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Central bank balance sheets and long-term interest rates: Revisiting Japan's unconventional monetary policy experience

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Abstract

This paper revisits the relationship between the central bank's balance sheet and long-term government bond yields, and reports estimates regarding the impact of the Bank of Japan's government bond purchase programs on nominal yields. Following previous studies quantifying the portfolio balance effect of asset purchases in discussions of the Federal Reserve's balance sheet policies, we estimate the relationship between the size and maturity structure of Japanese government bonds held by the public and the nominal 10-year yield. We find that the government bond purchase programs were effective in lowering the long-term interest rate and preventing an upward shift in the yield curve amid the government's increased financing needs.

JEL classification: E43, E52, E58, G12

Keywords: Asset purchase program; Balance sheet policy; Portfolio balance effect; Unconventional monetary policy.

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1. Introduction

In the years following the global financial crisis (GFC), central banks and economies experienced new environments, challenges, and consequences. At the GFC's onset, the major central banks in advanced economies quickly responded to unanticipated economic downturns by cutting policy rates to their effective lower bound. They then explored policy tools for unconventional monetary policies (UMPs). Central bank balance sheets have become the main driver of a range of quantitative easing (QE) policies (e.g., Chen et al., 2012; Baumeister and Benati, 2013; Gambacorta et al., 2014; Weale and Wieladek, 2016; Borio and Zabai, 2018; Hesse et al., 2018). Consequently, central balance sheets have been extensively expanded, and structured to exhibit a completely different picture from the pre-crisis period, raising a series of issues regarding balance sheet normalization and the future conduct of monetary policy.

Bernanke (2012) argues that QE works through the portfolio balance theory, which was first developed by Tobin (1969). Even when the central bank remains at the effective lower bound of the short-term nominal interest rate, its absorbing long-maturity assets can lower the yield curve if the preferred habitat theory's assumptions hold (e.g., Greenwood and Vayanos, 2010; Vayanos and Vila, 2021). He highlights this view because QE functions similar to conventional monetary policy. Although a substantial body of literature exists on portfolio balance channels' effectiveness, the empirical evidence is mixed. Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011, 2012), D'Amico et al. (2012), and D'Amico and King (2013) empirically support portfolio balance effects, while Thornton (2014), Williamson (2016), and Greenlaw et al. (2018) are particularly skeptical on QEs' impact.

This paper revisits the relationship between the central bank's balance sheet and long-term government bond yields, and reports estimates regarding the impacts of government bond purchase programs by the Bank of Japan on nominal yields. Following previous studies quantifying the portfolio balance effect of asset purchases in discussions of the Federal Reserve's balance sheet policies (Li and Wei, 2013; Engen et al., 2015; Bonis et al., 2017a,b), we estimate the relationship between the size and maturity structure of Japanese government bonds (JGB) held by the public on the nominal 10-year yield. We find that the government bond purchase programs were effective in lowering the long-term interest rates and preventing an upward shift in the yield curve amid the government's increased financing needs.

This study contributes to the literature on UMPs' effectiveness and empirical studies of the portfolio balance effect in Japan's QE experience. For example, Fukunaga et al. (2015) estimate the relationship between the maturity structures of JGB and the long-term government bond yield, focusing on the outstanding and average maturity of government bonds held by the public as a proxy for the remaining interest rate risk. Koeda (2017) uses a series of publicly held JGBs outstanding divided by their remaining maturities to estimate the portfolio balance effect in the JGB market through the preferred habitat term structure model. Koeda and Ueno (2022) propose a preferred habitat model in which the central bank is a preferred habitat investor, allowing the price elasticity of government bond demand to depend on its targeted yield. They employ the first factor of the principal component analysis on the series of JGBs outstanding by their remaining maturity years, as proposed by Koeda and Kimura (2022).

Li and Wei (2013), who estimate the portfolio balance effect in the US treasury market, employ privately held ten-year equivalents (TYE) over nominal GDP as a significant predictor of the treasury's term premium, as suggested by preferred habitat models (Greenwood and Vayanos, 2014). The TYE is defined as the dollar amount of 10-year securities that would imply an equivalent dollar duration as the holdings themselves, approximately equal to the outstanding amount of the portfolio multiplied by the average maturity, divided by 10 years. Their study reveals a statistically significant relationship between the TYE and the term premium. Subsequent studies have elaborated on their analysis to discuss the impacts of balance sheet normalization with privately held TYE, regarded as the summarized measure of the risk held in public and conceptually controlled by the Federal Reserve (e.g., Engen et al., 2015; Bonis et al., 2017a,b). In previous studies on Japan, Osada and Nakazawa (2024) exploit the TYE held by the public, but examine its ratio to the TYE of the issued outstanding.

The current study follows previous empirical analyses of Japan, but investigates the privately held TYE's relationship with long-term government bond yields as an alternative measure for the maturity structure of publicly held interest rate risk, in line with prior literature on the Federal Reserve's balance sheet policy (Krishnamurthy and Vissing-Jorgensen, 2012). Our study provides empirical evidence of QEs' quantitative impact on JGB yields, which appears to be consistent with the literature.

This paper contributes to the literature on UMPs' effectiveness as well as research examining public debt's role in the yield curve (e.g., Laubach, 2009; Meaning and Zhu, 2012; Chadha et al., 2013; Greenwood and Vayanos, 2014; Greenwood et al., 2010, 2015; Altavilla et al., 2015; Cœuré, 2018). In particular, this study highlights the consequences of accumulated public debt during the UMP period by explicitly focusing on the effects of both the central bank and debt management actions UMP experiences after the GFC.

The rest of the paper is organized as follows. Section 2 describes the estimation methodology and explains the security-by-security JGB data used for computing the TYE. Section 3 documents the evolving structure of the sizes and remaining maturities of the outstanding assets held by public and the Bank of Japan. Section 4 provides estimation results for the likely impact of changes in the remaining risk held by the public on long-term government bond yields, and discusses how Japan's UMP experience has affected nominal yields; Section 5 concludes.

2. Revisiting the portfolio-balancing effect

2-1. The Federal Reserve's model

To present evidence linking the supply of government bonds and the term premium of US treasury yields, Li and Wei (2013) estimate the following simple regression:

$$y_t = \alpha + \beta X_t + \gamma Z_t + \varepsilon_t, \quad (1)$$

where y_t is the estimate of a 10-year treasury term premium as provided by Kim and Orphanides (2012); X_t is the vector of supply factors regarding the treasury and MBS; and Z_t is the vector of control variables, including economic fundamentals and other determinants.

For the treasury's supply factor, Li and Wei (2013) use the privately held (outside the Federal Reserve) treasury outstanding in terms of the TYE; the latter is defined as the par amount of an on-the-run 10-year treasury note that would have the same par value outstanding, times the portfolio's average duration. The study calculates this as the par-value outstanding times the weighted average duration, divided by the duration of the on-the-run 10-year treasury note. The TYE converts the rich maturity structure of outstanding treasury securities into a summary measure consistent with the duration of risk in the financial market.

The Federal Reserve's large treasury purchases can be perceived as absorbing market investors' duration. Essentially, the Federal Reserve's duration of extraction can be translated by a marginal change in the privately held TYE, which can be calculated using the amount and changes in the maturity structure of the Federal Reserve's asset-purchase programs. Ihrig et al. (2012), Engen et al. (2015), and Bonis et al. (2017a,b) quantify the QEs' portfolio-balancing effect to illustrate the implications of the Federal Reserve's balance sheet normalization on treasury long-term yields. These are based on the regression result with the TYE estimated by Li and Wei (2013).

2-2. Security-by-security JGB data for Japan

This section describes how to construct a series of privately held TYEs for JGBs, which requires rich information about the security-by-security par-value outstanding and portfolio aggregates of both JGB issuances and Bank of Japan holdings.[1] Given the significant cost of collecting all the duration information for each JGB security in a time series, we calculate the TYE using each portfolio's average maturity, which is more easily obtained and a good approximation of the duration-based exact TYE. In mathematical terms, namely, the duration-based TYE equals to "the par value of portfolio" times "average portfolio duration" divided by "duration of the ten-year on-the-run JGB security;" and the maturity-based TYE equals to "the par value of portfolio" times "average portfolio remaining maturity" divided by 10.

For the government's bond issuances, we collect information about the par value outstanding and maturity for each JGB from the Ministry of Finance's website (Figure 1).[2] For the Bank of Japan portfolio, we obtain information from its website on the held JGB. We exclude treasury bills and bond securities with maturities of less than one year, following Li and Wei (2013). We also exclude inflation-linked and floating-rate bonds, following Fukunaga et al. (2015). We obtain privately held TYE by aggregating securities, each of which is issued

[1] The security-by-security JGB data compiled in this paper is available and current at the author's website, https://sites.google.com/site/jnakajimaweb/jgb.

[2] Missing figures are completed based on the *Japanese Bond Handbook* (*Ko-Shasai Binran*) released by the Japan Securities Dealers Association. Our dataset includes additional outstanding from a series of liquidity provisions. The market buy-back amounts are also included for inflation-linked and floating-rate bonds. Note that these two bonds are excluded in the following regression analysis.

less than the Bank's holdings.[3] As quarterly seasonality exists in the outstanding and resulting TYE, we take a three-month moving average for all figures when calculating the TYE.

In the regression, the series are converted to the ratio to nominal GDP. The quarterly series of the nominal GDP is linearly interpolated to a monthly frequency. Significant decreases in nominal GDP during the COVID-19 pandemic are smoothed out for the second and third quarters of 2020 by linearly interpolating between the first and fourth quarters of the same year. Note that the monthly security-by-security data for the Bank of Japan is only available from June 2001.

3. Privately held TYE of JGB

Figure 2, Panels (a) and (b) present the par value outstanding and the weighted average maturity for the total issuances, central bank holdings, and private holdings. Total JGB issuances have significantly accelerated their pace of increase since the GFC, and the total outstanding amount has almost doubled in the past decade. The Bank of Japan implemented large asset purchase programs in stages and absorbed a fraction of its total outstanding (Shiratsuka, 2010). The privately held outstanding amount decreased in early 2013, when the Bank introduced its Quantitative and Qualitative Monetary Easing (QQE) policy, which substantially expanded the pace of JGB purchases (Iwata and Fueda-Samikawa, 2013). The weighted average maturity of the total outstanding maturity gradually increased after the GFC. The QQE leverages the weighted average maturity of the Bank's portfolio by purchasing longer-term JGB securities. Still, the increasing trend of the weighted average maturity of privately held JGB portfolios was not significantly altered.

In Figure 2(c), the lines illustrate the proxy for the TYE ratio to the nominal GDP of the portfolios, calculated as the par-value outstanding times the weighted average maturity, divided by 10 years. The privately held TYE increased after the GFC even though the Bank of Japan implemented large-scale JGB purchases. In Figure 3, Panels (a) and (b) highlight the JGB outstanding by the remaining maturity. After the GFC, the Bank clearly increased the JGB

[3] Note that the outstanding of a few securities held by the Bank of Japan appeared to be larger than the issuance in their face values due to the Bank's lending JGB to the market participants in early 2023. For this case, we treat the privately held outstanding as zero when computing the TYE.

outstanding with a remaining maturity of one to five years on its balance sheet. However, the total outstanding in particular notably increased, with a remaining maturity from 5 to 10 years, leading to an unchanged upward trend of privately held TYE. Introducing the QQE disrupted the TYE trend, as more aggressive purchases of JGBs with longer remaining maturity than before substantially absorbed the market's interest rate risk. Figure 3(b) indicates that the Bank's JGB holdings increased, with a remaining maturity of 5 to 10 years, which decreased the privately held outstanding, as demonstrated in Figure 3(c).

Our analysis estimates the relationship between the supply factor and the nominal 10-year JGB yield. Therefore, we focus on the interest rate risk of the remaining maturity within the range of 10 years, plus or minus 10 years (i.e., from 1 to 20 years), by excluding JGBs with a remaining maturity greater than 20 years.[4] Figure 4 presents the evolving structure of JGB portfolios, with maturities remaining below 20 years. While the overall picture does not change significantly from Figure 2, the privately held TYE declined more dominantly under the QQE, as shown in panel (c). The privately held TYE reached a temporary bottom in 2018 when the pace of the Bank of Japan's purchasing of JGBs slowed. Since then, the TYE held in the Bank's balance sheet remained almost constant, except for a slight increase in 2022. Behind this development, the composition of Banks' JGB portfolios gradually changed, with an outstanding increase; however, the weighted average maturity declined. As the JGB issuance continued to follow its previous upward trend, the privately held TYE gradually increased during the COVID-19 pandemic, despite a slight decrease in 2022.

These observations are summarized in Figure 5 by the decomposition of the privately held TYE with a remaining maturity of less than 20 years. This figure depicts the change in the TYE since January 2008, and the changes in total issuances and the Bank of Japan's holdings in terms of the par value outstanding and the weighted average maturity. The Bank's JGB purchase programs contributed to a marginal decrease in the privately held TYE, with an increase in both

[4] Fukunaga et al. (2015) and other previous studies note that insurance companies and pension funds leaned toward longer-term JGB holdings and lengthened their portfolios' average maturity since the GFC. The study argues that these holders are not arbitragers, as they intentionally hold long-term JGBs to match their long-duration liabilities. Further, their outstanding in the JGB market should be excluded from an analysis of the relationship between the remaining interest rate risk in the market and the long-term term premium under the preferred-habitat theory. In their analysis, the arbitragers' outstanding and weighted average maturity are computed using detailed JGB holding records.

the outstanding and weighted average maturities of the Bank's JGB portfolio after introducing the QQE amid the large accumulation of public debt. The figure indicates that the Bank's lengthening of the weighted average maturity only marginally affected the privately held TYE when compared with the longer average maturity's greater upward contributions to the total issuance. From the GFC to the end of 2019, the Bank's bond purchase programs marginally decreased the privately held TYE by approximately 40% of the nominal GDP, while the total issuance leveraged the TYE by approximately 50% of the nominal GDP.

4. Estimating the portfolio-balancing effect

4-1. Data and settings

This section first explains the data and estimation methodology used for our empirical analysis. All the series used in the analysis were monthly, with an estimation period spanning June 2001 to August 2016. This is because the TYE series are available from June 2001, and the Bank of Japan introduced QQE with the Yield Curve Control (YCC) policy in September 2016. We limit the sample period from the one up to the YCC because under the YCC, the Bank aimed to purchase JGBs to maintain the 10-year yield at a specified level. As the yield was essentially controlled within this range, the portfolio balance effect could not be precisely estimated without additional assumptions and settings. For example, Osada and Nakazawa (2024) introduce several factors related to the YCC to derive a 10-year yield and estimate the portfolio balance effect, including the YCC period. In contrast, the current study takes an alternative approach of a more parsimonious regression model and limits our sample to August 2016 for the regression.[5]

We estimate Equation (1) in a manner similar to previous studies (e.g., Li and Wei, 2013; Fukunaga et al., 2015). While Li and Wei (2013) employed term premium estimates computed from Kim and Orphanides' (2012) term structure model, it is well-known that term premium estimates depend considerably on the model structure and assumptions. Additionally, there is

[5] Koeda and Wei (2023, 2024) investigate the YCC's effectiveness using security-by-security data and the term structure model, and Osada and Nakazawa (2024) analyze the YCC's influence on the JGB yield using the preferred-habitat regression model with additional variables that describe market expectations on the future course of the policy.

no publicly available long-run time-series estimate of long-term JGB term premiums. To overcome this difficulty, we set the regression's dependent variable as the JGB 10-year nominal yield less than the short-term policy rate as a proxy for the term premium, in which the policy rate can be regarded as a proxy for the expected rates.[6]

We use the series provided by the Ministry of Finance for a 10-year nominal yield in the regression.[7] For the short-term policy rate, we use a series of uncollateralized overnight call rates downloaded from the Bank of Japan's website. The set of independent variables includes various control variables explaining Japan's 10-year nominal yield and term premiums. We use industrial production and the VIX to control the cyclical components of real economy and global stock market sentiment, respectively. We then compute a gap measure for industrial production by subtracting from its period-by-period piecewise linear trends by testing structural breaks based on a cumulative sum test. We download the VIX from the Federal Reserve Economic Data (FRED) database. We also examine macroeconomic uncertainty using Japan's index as estimated by Shinohara et al. (2020) and Nakajima (2024).

Foreign interest rates—and particularly US nominal yields—substantially influence Japan's nominal yields. We control for this by using the trend and cycle of the US 10-year nominal yield. This trend captures global growth and development in long-term interest rates and the natural interest rate, partially driven by the global saving glut. This cycle describes the cyclical factors of the global economy and financial market risk sentiments. We use a fitted yield for a 10-year zero-coupon bond as produced by Kim and Wright (2005), downloaded from the Federal Reserve Board's website. Subsequently, we computed a centered moving average over 24 months for the trend series. The cycle series was calculated as a 10-year yield that was less than the trend.

Table 1 reports the results of the unit-root test based on the Phillips-Perron test statistics

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[6] To avoid an endogeneity problem in estimating the coefficient of the supply factor in Equation (1), we use face values of the outstanding JGB instead of its market values, following Li and Wei (2013) and Fukunaga et al. (2015).

[7] No publicly available long-run estimate exists for Japan's zero-coupon yields. The Ministry of Finance provides the yields to maturity of fixed-interest government bonds on a semiannual compounded basis. While the figures are not exactly zero-coupon yields, as Kikuchi and Shintani (2012) note, the monthly average figures are close to the estimate of zero-coupon yields as provided by Bloomberg, at least over our sample period.

with the null hypothesis that the series is the unit root, showing the one for several variables cannot be rejected. We examine Johansen's cointegration and find multiple cointegration relationships in our variables, as displayed in Table 2. As the series have unit roots and include a cointegration relationship, we use the fully modified ordinary least-squares method to obtain asymptotically unbiased estimates (Phillips and Hansen, 1990).

4-2. Estimation results

Table 3 reports the regression results from various sets of independent variables, which demonstrates that the 10-year yield's sensitivity to changes in the privately held TYE is significantly positive for all specifications. The estimated coefficient implies that a decrease of 1% of GDP in the privately held TYE pushes down the yield by approximately 1.0 to 2.5 bps. Given the standard error of 0.007 in specification (4), which exhibits the median of the size of TYE coefficient (0.016) across the specifications considered in the table, the one-standard error confidence intervals of the sensitivity range from 0.007 to 0.025. Therefore, 1% GDP in the privately held TYE corresponds to a yield of 0.7 to 2.5 bps.

Based on these results, we consider the estimated effects of changes in privately held TYE on the nominal 10-year yield absorbed by the Bank of Japan's JGB purchases during the period from the GFC to the end of 2019, which is obtained by multiplying the TYE coefficient in the regressions and its change during the period. The estimated impact was approximately 40 to 100 bp, based on the estimates across the specifications. This is the marginal downward pressure on the JGB yield, which faced upward pressure from the government's debt accumulation, implying that the Bank's JGB purchase programs effectively prevented an upward shift in the yield and even lowered the yield under the QQE.

This estimate is comparable to that of Sudo and Tanaka (2021), who use Japanese data to develop and estimate a dynamic stochastic general equilibrium model in which short- and long-term bonds are imperfect substitutes due to market segmentation and preferred habitats. Our estimate is similar to those provided by Fukunaga et al. (2015) and Osada and Nakazawa (2024); the QQE's implied impact on the JGBs' yield is also consistent with previous studies, such as Koeda and Kimura (2022) and Shiratsuka (2024).

This analysis has several caveats. First, we do not assume any structural change in the relationship between the supply factor (i.e., the JGBs' TYE) and the JGB nominal yield during the sample period.[8] The regression also does not consider any possible nonlinearity. Cœuré (2018) discussed the effectiveness of the ECB's asset purchase programs and notes that the share of outstanding central government bonds held by the private sector relates to the 10-year Bund term premium, although it is considerably non-linear and changes over time.

Second, previous studies have developed a range of analyses demonstrating that multiple factors affect long-term interest rates in UMPs (e.g., Marx et al., 2021). Aside from the portfolio-balancing effect, the signaling effect is another important mechanism through which a bond purchase program can transmit to the market price. As discussed by Clouse et al. (2003) and Eggertsson and Woodford (2003), the QE can lower the yield curve if the central bank's commitment to keeping the policy rate low for a long period is sufficiently strong, as per the expectations hypothesis.

A considerably large purchase of assets over a long duration can demonstrate a strong intention to commit to a low policy rate path. For instance, Krishnamurthy and Vissing-Jorgensen (2011) estimate the signaling effect of the Federal Reserve's large asset-purchasing programs by measuring changes in the future federal funds rate around important policy announcement dates, which appear to be quite sizable in pushing down long-term treasury yields. King (2019) empirically observes that the QE has a much smaller impact on yields via the portfolio-balancing effect than the changes in the expected future path of short-term interest rates. The OIS-implied 10-year rate in Japan declined by approximately 70 bp from 2010 to 2016. This lower expected policy rate path contributes to a decline in JGBs' 10-year yield. Koeda and Wei (2023) analyze the Bank of Japan's forward guidance and the YCC and found that forward guidance significantly affects the expected rate during the UMP period.

Third, previous studies discuss the natural interest rate as another relevant factor driving long-term interest rates (e.g., Laubach and Williams, 2003; Barsky et al., 2014; Holston et al., 2017). Our baseline analysis addresses this point by employing the trend of the US 10-year

[8] Our online Appendix reports back-tests of our regression model, evaluating fitted values of JGB yields over post-sample periods (i.e., the YCC period and afterward) to assess the model's forecast ability. This appendix is available at the author's website, https://sites.google.com/site/jnakajimaweb/jgb.

yield, the movement of which could include the natural rate trend in the United States, and assuming that it partly correlates with that in Japan. We also examine a regression analysis using an estimate of Japan's natural rate of interest developed by Nakajima et al. (2023) and found that the regression result is robust. A further analysis that integrates the natural rate of interest into the dynamics of the long-term interest rate may more precisely identify bond purchases' effectiveness, but this is left for future work.

5. Conclusion

This paper estimates the relationship between the supply factor of privately held government bonds and the long-term yield in Japan. Following previous studies regarding the likely effects of the Federal Reserve's balance sheet policy and normalization, we test their model using Japanese data to reveal that the long-term yield's sensitivity to the size and maturity structure of privately held government bond portfolios is statistically significant. Our empirical results demonstrate that the government bond purchase programs effectively decreased long-term yields and prevented an upward shift in the yield curve amid the government's increased financing needs.

Another source of the downward shift in the yield curve after the GFC is the safe asset scarcity channel (Caballero et al., 2016; Marx et al., 2021). With increased uncertainty in the economy, a strong need for safe assets may increase the premium of such assets and exert downward pressure on government bonds' long-term yields. Extracting a pure portion of this contribution is challenging within the current econometric framework. This will be an important focus for future work.

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Variable	Level	First difference
10-year JGB yield less call rate	-0.62	-11.03 ***
Industrial production	-3.17 **	—
VIX	-3.42 **	—
Macroeconomic uncertainty	-2.73 *	—
Call rate	-1.61	-7.52 ***
US 10-year yield trend	-1.15	-3.06 **
US 10-year yield cycle	-5.03 ***	—
Privately held TYE	1.89	-1.63 *

Table 1: Phillips-Perron unit root test. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Null hypothesis	Test statistics
None	160.2 ***
At most 1	95.3 **
At most 2	55.6

Table 2: Johansen's cointegration test for the series: 10-year JGB yields less call rate, industrial production, macroeconomic uncertainty index, call rate, US 10-year yield trend and cycle, and the privately held TYE. *** and ** indicate statistical significance at 1% and 5%, respectively.

Specification:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Industrial production	0.000			0.000			0.008
	(0.005)			(0.005)			(0.006)
VIX		0.001			0.000		0.000
		(0.005)			(0.005)		(0.004)
Macroeconomic uncertainty			1.050 ***			0.771 **	1.299 **
			(0.349)			(0.338)	(0.586)
Call rate	-0.512 **	-0.556 *	-0.530 ***	-0.419 *	-0.445	-0.433 ***	-0.721 ***
	(0.241)	(0.303)	(0.161)	(0.235)	(0.285)	(0.155)	(0.260)
Negative interest rate dummy				-0.498 ***	-0.479 **	-0.482 ***	-0.405 **
				(0.170)	(0.170)	(0.116)	(0.164)
US 10-year yield trend	0.664 ***	0.647 ***	0.582 ***	0.507 ***	0.507 ***	0.442 ***	0.495 ***
	(0.105)	(0.141)	(0.072)	(0.112)	(0.143)	(0.075)	(0.106)
US 10-year yield cycle	0.248 ***	0.251 **	0.241 ***	0.208 **	0.202 **	0.209 ***	0.158 *
	(0.899)	(0.123)	(0.061)	(0.088)	(0.117)	(0.058)	(0.088)
Privately held TYE	0.025 ***	0.024 ***	0.018 ***	0.016 **	0.016 **	0.010 **	0.007 *
	(0.007)	(0.009)	(0.005)	(0.007)	(0.007)	(0.005)	(0.006)
Constant	-2.551 ***	-2.478 ***	-2.643 ***	-1.551 ***	-1.567 ***	-1.579 ***	-2.233 ***
	(0.684)	(0.915)	(0.496)	(0.723)	(0.933)	(0.521)	(0.757)
Adjusted R-squared	0.688	0.688	0.701	0.726	0.726	0.733	0.735

Table 3: Regression result. The dependent variable is the JGB 10-year rate less call rate. The coefficients are estimated using the fully-modified OLS method. Robust standard errors are in parentheses. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

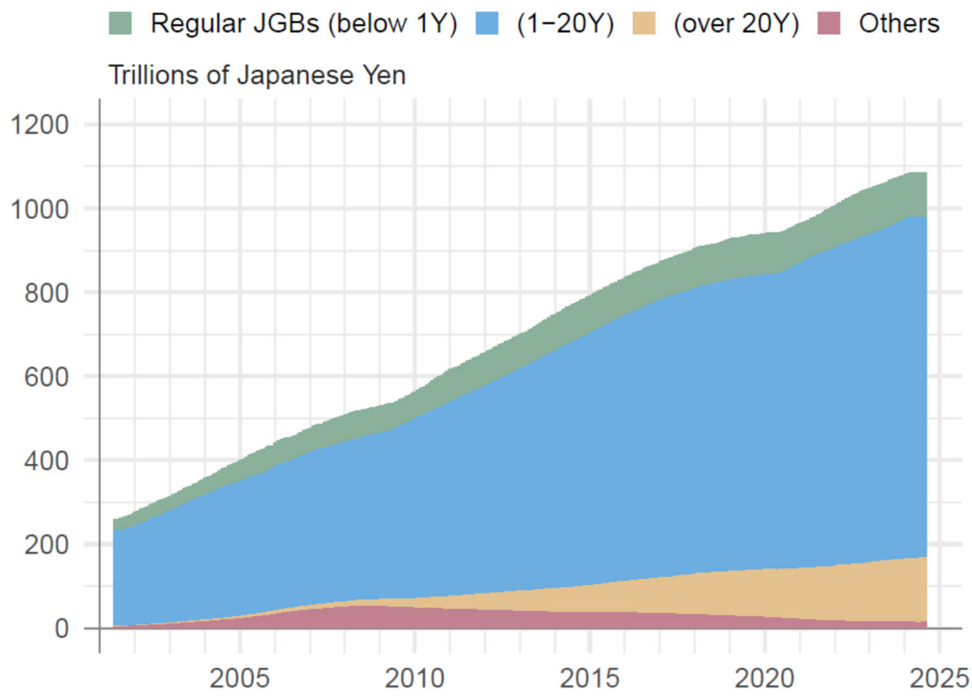

Figure 1: Par-value outstanding of JGBs. The remaining maturity splits regular JGBs: (i) below one year, (ii) from one to 20 years, and (iii) over 20 years. “Others” refers to the inflation-linked and floating-rate bonds. The three-month moving average is taken for all the series. The figures are calculated using information downloaded from the Ministry of Finance’s website. Some missing figures are from the *Japanese Bond Handbook* (*Ko-Shasai Binran*). Additional outstanding from a series of liquidity provisions is included. The buy-back amounts are included for inflation-linked and floating-rate bonds.

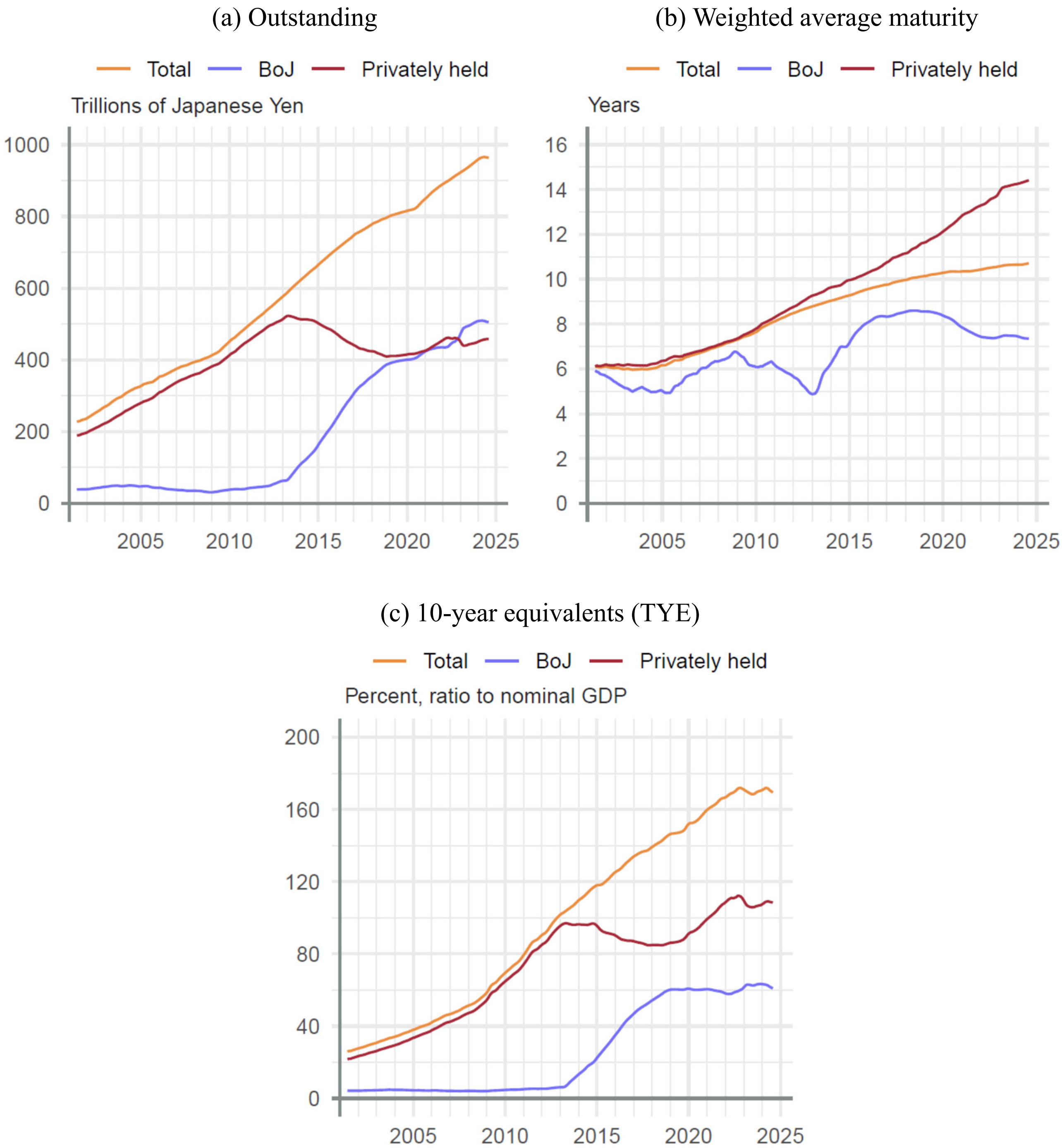

Figure 2: Privately held JGBs. The three-month moving average is taken for all the series. Treasury bills and bond securities with remaining maturities below one year are excluded. The proxy series of TYE is calculated as the par-value outstanding times the weighted average maturity, divided by 10 years. BoJ refers to the Bank of Japan.

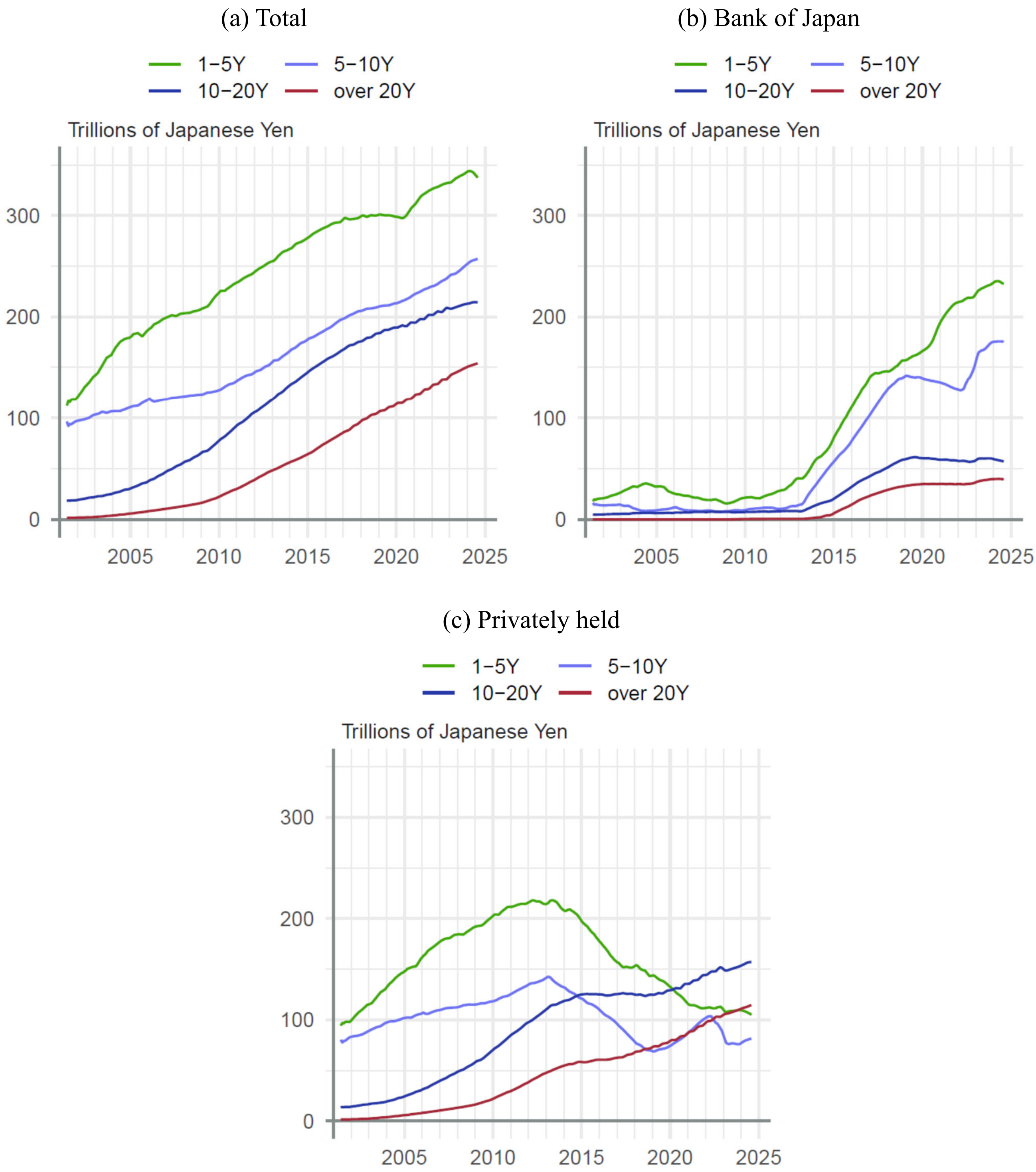

Figure 3: Par-value outstanding of JGBs by remaining maturity. The three-month moving average is taken for all the series.

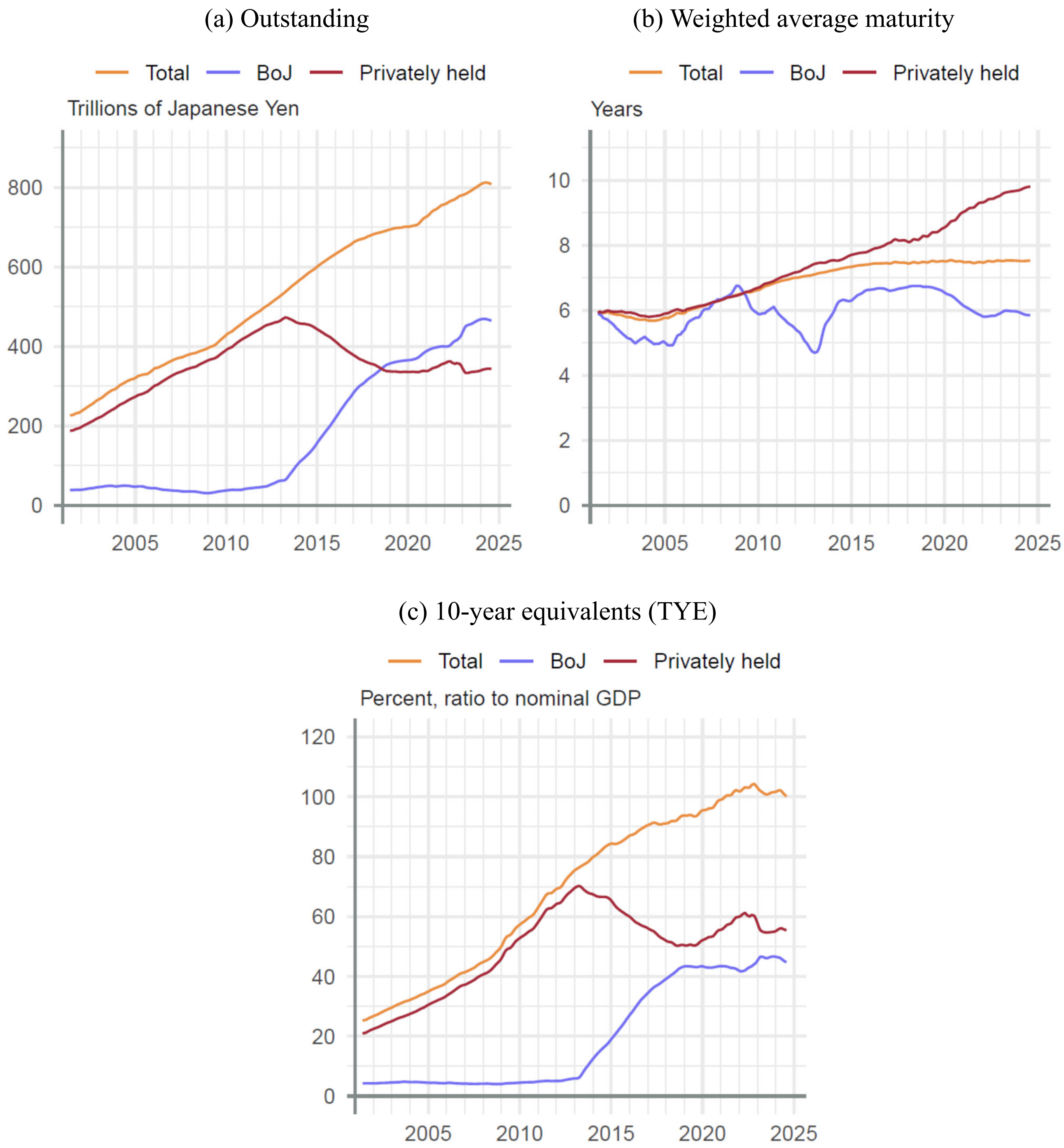

Figure 4: Privately held JGBs (remaining maturities below 20 years). The three-month moving average is taken for all the series. Treasury bills and bond securities with remaining maturities below one year are excluded. The proxy series of TYE is calculated as the par-value outstanding times the weighted average maturity, divided by 10 years. BoJ refers to the Bank of Japan.

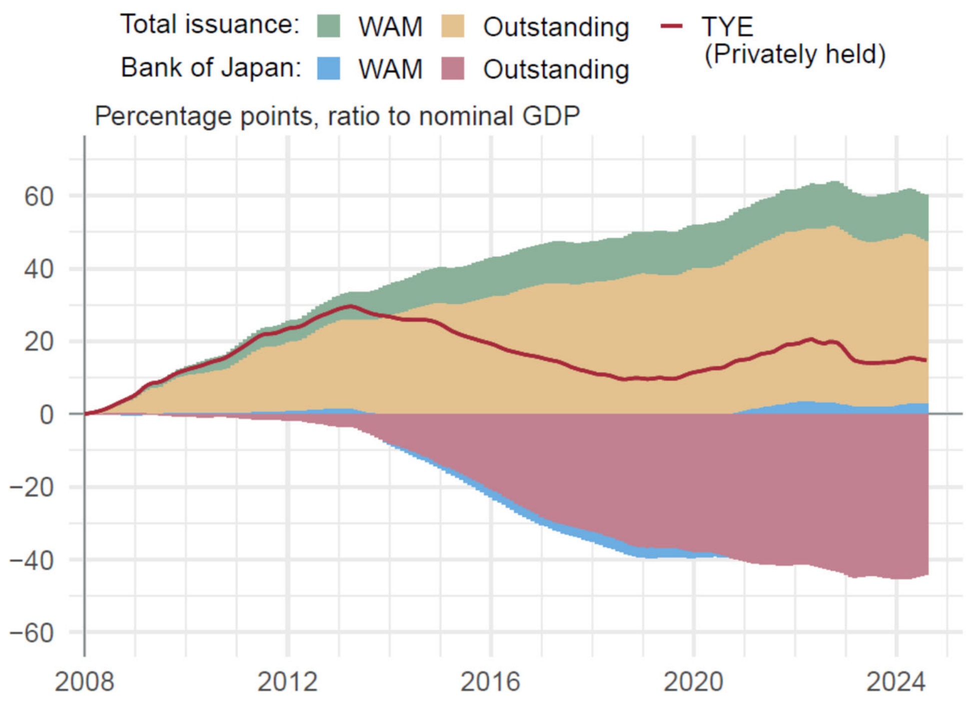

Figure 5: Changes in privately held JGBs (remaining maturities below 20 years) since January 2008. The three-month moving average is taken for all the series; WAM refers to the weighted average maturity.