

EFFECTIVENESS OF UNCONVENTIONAL MONETARY POLICY AT
THE ZERO LOWER BOUND: EVIDENCE FROM JAPAN

A Master's Thesis

by

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Ankara
June 2018

To Figen, Caner and Marine



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The Graduate School of Economics and Social Sciences
of
İhsan Doğramacı Bilkent University

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June 2018

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ABSTRACT

EFFECTIVENESS OF UNCONVENTIONAL MONETARY POLICY AT THE ZERO LOWER BOUND: EVIDENCE FROM JAPAN

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In this thesis I provide new evidence on unconventional monetary policy at the zero lower bound using Japanese data. After the recent financial crisis, undesirably low levels of inflation and policy rates being stuck at zero in the U.S. and the EU, unconventional monetary policy became a hot topic. Japan has near zero short term interest rates for over twenty years, which makes it a perfect laboratory for the topic. I show that even though interest rates are stuck at zero in Japan, monetary policy can affect asset prices through central bank communication. This combines earlier studies done for the U.S. and the EU.

Keywords: Bond Yields, Central Bank Communications, Japan, Unconventional Monetary Policy, Zero Lower Bound

JEL Codes: E52, E58, E43, G14

ÖZET

SIFIR ALT SINIRINDA KONVANSİYONEL OLMAYAN PARA POLİTİKALARININ ETKİNLİĞİ: JAPONYA ÖRNEĞİ

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Bu çalışmada sıfır alt sınırında konvansiyonel olmayan para politikası üzerine, Japonya verisi kullanılarak yeni bulgular sunulmuştur. Avrupa ve ABD’de son finansal krizi takip eden olağan dışı seviyelerde düşük enflasyon ve sıfıra yakın faiz oranları, konvansiyonel olmayan para politikası araştırmalarına ilgiyi arttırmıştır. Son yirmi yıldan uzun süredir sıfıra yakın kalan kısa vadeli faiz oranları Japonya örneğini bu konuda eşsiz bir araştırma laboratuvarı haline getirmektedir. Bu çalışmayla para politikasının, Japonya’da kısa süreli faizler sıfırda kısıtlı kalmış olmasına rağmen, finansal varlıkların fiyatlamasına etkisini merkez bankası iletişimleri yoluyla sürdürdüğü gösterilmiştir. Bu çalışma daha önce ABD ve Avrupa örnekleri üzerine yapılmış araştırmaları birleştirici niteliktedir.

Anahtar Kelimeler: Japonya, Konvansiyonel Olmayan Para Politikası, Merkez Bankası İletişimleri, Sıfır Alt Sınırı, Tahvil getirileri.

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CHAPTER 1

INTRODUCTION

In ordinary times central banks control the policy rates via open market operations to conduct monetary policy. When the nominal interest rates are near zero, clearly, lowering interest rates to create economic stimulus is no longer a possibility. Thus, at the zero lower bound (ZLB) central banks lose their primary policy tool and face deflationary spirals. As pointed out by Eggertson & Woodford (2003), “The key to dealing with this sort of situation in the least damaging way is to create the right kind of expectations regarding how the monetary policy will be used *after* the constraint is no longer binding, and the central bank again has room to maneuver”. It is now common understanding that controlling market expectations on the future path of monetary policy help central banks to control for the inflation expectations. Parallel to this argument and in the light of recent economic developments, central bank communications became increasingly important in the last couple of decades.

This study aims to study the effects of monetary policy at the ZLB on asset prices, by bringing in the evidence from Japan. Japan is a peculiar case of central banking due to its long struggle with deflation. The literature on the ZLB mainly focused on U.S. and European cases during and after the crisis. Connecting the literature with the Japanese data then plays an essential role in evaluating the effectiveness of the types of policies recently adopted by the west-

ern world. By showing the universality of previous results, I hope to contribute to our understanding regarding the policy tools central banks are armed with.

The Federal Reserve (FED) used unconventional policy tools intensively in the aftermath of 2008 financial crisis, where the U.S., in the second half of 2009, for the first time in history hit the ZLB. Apart from its main policy tool, the FED adopted multiple large-scale asset purchase (LSAP) programs in addition to forward guidance via FOMC announcements. Similar policies have been used by the European Central Bank during and after the crisis. Multiple studies documented immediate asset price reactions to the announcements, which is aligned with our economic understanding. The FED increased the lower bound of their target rate in January 2016, which was stuck at zero percent since January 2009. Thus, the ZLB experience of the U.S. was around seven years.

Numerous studies examine the effectiveness of LSAPs and forward guidance. Krishnamurthy & Vissing-Jorgensen (2011) find a signaling channel in both QE1 and QE2 announcements for the U.S., which works similar to forward guidance. This channel is of no surprise. Gurkaynak, Sack & Swanson (2005) (GSS henceforth), by extracting two principal components and rotating such that they yield economic meaning, show that before the financial crisis and QE programs, all monetary policy announcements had a path factor that is directly explaining market expectations of the future path of policy.

Following GSS, Brand, Buncic, & Turunen (2010) studied European Central Bank (ECB) communications on European bond yields. They exploit a feature of the ECB meetings where the policy decisions are directly available after the meeting, but the announcement is made later on in the same day. This way they can separately identify that target and path factors are indeed sufficient to capture two dimensions of monetary policy. According to their results, yield curve responses to path surprise exhibit a hump-shape: Mid-maturity yields respond

more than the short and the long end of the yield curve. However, responses to target surprise are downward sloping. Similar results are documented in this study for Japan.

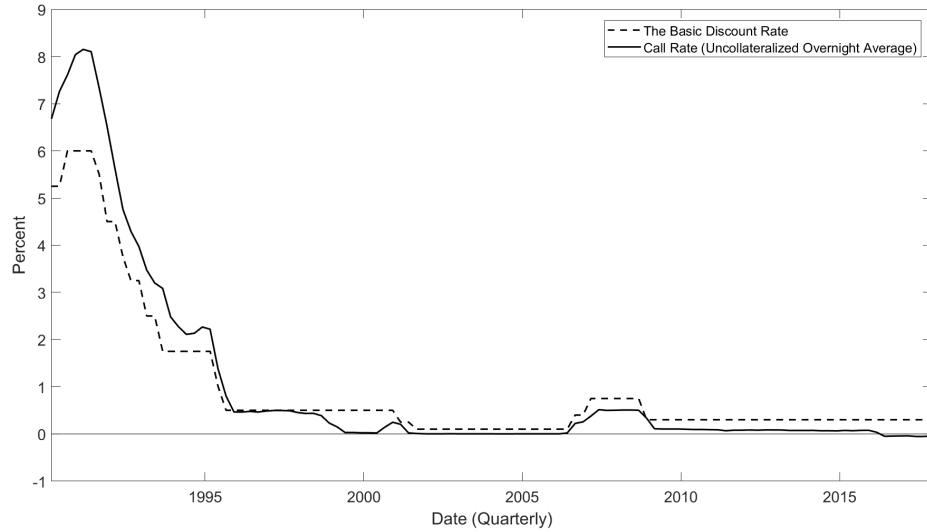


Figure 1: Bank of Japan Interest Rates

To my knowledge, these types of analyses have not been done for Japan, where the policy rates are stuck at the ZLB for over twenty years as it can be seen in Figure-1. Keeping in mind that ZLB experience of any other country was considerably shorter than this, Japan becomes an important laboratory of research on unconventional monetary policy at the zero bound. Arai (2016) using identification through heteroskedasticity (see Rigobon & Sack, 2004) show the BoJ forward guidance using data for 5, 10 and 20 year Japanese Government Bonds (JGB's) is effective for the period between 1998 and 2013. The nature of that study is based on differing variations in announcement days and non-announcement days and is unable to capture separate effects of policy action and the relevant statement. Nevertheless, for completeness, I briefly go through a similar exercise in section 2.1.

Gertler (2017) constructs a simple DSGE model to evaluate the effectiveness of forward guidance and quantitative easing programs adopted in Japan. The

results show weaker recovery compared to what contemporary macroeconomic models would indicate. This, on the other hand, is argued to be somewhat linked with market forces that are out of the control of the BoJ such as, tax hikes. I propose that this is not a lack of ability in the part of the BoJ to conduct monetary policy. My research show, in contrast, that the BoJ, in fact, successfully influenced expectations of the market participants. In particular, asset prices responded significantly to monetary policy statements.

My research focuses specifically on identifying separated effects of unconventional monetary policy announcements. Showing that the case of Japan is not an exception for the possibilities of policymaking would yield universality for previous studies. Moreover, following a GSS type decomposition on the BoJ announcements to identify policy factors would shed some light on market expectations and sensitivities for an economy stuck at the zero bound for such a long time.

The rest of the paper is organized as follows. Section 2.1 briefly goes through identifying the policy responses of asset prices. Section 2.2 describes the data, demonstrates the separated announcement effects from direct policy actions, and finally analyzes the effectiveness of major announcements. Section 2.3 evaluates the factor extraction using different data sets and different model specifications. Finally, section 3 concludes. I provide details on the GSS decomposition in the appendix.

CHAPTER 2

ASSET PRICE RESPONSES TO BOJ ANNOUNCEMENTS

The literature on estimating asset responses on monetary policy decisions is vast for the U.S.. Cook & Hahn (1989) regress daily changes of U.S. bond yields around FOMC announcements on changes in the fed funds target. Kuttner (2001) suggests the approach used in Cook & Hahn (1989) was subject to some degree of estimation bias. That is, some portion of the changes in policy rates are foreseeable. Bond yields would only respond to unexpected changes in the fed funds target. Therefore, following Cook & Hahn (1989) introduces attenuation bias.

Kuttner (2001) proposed a method to identify the unexpected part of policy actions to measure the asset reactions. The results show a strong relationship of asset prices on policy surprises in the U.S.. In contrast, Kuttner surprises are not applicable for the context of this study. As it has been argued above, interest rates in Japan are stuck at zero for a uniquely long period of time. Policy surprises derived using the Kuttner method, in this context would imply *no surprise* except for a handful of dates at which the BoJ changed their policy rates.

Gurkaynak et al. (2005) proposed another method to separate the asset price responses to policy actions and the relevant monetary policy statement. The

former is intuitively identical to what Kuttner surprises capture. The latter, on the other hand, is the more relevant component in central bank communication to analyze data in which the policy rate is stuck at zero, which is the case for Japan. Moreover, the result of Cook & Hahn (1989) indicate a decreasing impact of Fed policy changes as the maturity of the bond increases. GSS explained the decreasing sensitivities by showing the bonds in the longer end of the yield curve mainly responded to other monetary policy statements.

First I show, Japanese Government Bonds (JGB) have significant reaction to BoJ announcements. Then I proceed with decomposing the components of the announcements and show the market reaction is mainly due to other information in the statements rather than actions and variation in asset prices can be attributed to these factors.

2.1 Rigobon and Sack (2004) Revisited

Estimating the response of asset prices to policy decisions is challenging if one depends on using standard econometric methods. Policy actions and macroeconomic fundamentals have simultaneous co-movements as shown in equations 2.1 and 2.2. Asset prices, on the other hand, are affected by both, and the estimation via standard regressions are futile. Following this logic, I conduct a brief analysis using *identification through heteroskedasticity* as referred by Rigobon & Sack (2004) (R&S henceforth). This method assumes the noise in asset price movements are constant for the announcement and non-announcement days. In contrast, on announcement days without any other macro-related events, changes in asset prices can be attributed to the sum of the usual noise plus the additional signal received by the policy decision.

$$\Delta i_t = \beta \Delta y_t + \gamma z_t + \epsilon_t \tag{2.1}$$

$$\Delta y_t = \alpha \Delta i_t + z_t + \eta_t \quad (2.2)$$

Where Δi_t is the change in policy rates and y_t is the change in bond yields. ϵ_t is the policy shock and η_t is the shock to bond yields. It is assumed that these two shocks are uncorrelated. The structure represents a simultaneous movement on the common shock z_t .

Using the increased variance on announcement days, it is possible to isolate the response of asset prices to the policy announcements. For this study, I use handpicked MPC meeting dates that will be explained in section 2.2.1 and yield data for the JGB's of different maturities¹. I pin down the daily changes in bond yields at the end of the same day and one week before a specific monetary policy announcement. I use the daily call rate data from the Bank of Japan which is equivalent to federal funds rate for the Federal Reserve. A clear increase in variation on announcement dates for all the assets is evident in Table-1.

Table 1: Variance and Covariances on Announcement and Non-Announcement Dates

	Standard Deviation (in basis points)			Covar. With Policy Rate	
	Ann. Dates	Non-Ann. Dates		Ann. Dates	Non-Ann. Dates
ΔCall Rate	1.77	0.63	ΔCall Rate	-	-
Δ1-Year	1.91	0.64	Δ1-Year	0.0076	-0.0004
Δ2-Year	2.26	1.03	Δ2-Year	0.0020	0.0010
Δ3-Year	2.46	1.31	Δ3-Year	-0.0028	0.0007
Δ4-Year	2.82	1.68	Δ4-Year	-0.0042	0.0008
Δ5-Year	3.14	2.06	Δ5-Year	-0.0029	0.0007
Δ6-Year	3.68	2.60	Δ-Year	-0.0060	0.0005
Δ7-Year	4.16	3.00	Δ7-Year	-0.0093	0.0005
Δ8-Year	4.25	3.04	Δ8-Year	-0.0052	-0.0002
Δ9-Year	4.16	3.01	Δ9-Year	-0.0025	-0.0005
Δ10-Year	4.16	3.12	Δ10-Year	0.0020	-0.0003
Δ15-Year	4.59	3.44	Δ15-Year	-0.0017	0.0002
Δ20-Year	4.50	3.44	Δ20-Year	-0.0033	0.0004

I construct two matrices of two columns for each bond maturity. The two matrices are carrying data for the announcement and non-announcement days respectively as shown in equations 2.3 and 2.4. I estimate sample variance-covariance matrices of yield and call rate changes around the announcement and

¹The data I use covers bond yields of maturities 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15 and 20 years.

non-announcement days.

$$\text{Before Announcement: } B_{x \text{ years}} = \begin{bmatrix} \Delta \text{call rate}_{t-1} & \Delta y_{t-1}^{x \text{ years}} \\ \vdots & \vdots \end{bmatrix} \quad (2.3)$$

$$\text{On Announcement: } O_{x \text{ years}} = \begin{bmatrix} \Delta \text{call rate}_t & \Delta y_t^{x \text{ years}} \\ \vdots & \vdots \end{bmatrix} \quad (2.4)$$

I indicate announcement and non-announcement day parameters with a superscript A and NA respectively. After solving for the reduced form of equations 2.1 and 2.2 the variance-covariance matrices for announcement and non-announcement days take the form as follows:

$$\Omega_x^A = \begin{bmatrix} \sigma_\epsilon^A + \beta^2 \sigma_\eta^A + (\beta + \gamma)^2 \sigma_z^A & \alpha \sigma_\epsilon^A + \beta \sigma_\eta^A + (\beta + \gamma)(1 + \alpha \gamma) \sigma_z^A \\ \alpha^2 \sigma_\epsilon^A + \sigma_\eta^A + (1 + \alpha \gamma)^2 \sigma_z^A \end{bmatrix} \quad (2.5)$$

$$\Omega_x^{NA} = \begin{bmatrix} \sigma_\epsilon^{NA} + \beta^2 \sigma_\eta^{NA} + (\beta + \gamma)^2 \sigma_z^{NA} & \alpha \sigma_\epsilon^{NA} + \beta \sigma_\eta^{NA} + (\beta + \gamma)(1 + \alpha \gamma) \sigma_z^{NA} \\ \alpha^2 \sigma_\epsilon^{NA} + \sigma_\eta^{NA} + (1 + \alpha \gamma)^2 \sigma_z^{NA} \end{bmatrix} \quad (2.6)$$

I proceed with taking the difference of variance-covariance matrices for each matrix B_x and O_x as shown in equation 2.7. This process eliminates the common noise, and the remainder matrix carries the additional signal due to the statement. R&S show that the remainder matrix can be used asymptotically to identify the true response of yields to the announcements. I follow the proposed method of R&S and identify the sample estimates for the policy coefficients. For this, I divide the first element in the second column to the second element in the

second column of the remainder matrix D_x as shown in equation 2.8.

$$\Delta\Omega_x = \Omega^A - \Omega^{NA} \quad (2.7)$$

Equivalently:

$$\Delta\Omega_x = \frac{(\sigma_\epsilon^A - \sigma_\epsilon^{NA})}{(1 - \alpha\beta)^2} \begin{bmatrix} 1 & \alpha \\ \alpha & \alpha^2 \end{bmatrix} \quad (2.8)$$

Thus,

$$\hat{\alpha}_x = \frac{\Delta\Omega_x(2, 2)}{\Delta\Omega_x(1, 2)} \quad (2.9)$$

Where $\hat{\alpha}_x$ is the sample estimate of the coefficients of the policy decision on asset prices. Figure-2 illustrates a plot of the identified response coefficients of bonds with different maturities to the monetary announcements. The level of significance as can be seen in Table-2 is very high.

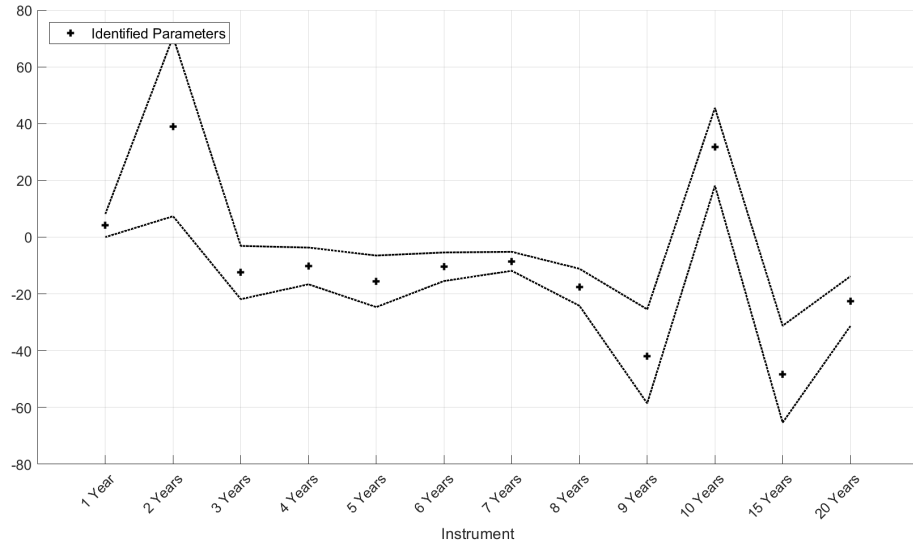


Figure 2: Identification Through Heteroskedasticity Parameters

The high positive responsiveness of 2 and 10-year yields in announcement days is somewhat puzzling. A partial explanation for this could be the way LSAPs

Table 2: Identification Through Heteroskedasticity Parameters

	1 Year Yield	2 Year Yield	3 Year Yield	4 Year Yield	5 Year Yield	6 Year Yield
Coefficient	4.09*	38.98**	-12.49***	-10.17***	-15.58***	-10.45***
	(2.09)	(16.13)	(4.79)	(3.30)	(4.64)	(2.57)
	7 Year Yield	8 Year Yield	9 Year Yield	10 Year Yield	15 Year Yield	20 Year Yield
Coefficient	-8.53***	-17.68***	-42.02***	31.82***	-48.31***	-22.58***
	(1.71)	(3.33)	(8.45)	(6.99)	(8.71)	(4.47)

t statistics in parentheses

Standard errors are asymptotic; derived using the delta method

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

are implemented. In April 2013 BoJ adopted the quantitative and qualitative easing policy. The October 2014 monetary policy statement by the BoJ states “The average remaining maturity of the Bank’s JGB purchases will be extended to about 7-10 years (an extension of about 3 years at maximum compared with the past)”. The sensitivity of 10-years, on the other hand, is much higher than that of yields between 7 to 10-years with a different sign. Due to extremely low covariances, and the structure of identification the identified parameters may be distorted. Using a proper sized OIS sample could shed some light on the signs and magnitudes of the sensitivities of yields to policy statements. Unfortunately, I have no access to the full set of OIS data and cannot test these results.

Regardless of the maturity specific sensitivities, It is clear that JGB yields respond significantly to policy decisions. This result is in line with that of Arai (2016). The Bank of Japan changed its policy rates only five times between 1998-2017. The asset responses on policy decisions then must be different in nature than Kuttner (2001) type surprises, however, they should still be related with monetary policy. A candidate is the statements that are associated with the monetary policy decisions.

GSS has shown that policy announcements have a two-dimensional impact on asset prices. One for the policy action itself namely a change in the policy rates, and one for the newly available information embedded in the statement. Identification through heteroskedasticity fails to pinpoint the source of the response of

asset prices. In the case of Japan, most policy actions are in the form of LSAPs and forward guidance. Thus, isolating the statement responses from responses to policy rate changes become invaluable from the perspective of analyzing the effectiveness of the unconventional monetary policy. In the next section, I conduct a GSS type decomposition and demonstrate that pure statement effects are the primary source of response to the BoJ announcements.

2.2 Decomposing Asset Pricing Responses To Monetary Policy Announcements

2.2.1 Data

Following the convention in the literature, as the federal funds rate, I use the call rate data to capture policy rate changes. I use 63 announcements between 1998 and 2017. The choice process of the announcements follows a simple and intuitive algorithm. I include all the statements that introduced new LSAPs, directly changed policy rates or declared new forms of monetary policy. In addition to those, I also include the announcements that deviated in the form of speech from statements preceding them. That is, I include all statements if it reflects *new* information about how the BoJ foresees the future or provides verbal evidence on the changing stance of policy that BoJ commits to.

In the decomposition process, I use bond yields for 1, 2, 3, 4 and 5-years of maturity. Following GSS (2005), Brand et al. (2010) and Arai (2016), to control for the market expectations I use daily changes of bond yields around monetary policy announcement days. To avoid simultaneity and isolating announcement effects from other macroeconomic developments, for all the instruments I take the difference between yields for each maturity on and before the announcement dates. Finally, I convert the differences into basis points.

One thing of importance to note is that JGB yields are extremely low compared to the U.S. and European bonds that have the same maturity. For Instance, U.S. Treasury Bonds of maturity 10-years and 20-years rarely fell below 2% and 4% respectively. Whereas 10-year JGB yields are below 2% for more than ten years, and 20-year JGB yields are below 4% for over twenty years. Shorter maturity bond yields are far less than 2% for Japan. The aim, therefore, of choosing such unusually long maturities in comparison to the convention, is to capture sufficient amount of variation and to make sure the instruments I use are not strictly bound by the ZLB.

I construct a data matrix Y with each row representing an announcement and columns separate different maturity bonds. Every element Δy_t^x is the daily yield difference for the given bond between announcement days and non-announcement days.

$$Y_{T \times N} = \begin{bmatrix} \Delta y_t^{callrate} & \Delta y_t^{1year} & \Delta y_t^{2year} & \Delta y_t^{3year} & \Delta y_t^{5year} \\ \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix} \quad (2.10)$$

Two factors are extracted² out of Y using principal components method, which are then rotated and rescaled such that they still explain the same amount of variation in columns of Y but can be intuitively interpreted. That is, target factor follows direct changes in call rates and path factor is capturing all else included in the announcements.

2.2.2 Results

The two extracted, rotated and rescaled factors explain 93.3% of all variation in the data and yield similar features documented by other studies. In Figure-3

²Please see the appendix to see the full method of extraction

and Figure-4 I plot the time series of target and path factors. For the sake of scale comparison I keep the y-axis fixed. It is evident that target factor played a weaker role in JGB pricing behavior compared to the path factor. For the selected period, the magnitude of path surprises long surpass the target surprises as it would have been expected due to very few changes made in the policy rates by the BoJ.

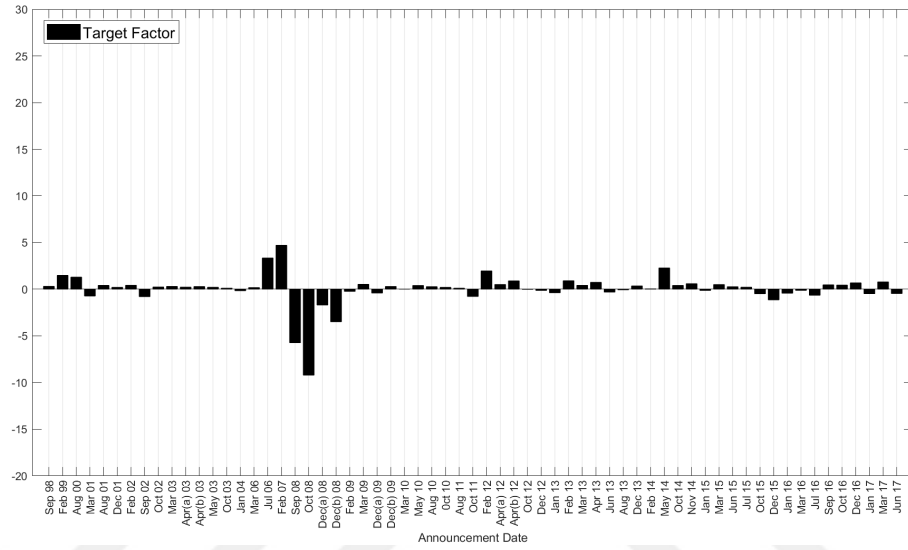


Figure 3: Target Factor Realizations for Different Announcements

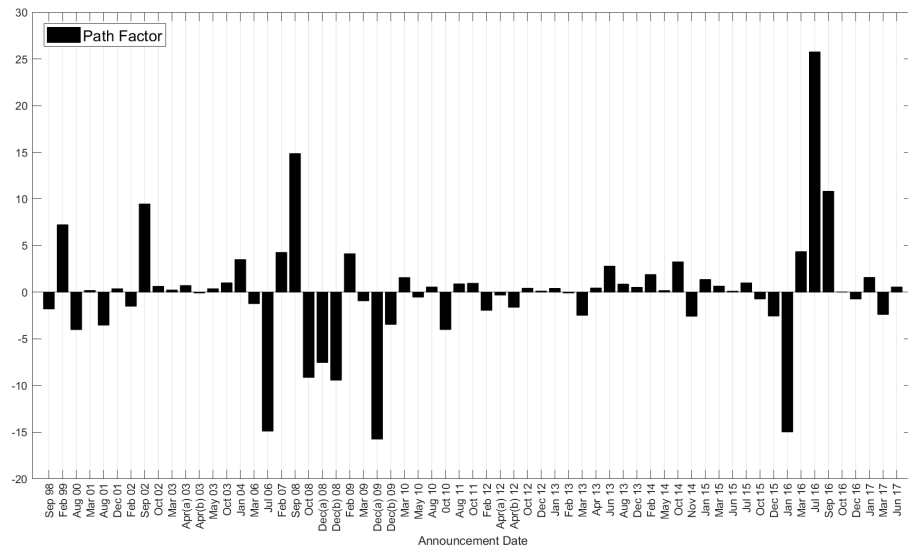


Figure 4: Path Factor Realizations for Different Announcements

I conduct an event study with the bond yields up to 5-years. I regress each instrument on the extracted factors. The results in Table-3 show that significance

for target factor is low without a particular pattern even for the shortest maturity yields. Path factor in comparison has a higher impact than the target factor for all the maturities longer than 1-year. High R^2 values are in line with the high variation explained by these two factors extracted via principal components method.

It can be seen in Table-3 that target factor loses explanatory power and statistical significance in the variation of yields as the maturity increases. In contrast path factor predominantly explains the variation in longer maturity bonds and remains significant for all maturities. This feature is consistent with the view “Not only do expectations about policy matter but... very little else matters”(Eggertsson & Woodford, 2003).

Table 3: Event Study (Full Model)

	Call Rate	1 Year Yield	2 Year Yield	3 Year Yield	5 Year Yield
Target Factor	1*** (57.60)	0.290* (2.15)	0.092 (0.56)	-0.107 (-0.60)	-0.181 (-0.79)
R^2	0.982	0.071	0.005	0.006	0.010
Target Factor	1*** (57.60)	0.290*** (6.77)	0.092* (2.64)	-0.107*** (-3.97)	-0.181 (-1.99)
Path Factor		0.290*** (23.33)	0.364*** (36.03)	0.401*** (51.15)	0.473*** (17.94)
R^2	0.982	0.908	0.956	0.978	0.844
Path Factor Marginal R^2		0.837	0.951	0.972	0.834

t statistics in parentheses

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

All dependent variables are calculated as the changes in basis points on announcement days

To confirm that the path factor does not owe its high performance to the fact that it is extracted from the instruments in Table-3, I use different maturity yields that were unused in the extraction process to conduct a new set of event studies. I regress the announcement day changes for longer maturity yields on the factors, and Table-4 shows a similar pattern to that of Table-3. Target factor is strictly less if at all significant where path factor remains statistically significant at 0.001% level for the entire set of yields. This result is a confirmation that longer maturity bonds react primarily to expectations of future monetary policy.

Policy rate changes can hardly influence longer-term interest rates. In contrast, central bank statements have strictly higher importance for the long-term rates. Path factor alone explains 83% and 50.4% of the total variation in 5 and 10-years bond yield movements respectively. The market participants update their expectations with newly available information carried in the BoJ announcements and take investment positions accordingly.

Table 4: Event Study With Unused Yields

	4 Year Yield	6 Year Yield	7 Year Yield	8 Year Yield	9 Year Yield	10 Year Yield	15 Year Yield	20 Year Yield
Target Factor	-0.193 (-0.94)	-0.310 (-1.17)	-0.446 (-1.50)	-0.310 (-1.01)	-0.217 (-0.72)	-0.0800 (-0.26)	-0.205 (-0.61)	-0.230 (-0.70)
R^2	0.014	0.022	0.035	0.016	0.008	0.001	0.006	0.008
Path Factor	0.445*** (26.90)	0.529*** (14.37)	0.555*** (11.12)	0.556*** (10.27)	0.530*** (9.43)	0.488*** (7.82)	0.439*** (5.52)	0.358*** (4.28)
R^2	0.925	0.780	0.685	0.643	0.601	0.505	0.341	0.240
Path Factor Marginal R^2	0.911	0.758	0.650	0.627	0.593	0.504	0.335	0.232

t statistics in parentheses

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

All dependent variables are calculated as the changes in basis points on announcement days

Jointly examining the event studies, It is clear that target factor has no systematic impact on longer-term yields. The confidence bands in Figure-5 for the path factor with the factor loadings indicate a hump-shaped effect for the entire spectrum of maturities. I report the confidence bands for the target as well, but it is evident that we cannot statistically reject the hypothesis that the effect of target factor is different from zero for maturities longer than one year.

Moreover, since the shorter maturity interest rates are already extremely close to zero, the BoJ can conduct monetary policy *only* via influencing market expectations. Nevertheless, Figure-5 also confirms that the BoJ is not hopeless in controlling the market expectations via central bank communication. My findings of maturity response in this analysis are similar to that of Brand et al. (2010) for the path factor, for which the shapes align. Likewise, target factor, although not strict, exhibits a downward slope for the statistically significant portion of the results.

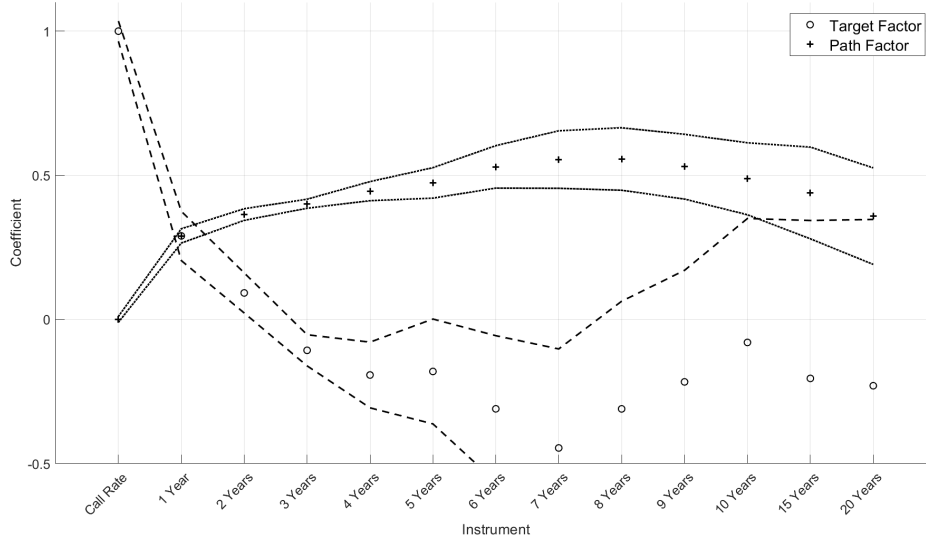


Figure 5: Factor Loadings (Rotated and Rescaled)

2.2.3 Major Events

It is crucial to understand the nature of announcements for the BoJ in evaluating the effectiveness of the unconventional monetary policy. Between 1998 and 2000 the BoJ changed the policy rates three times and in Figure-3 the target factor reacts accordingly. From 2000 until July 2006 no changes in the policy rate has been made and accordingly target factor had negligible jumps. The implication is that besides the anomalous crisis period, the BoJ was, clearly, stuck at the ZLB and was unable to conduct stimulating conventional monetary policy. The most significant positive jump in the graph came after the February 2007 announcement in which the policy rate was increased to 0.5%. In October 2008 the BoJ decreased the policy rate back to 0.3%, and this event caused the largest drop in target factor in my entire sample.

Path factor, on the other hand, has a much higher variation for the first half of my sample in comparison to the target. LSAP impacts are visible throughout the entire graph in Figure-4. For instance, September 2002 announcement in which the BoJ introduced a new method of LSAP caused a non-negligible

jump. In contrast to the target factor, which exhibits a positive jump, July 2006 announcement is associated with a significant drop in path factor. In this announcement, the BoJ raised its policy rate to 0.25% and emphasized to continue bond purchases at the current rate for a prolonged period of time. The entire announcement somewhat signals to a change in stance by the BoJ. The bank also emphasized the economic recovery being in line with their aims, and future policies would be implemented accordingly.

At this point, I briefly analyze the change in bond yields and confirm that yields of all maturities have changed negatively for the July 2006 announcement. This result implies that the market participants reacted to a signal of change in stance, and formed expectations on future tightening.

The announcement on July 2016 has by far the largest path factor realization, and the positive sign of the jump is not surprising. In this announcement, the BoJ introduced an enhancement on monetary policy. The package included an increase in different types of asset purchases in addition to the notion *qualitative and quantitative monetary easing with negative interest rates*. The drastic jump in path factor implies the market participants perceived the new course of action to be a promising new addition to the numerous attempts of the BoJ to improve the financial conditions of the economy.

The joint jump in yields of all maturities implies that the new information coming from the July 2016 announcement was perceived as a positive signal for the future path of the economy and monetary policy. This result can be linked with a strong commitment by the BoJ to ensure economic recovery. Evidently, the reaction was in line with the intentions of the BoJ. The market participants took this announcement as good news. Moreover, the bank successfully influenced long-term interest rates and market expectations via communication.

A summary on top-five major BoJ announcements (in absolute value) can

be found in Table-5 and Table-6. As the common understanding would imply, target factor is capturing the changes in policy rate. Path factor, on the other hand, is related with significant changes in policy stance, or adoptions of new and comprehensive policies.

Table 5: Highest Target Factor Realizations

Date	Summary
31-10-2008	•Policy rate reduced to 0.3% •The basic loan rate applicable under the complementary lending facility is lowered by 25 basis points to 0.5%
18-09-2008	BoJ emphasized the uncollateralized call rate to remain at 0.5%
21-02-2007	Policy rate raised to 0.5%
19-12-2008	Policy rate reduced close to 0%
14-07-2006	Policy rate raised to 0.25%

Table 6: Highest Path Factor Realizations

Date	Summary
29-07-2016	New policy “Enhancement of Monetary Easing” is implemented
01-12-2009	Announcement of a new funds-supplying operation to “encourage a further decline in longer term interest rates”
29-01-2016	New Framework for strengthening Monetary Easing: “Quantitative and Qualitative Monetary Easing With Yield Curve Control”
14-07-2006	The bank has maintained zero interest rates for an <i>extended</i> period, and the stimulus from monetary policy has been gradually amplified against the backdrop of steady improvements in economic activity and prices
18-09-2008	A mention on careful assessment of increased global risks and its potential reflection on domestic private demand. Emphasis made on future policies to be made in accordance

The work explained above indicates that Japan, although its long struggle with ZLB is unique, is not an exception for the effectiveness of the unconventional monetary policy. Table-5 and Table-6 show that the BoJ successfully influenced expectations of market participants via central bank communications on future intentions and new policy adoptions. This is an encouraging set of results in connecting the literature and show the universality of results derived for other countries.

2.3 Robustness

An important concern about the results shown above is whether the data and maturity selection for the analysis is appropriate. For this purpose, I repeat and compare factors extracted using a different model specification for the data matrix Y , followed by another experiment conducted using the overnight index swaps data.

2.3.1 A Limited Model

For robustness I use the GSS method on a data matrix Y with call rates and 1-year yields. as shown in equation 2.6. This is essentially a limited version of the previous analysis.

$$Y_{T \times N} = \begin{bmatrix} \Delta y_t^{callrate} & \Delta y_t^{1year} \\ \vdots & \vdots \end{bmatrix} \quad (2.11)$$

The literature follows factor extraction methods using up to 1-year yields and fed funds futures. Unfortunately, I do not have access to the futures for the short term rates. Essentially the following study is to check whether including higher maturity yields distort the results qualitatively. It can be inferred from Table-7 that the significance of the factors exhibit no qualitative change although quantitatively explanatory power drops for maturities of more than 1-year. It is also worth noting that the two factors extracted from two data series results with factors almost identically varied with the data. Hence, the new target factor explains variation in call rates and two factors jointly explain 1-year yield variation perfectly.

It can be inferred from Figure-6 that target factors from the full and limited models are identical in sign with slight differences in scale. A similar result can be

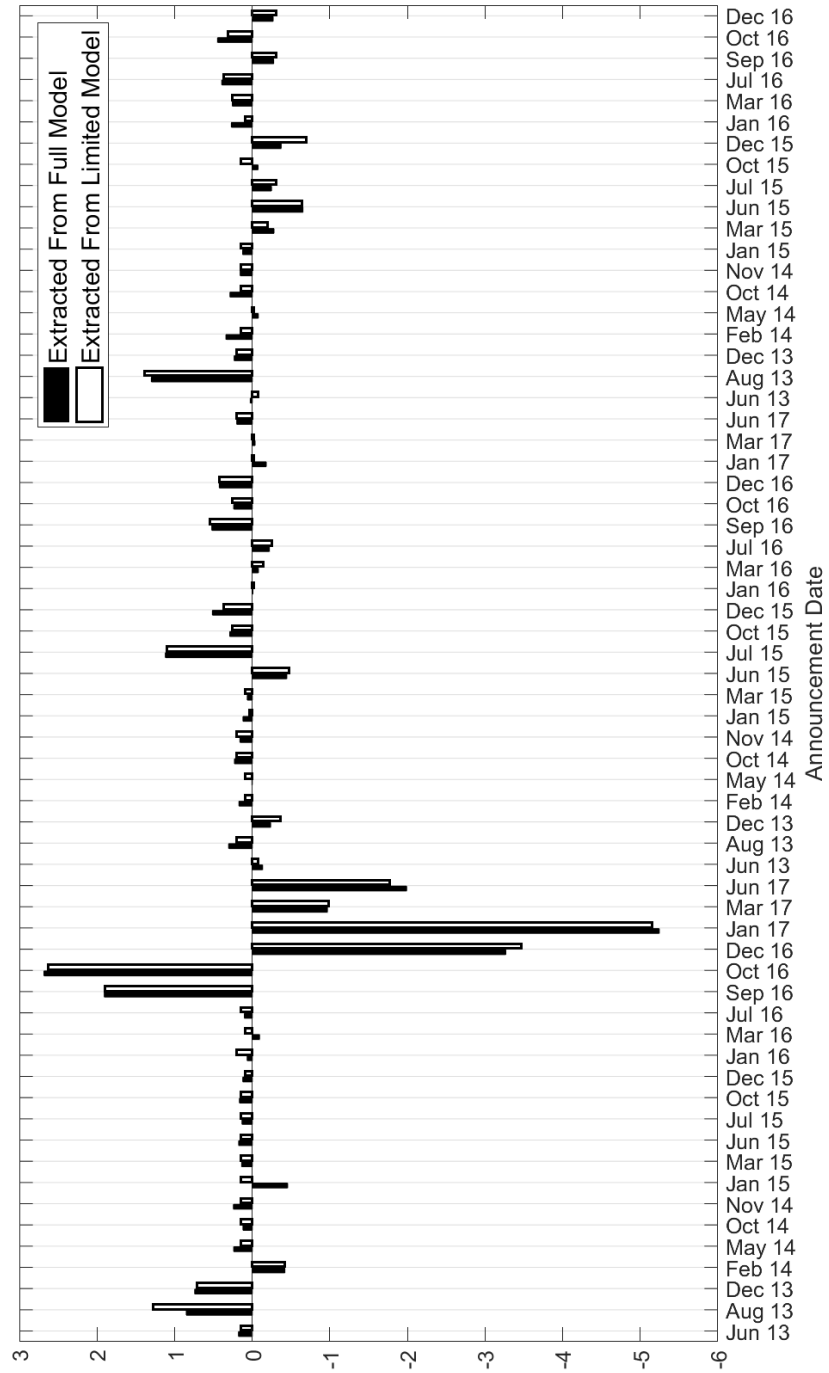


Figure 6: Target Factor Comparison: Full vs. Limited Model

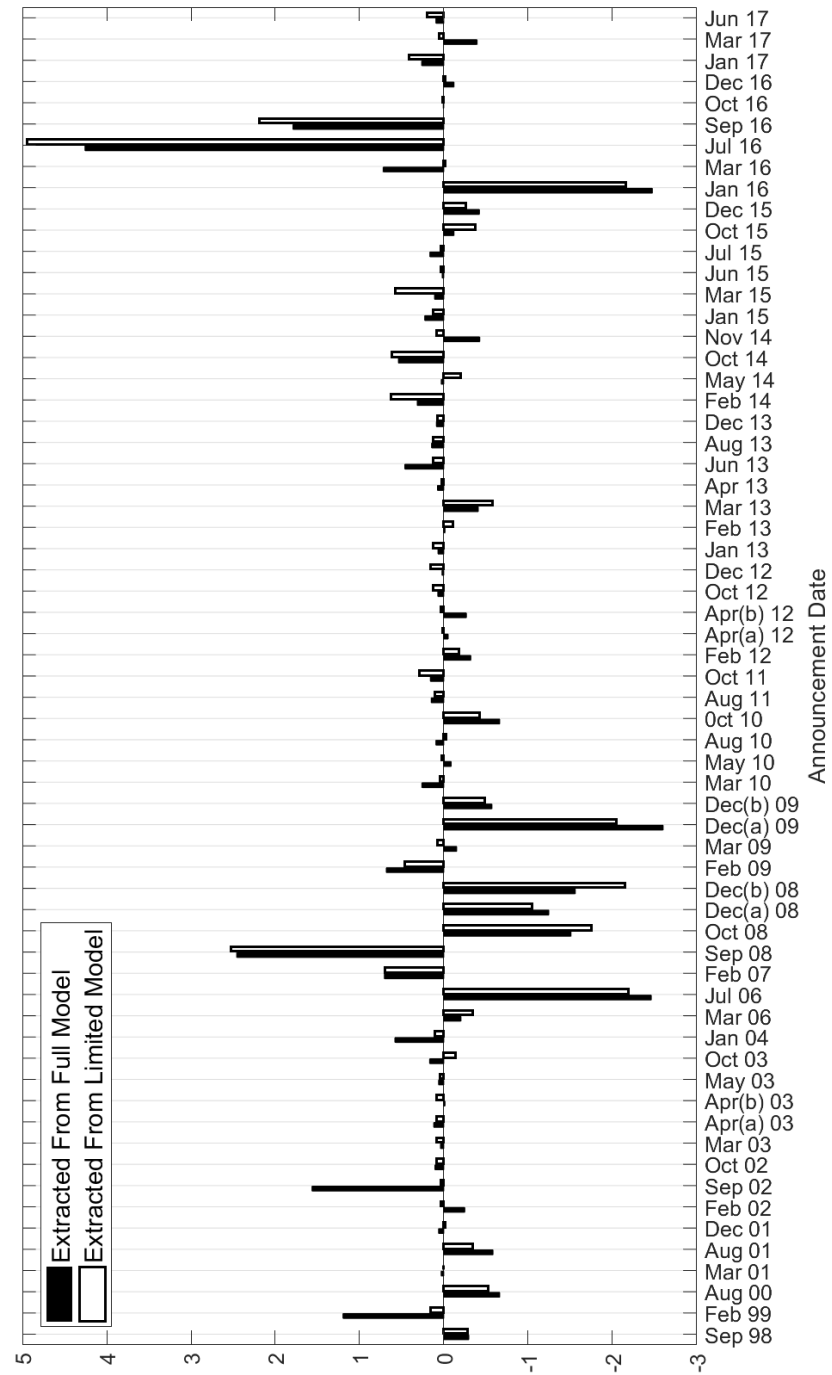


Figure 7: Path Factor Comparison: Full vs.Limited Model

Table 7: Event Study (Limited Model)

	Call Rate	1 Year Yield	2 Year Yield	5 Year Yield	10 Year Yield	20 Year Yield
Target Factor	1.000 (.)	0.241 (.)	0.064 (1.41)	-0.091 (-0.59)	0.065 (0.25)	-0.105 (-0.34)
Path Factor		0.241 (.)	0.280*** (26.99)	0.300*** (8.55)	0.284*** (4.82)	0.198** (2.81)
R^2	1.000	1.000	0.924	0.551	0.280	0.118

t statistics in parentheses

All dependent variables are calculated as the changes in basis points on announcement days

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

seen for the path factor in Figure-7. This implies the limited model qualitatively is not different than the original full model. Hence, the results derived above for the BoJ's ability in influencing markets at the ZLB are verified.

2.3.2 Overnight Index Swaps

Overnight index swaps (OIS) are essentially bets on what the interest rate will be in a given period of time. Therefore, they are extremely accurate proxies for measuring market expectations with available information. The final results provided in this study follow the GSS extraction for the OIS data. I collect OIS rates that are provided by Bloomberg for 1, 2, 3 and 5-year swaps. Combined with the call rates I generate a data matrix Y as in equation 2.5. Because the data in daily frequency is available for only the most recent five years, I cut down my sample of announcements and align it with the available data. Finally, I divide both original factors and the newly extracted factors to their respective standard deviation to keep them scale wise comparable. Results can be seen in Figure-8 and Figure-9

Target factor extracted using the OIS data is almost identical to the original target for the subsample of dates at which OIS data is available. Path factors, on the other hand, differ in magnitude without a particular pattern. Nevertheless, the sign of the path factors almost always agrees in the two extraction methods.

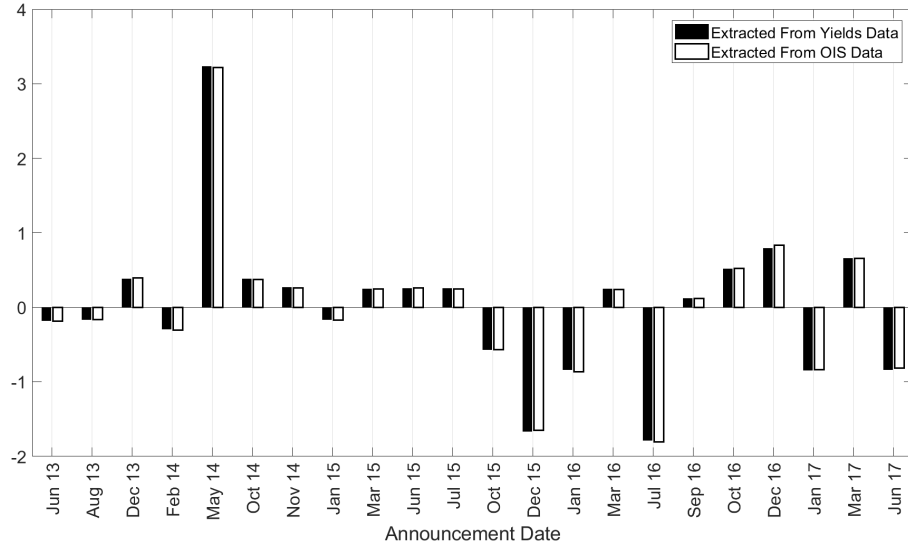


Figure 8: Target Factor Comparison: OIS vs. Yields

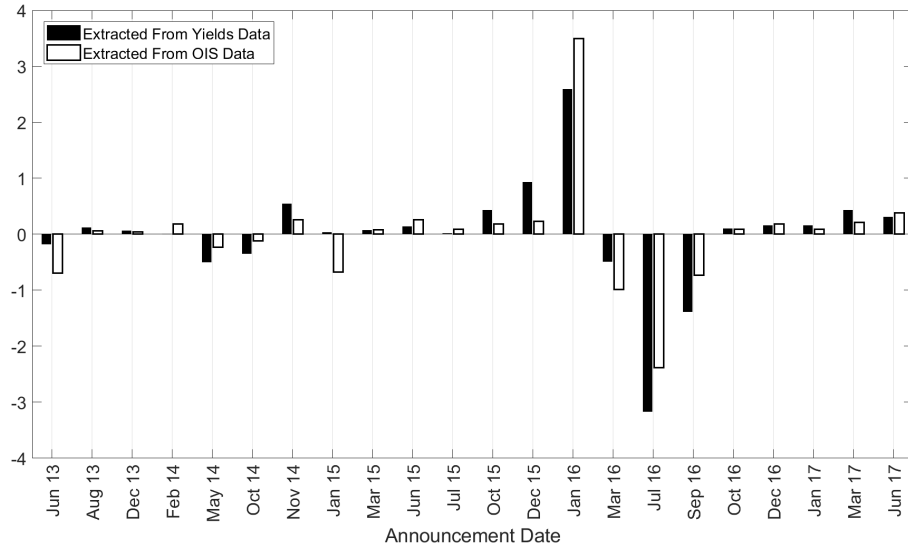


Figure 9: Path Factor Comparison: OIS vs. Yields

The only date in which path factors carry different signs is on the announcement of January 2015. On this date, the BoJ announced an extension of bank lending facilities. The original path factor seems to be very low for this specific announcement as presented in section 2.2.3 Figure-5. In contrast, the OIS study indicates a slightly higher response with a negative sign. This observation is possibly due to particularities of market conditions in the given time period and is beyond the scope of this study.

The span of the available data is very limited. Therefore, the sample size is very low to conduct an event study. For this reason, I do not report the factor loadings on factors extracted using the OIS. In summary, the OIS study supports the evidence found in the previous sections: The BoJ is capable of influencing markets at the ZLB.



CHAPTER 3

CONCLUSION

Japan has long been struggling with the zero lower bound. Numerous studies thus far, have shown that central banks were capable of influencing markets at the ZLB. Unconventional policies are reported to be effective for the European Central Bank and the Federal Reserve. I have conducted identification through heteroskedasticity to check whether JGBs respond to policy decisions and find that the answer is yes. This is in line with what Arai (2016) has reported.

I decomposed the response of bond yields to BoJ statements and also found that the qualitative results are in line with what has been reported in previous studies for other countries. In conclusion, The Bank of Japan, even after such a long experience at the ZLB, can conduct effective monetary policy. This result fills a gap in the previous literature and indicates universality on our understanding of unconventional monetary policy at the zero lower bound.

The BoJ implemented numerous packages of LSAPs throughout the 1998-2017 period. It is also evident from the differing language in their policy statements that forward guidance is a tool the BoJ actively uses. It would be an interesting extension, therefore, to conduct a Swanson (2017) type decomposition on path factors to split the LSAP and forward guidance effects. It would also be a useful extension to perform the type of study provided above with extended OIS data and yields up-to 1-year, then find factor loadings to evaluate maturity specific sensitivities. These extensions give room for future research on the topic.

REFERENCES

- Arai, N. 2016. The Effects of Monetary Policy Announcements at the Zero Lower Bound. *International Journal of Central Banking*.
- Brand, C., Buncic, D., & Turunen, J. 2010. The impact of ECB monetary policy decisions and communication on the yield curve. *Journal of the European Economic Association*, 8(6), 1266–1298.
- Cook, T., & Hahn, T. 1989. The effect of changes in the federal funds rate target on market interest rates in the 1970s. *Journal of Monetary Economics*, 24(3), 331–351.
- Eggertsson, G. B., & Woodford, M. 2003. The Zero Bound on Interest Rates and Optimal Monetary Policy. *Brookings Papers on Economic Activity*.
- Gertler, M. 2017. *Rethinking the Power of Forward Guidance: Lessons from Japan* (Tech. Rep.). National Bureau of Economic Research.
- Gurkaynak, R. S., Sack, B. P., & Swanson, E. T. 2005. Do actions speak louder than words? The response of asset prices to monetary policy actions and statements. *International Journal of Central Banking*.
- Krishnamurthy, A., & Vissing-Jorgensen, A. 2011. *The effects of quantitative easing on interest rates: channels and implications for policy* (Tech. Rep.). National Bureau of Economic Research.
- Kuttner, K. N. 2001. Monetary policy surprises and interest rates: Evidence from the Fed funds futures market. *Journal of Monetary Economics*, 47(3), 523–544.
- Rigobon, R., & Sack, B. 2004. The impact of monetary policy on asset prices. *Journal of Monetary Economics*, 51(8), 1553–1575.
- Swanson, E. T. 2017. *Measuring the effects of Federal Reserve forward guidance and asset purchases on financial markets* (Tech. Rep.). National Bureau of Economic Research.

APPENDICES



APPENDIX A

FACTOR EXTRACTION

Principle Components

Data Matrix Y is defined as

$$Y_{T \times N} = \begin{bmatrix} \Delta y_t^{callrate} & \Delta y_t^{1year} & \Delta y_t^{2year} & \Delta y_t^{3year} & \Delta y_t^{5year} \\ \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix} \quad (\text{A.1})$$

Data Matrix Y is assumed to follow the process

$$Y = F\Omega' + \eta \quad (\text{A.2})$$

where $F_{T \times k}$ is the matrix with the first k principle components in its columns. $\Omega'_{k \times N}$ is the factor loadings for each data series in Y . η are the idiosyncratic shocks.

Factor Rotation

Let U be an orthogonal matrix such that $UU' = I$. Then equation A.1 can be written as:

$$Y = FUU'\Omega' + \eta \quad (\text{A.3})$$

$$Z = FU \tag{A.4}$$

where

$$U = \begin{bmatrix} \alpha_1 & \beta_1 \\ \alpha_2 & \beta_2 \end{bmatrix} \tag{A.5}$$

Identification restrictions

Columns of Z are orthogonal such that

$$E[z_1 z_2] = 0 \tag{A.6}$$

$$F = \begin{bmatrix} f_1 & f_2 \end{bmatrix}$$

$$\begin{bmatrix} z_1 & z_2 \end{bmatrix} = \begin{bmatrix} f_1 & f_2 \end{bmatrix} \begin{bmatrix} \alpha_1 & \beta_1 \\ \alpha_2 & \beta_2 \end{bmatrix} = \begin{bmatrix} \alpha_1 f_1 + \alpha_2 f_2 & \beta_1 f_1 + \beta_2 f_2 \end{bmatrix} \tag{A.7}$$

$$E(z_1 z_2) = 0 \implies (\alpha_1 f_1)(\beta_1 f_1) + (\alpha_1 f_1)(\beta_2 f_2) + (\alpha_2 f_2)(\beta_1 f_1) + (\alpha_2 f_2)(\beta_2 f_2) = 0 \tag{A.8}$$

$$\implies \alpha_1 \beta_1 f_1^2 + \alpha_1 \beta_2 f_1 f_2 + \alpha_2 \beta_1 f_1 f_2 + \alpha_2 \beta_2 f_2^2 = 0 \tag{A.9}$$

$$\alpha_1 \beta_1 + \alpha_2 \beta_2 = 0 \tag{A.10}$$

Second factor z_2 does not load on first column of Y , that is:

$$Z = FU \tag{A.11}$$

$$\implies F = ZU^{-1} \tag{A.12}$$

$$U^{-1} = \frac{1}{\det(U)} \begin{bmatrix} \beta_2 & -\beta_1 \\ -\alpha_2 & \alpha_1 \end{bmatrix} \tag{A.13}$$

$$\implies ZU^{-1} = \begin{bmatrix} \frac{\beta_2 z_1 - \alpha_2 z_2}{\det(U)} & \frac{-\beta_1 z_1 + \alpha_1 z_2}{\det(U)} \end{bmatrix} \tag{A.14}$$

$$\implies ZU^{-1}\Omega' = \gamma_1 \frac{\beta_2 z_1}{\det(U)} - \gamma_2 \frac{\alpha_2 z_2}{\det(U)} - \gamma_2 \frac{\beta_1 z_1}{\det(U)} + \gamma_2 \frac{\alpha_1 z_2}{\det(U)} \tag{A.15}$$

$$\implies ZU^{-1}\Omega' = \frac{\gamma_1 \beta_2 - \gamma_2 \beta_1}{\det(U)} z_1 + \frac{\gamma_2 \alpha_1 - \gamma_1 \alpha_2}{\det(U)} z_2 \tag{A.16}$$

$$\gamma_2 \alpha_1 - \gamma_1 \alpha_2 = 0 \tag{A.17}$$

where γ_1 and γ_2 are the factor loadings of first two principle components on the Call Rates

$$\Omega = \begin{bmatrix} \gamma_1 & \gamma_2 \\ \vdots & \vdots \end{bmatrix} \tag{A.18}$$

then U can be solved as follows

$$\alpha_1 = \frac{\gamma_1}{\gamma_1 + \gamma_2} \quad (\text{A.19})$$

$$\alpha_2 = \frac{\gamma_2}{\gamma_1 + \gamma_2} \quad (\text{A.20})$$

$$\beta_1 = \frac{-\alpha_2 \text{Var}(f_2)}{\alpha_1 \text{Var}(f_1) - \alpha_2 \text{Var}(f_2)} \quad (\text{A.21})$$

$$\beta_2 = \frac{\alpha_1 \text{Var}(f_1)}{\alpha_1 \text{Var}(f_1) - \alpha_2 \text{Var}(f_2)} \quad (\text{A.22})$$

APPENDIX B

RESCALING

We want the first factor z_1 to move one-to-one with call rates and z_2 to have the same loading on Δf_t^{1year} as z_1 . To do this we simply run an OLS regressions as follows

$$\Delta f_t^0 = \psi_0 + \psi_1 z_1 + \epsilon_{1,t} \quad (\text{B.1})$$

and

$$\Delta f_t^{1year} = \phi_0 + \phi_1 z_1^* + \phi_2 z_2 + \epsilon_{2,t} \quad (\text{B.2})$$

where

$$z_1^* = \psi_1 z_1 \quad (\text{B.3})$$

$$z_2^* = \frac{\phi_2}{\phi_1} z_2 \quad (\text{B.4})$$

Thus we finally obtain rotated and standardized factors $Z = \begin{bmatrix} z_1^* & z_2^* \end{bmatrix}$ where z_1^* and z_2^* now are called target and path factors respectively.