 10, 2023. It is divided into two sub sample periods. The first period from April 4, 2013 to January 28, 2016 is named Sample A. The BOJ adapted a quantitative and qualitative easing policy. The second period from January 29 2016 to January 10, 2023 is Sample B. They adapted a negative interest rate policy. The movements of TB yields are shown in Figure 1. The descriptive statistics are provided in Table 1.

Figure 1

Table 1

3.Methodology

3.1. Unit Root Test

"The Augmented Dickey-Fuller (ADF) test" and the "Kwiatowski-Phillips-Schmidt-Shin (KPSS) test" are used. According to Dickey and Fuller (1979, 1981), "the ADF test defines the null hypothesis as unit roots exist and the alternative hypothesis as unit roots do not exist." Fuller (1976) provides a table for the ADF test. According to Kwiatkowski. et al (1992), "the KPSS test defines the null hypothesis as unit roots do not exist and the alternative hypothesis as unit roots exist." As conducted in Ito (2019), "first, the original data are checked to verify whether they contain unit roots". "Next, the data with first difference are analyzed to determine whether they have unit roots to confirm that they are I (1) process"

3.2. Johansen Cointegration Test

As described in Ito (2019), “the Johansen cointegration test is applied in the way detailed below after it is confirmed that the data used for analysis are non-stationary I (1) variables”. Johansen (1988) suggests “an analysis with the *k* order VAR model”. Here, “the VAR model is presented with *k* order against vector X_t with *p* variables”. Trace and maximal eigen value tests are conducted to analyze Treasury Bills in the maturities of three, six, 12 months. The critical values at the 5% level provided by Osterwald-Lenum (1992) are used.

$$X_t = \Pi_1 X_{t-1} + \ldots + \Pi_k X_{t-k} + \lambda + u_t \qquad (1)$$

According to Johansen (1988), “all the *p* elements of X_t are considered to be I (1) variables. u_t is an error term with a zero mean. λ is a constant term”.

As Stock and Watson (1988) shows, “an alternative interpretation of the cointegration among yields of different maturities arises from the relationship between cointegration and common trends”. They conclude that “when there are ($n-p$) linearly independent cointegration vectors for a set of *n* I (1) variables, then each of these *n* variables can be expressed as a linear combination of *p* I (1) common trends and ($n-p$) I (0) components”.

Applying the result to this study, Stock and Watson (1988) mentions that “there will be a couple of non-stationary common trends in the yield curve of different maturities”. Hall et al.’s (1992) work is relevant to this part of the analysis. They conduct “the Johansen cointegration test using the monthly data of the US Treasury bill data (11 series: one month through to 11 months) from 1970 through to 1988”. They find that “the entire series comprises 10 cointegration vectors and one common trend”. They also mention that “denoting the I (1) common trends by $W(t_1)$ … $W(t_n)$, a simple representation of how they link the yield curve is given by

$$R(1,t) = A(1,t) + b_1 W(t_1)$$
$$R(2,t) = A(2,t) + b_2 W(t_1) + b_2 W(t_2)$$
$$\ldots\ldots..$$
$$R(n,t) = A(n,t) + b_n W(t_1) + b_n W(t_2) \ldots . b_n W(t_n),$$

where $A(i,t)$ are I (0) variables”. Since $W(t_n)$ is I (1) and $A(i,t)$ are I (0), the observed long-run movement in each yield is mainly due to the common trend(s). Stock and Watson (1988) conclude that "$W(t_n)$ drives the time-series behavior of each yield and determines how the entire yield curve changes over time". According to Hall et al.'s (1992), "$W(t_n)$ is considered as something exogenous to the yield curve system". As to Ito (2019) points out, "when a single trend is found by the Johansen cointegration test, the yield curve is assumed to be moving as a result of a single trend caused by monetary policy expectations".

5.3. Granger Causality Test

Granger causality tests are applied to investigate the causalities among three TB yields. Following Toda and Yamamoto (1995), "the original data are usually transformed into the change ratio to avoid the problem of spurious regression, but using these data is considered to cause an error". They developed the Granger causality test in which non-stationary data are used directly.

According to their method, "the null hypothesis is tested by adding trend term t and p + 1 (original lag plus one) for the estimation of the three equations mentioned below". As outlined below, these three equations are used to test four TB yields: for example, equation (2) shows whether the TB yields of six, and twelve Granger-cause the TB yields of three month. The akaike information criterion (AIC) standard is used for the original number of lags.

$$TB\ \ three\ \ M = \kappa_0 + \lambda t + \sum_{i=1}^{p+1} \alpha_i TB\ \ six\ \ M_{t-1} + \sum_{i=1}^{p+1} \beta_i TB\ \ twelveM_{t-1} + u_t \quad (2)$$

$$TB\ \ six\ \ M = \kappa_0 + \lambda t + \sum_{i=1}^{p+1} \alpha_i TB\ \ three\ \ M_{t-1} + \sum_{i=1}^{p+1} \beta_i TB\ \ twelveM_{t-1} + u_t \quad (3)$$

$$TB\ \ twelve\ \ M = \kappa_0 + \lambda t + \sum_{i=1}^{p+1} \alpha_i TB\ \ one\ \ M_{t-1} + \sum_{i=1}^{p+1} \beta_i TB\ \ six\ \ M_{t-1} + u_t \quad (4)$$

4.Results

4.1 Unit Root Test

First, ADF and KPSS tests are conducted on original series of both Samples A and B. The results of ADF tests without trend show that original series have unit roots. On the other hand, the results of ADF tests with trend show that original series do not contain unit root. The results of KPSS level and trend stationarities tests indicate that original series have unit roots. Considering both results, it is safe to regard original series have unit roots to avoid a problem of spurious regression as mentioned in Granger and Newbold (1974). Results are shown in Tables 2 and 3.

Table 2

Table3

Next, ADF and KPSS tests are conducted on first differenced series. All results of ADF and KPSS tests show that first differenced series do not have unit roots. It can be concluded that all data used for the analyses are non-stationary I (1) variables. Results are shown in Tables 4 and 5.

Table 4

Table 5

4.2 Johansen Cointegration Test

Johansen cointegration tests are applied on the original series of both Samples A and B. The results of Sample A show that the series have one cointegration vector and two common trends. On the other hand, the results of Sample B show that the series have two cointegration vectors and one common trend. As Ito (2019) points out, "when a single trend is found by the Johansen cointegration test, the entire yield curve is assumed to be moving as a result of a single trend". TB yield curve of Sample A is driven by two common trends, but TB yield curve of Sample B is driven by a single common trend. It is something exogenous to yield curve. It is caused by a monetary policy expectation. The results are shown in table 6.

Table 6

4.3 Granger Causality Test

Granger causality tests developed by Toda and Yamamoto (1995) are conducted on the original series of both Samples A and B. The results of Sample A show that there are mutual causalities except for from TB of one month to TB of six months. On the other hand, the results of Sample

B show that there are mutual causalities in all maturities. The yield curve of Sample A is driven by mutual causalities except for from three-month TB to six-month TB. But the yield curve of Sample B is driven by mutual causalities in all maturities. The results are shown in table 7

Table 7

5.Conclusion

This paper analyzes the yield curve of TBs under Different Regimes of non-traditional monetary policy in Japan. The maturities of TBs are three, six, and twelve months. Non-traditional monetary policy refers to a quantitative and qualitative easing policy and a negative interest rate policy. TB yield curve under a quantitative and qualitative easing policy is driven by two common trends with mutual causalities except for from three- to six- month TB. But TB yield curve under a negative interest rate policy is driven by a single common trend with mutual causalities in all maturities.

When the BOJ adapted a quantitative and qualitative easing policy, zero bound restriction existed. The notion of market practitioners that the BOJ would not adapt a negative interest rate policy gave a less volatilities in the TB market in comparison with a regime of a negative interest rate policy. After the BOJ decided to adapt a negative interest rate policy, zero bound restriction was lifted. The market practitioners expected that the policy rate decided by the BOJ might be lowered. The expectation gave a room for TB yields to be moving more than before.

This expectation caused more volatilities in the TB market under the regime of a negative interest rate policy than a quantitative and qualitative easing policy. This is why TB yield curve under a negative interest rate policy is driven by a single common trend with mutual causalities in all maturities. In other words, normal transmission function of TB yield curve recovered by the introduction of a negative interest rate policy

This paper analyzes only TB market in Japan. There is a room to expand this research to other countries with an experience of a negative interest rate policy.

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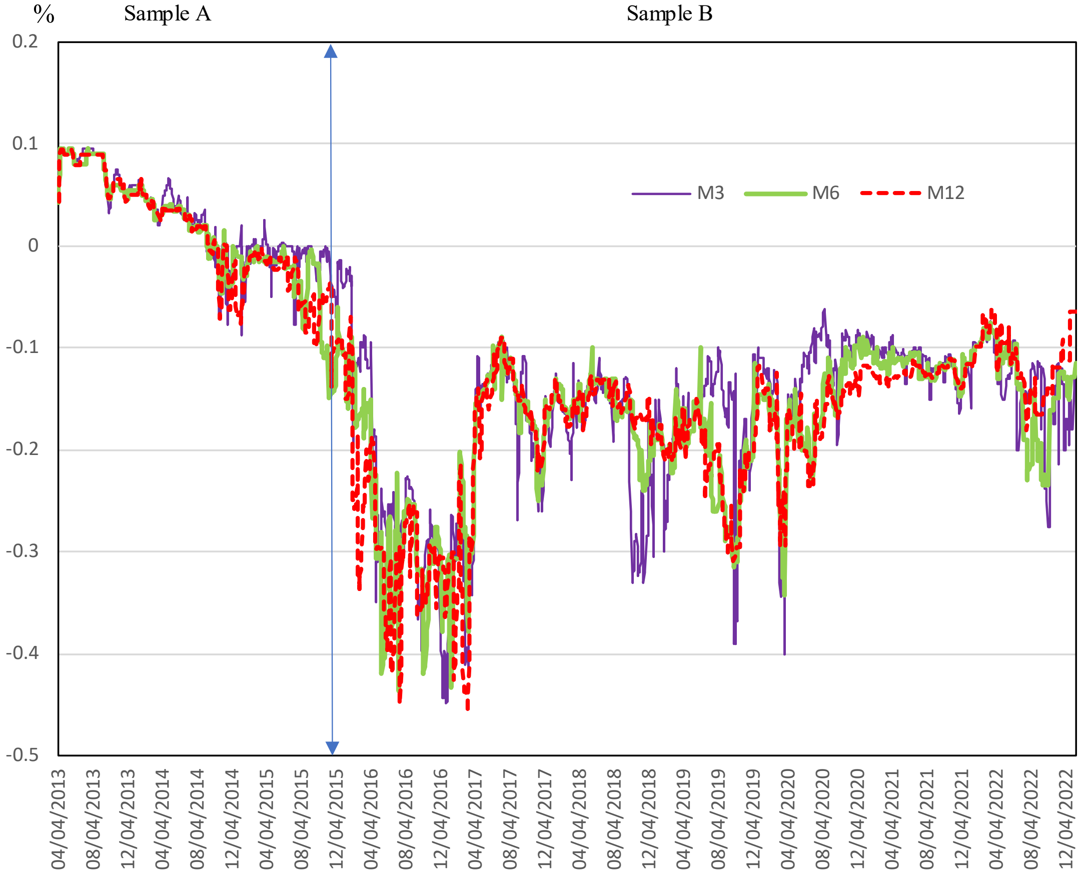
Figure 1 Movement of Tresury Bills



Notes: Sample A is from April 4, 2013 to January 28, 2016.
Sample B is from Januray 29, 2016 to Januray 10, 2023.
Data are provided by a major Japanese security company.

Table 1 Descriptive statistics

Variable	Average	SD	Min	Max	Median
Sample A					
M3	0.02	0.04	-0.09	0.10	0.02
M6	0.01	0.06	-0.16	0.10	0.02
M12	0.01	0.06	-0.15	0.10	0.02
Sample B					
M3	-0.17	0.08	-0.45	-0.06	-0.14
M6	-0.18	0.07	-0.44	-0.08	-0.16
M12	-0.18	0.08	-0.46	-0.06	-0.16

Notes: Sample A is from April 4, 2013 to January 28, 2016.
Sample B is from Januray 29, 2016 to Januray 10, 2023.

Table 2 ADF test - original series

Variable	Without Trend	With Trend
Sample A		
M3	-1.872	-4.509*
M6	-1.200	-4.777*
M12	-0.486	-3.162*
Sample B		
M3	-1.916	-5.756*
M6	-1.289	-4.122*
M12	-1.403	-4.597*

Notes : * indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend) and -3.41(With Trend） .
Sample A is from April 4, 2013 to January 28, 2016.
Sample B is from Januray 29, 2016 to Januray 10, 2023.

Table 3 KPSS test - original series

	Lag=4		Lag=12	
Variable	η_μ	η_τ	η_μ	η_τ
Sample A				
M3	11.727*	1.048*	4.703	0.500*
M6	11.695*	0.517*	4.639*	0.231*
M12	12.374*	0.274*	4.914*	0.135*
Sample B				
M3	10.249*	0.643*	4.217*	0.272*
M6	10.544*	0.995*	4.219*	0.406*
M12	14.150*	1.380*	5.660*	0.566*

Notes: * indicates significance at the 5 % level.
5% critical values are 0.463(level stationary), 0.146 (trend stationary).
$\eta_\mu$indicates level stationarity. η_τ indicates trend stationarity.
Sample A is from April 4, 2013 to January 28, 2016.
Sample B is from Januray 29, 2016 to Januray 10, 2023.

Table 4 ADF test - first differenced series

Variable	Without Trend	With Trend
Sample A		
ΔM3	-10.057*	-24.907*
ΔM6	-9.605*	-12.567*
ΔM12	-11.587*	-28.107*
Sample B		
ΔM3	-7.854*	-24.728*
ΔM6	-9.578*	-12.564*
ΔM12	-7.904*	-27.833*

Notes : * indicates significance at the 5 % level.

5% critical values are -2.86(Without Trend) and -3.41(With Trend）.

Sample A is from April 4, 2013 to January 28, 2016.

Sample B is from Januray 29, 2016 to Januray 10, 2023.

Table 6 Johansen cointegration test

Null	Alternative	Test Statistics	5% Critical Value	Test Statistics	5% Critical Value
Sample A		Maximal Eigenvalue Test		Trace Test	
r = 0	r = 1	24.159*	22.00	41.338*	34.91
r ≦ 1	r = 2	14.105	15.67	17.178	19.96
r ≦ 2	r = 3	3.07	9.24	3.073	9.24
Sample B					
r = 0	r = 1	103.927*	22.00	160.685*	34.91
r ≦ 1	r = 2	49.048*	15.67	56.759*	19.96
r ≦ 2	r = 3	7.711	9.24	7.711	9.24

Notes: * indicates significance at 5 % level.

Critical values are cited from Osterwald-Lenum (1992).

Sample A is from April 4, 2013 to January 28, 2016.

Sample B is from Januray 29, 2016 to Januray 10, 2023.

Table 7 Granger causality test

Variables	Test Statistics	Variables	Test Statistics
Sample A		Sample B	
M3 → M6	1.103	M3 → M6	4.356*
M3 → M12	2.850*	M3 → M12	8.057*
M6 → M3	2.365*	M6 → M3	7.677*
M6 → M12	2.860*	M6 → M12	11.357*
M12 →M3	2.405*	M12 →M3	3.466*
M12 →M6	4.460*	M12 →M6	11.568*

Notes: * indicates significance at the 5 % level.
As for the number of lags, one is added to AIC selection.
Sample A is from April 4, 2013 to January 28, 2016.
Sample B is from Januray 29, 2016 to Januray 10, 2023.