

Scarcity and Spotlight Effects on Term Structure: Quantitative Easing in Japan

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Motivation

- ▶ We examine the impacts of the central bank's purchases on liquidity as well as yield in the sovereign bond market.
 - ▶ How the term-structures of liquidity and yield are affected?
- ▶ Since the scale of the Quantitative Easing (QE) programs conducted by the Bank of Japan is unprecedented in terms of purchasing amount and broad coverage, we can observed the impacts on individual bonds (JGBs) which include long-term to short-term, on-the-run and off-the-run so on.
(Monthly purchase amount / Outstanding = 1.30%)

Outstanding amounts and BoJ's holding ratio

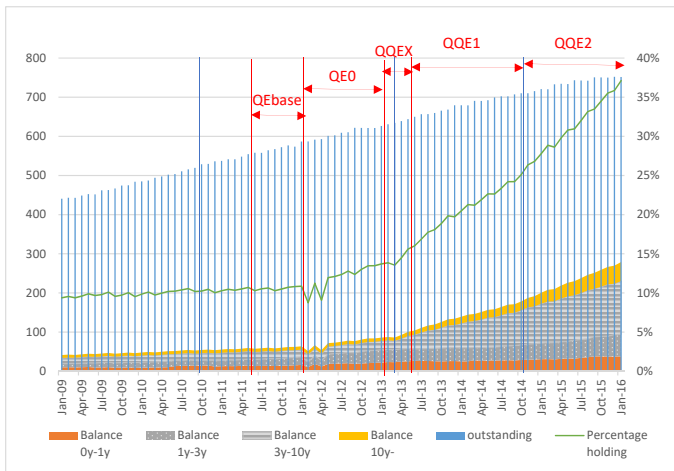


Figure 1: Outstanding amounts and BoJ's holding amounts of nominal JGBs in trillions of yen. The green line is BoJ's holding ratio.

Change in liquidity term structure

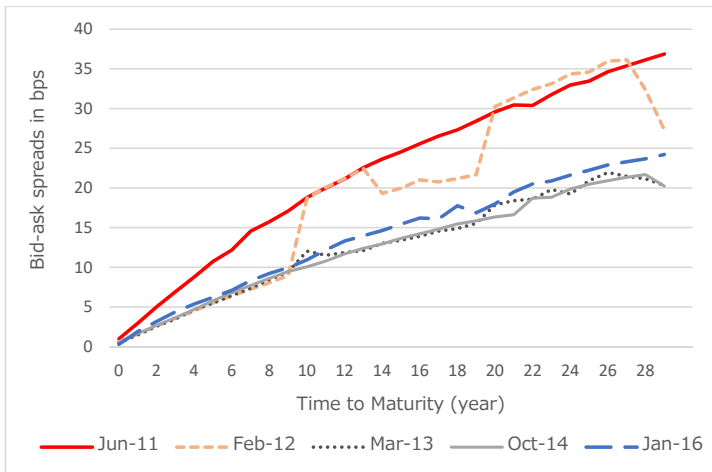
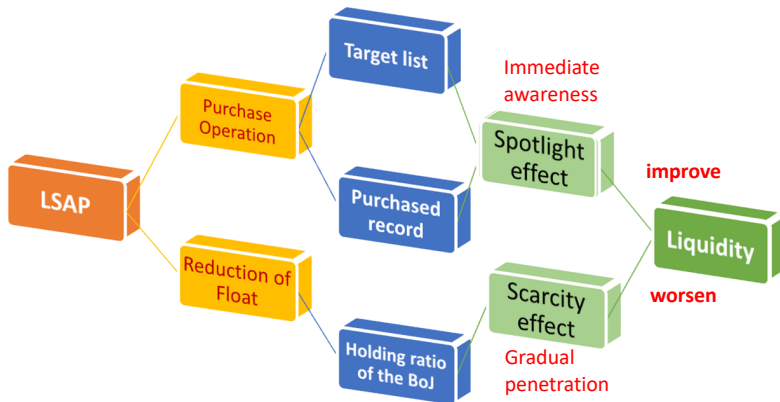


Figure 2: Liquidity term structure of the bid-ask spread

Scarcity effect and spotlight effect

- ▶ We consider two opposing effects of the BoJ's purchases.
- ▶ “Scarcity effect”
which results from the reduction in liquidity as a consequence of shrinkage in the available bonds in the market.
- ▶ “Spotlight effect”
which causes an improvement in liquidity, arising from focusing attention on individual bonds selected for purchase by the central bank.

Effect chart of liquidity



Effect on bond yield

- ▶ Due to massive demand from the BoJ, purchase operations should lead to a decline in the yield. (Spotlight effect)
- ▶ Increasing scarcity should be a discounting factor for the bond price. (Scarcity effect)

Research issues and hypotheses

1. Since the spotlight effect at the macro level is stronger than the scarcity effect, QE, on average, induces an improvement in liquidity.
2. Liquidity is higher on reverse auction days because bond spotlight effects, captured by inclusion in the target list or the purchase of a particular bond, decrease the bid–ask spread.
3. The scarcity of bonds increases illiquidity, which is accentuated when there is a scarcity of even substitutable bonds, such as those with similar maturity.
4. Bond yields are lower on reverse auction days because of bond spotlight effects, captured by inclusion in the target list or purchase of a particular bond, which raise bond prices.
5. Bond yields across bonds are lower due to the spotlight effect, which is mitigated by greater bond illiquidity (scarcity).

Contributions

- ▶ We address explicitly the spotlight effect created by the central bank's purchase program.
- ▶ We investigate how the scarcity of net available bonds affects bond market illiquidity.
 - ▶ From the cross-sectional analysis, an improvement in liquidity is shown through the spotlight effect and a deterioration in liquidity is observed through the scarcity effect.
 - ▶ As for the yield, both the spotlight effect and scarcity effect work in the same direction.
- ▶ We explore the effects of the BoJ's purchases bond-by-bond categorized by three bond life stages.

Literature

1. Term structure of liquidity
Goyenko et al. (2011), Krishmurthy (2002), Amihud and Mendelson (1991)
2. Channels (scarcity, duration risk, signaling, . . .)
Vayanos and Vila (2009), D'Amico et al. (2012)
3. Scarcity
Blattner and Joyce (2016), Joyce and Tong (2012)
4. Spotlight effect of stock market
Harris and Gruel (1986), Beneish and Gardner (1995), Beneish and Whaley (1996)
5. The BoJ's QQE
Iwatsubo and Taishi (2017), Fukunaga et al. (2015)
6. Empirical method
Friewald et al. (2012)

Our Sample Period

To make a comparative study, samples are split into five periods.

QEbase	6/1/2011 to 1/31/2012	8 months
QE0	2/1/2012 to 2/27/2013	13 months
QQEX	2/28/2013 to 5/31/2013	3 months
QQE1	6/1/2013 to 10/30/2014	17 months
QQE2	10/31/2014 to 1/28/2016	15 months

Data

- ▶ Sample: Nominal Japanese Government Bond
2-, 5-, 10-, 20-, 30- and 40-year bonds
- ▶ Data source:
 - ▶ Bloomberg: bid and ask price, last price (end of day quotes), macro indices
 - ▶ Bank of Japan: holding amount of JGBs, purchase operation
 - ▶ Ministry of Finance: auction of newly issued JGBs
 - ▶ Reuters news and Nikkei news: Target list
 - ▶ Quick: macro indices

Spotlight variables

$ftarget_{n,t}$: First target dummy, which equals one when security n is targeted the first time at time t

$target_{n,t}$: Target dummy, which equals one when security n is targeted for the second or later time at time t

$purchased_{n,t}$: Amount purchased in the previous auction of targeted security n as a percentage of its amount outstanding

Scarcity variables

$$h_{n,t} = \frac{H_{n,t}/O_{n,t}}{\sum_n H_{n,t}/\sum_n O_{n,t}} \quad (1)$$

where $O_{n,t}$ is outstanding amount of security n and $H_{n,t}$ is the amount of security n held by the BoJ at time t .

$$sh_{n,t} = \frac{sH_{n,t}/sO_{n,t}}{\sum_n H_{n,t}/\sum_n O_{n,t}} \quad (2)$$

where $sO_{n,t}$ is defined as the outstanding of all bonds with remaining maturities of between $u - 1$ and $u + 1$ years if the remaining maturity τ of security n satisfies $u < \tau \leq u + 1$, where $u = 0, 1, \dots, 40$. The BoJ's holding substitutes $sH_{n,t}$ is defined in the similar way.

Empirical analysis of liquidity

We investigate the market liquidity by three empirical analyses.

1. Overall impact of the periods on liquidity (Welch two sample t test)
2. Time-series analysis of the spread change
3. Cross-sectional analysis of bid–ask spread (level)

1.0 Overall impact of the QQE periods on liquidity

- ▶ We test the overall impact on liquidity by comparing the average bid–ask spread period by period.
- ▶ We perform Welch two-sample t -test.

1.1 Differences in the bid–ask spreads for two sample periods

We test the overall impact on liquidity by comparing the average bid–ask spread period by period.

		QE0	QEX	QEQ	QEQ
0–1 y	QEbase	–0.028 **	–0.304 ***	–0.096 ***	–0.020
1–3 y		–0.409 ***	–0.516 ***	0.033	0.090 ***
3–10 y		1.177 ***	–1.865 ***	2.048 ***	–0.702 ***
10 y-		–7.184 ***	–11.114 ***	–11.482 ***	–10.323 ***
0–1 y	QE0		–0.276 ***	–0.068 ***	0.008
1–3 y			–0.106 ***	0.443 ***	0.500 ***
3–10 y			–3.042 ***	0.871 ***	–1.879 ***
10 y-			–3.930 ***	–4.298 ***	–3.139 ***
0–1 y	QEX			0.208 ***	0.284 ***
1–3 y				0.549 ***	0.606 ***
3–10 y				3.913 ***	1.163 ***
10 y-				–0.368 ***	0.792 ***
0–1 y	QEQ				0.076 ***
1–3 y					0.057 **
3–10 y					–2.750 ***
10 y-					1.159 ***

Table 1: Differences in the bid–ask spreads for two sample periods

1.2 Results of the difference test

- ▶ Comparisons with the preceding period confirm that the improvements in liquidity are observed in the former two periods and deteriorations are observed in latter two periods.
- ▶ There is a largest reduction of the spread for bonds with a maturity longer than 10 years throughout four periods.
- ▶ This indicates aggressive purchase of longer-term bonds by the BoJ. These results are consistent with the BoJ shifting toward longer-maturity bonds in the QQE periods.

2.0 Regression model for spread change

- ▶ We examine spotlight effects on time-series liquidity innovation through daily changes in bid–ask spreads.
- ▶ Our time-series specification is determined by conducting a panel regression with bond fixed effects.
- ▶ We investigate whether the inclusion in an auction target list or actual purchase tightens the bid–ask spread.
- ▶ We consider the following regression model of change in spread:

2.1 Regression model for spread change

$$\begin{aligned}
 \Delta sprd_{n,t,t-1} = & \alpha + \sum_i \beta_i S\ potlight_{n,t}^i + \sum_j \gamma_j Lagged_{n,t-1}^j + \sum_k \theta_k Macro_i^k \\
 & + \sum_l \kappa_l Newly_{n,t}^l + \sum_m \lambda_m Control_{n,t}^m + \epsilon_{n,t}
 \end{aligned} \tag{3}$$

where

- $\Delta sprd_{n,t,t-1}$: Daily change in bid–ask spread
- $S\ potlight$: $target_{n,t}$, $f\ target_{n,t}$ and $purchased_{n,t}$
- $Lagged$: Spread change lagged and yield change lagged
- $Newly$: Amount of the substitutes being newly issued at $t - 1, t, t + 1$
- $Macro$: Change in TOPIX, global bonds and JGB VIX, Dummy of Fed and ECB announcement dates
- $Control$: Program announcement date, drop and first drop dummies remaining time to maturity τ and τ^2

2.2 Time-series regression of change in bid-ask spread

Hypothesis1 Since the spotlight effect at the macro level is stronger than the scarcity effect, QE, on average, induces an improvement in liquidity.

Hypothesis2 Liquidity is higher on reverse auction days because bond spotlight effects, captured by inclusion in the target list or the purchase of a particular bond, decrease the bid-ask spread.

		QEbase	QE0	QQEX	QQE1	QQE2
Spotlight	Target	-0.3967 (-1.37)	-0.0254 (-0.26)	0.1725 (0.37)	0.0647 (0.57)	0.0059 (0.04)
	Targeted the first time	-0.9702 * (-1.75)	-0.1639 (-0.92)	1.9551 *** (2.92)	-0.1785 (-1.23)	-0.1161 (-0.42)
	Purchased	0.0589 (1.38)	0.0036 (0.42)	0.0031 (0.10)	-0.0098 (-1.22)	-0.0398 * (-1.75)
Lagged	Change in yield lagged	-0.0843 (-0.92)	0.0116 (0.43)	-0.0083 (-0.25)	-0.0326 (-1.24)	-0.0039 (-0.09)
	Change in spread lagged	-0.4983 *** (-9.75)	-0.4429 *** (-9.69)	-0.4832 *** (-4.25)	-0.4561 *** (-11.42)	-0.4734 *** (-20.96)

2.2 Time-series regression of change in bid-ask spread

		QEbase	QE0	QQEX	QQE1	QQE2
Macro	TOPIX change	0.0117	-0.0663	0.0587	0.0039	0.0841
	US and Germany bond change	-0.9219	-1.8398	-1.7217	-1.3223	1.6991
	JGB VIX change	1.7856 **	0.1080	-0.4615 *	0.1768	0.1117
	Fed announcement date (-)	0.0357	0.1646	0.3070	0.0477	-0.6221 ***
	Fed announcement date (+)	-0.6432	0.9432	-0.0883	-0.6024	-0.0197
	ECB announcement date (-)	-1.4531 ***	0.3749 **	-0.0219	0.1404	-0.9527 ***
	ECB announcement date (+)	0.3902	0.1934	2.2428 **	-0.1746	-0.0838
Newly	Newly issued (issue date)	0.0533	0.0112	0.0129	-0.0518 **	0.0042
	Newly issued (day before the issue)	0.0001	0.0286	-0.0012	-0.0024	0.0003
	Newly issued (day after the issue)	-0.0272	-0.0715	0.0095	0.0185	-0.0243
Control	Program announcement	-0.0071	0.1806	1.0819 ***	NA	-2.7667 ***
	Drop	-0.2939	0.0793	0.3010 *	0.0175	-0.1736
	Dropped the first time	-0.2193	-0.0673	0.1234	-0.3401 *	0.2950
	<i>t</i> _{tm}	-0.1688	0.1287	-0.7356	0.0430	0.0050
	<i>t</i> _{tm} ²	0.0218	0.0003	0.0461	0.0003	0.0010
	Observations	41798	70437	16901	93709	82143
Adjusted R ²	0.2513	0.1953	0.2255	0.2062	0.2242	

Table 2: Regression of the spread change with bond-fixed effect.

2.3 Results of regression for the yield change

The significances of Table 2 are calculated from two two-way cluster robust standard errors.

- ▶ The coefficients for *f_{target}* and *target* in QEbase and QE0 are estimated with a negative sign, but they are insignificant at the 5% level.
- ▶ The coefficients for *f_{target}* and *purchased* in QQE1 and QQE2 are estimated with negative sign, but they are insignificant at the 5 % level.
- ▶ We don't find supporting evidence on Hypothesis2 from the time-series analysis.
- ▶ Program announcement at QQE2 shows the largest improvement in liquidity (−2.77 bps).

3.0 Cross-sectional regression model for spread

$$\begin{aligned}
 sprd_{n,t} = & \alpha + \sum_i \beta_i S potlight_{n,t}^i + \sum_j \gamma_j S carcity_{n,t}^j \\
 & + \sum_k \theta_k Control_{n,t}^k + \epsilon_{n,t}
 \end{aligned} \tag{4}$$

where

$sprd_{n,t}$: Bid–ask spread percentage

$S potlight$: $target_{n,t}$, $ftarget_{n,t}$ and $purchased_{n,t}$

$S carcity$: Relative holding ratio $h_{n,t}$ and those of substitutes' $sh_{n,t}$

$Control$: Drop and first drop dummies, coupon, the logarithm of outstanding $lnO_{n,t}$, τ and τ^2

We run the regression with daily time dummies for each period.

3.1 Cross-sectional regression

Hypothesis2 Liquidity is higher on reverse auction days because bond spotlight effects, captured by inclusion in the target list or the purchase of a particular bond, decrease the bid–ask spread.

Hypothesis3 The scarcity of bonds increases illiquidity, which is accentuated when there is a scarcity of even substitutable bonds, such as those with similar maturity.

		QEbase	QE0	QQEX	QQE1	QQE2
Spotlight	<i>target</i>	0.3952	0.7259 **	1.0320 **	0.9020 ***	0.1657
	<i>ftarget</i>	-1.2964 **	-0.2763	1.7345	2.1848 ***	0.0418
	<i>purchased</i>	-0.0481	-0.1829 ***	-0.0411	-0.0871 **	-0.0354 **
Scarcity	<i>h</i>	0.4805 ***	2.0204 ***	0.3870 ***	1.5225 ***	0.3293 ***
	<i>sh</i>	3.5080 ***	-1.4294 *	-0.4808 ***	2.2008 *	0.4621 ***
Control	Dropped	0.5772	0.0548	0.3284	-0.4948	-0.0768
	Dropped the first time	0.9506	-1.1820	0.1408	0.3904 **	-0.6511
	Coupon	-0.7312 ***	-1.1270 ***	-0.0067	0.5545	0.2028 ***
	Amount outstanding	-4.3079 ***	-3.4814 ***	-0.9338 ***	-2.8407 ***	-0.1144 *
	<i>ttm</i>	2.1679 ***	1.5304 ***	1.0542 ***	1.0798 ***	1.2146 ***
	<i>ttm</i> ²	-0.0229 ***	-0.0191 ***	-0.0070 ***	-0.0081 ***	-0.0118 ***
	Observations	41990	70748	16974	94119	82492
	Adjusted R squared	0.84	0.68	0.91	0.91	0.65

Table 3: Cross-sectional regression of the bid–ask spread

3.2 Results of cross-sectional regression

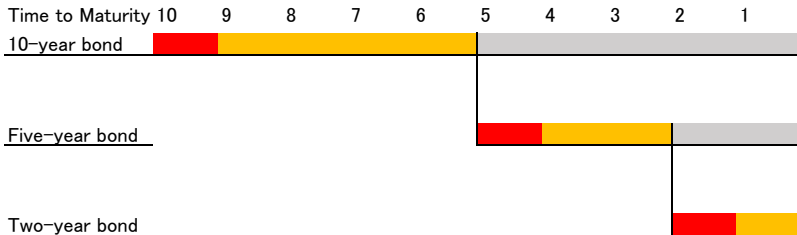
The significances are calculated from two-way cluster robust standard errors.

- ▶ Among spotlight effects variables, *purchased* has significantly negative coefficients in QE0 (-0.183), QQE1 (-0.087), and QQE2 (-0.035). This result is consistent with Hypothesis 2.
- ▶ *target* has a significantly positive coefficient in QE0 (0.726) and QQE1 (0.902), however.
- ▶ The relative holding ratio of a bond exhibits significant explanatory power throughout the periods.
- ▶ The relative holding ratio of its substitutes affects the illiquidity of a bond in QEbase, QQE1 and QQE2.
- ▶ The higher the holding ratio, the larger the bid–ask spread, as expected, which is consistent with Hypothesis 3.

6.0 Three life stages of bond liquidity

- ▶ We further explore the liquidity term structure by introducing three bond life stages according to the literature on the bond liquidity.
- ▶ We specify three distinct bond life stages corresponding to the bond liquidity levels
 1. “Fresh” bonds are those within one year of issuance.
 2. “Shadow” bonds have time to maturity that enters into the range of other original maturity bonds.
 3. We define “old” bonds as those between fresh and shadow bonds.

Bond Life Stages, “Fresh”, “Old” and “Shadow” In case of 10 year bonds



Three Bond Life Stages



Research issues and hypotheses (continued)

- 6. (a) The spotlight effect on the liquidity of old bonds is greater than that on the liquidity of fresh bonds.
(b) The spotlight effect on the liquidity of shadow bonds is mitigated by their high illiquidity.
- 7. (a) The spotlight effect on the yield of old bonds is greater than that on the yield of fresh bonds.
(b) The spotlight effect on the yield of shadow bonds is mitigated by their high illiquidity.

6.1 Model for investigating life stages 1

We firstly add old bond and shadow bond dummies to the cross-sectional regression model in Eq. (4) to examine the overall effect of the life stage on the bid–ask spread;

$$\begin{aligned}
 sprd_{n,t} = & \alpha + \sum_i \beta_i S potlight^i_{n,t} + \sum_j \gamma_j S carcity^j_{n,t} + \sum_l \kappa_l S tage^l_{n,t} \\
 & + \sum_k \theta_k Control^k_{n,t} + \epsilon_{n,t}
 \end{aligned} \tag{5}$$

where the term $\{S tage^l_{n,t}\}$ includes $old_{n,t}$ and $shadow_{n,t}$.

We run time fixed regression for each period with life stage dummies.

6.2 Cross-sectional regression with life stage dummies

		QEbase	QE0	QQEX	QQE1	QQE2
Spotlight	Target	0.286	0.550 *	1.020 **	0.718 ***	0.155
	Targeted the first time	-0.579	0.486	1.870	2.306 ***	0.026
	Purchased	-0.017	-0.145 ***	-0.029	-0.062 **	-0.037 **
Scarcity	<i>h</i>	0.406 **	1.992 ***	0.376 ***	1.424 ***	0.348 ***
	<i>sh</i>	3.477 ***	-1.279	-0.434 **	2.859 **	0.321 *
Life stage	Old bond dummy	1.109 ***	1.090 **	0.390 **	-0.344	-0.142
	Shadow bond dummy	1.315 **	1.956 **	0.531 **	3.375 ***	0.238 **
Control	Drop	0.374	-0.093	0.329	0.030	-0.024
	Dropped the first time	1.112	-0.945	0.167	0.389	-0.655
	Coupon	-0.835 **	-1.419 ***	-0.101	-0.127	0.138 *
	Outstanding amount	-4.206 ***	-3.244 ***	-0.896 ***	-2.130 ***	-0.045
	<i>ttm</i>	2.1727 ***	1.6212 ***	1.0721 ***	1.4004 ***	1.2383 ***
	<i>ttm</i> ²	-0.0229 ***	-0.0206 ***	-0.0073 ***	-0.0140 ***	-0.0122 ***
	Observations	41990	70748	16974	94119	82492
	Adjusted <i>R</i> ²	0.837	0.682	0.908	0.673	0.840

Table 4: Impact of three life stages of term structure on spread

6.3 Results of regression of the spread with life stage dummies

- ▶ The life stage dummies show the bid–ask spreads of fresh bonds are tighter than those of old bonds until QQE1, but in QQE1 and QQE2 this measure becomes indifferent. This indifference of the liquidity must result from the spotlight effect on old bonds.
- ▶ On the other hand, the bid–ask spreads of shadow bonds are wider than those of fresh bonds throughout the periods.

6.4 Model for investigating life stages 2

Secondly, we add the cross terms of fresh and shadow bond dummies with the spotlight and scarcity effects variables to examine the structural break along the bond life stage.

$$\begin{aligned}
 sprd_{n,t} = & \alpha + \sum_i \beta_i S potlight_{n,t}^i + \sum_j \gamma_j S carcity_{n,t}^j \\
 & + \sum_i \sum_l \kappa_{i,l} Stage_{n,t}^l \times S potlight_{n,t}^i + \sum_j \sum_m \lambda_{j,m} Stage_{n,t}^m \times S carcity_{n,t}^j \\
 & + \sum_k \theta_k Control_{n,t}^k + \epsilon_{n,t}
 \end{aligned} \tag{6}$$

where the term $\{Stage_{n,t}^l \times S potlight_{n,t}^i\}$ ($\{Stage_{n,t}^m \times S carcity_{n,t}^j\}$) includes $old_{n,t}$, $shadow_{n,t}$ and the cross term of the two variables with the three spotlight variables (the two scarcity effect variables).

6.5 Impact of three life stages on liquidity through spotlight and scarcity effects

Hypothesis 6 (a) The spotlight effect on the liquidity of old bonds is greater than that on the liquidity of fresh bonds. (b) The spotlight effect on the liquidity of shadow bonds is mitigated by their high illiquidity.

		QEbase	QE0	QQEX	QQE1	QQE2
Spotlight	Target	0.6242	0.4364	0.9665 ***	0.0961	0.2132
	Targeted the first time	-0.8073	0.2212	0.9754	0.1393	-0.4618
	Purchased	0.0165	0.0121	-0.0293 **	0.0187	-0.0286 *
Scarcity	<i>h</i>	-1.0578 **	-0.6436 ***	-0.2093 **	-0.2208	-0.1006
	<i>sh</i>	7.4149 ***	3.1733 ***	1.0503 ***	4.3544 ***	0.6366 *
Control	Drop	0.0788	0.3743	0.3402	-0.1713	-0.1034
	Dropped the first time	0.1262	-0.5687	-0.1177	0.2848	-0.5538
	Coupon	-0.4511 **	-0.9061 ***	0.0321	-0.5935	0.1012
	Outstanding amount	-3.5056 ***	-2.4040 ***	-0.6596 ***	-2.2351 ***	-0.0139
	<i>t_{tm}</i>	2.1562 ***	1.5942 ***	1.1001 ***	1.4822 ***	1.2449 ***
	<i>t_{tm}²</i>	-0.0203 ***	-0.0169 ***	-0.0074 ***	-0.0160 ***	-0.0124 ***
	Observations	41990	70748	16974	94119	82492
	Adjusted R squared	0.846	0.707	0.910	0.687	0.841

6.5 (continued) Impact of three life stages on liquidity through spotlight and scarcity effects

		QEbase		QE0		QQEX		QQE1		QQE2	
Life stage	Old bond dummy	2.9632	***	1.0528		1.0296	***	0.4335		-0.2040	
Cross term	Target	-0.5408	*	-0.1640		0.0161		0.0050		-0.1006	
with Old	Targeted the first	NA		NA		9.2669	***	NA		NA	
	Purchased	-0.0107		-0.3614	***	-0.0253		0.1691	***	-0.0277	
	<i>h</i>	1.5702	***	3.2716	***	0.4784	***	0.9974	***	0.2701	**
	<i>sh</i>	-2.7195	***	-2.1793	***	-0.8797	***	-1.8456	***	-0.1733	
Life stage	Shadow bond dummy	8.6958	***	8.3974	***	2.0923	***	-0.1166		-0.0985	
Cross term	Target	-0.2692		0.8202	*	-0.0006		1.4637	***	-0.0322	
with Shadow	Targeted the first time	NA		-3.3587	***	-1.6824	*	NA		NA	
	Purchased	0.1327		-0.2452	***	0.0788		-0.4091	*	-0.0801	*
	<i>h</i>	1.5807	***	2.4932	***	0.7205	***	3.2723	***	0.8531	***
	<i>sh</i>	-7.6603	***	-7.2424	***	-1.9556	***	-0.1905		-0.4287	

Table 5: Impact of three life stages on spread through scarcity effects

6.6 Results of regression of the spread with life stage variables

- ▶ The relative holding ratio of the bond is estimated as a positive value for the old and shadow bonds throughout the periods.
- ▶ On the other hand, fresh bonds show better liquidity associated with the relative holding ratio. A rising holding ratio works as a signal of the strong demand from the BoJ. The Hypothesis 6(b) is not supported for the fresh bonds.

Empirical analysis of the LSAP effect on yield

We investigate the LSAP effect on yield by two empirical analyses.

4. Time-series analysis of the yield change
5. Cross-sectional analysis of the bond yield (level)

4.0 Regression model for yield change

- ▶ The spotlight effect is expected to affect the bond price significantly because it indicates strong demand for government bonds.
- ▶ We investigate whether the inclusion in an auction target list or the actual purchase affects the bond yield.
- ▶ We consider the following regression model of change in yield:

4.1 Regression model for yield change

$$\begin{aligned} \Delta Y_{n,t,t-1} = & \alpha + \sum_i \beta_i S\text{potlight}_{n,t}^i + \sum_j \gamma_j \text{Lagged}_{n,t-1}^j + \sum_k \theta_k \text{Macro}_t^k \\ & + \sum_l \kappa_l \text{Newly}_{n,t}^l + \sum_m \lambda_m \text{Control}_{n,t}^m + \epsilon_{n,t} \end{aligned} \quad (7)$$

where

$\Delta Y_{n,t,t-1}$: Daily change in the bond yield

$S\text{potlight}$: $\text{target}_{n,t}$, $f\text{target}_{n,t}$ and $\text{purchased}_{n,t}$

Lagged : Yield change lagged and yield curve fitting error lagged

Newly : Amount of the substitutes being newly issued at $t - 1$, t , $t + 1$

Macro : Change in TOPIX, global bonds, cross currency swap and Dummy of Fed and ECB announcement days

$\text{Control}_{n,t}^i$: Program announcement date, drop and first drop dummies, Remaining time to maturity τ and τ^2

4.2 Time-series regression of change in the bond yield

Hypothesis4 Bond yields are lower on reverse auction days because of bond spotlight effects, captured by inclusion in the target list or purchase of a particular bond, which raise bond prices.

		QEbase	QE0	QQEX	QQE1	QQE2
Spotlight	Target	-0.4248 *** (-4.06)	-0.1520 (-1.01)	-0.5660 (-0.76)	-0.3092 *** (-3.67)	-0.3352 ** (-2.35)
	Targeted the first time	-0.5280 *** (-2.71)	-0.2484 (-1.59)	-1.0090 (-0.62)	0.0873 (0.37)	0.0443 (0.21)
	Purchased	0.0339 * (1.72)	0.0097 (0.79)	0.0324 (0.68)	0.0041 (0.86)	0.0094 (1.28)
Lagged	Change in yield lagged	0.0869 * (1.93)	-0.0725 (-1.13)	0.1095 (1.11)	-0.3678 *** (-2.63)	-0.1259 ** (-2.55)
	Svensson fitting error lagged	-0.1897 *** (-5.85)	-0.0583 ** (-2.52)	-0.0602 ** (-2.32)	-0.0531 *** (-3.31)	-0.0149 ** (-2.00)

4.3 Time-series regression of change in the bond yield (continued)

		QEbase	QE0	QQEX	QQE1	QQE2
Macro	TOPIX change	0.3893 ***	0.2528 ***	0.3008 **	0.1738 ***	-0.0073
	US and Germany bond change	4.6867 ***	8.2759 ***	16.3733 **	8.1378 ***	14.5741 ***
	US/JPN cross currency swap	-0.0412	0.0519	-0.2077	-0.0960 *	-0.0435
	Fed announcement date (-)	-0.6075 ***	0.4899	-1.4742 *	0.5405	0.1275
	Fed announcement date (+)	-0.6397 ***	-0.7687 **	-1.3049 **	-0.3168	-1.1439 **
	ECB announcement date (-)	-0.5427	-0.4798 *	-2.3549 ***	0.4714 **	0.2224
	ECB announcement date (+)	0.5101 *	0.0386	2.1457 ***	0.0030	0.0725
Newly	Newly issued (issue date)	-0.0385 **	0.0235 *	-0.0352	0.0068	0.0185
	Newly issued (day before the issue)	-0.0117	-0.0097	0.0184	0.0311 ***	0.0190
	Newly issued (day after the issue)	-0.0253	0.0222 **	-0.0241	-0.0044	0.0120
Control	Program announcement	0.0816 (0.63)	-0.2126 (-0.70)	-8.3111 *** (-16.11)	NA	-0.8463 ** (-2.12)
	Drop	-0.7298 *** (-3.86)	0.0178 (0.14)	-0.5993 (-0.91)	-0.1542 * (-1.77)	-0.1118 (-0.44)
	Dropped the first time	-0.4271 ** (-2.47)	-0.1235 (-0.60)	-1.3210 * (-1.92)	-0.5747 ** (-2.41)	0.0057 (0.01)
	<i>ttm</i>	0.0501	0.3669	-6.1085 **	0.0476	0.0644
	<i>ttm</i> ²	-0.0072	-0.0080	-0.1426	-0.0024	-0.0021
	Observations	41798	70437	16901	93709	82143
Adjusted R ²	0.2292	0.1662	0.2140	0.1759	0.1111	

Table 6: Regression of the yield change with bond-fixed effect.

4.4 Results of regression for the yield change

- ▶ The spotlight effect captured by inclusion in the target list increases the price decline throughout the periods and significant negative coefficients are estimated in QEbase, QQE1, and QQE2.
- ▶ $purchased_{n,t}$ has a positive coefficient that is marginally significant only in QEbase.

5.0 Cross-sectional regression model for bond yield

$$\begin{aligned}
 Y_{n,t} = & \alpha + \sum_i \beta_i S\text{potlight}_{n,t}^i + \sum_j \gamma_j S\text{carcity}_{n,t}^j \\
 & + \sum_k \theta_k \text{Control}_{n,t}^k + \epsilon_{n,t}
 \end{aligned}
 \tag{8}$$

where

$Y_{n,t}$: Yield to maturity of security n at time t

$S\text{potlight}$: $\text{target}_{n,t}$, $f\text{target}_{n,t}$ and $\text{purchased}_{n,t}$

$S\text{carcity}$: Relative holding ratio of a bond $h_{n,t}$ and those of substitutes' $sh_{n,t}$

Control : Drop and first drop dummies, coupon and the logarithm of outstanding $\ln O_{n,t}$, τ and τ^2

We run the regression with daily time dummies for each period.

5.1 Cross-sectional regression for bond yield

The significances are calculated from two-way cluster robust standard errors.

Hypothesis5 Bond yields across bonds are lower due to the spotlight effect, which is mitigated by greater bond illiquidity (scarcity).

		QEbase	QE0	QQEX	QQE1	QQE2
Spotlight	<i>target</i>	-1.694 **	-2.642 ***	-4.593 ***	-2.722 ***	-1.797 ***
	<i>ftarget</i>	-1.031	-2.118 *	-11.468 **	-3.339 **	0.040
	<i>purchased</i>	0.855 ***	0.060	0.004	-0.081	0.231 ***
Scarcity	<i>h</i>	-0.369	-0.961 *	-1.437 **	-1.185 *	-0.273
	<i>sh</i>	11.605 ***	14.741 ***	11.322 ***	-14.683 ***	-16.621 ***
Control	Dropped	-5.531 ***	-4.114 **	-6.263 ***	-2.830 *	-5.096 **
	Dropped the first time	-0.266	-2.490 *	0.761	1.463	0.483
	Coupon	-0.399	-1.421	-1.838 **	-1.926 *	-1.097
	Amount outstanding	-1.841 **	-3.188 ***	-3.110 ***	-3.739 ***	-0.846
	<i>ttm</i>	14.058 ***	13.217 ***	11.133 ***	8.389 ***	5.690 ***
	<i>ttm</i> ²	-0.202 ***	-0.173 ***	-0.142 ***	-0.091 ***	-0.030 ***
	Observations	41990	70748	16974	94119	82492
	Adjusted R ²	0.99	0.98	0.96	0.96	0.97

Table 7: Cross-sectional regression of the bond yield

5.3 Results of cross-sectional regression of the yield

- ▶ The adjusted R-squared values of the cross-sectional yield are very high, from 0.963 to 0.986.
- ▶ Target dummies mostly have significantly negative coefficients throughout the periods. This finding is consistent with Hypothesis 5.
- ▶ As for the yield, the target dummies rather than *purchased* create the spotlight effect.
- ▶ The two variables related to the scarcity effect have opposite effects on yield in QQE1 and QQE2.

7.0 Analysis of the yield with life stage dummies

We run time fixed regressions of the bond yield using the same regressors as those of the spread (Eq. 5 and Eq. 6).

$$Y_{n,t} = \alpha + \sum_i \beta_i S \text{potlight}_{n,t}^i + \sum_j \gamma_j S \text{carcity}_{n,t}^j + \sum_l \kappa_l S \text{stage}_{n,t}^l + \sum_k \theta_k \text{Control}_{n,t}^k + \epsilon_{n,t}$$

$$Y_{n,t} = \alpha + \sum_i \beta_i S \text{potlight}_{n,t}^i + \sum_j \gamma_j S \text{carcity}_{n,t}^j + \sum_i \sum_l \kappa_{i,l} S \text{stage}_{n,t}^l \times S \text{potlight}_{n,t}^i + \sum_j \sum_m \lambda_{j,m} S \text{stage}_{n,t}^m \times S \text{carcity}_{n,t}^j + \sum_k \theta_k \text{Control}_{n,t}^k + \epsilon_{n,t}$$

7.1 Cross-sectional regression of the yield with life stage dummies

		QEbase	QE0	QQEX	QQE1	QQE2
Spotlight	Target	-1.485 *	-3.181 ***	-4.951 ***	-2.698 ***	-1.902 ***
	Targeted the first time	-2.806 ***	-3.473 ***	-11.728 **	-5.080 ***	-2.623 *
	Purchased	0.790 ***	0.061	0.081	-0.149 **	0.022
Scarcity	<i>h</i>	-0.221	-1.049 **	-1.214 **	-1.227 **	-0.071
	<i>sh</i>	11.863 ***	16.255 ***	13.454 ***	-15.025 ***	-18.778 ***
Life stage	Old bond dummy	-2.776 **	-2.939 **	-1.605	-2.496 *	-5.209 ***
	Shadow bond dummy	-2.802 *	1.840	5.662 ***	-2.826	-1.074
Control	Drop	-5.023 ***	-3.857 **	-4.871 **	-2.724	-3.991 **
	Dropped the first time	-0.591	-2.741 *	0.178	1.191	-0.746
	Coupon	-0.180	-1.761	-2.977 **	-1.441	-1.078
	Outstanding amount	-2.001 *	-2.342 **	-1.444	-3.866 ***	-0.027
	<i>t</i> _{tm}	14.0922 ***	13.7613 ***	12.0401 ***	8.3445 ***	5.9108 ***
	<i>t</i> _{tm} ²	-0.2032 ***	-0.1833 ***	-0.1591 ***	-0.0914 ***	-0.0358 ***
	Observations	41990	70748	16974	94119	82492
	Adjusted <i>R</i> squared	0.986	0.978	0.964	0.970	0.967

Table 8: Impact of three life stages of term structure on yield

7.2 Results of regression of the yield with life stage dummies

- ▶ The life stage dummies show that the bond yields of the old bonds are lower than those of fresh bonds throughout all the periods except QEEX.
- ▶ The yield of the shadow bonds shows mixed results. The results are inconsistent with an illiquidity premium for shadow bonds.

7.3 Impact of three life stages on liquidity through spotlight and scarcity effects

Hypothesis7 (a) The spotlight effect on the yield of old bonds is greater than that on the yield of fresh bonds. (b) The spotlight effect on the yield of shadow bonds is mitigated by their high illiquidity.

		QEbase	QE0	QQEX	QQE1	QQE2
Spotlight	Target	0.0642	-1.5925 ***	-3.9953 **	-0.8712 **	-0.8741 *
	Targeted the first time	-1.9192 **	-1.6809 *	-8.3201 **	-2.1030	-0.5687
	Purchased	-0.3964 **	-0.1354 **	-0.1268 **	-0.2409 ***	0.0374
Scarcity	<i>h</i>	5.2198 ***	3.1120 ***	3.4527 ***	0.6544	1.5951 **
	<i>sh</i>	6.8031 ***	9.4723 ***	5.4321 **	-20.6204 ***	-31.0883 ***
Control	Drop	-4.6783 ***	-4.8825 ***	-5.2934 **	-2.1489	-2.9973 *
	Dropped the first time	0.4081	-4.0158 ***	2.5881	0.7383	-0.6175
	Coupon	-0.6886	-2.7678 ***	-4.3313 ***	-2.3312 **	-0.8016
	Outstanding amount	-3.0378 ***	-4.0058 ***	-3.3989 ***	-5.2003 ***	-0.2617
	<i>t</i> _{tm}	14.2324 ***	13.8512 ***	11.9203 ***	8.4093 ***	5.9390 ***
	<i>t</i> _{tm} ²	-0.2107 ***	-0.1921 ***	-0.1631 ***	-0.0953 ***	-0.0370 ***
	Observations	41990	70748	16974	94119	82492
	Adjusted <i>R</i> squared	0.9873	0.9811	0.9674	0.9720	0.9679

7.3 (continued) Impact of three life stages on bond yield through spotlight and scarcity effects

		QEbase	QE0	QQEX	QQE1	QQE2
Life stage	Old bond dummy	-3.0083	-0.7151	0.0432	-3.6409	-18.0194 ***
Cross term	Target	-3.0672 ***	-2.4418 ***	-0.6652	-1.1017 ***	-0.7640
with Old	Targeted the first time	NA	NA	-28.5269 ***	NA	NA
	Purchased	2.3025 ***	0.5727 ***	0.1757	-0.1819	-0.4539 **
	<i>h</i>	-5.1953 ***	-4.9860 ***	-2.6321 *	0.0273	1.1570
	<i>sh</i>	1.5489	0.8366	-2.4615	0.4842	10.3908 **
Life stage	Shadow bond dummy	-14.2984 ***	-10.4237 ***	-4.7100	-13.8675 ***	-13.3044 ***
Cross term	Target	-1.8257 ***	-2.8269 ***	-1.4814 **	-2.8206 ***	-1.4230 ***
with Shadow	Targeted the first time	NA	-5.9714	7.1551 ***	NA	NA
	Purchased	0.7229 **	-0.1513	0.1528	0.3185 *	0.2282
	<i>h</i>	-5.8521 ***	-3.9059 ***	-5.4797 ***	-4.4433 ***	-4.5498 ***
	<i>sh</i>	12.8979 ***	13.0348 ***	12.9381 ***	15.5155 ***	15.0151 ***

Table 9: Impact of three life stages on yield through spotlight and scarcity effects

7.4 Results of regression of the yield with life stage variables

- ▶ Spotlight effect such as being targeted contributes to lowering the yield not only for fresh bonds but also old or shadow bonds, and furthermore, a greater impact is estimated for old and shadow bonds. This means the BoJ demand boost prices, which supports Hypothesis 7(a).
- ▶ Fresh bonds show the higher yield associated with the holding ratio. However, for shadow bonds and old bonds before QQEX, the impacts of holding ratio decrease bond yield on the contrary. A larger holding ratio means a longer age for these bonds, which is not consistent with Hypothesis 7(b).

Conclusion

- ▶ We figure out the impact of LSAPs on JGB market focusing the spotlight and scarcity effects.
- ▶ Improvement of liquidity are shown by spotlight effect, and then, deterioration of liquidity are observed by scarcity effect.
- ▶ The spotlight effect is associated with BoJ's clear announcements of the LSAP programs and purchases in subsequent operations.
- ▶ The results suggest that an aggressive QE program can eventually adversely affect the government bond market's liquidity and that the execution of such an LSAP program requires caution.