The Impact of Unconventional Monetary Policies on the USD/JPY Exchange Rate

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Abstract

This essay analyzes the impact of unconventional monetary policies in Japan on the USD/JPY exchange rate. Similar to interest rates and inflation, exchange rates are a key indicator of the status of an economy and thus, important to understand how it is affected under such policies. Linear regression analyses are used to study the impacts of these monetary policies on the exchange rate. I find that on average the change in Japan's overnight rate is statistically significant but these results are not stable over time. Unconventional monetary announcements in the United States have a negative but small impact on the daily exchange rate.

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1 Introduction

Following the global financial crisis of 2007–2008, many conventional monetary policies became ineffective as interest rates approached and, in some economies, hit the zero-lower bound. As concerns about deflation and financial stability arise under such settings, central banks turned to unconventional monetary policies (UMPs) to combat deflation and induce liquidity and economic growth. Developed economies including the Japan and the United States implemented different forms of UMPs, including forward guidance and large-scale asset purchases (LSAPs), commonly referred to as quantitative easing.

Forward guidance is a monetary policy tool used to provide information about the expectations for the future policy rate path. It allows central banks to mitigate the impact of the zero lower bound (ZLB) by committing to a future policy path through announcements. Campbell et al. (2012) classify forward guidance into two types: Delphic and Odyssean. Delphic forward guidance refers to the communication strategy in which the central bank publicly states a forecast about intended monetary actions or macroeconomic performance to the market and public. Odyssean forward guidance refers to the central bank's public commitment to a future policy path. Shirai (2013) categorizes forward guidance into three forms: open-ended, calendar-based and state- (threshold-) based. Open-ended forward guidance is an abstract description of the duration of monetary policy easing, calendar-based forward guidance is an abstract description with a specific date for monetary easing, and state-contingent forward guidance is a specific description of economic conditions in which the policy is executed.

The Bank of Japan (BoJ) was the first major central bank to implement forward guidance in 1999 following their banking crisis in the 1990s when they experienced a liquidity trap and entered the ZLB. During a press conference in April 1999, Masaru

Hayami, the Governor of the BoJ, indicated that "the Bank will maintain the zero interest rate policy until deflationary concerns are dispelled". This was an open-ended forward guidance on the continuation of the zero interest rate policy and it was aimed to be an accommodative monetary policy tool under the zero lower bound.

LSAPs involve large-scale purchases of securities, generally long-term government bonds, with the objective of influencing long-term yields through various transmission channels: signalling and portfolio rebalancing. Signalling influences future short-term interest rate expectations and portfolio rebalancing changes the supply of asset classes (Hausken and Ncube, 2013). Again, the Bank of Japan was the first central bank to implement quantitative easing in 2001. The Federal Reserve System implemented three LSAP programs following the financial crisis, in November 2008, November 2010 and September 2012.

The global financial crisis further deteriorated the economy in Japan as they were still experiencing consequences from their financial crisis from the early 1990s. As the pioneers of forward guidance, the BoJ reintroduced this monetary policy tool in 2009, following the 2008 crisis. During the monetary policy meeting on October 5, 2010, the BoJ announced their commitment to maintain a zero policy rate until their price stability goal was in sight. Along with forward guidance, the BoJ incorporated quantitative easing and diversified their asset purchases to include government and corporate bonds, real-estate investment funds and exchange-traded funds. Consequently by 2012, Japan's central bank asset to GDP ratio reached a high of approximately 66 percent. Aside from the substantial increase in central bank assets to GDP, real GDP in Japan fell by 9 percent from the peak, inflation entered negative territory and policy rates remained near-zero and eventually turned negative (Dell'Ariccia et al., 2018). Additionally, upon announcing the 2% inflation target in 2013, the BoJ used forward guidance as an instrument to anchor inflation expectations at the target level. Furthermore, in 2013, the BoJ also

introduced quantitative and qualitative monetary easing (QQE) in which a crucial element is forward guidance. In contrast to the forward guidance used previously, under QQE, forward guidance provides clearer and stronger commitments.

Although unemployment in Japan has been low relative to that in other economies, persistent deflation reflects a negative output gap and low economic expectations. Moreover, deflation contributes to firms' pessimism as the long-term appreciation trend of the yen has been linked to deflation. Combined with the rapid increase in the aged population, the decline in total population and slow pace of structural reforms, this has resulted in uncertainty regarding the future. In particular, households are saving more and firms are discouraged from investing, both risk-averse investment strategies (Shirai, 2013). These decisions could have severe negative consequences and thus, the BoJ turned to forward guidance to anchor inflation expectations at the target level and to achieve economic recovery.

Monetary policy plays an important role in financial markets, in particular, it is a key driver of asset prices—one channel being exchange rates. The exchange rate plays a crucial role in a country's export and import levels and thus, is an important determinant of a country's relative economic state. A majority of existing literature on unconventional monetary policy has studied its impact on variables including asset prices, interest rates, bond yields and inflation but not the exchange rate.

The objective of this essay is to analyze the impact of these monetary policies in Japan on the USD/JPY exchange rate. In order to study this question, I use daily data on interest rates and the exchange rate from January 1, 1999 to May 31, 2019. I also collect the unconventional monetary policy announcements in Japan and the United States during this period. In the linear regression analysis, I control for both conventional and foreign monetary policy.

Furthermore, I construct indicator functions for expansionary and contractionary announcements in both countries to investigate the separate effects

of these announcements. I examine whether the impact of these announcements is stronger when the event coincides with a change in the policy rate. Additionally, I test for the stability of these relationships under two different time period divisions (i) pre- and post- global financial crisis and (ii) pre- and post- QQE and the introduction of the 2% inflation target in Japan.

I find that the change in Japan's overnight rate has a positive impact on the exchange rate, on average, but on a small scale. This provides some evidence that traditional measures of relative monetary policy provide statistically significant results. In contrast to expansionary unconventional monetary policy announcements, contractionary announcements are statistically significant in both Japan and the United States, on average. However, these results are not stable across different time periods.

The remainder of the essay is structured as follows. Section 2 reviews the literature on the effectiveness of unconventional monetary policies and its impact on macroeconomic and financial variables. Section 3 introduces the unconventional monetary policy announcements in both Japan and the United States. Section 4 describes the interest rate and exchange rate data used in this essay. Section 5 discusses the results from the linear regression analyses. Section 6 contains concluding remarks.

2 Related Literature

2.1 Inoue and Rossi (2019): VAR Method

The global financial crisis triggered a wave of research on the effects of unconventional monetary policies during the zero lower bound period. Inoue and Rossi (2019) is a recent study that examines the effects of conventional and unconventional monetary policy on spot exchange rates in the United States. The

study focuses on real exchange rates to determine whether the transmission channel is due to changes in the real interest rate. They identify monetary policy shocks as shifts in the entire term structure of interest rates on monetary policy announcement dates. This is done to capture the unconventional forms of monetary policy embedded in the shifts. Additionally, changes in market expectations on future foreign yields are incorporated in the shock. Using the functional VAR approach as in Inoue and Rossi (2018), they find that under monetary easing, the US dollar relative to the currency of Japan, Canada, the Euro-Area and the United Kingdom depreciates.

The authors use a functional shock measured as the difference between the yield curve at the end of the announcement day and the yield curve the day before the announcement as opposed to the change in U.S. term structure relative to that of other countries. They also assume that foreign monetary policy does not react to the U.S. shock within the same time window. The overall effect is the linear combination of the changes in the term structure yields. The VAR model they use is estimated with change in log of the exchange rate and the change in each of the available raw yields at daily frequency.

This experiment is also repeated using real exchange rates and real interest rates to show that the transmission channel is due to the changes in real interest rates. Using the Fisher equation, the authors estimate the real interest rate as the nominal interest rate minus the expected inflation. They use the US inflation linked swap rates from Thomson Reuters Datastream. Additionally, the study is extended to investigate the exchange rate response to endogenous movements with the foreign term structure taken into account. They analyze the changes in the relative term structure due to a domestic monetary policy shock, that is the relative shifts of domestic and foreign yield curves.

2.2 Swanson (2017): High Frequency Approach

In many cases, forward guidance is announced contemporaneously with asset purchases and thus, there is limited research on analyzing the independent effects. However, the study done by Swanson (2017), provided new estimates of the separate effects of forward guidance and LSAPs in the United States. He extends the high-frequency approach of Gürkaynak et al. (2005) to address three challenges of measuring these effects: i) separating the effects of forward guidance and LSAPs ii) determining the size of the unexpected component of each announcement and iii) separating the effect of surprise announcements through inaction rather than action.

Using a dataset from July 1991 to October 2015 obtained from the staff of the Federal Reserve Board, Swanson collects the asset price responses into a $T \times n$ matrix X. The columns of matrix X correspond to the n different assets and the rows correspond to the FOMC announcements. The elements (x_{ij}) report the 30-minute responses of the jth asset to the ith FOMC announcement. In the estimation, only the assets that are most closely related to monetary policy are included in matrix X. This data was denoted in terms of a factor model, $X = F\Lambda + \epsilon$, where the columns of F are taken as follows:

(i) the surprise component of the change in the federal funds rate around each FOMC meeting

(ii) the surprise component of the change in forward guidance

(iii) the surprise component of any LSAP announcement

(iv) any additional dimension of news about monetary policy or the economy that is systematically revealed in FOMC announcements

The unobserved factors F are then estimated and Swanson finds that rank three is not rejected at a 10% significance level. Thus, he extracts the first three

components of X which correspond to the elements of the FOMC announcements with the greatest systematic impact on the assets. Swanson makes three impositions:

(i) changes in LSAP have no effect on the current federal funds rate

(ii) changes in forward guidance have no effect on the current federal funds rate

(iii) restrict that LSAP effect is as small as possible in the pre-ZLB period

Swanson defines forward guidance as the component of FOMC announcement that conveys information about the future policy rate path above the change in federal fund rates. He finds that forward guidance is more (less) effective at moving short- (long-) term yields relative to LSAPs. Forward guidance effects peak at one year maturities and diminish. He also finds that a one standard deviation change in forward guidance led to an appreciation of the US dollar by approximately 0.25–0.35 percent and a decline in stock price of about 0.25 percent. These results are highly statistically significant. On the other hand, LSAPs led to a depreciation of the US dollar by approximately 0.2–0.3 percent and a rise in stock prices of about 0.1 percent. These results are not statistically significant. His findings are intuitive; the value of the dollar increases as interest rates increase because domestic investments become more attractive to investors.

2.3 Other Related Literature

Galí (2018) examines the effectiveness of forward guidance policies on the exchange rate in a open economy model for the Euro area. In his baseline calibration, he finds that forward guidance policies increase some variables, such as nominal exchange rates, with the degree of an economy's openness and decrease others, such as real exchange rates. In addition, he finds that the theory is inconsistent with empirical

results, which show that near (distant) future expectations of interest rate differentials have larger (smaller) effects and thus, concludes that there exists a forward guidance exchange rate puzzle.

Stavrakeva and Tang (2015) examined the link between monetary policy and exchange rates by decomposing quarterly exchange rate changes into two building blocks: (i) a standard no-arbitrage asset pricing equation and (ii) forecasting models of exchange-rate changes and policy rates. This approach allows for fewer theoretical restrictions. In addition, they focus on two forecasting models: a Taylor rule with policy rate smoothing and a yield factor model to allow expectation estimations at all future horizons. By focusing on monetary policy terms that capture the direct link between changes in the exchange rate and monetary policy, the authors are able to separate the effects of interest rate persistence from other factors, such as forward guidance, that might affect future expectations. They find that higher contemporaneous and expected future policy rates tend to appreciate a currency.

Ueda (2012) studied the non-traditional monetary policy measures adopted by the Bank of Japan over a 20 year period. The implementation of a strong explicit commitment on policy rates from 1999–2006 was an effective strategy. The Bank of Japan's commitment resulted in strong effects on expected future short-term rates according to Ugai (2007). The author finds forward guidance of future policy rates and targeted asset purchases move asset prices in the expected direction. Furthermore, Ueda finds that most monetary easing failed to weaken the Japanese yen and also failed to stop the deflationary trend experienced by the Japanese economy.

Overall, there has not been much research on the impact of unconventional monetary policies on the exchange rate. Similar to the related literature mentioned in this section, this essay measures the effects of unconventional monetary policy, both forward guidance and quantitative easing, on the USD/JPY exchange rate.

This essay differs from previous studies by controlling for both conventional and foreign unconventional monetary policy announcements. In particular, this essay will control for policy announcements in the United States because those announcements may influence the USD/JPY exchange rate. In contrast to the work done by Swanson (2017), I examine the separate effects of expansionary and contractionary unconventional monetary policy announcements. Lastly, I investigate whether the movement in the exchange rate is a predictor of the expected policy rate or a surprise in policy rate.

3 Unconventional Monetary Policy

The Bank of Japan has had four policy phases since the first implementation of unconventional monetary policy in 1999: (i) zero interest rate policy (ZIRP) from February 1999 to August 2000, (ii) quantitative easing policy (QE) from March 2001 to March 2006, (iii) comprehensive monetary easing from October 2010 to April 2013 and (iv) quantitative and qualitative monetary easing (QQE) from April 2013 to the present. With each phase, the relationship between the price stability objective and forward guidance has become more comprehensive.

After the global financial crisis, the Federal Reserve purchased longer-term Treasury securities to put downward pressure on longer-term interest rates. The Federal Open Market Committee used forward guidance to return inflation to 2% and to support economic activity. From November 2008 to September 2012, the Federal Reserve undertook three large-scale asset purchase programs before tapering their asset purchases in December 2013. In 2014, they announced their intention to normalize the balance sheet and by October of that year, they concluded their asset purchase program.

In this study, I collected the unconventional monetary policy announcements for

Japan and the United States from January 1, 1999 to May 31, 2019. The announcements made by the Federal Reserve are included to control for foreign monetary policy announcements that may influence the USD/JPY exchange rate. The announcements shown in Table 1 (for Japan) and Table 2 (for the U.S.) cover all the major unconventional monetary policy announcements made by the Bank of Japan and the Federal Reserve System. In the case of the United States, all key monetary policy announcements are taken from the Timeline of Policy Actions and Communications on the Federal Reserve System's official website. A few announcement dates prior to the financial crisis were included for the United States as the FOMC began using forward guidance in the early 2000s. These announcement dates were collected from Meade et al. (2015). In the case of Japan, the announcement dates were collected from the Statements of Monetary Policy published on the official Bank of Japan website. During this period, there were a total of 55 and 39 unconventional monetary policy announcements in Japan and the United States, respectively.

These announcements are categorized as contractionary and expansionary. Contractionary announcements include announcements in which the central bank raises the policy rate or decreases the money supply. These announcements are identified with an asterisk ($*$) in Tables 1 and 2. Expansionary announcements include announcements in which the central bank lowers the policy rate or increases the money supply through asset purchases.

In this study, it is possible that some announcements, news releases and speeches that are potentially relevant may have been omitted. The omission of such events may result in an upward or downward bias, depending on how these announcements affect the market's expectation of future policies (Krishnamurthy and Vissing-Jorgensen, 2011). In addition, the judgement of the categorization of an announcement varies depending on how the two types of announcements are defined. In this essay, any

announcement that states a slowdown in the pace of asset purchases is categorized as contractionary.

4 Interest Rate and Exchange Rate Data

To study the impact of all these announcements, I next describe the data on the interest rates and the USD/JPY exchange rate. The analysis will then be able to measure the impact on the exchange rate while controlling for both conventional and foreign monetary policy measures.

The daily nominal exchange rate (data available for business days) is obtained from the Federal Reserve Economic Data (FRED) for the period from January 1, 1999 to May 31, 2019 and shown in Figure 1. This is the noon buying rate in New York City measured as U.S. dollar (USD) per Japanese yen (JPY) and it will be denoted as S_t. The Japanese overnight rate ($i_t^{J,p}$) is the Bank of Japan's uncollaterized overnight rate measured as the daily average (updated every business day) and is collected from the Bank of Japan's Time Series Data Search. The federal funds rate ($i_t^{US,p}$) is collected from FRED. It is used as an indicator of monetary policy since Bernanke and Blinder (1992) concluded that it is "a good indicator of monetary policy actions" and that it is "extremely informative about future movements of real macroeconomic variables" (Bernanke and Blinder, 1992, 1). Both Japan's overnight rate and the federal funds rate were collected for the time period from January 1, 1999 to May 31, 2019 as shown in Figure 2.

Additionally, the yield spread difference of both countries will also be examined as it may be a predictor of future economic activity (Bauer and Mertens, 2018). Movements in the exchange rate depend on both current and expected future relative monetary policy. The yield curve represents the relationship between long-term and short-term interest rates on government bonds. Under expansionary unconventional

monetary policy, the yield curve is generally flattened as the long-term interest rate tends to be lower (in other words, the difference between the long-term and short-term interest rate is smaller).

More recently, many developed economies including the United States and Japan, have experienced an inverted yield curve in which the long-term interest rates are lower than short-term interest rates. This is an indication of low future output growth and the possibility of a recession. In this essay, the yield spread will be defined as the difference between the 5-year government bond rate ($i_t^{J,5}$, $i_t^{US,5}$) and the 1-year government bond rate ($i_t^{J,1}$, $i_t^{US,1}$) in both Japan and the United States, respectively. The difference in the bond yield spreads will be defined as $b_t \equiv (i_t^{J,5} - i_t^{J,1}) - (i_t^{US,5} - i_t^{US,1})$.

The Japanese government bond yields are collected from the Ministry of Finance Japan at a daily (business day) frequency and the daily U.S. Treasury yields are collected from the US Department of Treasury for the period from January 1, 1999 to May 31, 2019. For all non-business days, the time series data is set equal to that on the previous business day. The bond yields are shown in Figure 4.

In the regression analysis, I construct an indicator function for the unconventional monetary announcements. These announcements will take a value of negative one in the event that there is an expansionary announcement (loosening of monetary policy), positive one in the event there is a contractionary announcement (tightening of monetary policy) and zero otherwise. Under this specification, announcements in Japan are associated with a positive coefficient reflecting an appreciation in the yen. Thus the nominal exchange rate will be defined as US dollar per Japanese yen. Similarly, announcements in the United States are associated with a negative coefficient reflecting a depreciation in the exchange rate. The announcements will be denoted as U^J and U^{US} for Japan and the United States, respectively.

5 Statistical Evidence

Using the data described in Sections 3 and 4, I now examine whether the exchange rate reacts to the measures of conventional and unconventional monetary policy in both countries. I will then examine the independent impact of the types of announcements (expansionary and contractionary) and check on the stability of these relationships over time. Lastly, I will investigate whether the exchange rate is a predictor of future monetary policy.

5.1 Effects of Monetary Policy Changes

Recall the goal of the essay to analyze whether unconventional monetary policy in Japan influences the USD/JPY exchange rate. I first examine whether the exchange rate reacts to these changes. There are two key features of the statistical framework in this essay: (i) control for conventional monetary policy and (ii) control for foreign monetary policy.

This section presents the results of the regressions of the percent change of the nominal exchange rate on the various regressors shown in Table 3. The log of the nominal exchange rate (USD/JPY) at time t is denoted as s_t and an increase in s_t denotes an appreciation of the Japanese yen. The percent change of the exchange rate is denoted as $\Delta s_t \equiv s_t - s_{t-1}$ and is shown in Figure 3. The change in the policy rate is denoted as $\Delta i_t^{J,p} \equiv i_t^{J,p} - i_{t-1}^{J,p}$ and $\Delta i_t^{US,p} \equiv i_t^{US,p} - i_{t-1}^{US,p}$ for Japan and the United States, respectively.

Recall that expansionary announcements are set to be negative one in the data. Based on theory, one would expect the change in Japan's overnight rate and unconventional monetary policy announcements to have a positive effect on the yen and the change in the federal funds rate and U.S. monetary policy announcements to have a negative effect on the yen. To obtain unbiased standard errors and to

account for heteroskedasticity all standard errors are robust using the `robust` command in Stata.

First, I analyze the individual effects of the regressors on the percent change of nominal exchange rate in Table 4. This regression uses 7455 observations from January 1, 1999 to May 31, 2019. I would expect an expansionary policy change in Japan (the U.S) to lead to a depreciation (appreciation) in the yen and a contractionary policy change in Japan (the U.S) to lead to an appreciation (depreciation) in the yen. Table 4 shows that the change in Japan's overnight rate is highly significant and consistent with theory. A one percentage point increase in Japan's overnight rate is associated with a 2.25% appreciation in the yen. Second, unconventional monetary announcements in the U.S. are significant at the 10% level and result in a 0.14% depreciation in the exchange rate. This result is also consistent with theory. The other three rows show that the change in the federal funds rate, unconventional monetary policy announcements in Japan and the difference in the change of policy rates in Japan and the U.S. are not statistically significant.

Next, I examine in Table 5 whether the combination of these regressors has an effect on the exchange rate. The baseline regression hereafter, is:

$$\Delta s_t = \beta_0 + \beta_1 \Delta i_t^{J,p} + \beta_2 \Delta i_t^{US,p} + \beta_3 U^J + \beta_4 U^{US} + \epsilon_t. \tag{1}$$

Again, there are 7455 observations from January 1, 1999 to May 31, 2019. Notice that the impact of $\Delta i_t^{J,p}$ on the exchange rate on that day still remains highly significant, on average. Although the result is highly significant, notice it is small in scale; a one percentage point increase in the change in Japan's overnight rate results in a 2.15% increase in the exchange rate. Additionally, announcements in the U.S. remain significant at the 10% level and consistent with the monetary model of the

exchange rate. An unconventional policy announcement in the U.S. results in a 0.14% depreciation in the yen.

The last column includes the changes in market interest rates at 1-year and 5-year maturities. Although these are endogenous of the exchange rate, market interest rates may be indicators of expected future monetary policy and thus are included in the baseline regression. With these two additional regressors, the effects of $\Delta i_t^{J,p}$ and U^{US} remain significant; however, the change in Japan's overnight rate is less statistically significant than before. The changes in the 1-year and 5-year maturity bond yields are significant at the 10% and 5% level, respectively. Notice the sign of $\Delta i_t^{J,5}$ is puzzling. One would expect an increase in the 5-year yield to be associated with an appreciation of the yen and not a depreciation as the results show.

As I include the indicators of U.S. monetary policy, I want to control for the change in the slope of the U.S. yield curve and Table 6 presents these findings. Recall from Table 3 that $b_t = (i_t^{J,5} - i_t^{J,1}) - (i_t^{US,5} - i_t^{US,1})$.

Figure 5 shows the yield curves for both Japan and the U.S. and the difference in the two spreads. It shows that there were multiple days when the U.S. experienced an inverted yield curve and Japan recently experienced an inverted yield curve (June 2016 and March 2019) but only for a short period of time. Hofmann et al. (2019) examine the relationship between exchange rates and sovereign spreads in emerging market economies and find that an appreciation of the domestic currency against the U.S. is associated with the compression of the yield spread in both domestic and foreign bonds.

Up until now, the only detectible effects of policy measure are the change in Japan's overnight rate, $\Delta i_t^{J,p}$, and unconventional monetary policy announcements in the U.S., U^{US}, as shown in Tables 4 and 5. This continues to be true when the change in the yield spread difference, $\Delta b_t \equiv b_t - b_{t-1}$, is added to the baseline regression shown in Table 6. The last column interacts the unconventional monetary

policy announcements with Δb_t, the change in the yield spread difference, but the results show there is no statistically significant effect.

In Table 6, market bond yields and spreads were treated as if they are exogenous but realistically, they are endogenous. Next, I investigate whether the regressors from the baseline regression in equation (1) have an impact on the yield spreads and the difference in the yield spreads in Table 7. The purpose of this regression is to examine whether the bond market and the foreign exchange market react in the same way. The bond yield curves flatten when long-term rates tend to be lower and this change may affect the exchange rate today. The flattening of the yield curve will be reflected by a negative coefficient.

When Δb_t and the change in Japan's yield spread, denoted as $\Delta(i_t^{J,5} - i_t^{J,1}) = (i_t^{J,5} - i_t^{J,1}) - (i_{t-1}^{J,5} - i_{t-1}^{J,1})$, are taken as the regressand, the change in Japan's overnight rate is significant at the 5% and 1% level, respectively. The second column shows that an increase in the $\Delta i_t^{J,p}$ flattens the yield curve (i.e. decrease in the yield spread) in Japan relative to the one in the U.S. by 0.09 percentage points, on average. The third column shows that an increase in $\Delta i_t^{J,p}$ flattens the yield curve in Japan by 0.07 percentage points, on average. The last column shows that these regressors have no statistically significant effect on the U.S. yield spread. When there is an increase in the policy rate, short-term rates follow. When the short-end of the yield curve increases, the yield spread decreases and flattens the curve. The long-end of the curve is influenced by market expectations, if the bond market believes that policy rates are set too high, future inflation expectations decrease and long-term interest rates decrease relative to short-term interest rates, flattening the yield curve. Both significant results are consistent with what one would expect.

5.2 Stability Testing

5.2.1 Announcement Type

As mentioned earlier in Section 3, unconventional monetary policy announcements can be categorized as (i) contractionary in which the central bank raises policy rates or decreases the money supply or (ii) expansionary in which the central bank lowers policy rates or increases the money supply. These announcements are denoted as $U^{J,C}$, $U^{US,C}$, $U^{J,E}$ and $U^{US,E}$ for contractionary and expansionary announcements in Japan and the U.S, respectively. Up until now, I have assumed implicitly that the effects of these unconventional monetary policy announcements are similar in scale but opposite in sign. It is possible that this is not correct. Table 8 investigates whether expansionary and contractionary announcements have different effects.

Recall that expansionary announcements take a value of negative one and contractionary announcements take a value of positive one. One would expect an expansionary announcement in Japan (the U.S.) to result in the depreciation (appreciation) of the yen and a contractionary announcement in Japan (the U.S.) to result in the appreciation (depreciation) of the yen. Thus, announcements in Japan should have a positive coefficient and announcements in the U.S. should have a negative coefficient.

The second column in Table 8 has three findings. First, $\Delta i_t^{J,p}$ is the most statistically significant variable and has the largest effect on the daily exchange rate. A one percentage point increase in $\Delta i_t^{J,p}$ results in a 2.19% appreciation of the yen. Second, contractionary announcements in Japan have a negative effect at the 5% level, resulting in the depreciation of the yen. This result is puzzling, although not on a large scale. Lastly, contractionary announcements in the U.S. have a negative effect at the at the 5% level. This is a finding you would expect. On average, contractionary announcements in both Japan and the U.S. are statistically

significant; however, expansionary announcements are not.

The third column examines whether the impact is greater on dates when changes in the policy rate coincide with an unconventional monetary policy announcement. Indicator functions are used to measure the event of policy rate changes; a value of one is given if the event is true and a value of zero is given otherwise. Expansionary policy rate changes are denoted as $I(\Delta i_t^{J,p} < 0)$ and $I(\Delta i_t^{US,p} < 0)$ and contractionary policy changes are denoted as $I(\Delta i_t^{J,p} > 0)$ and $I(\Delta i_t^{US,p} > 0)$ for Japan and the U.S., respectively. The occurrences of these simultaneous events are shown in Figure 6.

There are two findings in the third column. The change in Japan's overnight rate and contractionary announcements in Japan remain significant at the 1% and 5% levels, respectively. It is important to note that in Japan, all contractionary announcements coincided with an increase in the overnight rate and thus, $U^{J,C}$ captures the effect of the simultaneous event. Again, contractionary announcements in Japan have a negative effect, resulting in a depreciation of the yen. This result is puzzling, although not it is on a large scale.

One might expect that a change in the policy rate coinciding with a policy announcement would result in a stronger impact on the daily exchange rate. It is interesting to find that this is not the case. Contractionary announcements in the United States which were statistically significant in column 2 are no longer statistically significant. In addition, the simultaneous event of an increase in the federal funds rate and a contractionary announcement in the U.S. does not result in a stronger impact on the exchange rate.

5.2.2 Time Periods

Tables 9 and Table 10 investigate whether the results discussed in Table 8 are stable over time. The regressions shown in Table 8 will be examined over two additional period divisions: (i) January 1, 1999 to December 31, 2006 and January 1, 2007 to

May 31, 2019 (ii) January 1, 1999 to December 31, 2012 and January 1, 2013 to May 31, 2019. The two divisions correspond to the occurrence of (i) the global financial crisis, after which the implementation of unconventional monetary policies became more prominent in both the United States and Japan, and (ii) the introduction of the quantitative and qualitative monetary easing and the 2% inflation target in Japan.

The second and third columns in Table 9 show the results of the regression for the period prior to the financial crisis. Prior to the financial crisis there were no expansionary announcements in the United States. The change in the federal funds rate, $\Delta i_t^{US,p}$, has a positive effect on the exchange rate and is statistically significant but this result is inconsistent with the monetary policy model of exchange rate. A one percentage point increase in the federal funds rate, on average, results in an appreciation in the yen. Recall that expansionary announcements are set to be negative one. Expansionary announcements in Japan are significant at the 5% level and result in an appreciation in the yen. This result is not what one would expect. Notice that the change in Japan's policy rate is not statistically significant during this time period, although it has been significant in the results discussed thus far.

When the effects of the change in the policy rate occurring simultaneously with an announcement are included in the regression shown in the third column, $\Delta i_t^{US,p}$ remains significant at the 5% level. Expansionary announcements in Japan are now more statistically significant, although the sign is still puzzling. Additionally, the event of a contractionary announcement in the U.S. coinciding with the tightening of the federal funds rate is statistically significant at the 5% level. This event results in the depreciation of the yen, on average, and it is a result we would expect.

The last two columns in Table 9 show the results of the regression for the period during and following the financial crisis. The change in Japan's overnight rate, $\Delta i_t^{J,p}$, is now significant at the 5% level. Contractionary announcements in both Japan and the U.S. are significant at the 10% and 5% level, respectively. These announcement

in both countries lead to a depreciation of the yen. This is not consistent with theory. Contractionary announcements in Japan are expected to result in the appreciation of the yen, thus, reflected by a positive coefficient. However, the results in columns 4 and 5 show otherwise. Column 5 shows the results of the regression with the inclusion of the simultaneous events of a policy change and policy announcement. These additions are not statistically significant. Furthermore, with these inclusions, contractionary announcements in the U.S. are no longer significant.

The second and third columns in Table 10 show the results of the regression for the period prior to the introduction of the QQE and the 2% inflation target. The change in Japan's overnight rate is highly significant. On average, a one percentage point increase in the overnight rate is associated with a 2.3% appreciation of the yen. Contractionary announcements in Japan are significant at the 5% level. Again, the sign of this result is puzzling. When the the interaction terms are added, as shown in the third column, the change in Japan's overnight rate and contractionary announcements in Japan remain significant at the 1% and 5% level, respectively. The event of a contractionary announcement in the U.S. coinciding with the tightening of the federal funds rate results is significant at the 5% level and results in the depreciation of the yen, on average.

The results following the introduction of the QQE and the 2% inflation target are shown in the last two columns of Table 10. During this period, there were no contractionary announcements in Japan. Surprisingly, the change in Japan's overnight rate is no longer significant. Contractionary announcements in the U.S. are significant and the occurrence of such an announcement results in a 0.23% depreciation in the yen, on average. After including the interaction terms, expansionary announcements in Japan are now significant at the 5% level and the contractionary announcements in the U.S. are no longer significant. Expansionary announcements in Japan result in a 1.7% depreciation in the Japanese yen, on

average. When these announcements coincide with a decrease in the overnight rate, the result is significant at the 5%. Recalling that expansionary announcements are set to negative one, I would expect this simultaneous event to have a positive impact on the exchange rate to reflect a depreciation in the yen. Interestingly, it results in a 2.5% appreciation in the Japanese yen which is not what one would expect.

Overall, columns 2 and 4 and columns 3 and 5 in Table 9 and Table 10 show that the results are not stable across time and the effect of unconventional monetary policy announcements on the exchange rate depends on different time periods.

5.3 Measuring Expectations

As we saw in Tables 9 and 10 the measured impact of the change in Japan's overnight rate is not stable over time. One possibility is that the exchange rate may react to a surprise or shock in policy and not the actual policy (which can be looser or tighter than expected).

I do not have daily expected policy rate data and one does not know what information the market or monetary policy reacts to about the state of the economy. However, I can test whether the exchange rate reacts to information that signals future changes in the policy rate. In particular, I can test whether the change in the exchange rate forecasts changes in the policy rate since the last monetary policy meeting. If changes in the policy rate are anticipated and already discounted then it may not react on that day. If movements in the exchange rate depend on current and expected monetary policy then an early change in the exchange rate may forecast monetary policy.

I collected the dates of the monetary policy meetings for Japan and the United States from the websites of the Bank of Japan and Board of Governors of the Federal Reserve System. The U.S. had a total of 192 meetings and conference calls and Japan had 292 from January 1, 1999 to May 31, 2019. There are 8 meetings every calendar

year in the U.S. and some years had additional conference calls. Japan averaged 15 meetings a year until 2015 when the Bank of Japan started to have 8 monetary policy meetings per year. A majority of the meetings in Japan and the U.S. took place over two days but for this analysis only the first date is used. Meeting dates which took place less than 5 days apart were not considered.

Let k count the meeting dates. The change in the policy rate $\Delta i_k^{country,p}$ is the difference in the policy rate between two such dates, where $\Delta i_k^{country,p} \equiv i_k^{country,p} - i_{k-1}^{country,p}$. The regressor, $s_{(k-1)+1/2-(k-1)}$, is the difference in exchange rates between the midpoint of two consecutive meeting dates, $(k-1)+1/2$, and the first of the the two dates, $k-1$. For example, in Japan, the first two monetary policy meetings in 1999 were held on January 19 and February 12. The change in the overnight rate would then be the difference between the policy rate on February 12 and January 19. The corresponding midpoint date is January 31 and thus, $s_{(k-1)+1/2-(k-1)}$ is difference between the exchange rate on January 31 and January 19. If a midpoint day falls on a half day, the following date is used.

Again, my aim is to see whether the exchange rate depends on future monetary policy by seeing whether it forecasts that policy. If some news occurred between January 19, 1999 and January 31, 1999, the foreign exchange market reaction could lead to a policy change. The exchange rate depends on future monetary policy and thus, should react before the next meeting date. Thus, the regression is:

$$\Delta i_k^{country,p} = \beta_0 + \beta_1 s_{(k-1)+1/2-(k-1)} + \epsilon_k. \tag{2}$$

Table 11 shows that the exchange rate is not statistically significant. This means I cannot use this regression to model the expected policy rate or, in turn, to measure the surprise in the policy rate.

6 Conclusion and Future Work

The global financial crisis initiated a wave of research on the effects of unconventional monetary policy on macroeconomic and financial variables, including interest rates and asset prices. The exchange rate is an important determinant of a country's economic state but still underrepresented in this area of study.

This essay has analyzed the impact of unconventional monetary policy in Japan on the USD/JPY exchange rate while controlling for both conventional and foreign monetary policy measures. Unconventional monetary policy announcements are represented by indicator functions. Expansionary announcements are set to be negative one, contractionary announcements are set to be positive one and a value of zero is set otherwise.

I find that the only consistently detectible effect is the change in Japan's overnight rate. On average, a one percentage point increase in the overnight rate results in an appreciation in the Japanese yen of approximately 2%. This result is consistent with theory, but not stable over time. The market rates in Japan, which are possible indicators of monetary policy, are also statistically significant.

Interestingly, unconventional monetary policy announcements in Japan were not statistically significant, on average. However, when the announcement types are differentiated from one another, contractionary announcements in Japan were statistically significant at the 5% level over the entire period of the analysis. Under different time period divisions, expansionary announcements in Japan were only statistically significant and consistent with theory following the introduction of the 2% inflation target and QQE in Japan. All these findings are small in scale.

On the other hand, unconventional monetary policy announcements in the U.S. are statistically significant, on average. However, when independent effects of the announcement types are taken into account, expansionary announcements in the U.S.

are not significant. This result is surprising since the U.S. had performed three large scale asset purchase programs following the global financial crisis to promote economic growth, and thus, one would expect these announcements to have an impact on the USD/JPY exchange rate.

On average, contractionary announcements are statistically significant but expansionary announcements are not in both Japan and the U.S. over the entire period of the study. Furthermore, it is interesting to find that the simultaneous events of a change in the policy rate and an unconventional monetary policy announcement do not strengthen the impact of the policy change and these results are also not statistically significant on average.

Lastly, there were some statistically significant results which were inconsistent with theory but small in scale. These findings include the change in the 5-year maturity yield, the event of contractionary announcements in Japan, expansionary announcements in Japan and the event of an expansionary announcement in Japan coinciding with a fall in the overnight rate prior to the global financial crisis.

This study showed that there are more statistically insignificant results than significant ones. In addition, the significant results are not stable across time. Statistical insignificance is not new when trying to explain nominal exchange rate changes with contemporaneous regressors. But there is some evidence from this essay that traditional measures of relative monetary policy, while controlling for foreign measures, provide statistically significant results.

In future research it would be interesting to conduct this analysis using higher frequency data, for example in a one hour window, due to the fact that the exchange rate may move upon the announcement release. Additionally, this study can be adapted to other economies such as the United Kingdom or the Euro Area where the policy rate has not been around the zero lower bound for the period of the analysis.

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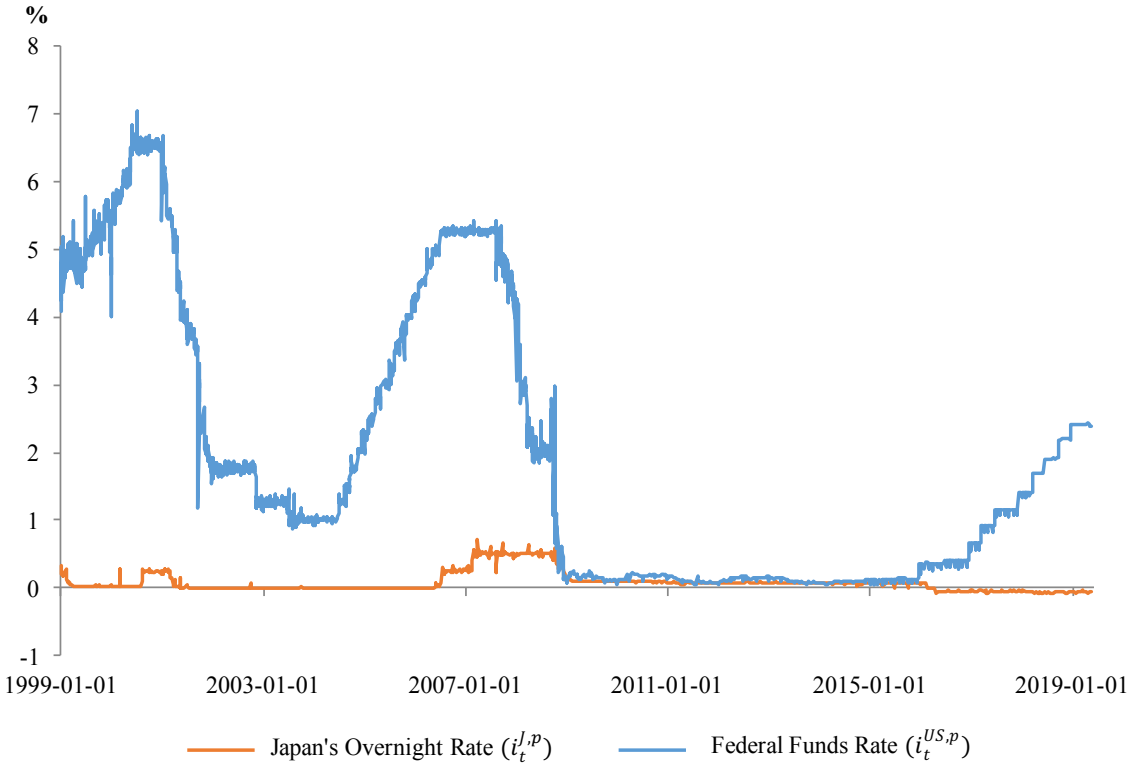
Figure 1: Nominal Exchange Rate (USD/JPY)

Last Observation: May 31, 2019

Source: Federal Reserve Economic Data, Series code: DEXJPUS
Note: This series is denoted as S_t

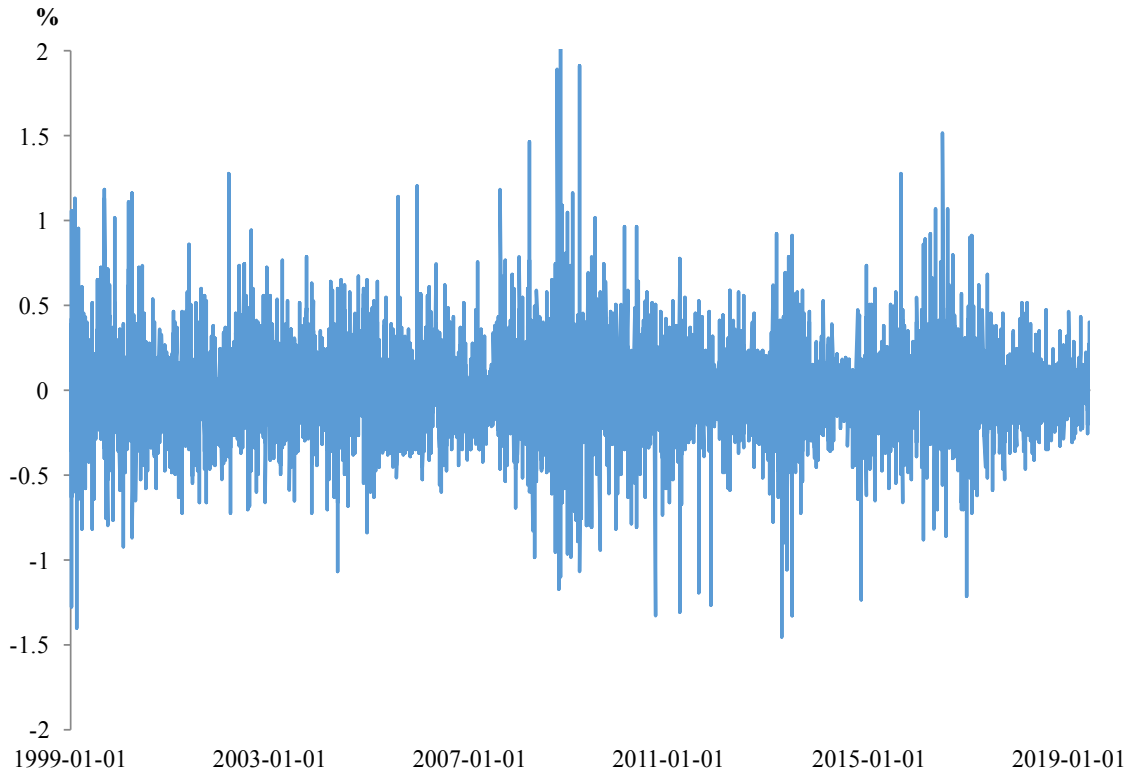
Figure 2: Central Bank Policy Rates



Last Observation: May 31, 2019

Sources: Bank of Japan, Series code: FM01'STRDCLUCON
and Federal Reserve Economic Data, Series code DFF

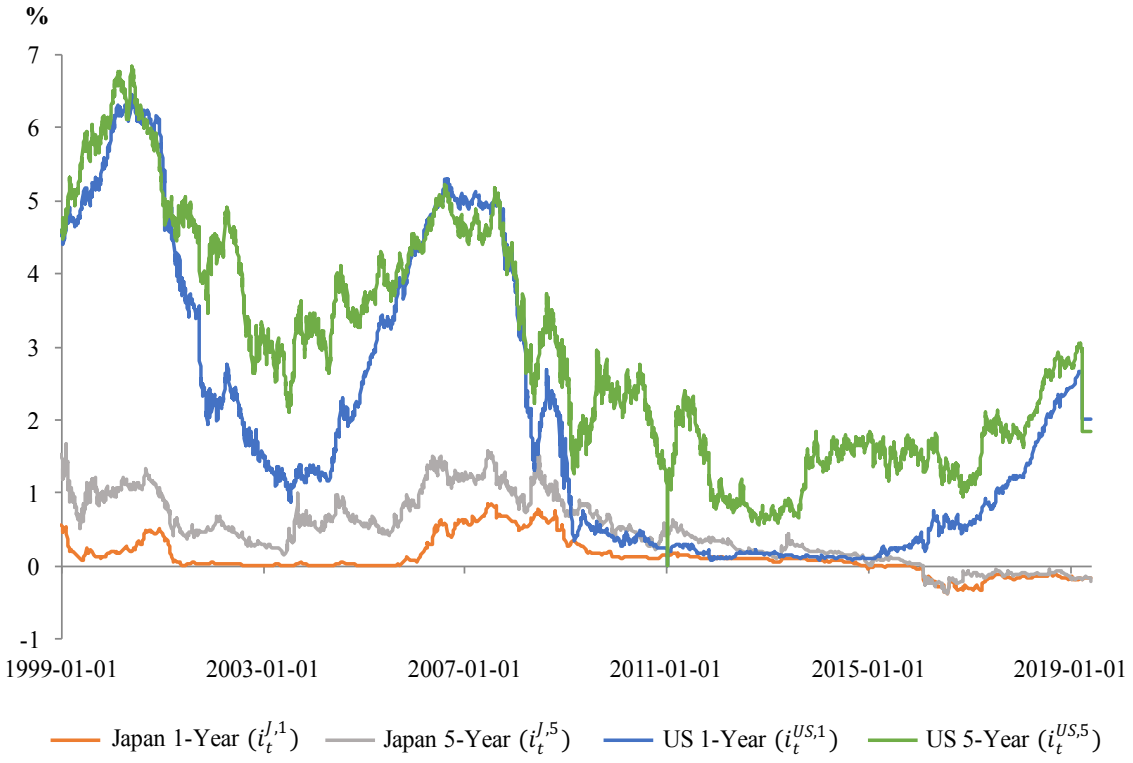
Figure 3: The Percent Change in Nominal Exchange Rate (USD/JPY)



Last Observation: May 31, 2019

Source: Federal Reserve Economic Data, Series code: DEXJPUS
Note: This series is denoted as $\Delta s_t = s_t = s_{t-1}$ where $s_t \equiv log(S_t) * 100$.

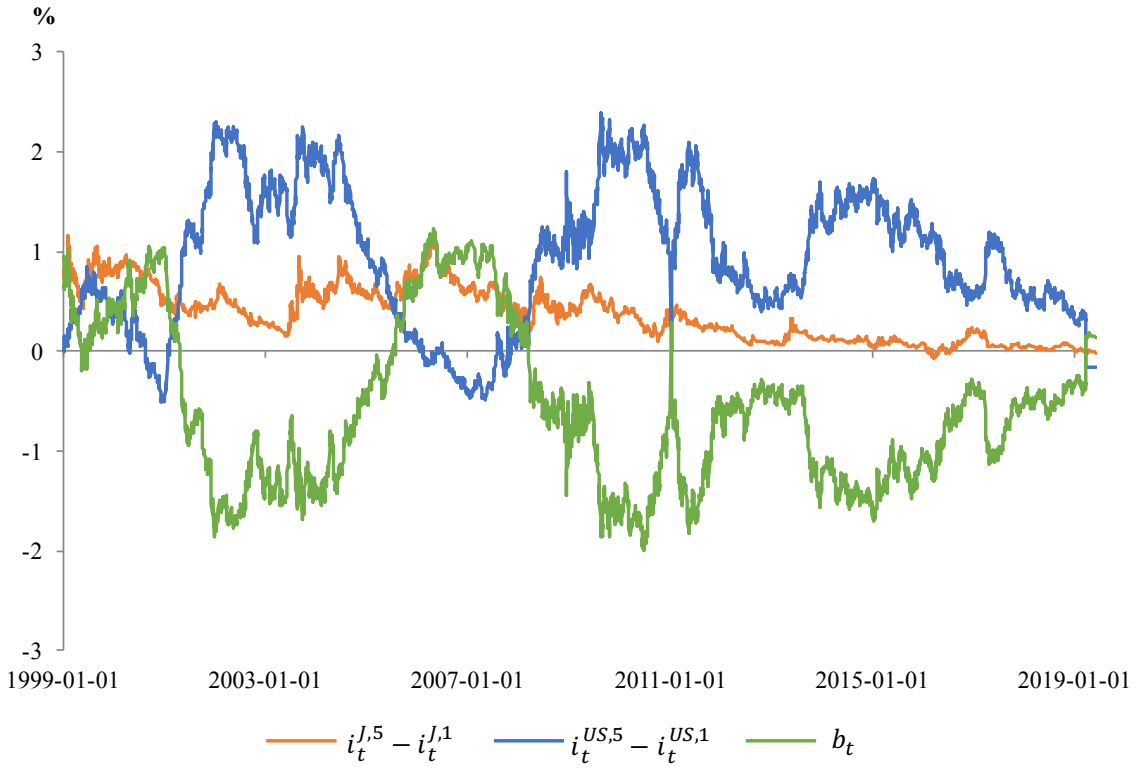
Figure 4: Government Bond Yields



Last Observation: May 31, 2019

Sources: Ministry of Finance Japan, Series: Interest Rates, Historical Data and US Department of Treasury, Series: Daily Treasury Yield Curve Rates

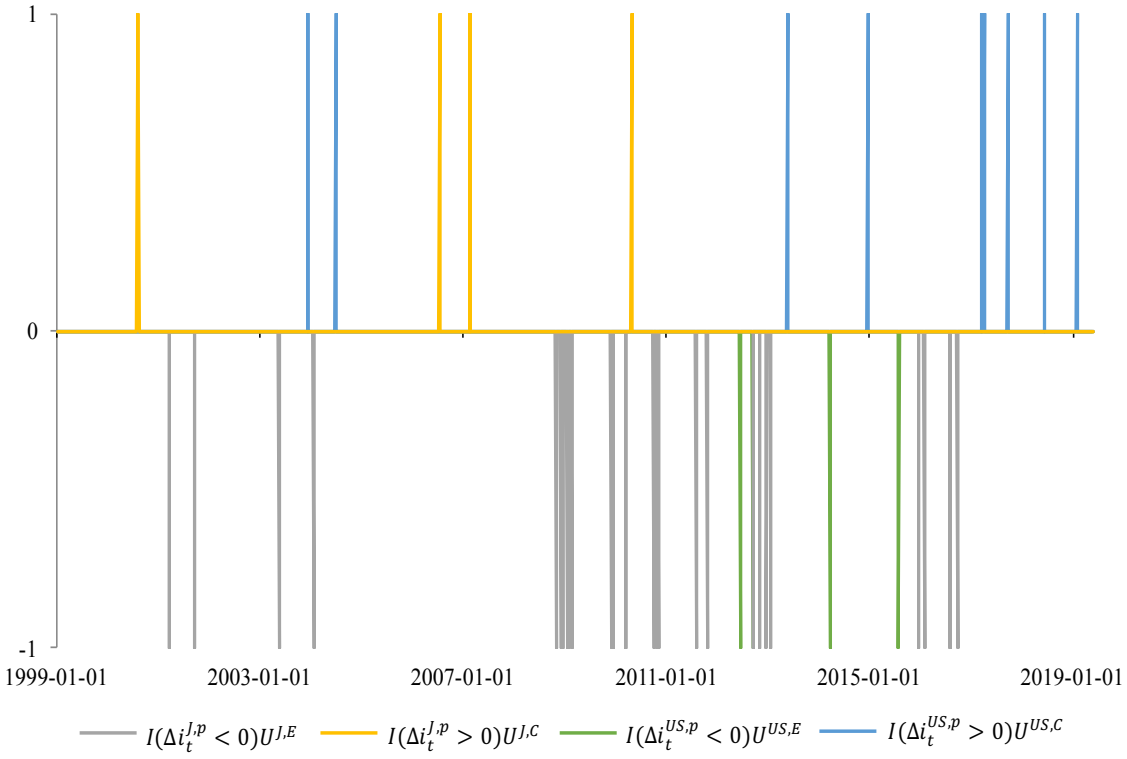
Figure 5: Yield Spreads and the Yield Spread Difference



Last Observation: May 31, 2019

Sources: Ministry of Finance Japan, Series: Interest Rates, Historical Data
and US Department of Treasury, Series: Daily Treasury Yield Curve Rates
Note: $i_t^{J,5} - i_t^{J,1}$ is the Japanese yield spread, $i_t^{US,5} - i_t^{US,1}$ is the U.S. yield spread and b_t is the difference in the yield spreads in Japan and the U.S., defined as $b_t = (i_t^{J,5} - i_t^{J,1}) - (i_t^{US,5} - i_t^{US,1})$.

Figure 6: Interaction Terms



Last Observation: May 31, 2019

Note: This figure shows the simultaneous occurrence of a policy change and an unconventional monetary policy (UMP) announcement. Indicator functions are used to represent the event of a policy change; a value of one is given if the event is true and a value of zero otherwise. The grey (yellow) lines represent the event of a decrease (increase) in the overnight rate coinciding with an expansionary (contractionary) UMP announcement in Japan. The green (blue) lines represent the event of a decrease (increase) in the federal funds rate coinciding with an expansionary (contractionary) UMP announcement in the U.S..

Table 1: Unconventional Monetary Policy Announcements in Japan

Date	Announcement
April 22, 1999	Initial forward guidance announcement from remarks made by Governor Masaru Hayami at a press conference: "I think that the Bank will maintain the zero interest rate policy (ZIRP) until deflationary concerns are dispelled."
August 11, 2000*	ZIRP lifted: The Bank of Japan will encourage the uncollateralized overnight call rate to move on average around 0.25%.
March 19, 2001	Initial quantitative easing announcement: The quantitative easing policy continues to be in place until the core CPI registers stably at zero percent or an increase year on year.
August 14, 2001	(i) The Bank of Japan will increase its outright purchases of long-term government bonds from ¥400 billion to ¥600 billion per month in order to smoothly provide liquidity under the new guideline (ii) The outstanding balance of current accounts held at the Bank of Japan will be raised from around ¥5 trillion to around ¥6 trillion.
September 18, 2001	(i) The Bank of Japan will provide ample liquidity to the money market by aiming at maintaining the outstanding balance of current accounts held at the Bank at above ¥6 trillion. (ii) The official discount rate will be reduced by 0.15 percentage points to 0.10 percent.
December 19, 2001	(i) The Bank of Japan will conduct money market operations, aiming at the outstanding balance of the current accounts at the Bank at around ¥10 trillion to ¥15 trillion. (ii) The Bank of Japan will increase its outright purchase of long-term government bonds from the current ¥600 billion per month to ¥800 billion per month.
February 28, 2002	(i) The Bank of Japan will provide more liquidity to meet a surge in demand irrespective of the target of current account balances, around ¥10 to ¥15 trillion. (ii) In order to provide liquidity smoothly, the Bank will increase the outright purchase of long-term government bonds from the current ¥9.6 trillion per year to ¥12 trillion per year.

September 18, 2002	The Policy Board introduces the purchase/sale of Japanese government securities with repurchase agreements.
October 30, 2002	(i) The Bank of Japan will conduct money market operations aiming at the outstanding balance of current accounts held at the Bank at around ¥15 to ¥20 trillion. (ii) The Bank of Japan will increase its outright purchase of long-term government bonds from the current ¥1 trillion per month to ¥1.2 trillion per month.
March 25, 2003	The Bank of Japan will conduct money market operations, aiming at the outstanding balance of current accounts held at the Bank at around ¥17 trillion to ¥22 trillion.
April 30, 2003	The Bank of Japan will conduct money market operations, aiming at the outstanding balance of current accounts held at the Bank at around ¥22 trillion to ¥27 trillion.
May 20, 2003	The Bank of Japan will conduct money market operations, aiming at the outstanding balance of current accounts held at the Bank at around ¥27 trillion to ¥30 trillion.
October 10, 2003	(i) The Bank of Japan will conduct money market operations, aiming at the outstanding balance of current accounts held at the Bank at around ¥27 trillion to ¥32 trillion. (ii) Enhancement of Monetary Policy Transparency: The Bank is currently committed to maintaining the quantitative easing policy until the core CPI registers stably zero percent or an increase.
January 20, 2004	The Bank of Japan will conduct money market operations, aiming at the outstanding balance of current accounts held at the Bank at around ¥30 to ¥35 trillion.
March 9, 2006	The Bank of Japan will encourage the uncollateralized overnight call rate to remain at effectively zero percent.
July 14, 2006*	The Bank of Japan will encourage the uncollateralized overnight call rate to remain at around 0.25 percent.
February 21, 2007*	The Bank of Japan will encourage the uncollateralized overnight call rate to remain at around 0.5 percent.
October 31, 2008	The Bank of Japan will lower the uncollateralized overnight call rate by 20 basis points and encourage it to remain at around 0.3 percent.

December 2, 2008	The Bank of Japan introduces Special Funds-Supplying Operations to facilitate corporate financing.
December 19, 2008	(i) The Bank of Japan will lower the uncollateralized overnight call rate by 20 basis points and encourage it to remain at around 0.1 percent. (ii) The Bank of Japan will lower the basic loan rate applicable under the complementary lending facility by 20 basis points to 0.3 percent. (iii) Interest rate applied to the complementary deposit facility will be 0.1 percent. (iv) The amount of outright purchases of Japanese government bonds (JGBs) will be increased from ¥14.4 trillion to ¥16.8 trillion per year.
January 22, 2009	The Bank of Japan decides to begin outright purchases of commercial paper and asset-backed commercial paper, and to expand the range of JGBs accepted in outright purchases.
February 3, 2009	The Bank of Japan resumes purchases of stocks held by financial institutions.
February 19, 2009	The Bank of Japan expands special funds-supplying operations and outright purchases of commercial paper, and begins outright purchases of corporate bonds.
March 18, 2009	The amount of outright purchases of JGBs will be increased by ¥4.8 trillion from ¥16.8 trillion to ¥21.6 trillion per year.
July 15, 2009	The Bank of Japan extends the period for outright asset purchases and special funds-supplying operations.
October 30, 2009	The Bank of Japan extends its special funds-supplying operations, and intends to provide ample liquidity funds-supplying operation against pooled collateral.
December 1, 2009	Further Enhancement of Easy Monetary Conditions: The Bank of Japan introduces a 3-month funds-supplying operation at the fixed target interest rate of 0.1 percent against pooled collateral up to a total amount of ¥10 trillion to encourage a further decline in longer-term interest rates.
December 18, 2009	The Policy Board clarifies the expression of the "understanding of medium- to long-term price stability" by eliminating the possibility of the zero percent price change.

March 17, 2010	The Bank of Japan will expand the measure to encourage a decline in longer-term interest rates by substantially increasing the amount of funds to be provided through the fixed-rate operation
April 30, 2010*	The Bank of Japan ended its stock purchasing program.
May 21, 2010	The Bank decides to compile and announce a preliminary framework for the Fund-Provisioning Measure to support strengthening the foundations for economic growth.
August 30, 2010	The Bank of Japan newly introduced a six-month term in the fixed-rate funds-supplying operation against pooled collateral with a maximum amount of ¥10 trillion.
October 5, 2010	Comprehensive Monetary Easing: (i) The Bank of Japan will encourage the uncollateralized overnight call rate to remain at around 0 to 0.1 percent. (ii) The Bank of Japan will maintain the virtually zero interest rate policy until it judges, on the basis of the "understanding of medium- to long-term price stability," that price stability is in sight. (iii) The Bank establishes an Asset Purchase Program (APP) to purchase financial assets and conduct fixed-rate funds-supplying operations.
October 28, 2010	The Bank releases operational details of the APP with a total amount of ¥35 trillion.
November 5, 2010	The Bank of Japan releases operational details exchange traded funds (ETFs) and Japan real estate investment trust (J-REIT) purchases set forth in the "Principal Terms and Conditions for Purchases of ETFs and J-REITs conducted through the Asset Purchase Program"
March 14, 2011	Enhancement of Monetary Easing: The Policy Board decided to increase the amount of the APP, mainly of the purchases of risk assets, by about ¥5 trillion to about ¥40 trillion in total.
June 14, 2011	The Bank establishes a new line of credit for equity investment and asset-based lending with a total amount of loans of ¥500 billion.

August 4, 2011	Enhancement of Monetary Easing: The Policy Board decided to enhance monetary easing by increasing the total size of the APP by about ¥10 trillion from about ¥40 trillion to about ¥50 trillion.
October 27, 2011	Enhancement of Monetary Easing: The Bank expands the amount of APP by purchasing an additional ¥5 trillion in JGBs to ¥55 trillion.
February 14, 2012	Enhancement of Monetary Easing: (i) The Bank of Japan judges the "price stability goal in the medium to long term" to be within a positive range of 2% or lower in terms of the year-on-year rate of change in the CPI, and sets a goal at 1% for the time being. (ii) For the time being, the Bank will pursue powerful monetary easing by conducting its virtually zero interest rate policy and by implementing the APP mainly through the purchase of financial assets, with the aim of achieving the goal of 1%. (iii) Monetary easing will be continued until the Bank judges that the 1% goal is in sight on the condition of identifying no significant risk, including the accumulation of financial imbalances. (iv) The Bank increases the total size of the APP by about ¥10 trillion to about ¥65 trillion and by the end of 2012, the amount outstanding of the Program will be increased by about ¥22 trillion from the current level of around ¥43 trillion.
March 13, 2012	The Policy Board increases the growth-supporting funding facility by ¥2 trillion to ¥5.5 trillion.
April 27, 2012	Enhancement of Monetary Easing: The Bank decided to increase the total size of the Program by about ¥5 trillion, from about ¥65 trillion to about ¥70 trillion.
July 12, 2012	The Bank increases the outright purchase of Treasury discount bills by about ¥5 trillion and reduces the amount of the fixed-rate funds-supplying operation against pooled collateral by about ¥5 trillion.
September 19, 2012	Enhancement of Monetary Easing: The Bank decided to increase the total size of the Program by about ¥10 trillion to about ¥80 trillion.

October 30, 2012	Enhancement of Monetary Easing: The Bank decided to increase the total size of the Program by about ¥11 trillion, from about ¥80 trillion to about ¥91 trillion in order to make financial conditions for such economic entities as firms and households even more accommodative by further encouraging a decline in longer-term market interest rates and a reduction in risk premiums.
December 20, 2012	Enhancement of Monetary Easing: The Bank decided to increase the total size of the APP by about ¥10 trillion, from about ¥91 trillion to about ¥101 trillion.
January 22, 2013	Introduction of the "Price Stability Target": (i) The Bank of Japan sets the price stability target at 2% (ii) The Bank of Japan will pursue monetary easing and aim to achieve the 2% target at the earliest possible time, on the condition that there is no significant risk to the sustainability of economic growth, including from the accumulation of financial imbalances. Introduction of the "open-ended asset purchasing method" : (i) The Bank of Japan will pursue aggressive monetary easing, aiming to achieve the 2% target, through a virtually zero interest rate policy and purchases of financial assets, as long as the Bank judges it appropriate to continue with each policy measure respectively. (ii) The total size of the APP will be increased by about ¥10 trillion in 2014 and is expected to be maintained thereafter.
April 4, 2013	Introduction of "Quantitative & Qualitative Monetary Easing": (i) The Bank will achieve the price stability target of 2% at the earliest possible time, with a time horizon of about two years. (ii) The Bank will double the monetary base and the amounts outstanding of Japanese government bonds (JGBs) and exchange-traded funds (ETFs) in two years, and more than double the average remaining maturity of JGB purchases. (iii) The Bank will continue with the QQE, aiming to achieve the price stability target of 2%. The Bank of Japan will conduct money market operations so that the monetary base will increase at an annual pace of about ¥60 trillion to ¥70 trillion.

October 31, 2014	Expansion of the QQE: The Bank of Japan will conduct money market operations so that the monetary base will increase at an annual pace of about ¥80 trillion (an addition of about ¥10 to ¥20 trillion compared with the past).
December 18, 2015	Introduction of Supplementary Measures for QQE
January 29, 2016	Introduction of "QQE with a Negative Interest Rate": The Bank will apply a negative interest rate of minus 0.1% to current accounts that financial institutions hold at the Bank. It will cut the interest rate further into negative territory if judged as necessary.
July 29, 2016	Enhancement of Monetary Easing: The Bank will purchase ETFs so that their amount outstanding will increase at an annual pace of about ¥6 trillion (almost double the previous pace of about ¥3.3 trillion).
September 21 2016	The introduction of a new framework: "QQE with Yield Curve Control" by strengthening the two previous policy frameworks (QQE and QQE with Negative Interest Rate).
July 31 2018	Strengthening the Framework for Continuous Powerful Monetary Easing: The Bank of Japan intends to maintain the current extremely low levels of short- and long-term interest rates for an extended period of time.
April 25, 2019	Clarification of forward guidance for policy rates: The Bank intends to maintain the current extremely low levels of short- and long-term interest rates for an extended period of time, at least through around spring 2020, taking into account uncertainties regarding economic activity and prices including developments in overseas economies and the effects of the scheduled consumption tax hike.

* indicates a contractionary announcement, all other announcements are expansionary

Source: `https://www.boj.or.jp/en/mopo/mpmdeci/state_all/index.htm/`

Table 2: Unconventional Monetary Policy Announcements in the United States

Date	Announcement
August 12, 2003*	The FOMC states "policy accommodation could be maintained" for a considerable period.
December 09, 2003*	The Committee believes that it can be patient in removing its policy accommodation.
January 04, 2004*	The FOMC states "policy accommodation can be removed at a pace that is likely to be measured."
May 04, 2004*	The FOMC states "policy accommodation can be removed at a pace that is likely to be measured."
June 30, 2004*	The FOMC raises the target for the federal funds rate by 25 basis points to 1.25%.
November 25, 2008	The Fed announces its intention to purchase up to $500 billion of agency mortgage-backed securities and up to $100 billion of agency debt. These purchases referred to as LSAP1.
December 16, 2008	The FOMC lowers it target for the federal funds rate to a range of zero to 1/4 percent and states "weak economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time."
March 18, 2009	The FOMC announces it expects to keep the federal funds rate between 0 and 25 basis points for "an extended period", and that it will purchase $750 billion of mortgage-backed securities (MBS), $300 billion of longer-term Treasuries, and $100 billion of agency debt.
August 10, 2010	The Fed maintains its holdings of securities at current level by reinvesting the principal payments from agency MBSs and debt in longer-term Treasuries.
September 21, 2010	The FOMC emphasizes that it is "prepared to provide additional accommodation if needed to support the economic recovery and to return inflation, over time, to levels consistent with its mandate."
November 3, 2010	The FOMC announces a second LSAP program and intends to purchase an additional $600 billion of longer-term Treasuries.
August 9, 2011	The FOMC announces it expects to maintain the federal funds rate between 0 and 25 basis points "at least through mid-2013."

September 21, 2011	The FOMC announces a maturity extension program (MEP), also referred to as "Operation Twist", and it will sell $400 billion of short-term Treasuries and use the proceeds to buy $400 billion of long-term Treasuries with a remaining maturity of 6 to 30 years.
January 25, 2012	The FOMC announces it expects to keep the federal funds rate between 0 and 25 basis points "at least through late 2014"
June 20, 2012	The FOMC continues its current purchasing pace of $45 billion per month.
March 20, 2012	The FOMC refines the conditions of the APP: pace, size and composition which depend on the extend of progress towards its economic objectives.
September 13, 2012	The FOMC announces it expects to keep the federal funds rate between 0 and 25 bps "at least through mid-2015", and launches its third LSAP program consisting of open-ended purchases of $40 billion MBSs per month for the indefinite future.
December 12, 2012	The FOMC ends the MEP and announces it will purchase $45 billion of longer-term Treasuries per month for the indefinite future and that it expects to keep the federal funds rate between 0 and 25 basis points at least as long as the unemployment remains above 6.5% and inflation expectations remain subdued.
May 1, 2013	The FOMC refines the conditions of the APP: pace, size and composition which depend on the inflation outlook.
May 22, 2013*	Bernanke states "could in the next few meetings, take a step down in [its] pace of purchases".
June 19, 2013*	During the press conference, the Chairman comments that the FOMC "currently anticipates that it would be appropriate to moderate the monthly pace of purchases later this year."
December 18, 2013*	The FOMC announces it will start to taper its purchases of longer-term Treasuries and MBSs to paces of $40 billion and $35 billion per month, respectively. Additionally, the FOMC announces it "likely will be appropriate to maintain the current target range for the federal funds rate well past the time that the unemployment rate declines below 6-1/2 percent, especially if projected inflation continues to run below the Committee's 2 percent longer-run goal."

March 19, 2014	The FOMC states the federal funds rate target will be maintained at current target range for "a considerable time after the asset purchase program ends, especially if projected inflation continues to run below the Committee's 2 percent longer-run goal, and provided that longer-term inflation expectations remain well anchored."
September 17, 2014*	The FOMC announces it intends to hold "no more securities than necessary to implement monetary policy efficiently and effectively" and to hold "primarily Treasury securities" in the longer run.
October 29, 2014*	The FOMC states that "it likely will be appropriate to maintain the 0 to 1/4 percent target range for the federal funds rate for a considerable time following the end of its asset purchase program this month." Additionally, it will "conclude its asset purchase program this month." The policy of reinvesting the principal of maturing securities is maintained.
December 17, 2014*	The FOMC announces that "it can be patient in beginning to normalize the stance of monetary policy."
March 18, 2015	The FOMC announces that "an increase in the target range for the federal funds rate remains unlikely at the April FOMC meeting."
July 29, 2015	The FOMC alters the guidance referring to "further improvement" in the labor market to "some further improvement."
October 28, 2015	The FOMC replaces the clause "how long it will be appropriate to maintain [the target range]" with "whether it will be appropriate to raise the target range at its next meeting."
December 16, 2015*	The FOMC increases the target range for the first time since prior to the financial crisis.
March 15, 2017*	The Committee now emphasizes a "symmetric inflation goal" and "only gradual increases" is replaced with "gradual increases" in the future federal funds rate path.
April 5, 2017*	The FOMC March 2017 meeting minutes state that "reductions in the Federal Reserve's securities holdings should be gradual and predictable, and accomplished primarily by phasing out reinvestments."

June 14, 2017*	The FOMC states that it "expects to begin implementing a balance sheet normalization program this year."
July 26, 2017*	The FOMC states that it expects to being its balance sheet normalization program.
September 20, 2017*	The FOMC announces "in October, the Committee will initiate the balance sheet normalization program described in the June 2017 Addendum to the Committee's Policy Normalization Principles and Plans."
January 31, 2018*	The expression "gradual increase" is replaced with "further gradual increase".
June 13, 2018*	The FOMC removes the statement that the federal funds rate is "likely to remain, for some time, below levels that are expected to prevail in the longer run."
September 26, 2018*	The FOMC eliminates a statement that has been in place since December 2015: "the stance of monetary policy remains accommodative," which had been in place since December 2015."
January 30, 2019*	The FOMC conveys that it "will be patient as it determines what future adjustments to the target range [. . .] may be appropriate to support these outcomes."

* indicates a contractionary announcement , all other announcements are expansionary

Source: `https://www.federalreserve.gov/monetarypolicy/review-of-monetary-policy-strategy-tools-and-communications-fed-listens-timelines.htm`

Table 3: Description of Regressors

Regressor	Description
Δs_t	Precent change of nominal exchange rate (in logs)
$\Delta i_t^{J,p}$	Change in Japan's overnight rate
$\Delta i_t^{US,p}$	Change in federal funds rate
$\Delta i_t^{J,p} - \Delta i_t^{US,p}$	Difference policy rate change differential
U^J	Japan unconventional monetary policy announcements
U^{US}	U.S. unconventional monetary policy announcements
$i_t^{J,1}$, $i_t^{J,5}$	Japanese government bonds at 1-year and 5-year maturities
$i_t^{US,1}$, $i_t^{US,5}$	U.S. government bonds at 1-year and 5-year maturities
b_t	Difference in yield spread, $(i_t^{J,5} - i_t^{J,1}) - (i_t^{US,5} - i_t^{US,1})$

Table 4: Preliminary Statistics

	Δs_t	Δs_t	Δs_t	Δs_t	Δs_t
Regressor			coefficient		
$\Delta i_t^{J,p}$	2.2477***	–	–	–	–
	(0.8291)	–	–	–	–
$\Delta i_t^{US,p}$	–	0.2335	–	–	–
	–	(0.1532)	–	–	–
U^J	–	–	0.0156	–	
	–	–	(0.1372)	–	–
U^{US}	–	–	–	-0.1428*	–
	–	–	–	(0.0827)	–
$\Delta i_t^{J,p} - \Delta i_t^{US,p}$	–	–	–	–	-0.1794
	–	–	–	–	(0.1528)
R^2	0.0026	0.0012	0.0000	0.0004	0.0007
N	7455	7455	7455	7455	7455

Notes: Data from January 1, 1999 to May 31, 2019. Robust standard errors are in parentheses. Significance levels: *10%, **5%, ***1%. This table reports the individual effects of the regressors on the percent change of nominal exchange rate, Δs_t, where S_t is the nominal exchange rate (USD/JPY) and $s_t \equiv 100 * log(S_t)$.

Table 5: Policy Changes and Exchange Rate Appreciation

Regressor	Δs_t coefficient	Δs_t coefficient
$\Delta i_t^{J,p}$	2.155***	2.0351**
	(0.8318)	(0.8327)
$\Delta i_t^{US,p}$	0.2117	0.2074
	(0.1527)	(0.1526)
U^J	0.0025	-0.0024
	(0.1377)	(0.1375)
U^{US}	-0.1436*	-0.1458*
	(0.0832)	(0.0837)
$\Delta i_t^{J,1}$	–	3.2944*
	–	(1.8619)
$\Delta i_t^{J,5}$	–	-1.1602**
	–	(0.5764)
R^2	0.0039	0.0055
N	7455	7455

Notes: Data from January 1, 1999 to May 31, 2019. Robust standard errors are in parentheses. Significance levels: *10%, **5%, ***1%. This table reports the effect of the combination of the regressors from Table 4. The table also reports the effects of changes in the market interest rates at 1-year and 5-year maturities in Japan as they may be indicators of expected future monetary policy.

Table 6: Changes in Yield Curve and UMP

Regressor	Δs_t coefficient	Δs_t coefficient
$\Delta i_t^{J,p}$	2.168***	2.1769***
	(0.8323)	(0.8331)
$\Delta i_t^{US,p}$	0.2108	0.2104
	(0.153)	(0.153)
U^J	0.004	0.0077
	(0.1376)	(0.1356)
U^{US}	-0.1428*	-0.145*
	(0.083)	(0.083)
Δb_t	0.151	0.1371
	(0.2037)	(0.2066)
$\Delta b_t U^J$	–	-0.7012
	–	(0.9644)
$\Delta b_t U^{US}$	–	1.7045
	–	(1.9099)
R^2	0.0041	0.0042
N	7455	7455

Notes: Data from January 1, 1999 to May 31, 2019. Robust standard errors are in parentheses. Significance levels: *10%, **5%, ***1%. This table reports the effect of the change in the bond yield spread difference, Δb_t, where $b_t = (i_t^{J,5} - i_t^{J,1}) - (i_t^{US,5} - i_t^{US,1})$. The last two regressors are the interaction terms between Δb_t and the unconventional monetary policy announcements in Japan and the U.S..

Table 7: Policy and Bond Yield Changes

Regressor	Δb_t coefficient	$\Delta(i_t^{J,5} - i_t^{J,1})$ coefficient	$\Delta(i_t^{US,5} - i_t^{US,1})$ coefficient
$\Delta i_t^{J,p}$	-0.086**	-0.0735***	0.0125
	(0.044)	(0.0243)	(0.0409)
$\Delta i_t^{US,p}$	0.0058	-0.0032	-0.009
	(0.0071)	(0.0045)	(0.0059)
U^J	-0.0097	0.0002	0.0099
	(0.0095)	(0.0029)	(0.0087)
U^{US}	-0.0048	-0.0017	0.0031
	(0.0057)	(0.0018)	(0.0054)
R^2	0.0011	0.0032	0.0008
N	7455	7455	7455

Notes: Data from January 1, 1999 to May 31, 2019. Robust standard errors are in parentheses. Significance levels: *10%, **5%, ***1%. This table reports the effects of the regressors on the change in the yield spread difference, Δb_t, and the change in the yield spreads in Japan, $\Delta(i_t^{J,5} - i_t^{J,1})$, and the U.S., $\Delta(i_t^{US,5} - i_t^{US,1})$. A negative coefficient reflects the flattening of the yield curve.

Table 8: Announcement Type and Exchange Rate Appreciation

	Δs_t	Δs_t
Regressor	coefficient	coefficient
$\Delta i_t^{J,p}$	2.19***	2.2205***
	(0.8312)	(0.8318)
$\Delta i_t^{US,p}$	0.2098	0.2139
	(0.1528)	(0.1527)
$U^{J,C}$	-0.44**	-0.4406**
	(0.1962)	(0.1964)
$U^{J,E}$	0.036	0.139
	(0.1469)	(0.2129)
$U^{US,C}$	-0.2294**	-0.1034
	(0.0945)	(0.1125)
$U^{US,E}$	-0.0455	-0.1113
	(0.1399)	(0.1651)
$I(\Delta i_t^{J,p} < 0)U^{J,E}$	–	-0.2
	–	(0.2927)
$I(\Delta i_t^{US,p} > 0)U^{US,C}$	–	-0.2941
	–	(0.1822)
$I(\Delta i_t^{US,p} < 0)U^{US,E}$	–	0.2705
	–	(0.2939)
R^2	0.0045	0.005
N	7455	7455

Notes: Data from January 1, 1999 to May 31, 2019. Robust standard errors are in parentheses. Significance levels: *10%, **5%, ***1%. Expansionary announcements are set to negative one and contractionary announcements are set to positive one. $U^{J,E}$, $U^{US,E}$, $U^{J,C}$ and $U^{US,C}$ denote the expansionary and contractionary UMP announcements in Japan and the U.S., respectively. Indicator functions are used to represent the event of a policy change; a value of one is given if the event is true and a value of zero otherwise.

Table 9: Pre- and Post- Financial Crisis

Year	Jan 1, 1999 - Dec 31, 2006		Jan 1, 2007 - May 31, 2019	
Regressor	Δs_t coefficient	Δs_t coefficient	Δs_t coefficient	Δs_t coefficient
$\Delta i_t^{J,p}$	1.2816	1.2772	2.7127**	2.8245**
	(1.2201)	(1.2212)	(1.1255)	(1.1286)
$\Delta i_t^{US,p}$	0.2406*	0.2378*	0.1667	0.1708
	(0.1357)	(0.1366)	(0.3416)	(0.3414)
$U^{J,C}$	-0.3918	-0.3917	-0.4814*	-0.4841*
	(0.2877)	(0.2878)	(0.2664)	(0.2679)
$U^{J,E}$	-0.2834**	-0.3712***	0.1557	0.4834
	(0.1164)	(0.1418)	(0.1944)	(0.3127)
$U^{US,C}$	-0.2105	0.0713	-0.2375**	-0.1625
	(0.2328)	(0.1034)	(0.1009)	(0.1412)
$U^{US,E}$	–	–	-0.0486	-0.1318
	–	–	(0.1421)	(0.1746)
$I(\Delta i_t^{J,p} < 0)U^{J,E}$	–	0.3079	–	-0.5484
	–	(0.2063)	–	(0.392)
$I(\Delta i_t^{US,p} > 0)U^{US,C}$	–	-0.7044*	–	-0.1713
	–	(0.4197)	–	(0.1938)
$I(\Delta i_t^{US,p} < 0)U^{US,E}$	–	–	–	0.2929
	–	–	–	(0.2994)
R^2	0.0049	0.0059	0.0062	0.0084
N	2921	2921	4534	4534

Notes: Data from January 1, 1999 to May 31, 2019. Robust standard errors are in parentheses. Significance levels: *10%, **5%, ***1%. Expansionary announcements are set to negative one and contractionary announcements are set to positive one. $U^{J,E}$, $U^{US,E}$, $U^{J,C}$ and $U^{US,C}$ denote the expansionary and contractionary UMP announcements in Japan and the U.S., respectively. Indicator functions are used to represent the event of a policy change; a value of one is given if the event is true and a value of zero otherwise.

Table 10: Pre- and Post- QQE and the 2% Inflation Target in Japan

Year	Jan 1, 1999 - Dec 31, 2012		Jan 1, 2013 - May 31, 2019	
	Δs_t	Δs_t	Δs_t	Δs_t
Regressor	coefficient	coefficient	coefficient	coefficient
$\Delta i_t^{J,p}$	2.3393***	2.2999***	0.5117	1.3276
	(0.8756)	(0.8774)	(2.0262)	(1.9414)
$\Delta i_t^{US,p}$	0.2304	0.2296	-0.5428	-0.4135
	(0.1546)	(0.1549)	(0.9546)	(0.9489)
$U^{J,C}$	-0.4471**	-0.4462**	–	–
	(0.1974)	(0.1972)	–	–
$U^{J,E}$	-0.0121	-0.1529	0.2996	1.6999**
	(0.1087)	(0.1357)	(0.649)	(0.7285)
$U^{US,C}$	-0.2189	0.0628	-0.2296**	-0.1598
	(0.2323)	(0.1032)	(0.1019)	(0.1427)
$U^{US,E}$	-0.1283	-0.1607	0.1307	0.0887
	(0.1919)	(0.203)	(0.1367)	(0.2008)
$I(\Delta i_t^{J,p} < 0)U^{J,E}$	–	0.2836	–	-2.5321**
	–	(0.2127)	–	(0.995)
$I(\Delta i_t^{US,p} > 0)U^{US,C}$	–	-0.7042*	–	-0.159
	–	(0.4189)	–	(0.1958)
$I(\Delta i_t^{US,p} < 0)U^{US,E}$	–	0.2644	–	0.1237
	–	(0.5223)	–	(0.2044)
R^2	0.0061	0.0071	0.0035	0.0288
N	5113	5113	2342	2342

Notes: Data from January 1, 1999 to May 31, 2019. Robust standard errors are in parentheses. Significance levels: *10%, **5%, ***1%. Expansionary announcements are set to negative one and contractionary announcements are set to positive one. $U^{J,E}$, $U^{US,E}$, $U^{J,C}$ and $U^{US,C}$ denote the expansionary and contractionary UMP announcements in Japan and the U.S., respectively. Indicator functions are used to represent the event of a policy change; a value of one is given if the event is true and a value of zero otherwise.

Table 11: Forecasting Policy Rate Changes

$$\Delta i_k^{country,p} = \beta_0 + \beta_1 s_{(k-1)+1/2-(k-1)} + \epsilon_k$$

	Japan	U.S.
$s_{(k-1)+1/2-(k-1)}$	-0.0015	-0.0052
	(0.0009)	(0.0070)
R^2	0.0167	0.0041
N	290	187

Notes: Data from January 1, 1999 to May 31, 2019. Robust standard errors are in parentheses. Significance levels: *10%, **5%, ***1%. The regression tests whether the change in the exchange rate forecasts changes in the policy rate since the last monetary policy meeting.