Breaching The Zero Lower Bound:

Are Negative Interest Rates an Effective Monetary Policy Tool?

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Abstract

This paper studies the effects and implementation of negative interest rate policies using high-frequency event study methods to determine if negative interest rates on excess reserves are effective in transmitting monetary policy through lowering rates at the long end of the yield curve. Building upon previous studies of monetary policy effectiveness through use of these methods, statistically significant and lasting rate movements for long rates and expectations were only found in Japan. In Germany however, rates uncharacteristically increased, similar to the "Greenspan Conundrum". Several factors, including a change in risk premia, inflationary or growth expectations, or significant outflows are explored as possible reasons.

I. Negative Interest Rate Policies

On June 5th, 2014, Mario Draghi shocked the international financial community when he announced that the European Central Bank would be the first major central bank to implement a negative interest rate on overnight deposits. Faced with increasingly bleak economic growth outlooks across the Eurozone and the prospect of a deflationary spiral in the heart of the union, Draghi and the rest of the board decided that increased asset purchases and long term refinancing operations were no longer enough to stimulate growth and guide the European economy towards its elusive price target of two percent. In January of 2016, BOJ President Haruhiko Kuroda followed suit and announced a similar negative interest rate policy, adding to the list of central banks that include Bank of Switzerland, Sweden and Denmark. These actions have ushered in a new monetary

reality composing of unconventional policies that will have far-reaching consequences for future responses to shocks and crises.

Before the Financial Crisis of 2008-2011 many economists, central bankers and financiers operated under a paradigm believing that targeted interest rate policies could not breach the Zero Lower Bound. Despite the occurrence of negative nominal term structures in times of financial stress, seen in the U.S. in 2008 and in Japan in the early 1990's, these were viewed as anomalies and blips emblematic of a flight to safety and overreactions to macroeconomic uncertainty. When the Federal Reserve was one of the first to hit the Zero Lower Bound in 2009, Ben Bernanke sought to circumnavigate this perceived barrier by embarking upon an ambitious asset-purchasing program known as Quantitative Easing to inject liquidity and lower real rates further to stimulate economic activity. QEI and its successors, QEII, Operation Twist and QEIII have generally been regarded as successful in their goals of lowering rates (Gagnon et al., 2010 and Joyce et al., 2010, 2011), but even they were once viewed as taboo and there are still many who believe the risks far outweigh the benefits. It should come as no surprise that the success and efficacy of negative interest rate policies are still up for debate and that the use of such policies has been extremely controversial. BOE governor Mark Carney recently stated in August of 2016: "it is very clear that 'lower bound' is a positive number… I am not a fan of negative rates" compared to Ben Bernanke who in the same year was quoted as saying "…overall, as a tool of monetary policy, negative interest rates appear to have both modest benefits and manageable costs."

The lack of a clear consensus on the use of negative interest rates, highlighted by the contrasting opinions of two stalwarts of the field shown above, demonstrates the clear

demand for strong empirical research and analysis on the effectiveness of such policies and its consequences. While there are hundreds of thousands of pages of research on the quantitative effects of conventional monetary policy on macroeconomic factors, asset prices, expectations and rates, the same analysis on unconventional policies is trivial and highly qualitative (Blinder, 2012). As Central Banks struggle to increase rates and add ammunition due to sluggish growth and sticky prices, it is ever more likely that these new monetary tools will likely be used in countercyclical responses in the future. Many economists and central bankers, including Blinder, Summers, and Yellen have attempted to direct the academic community to study these policies further in response to these conclusions, but the current literature is sparse and focuses almost exclusively on the effects of asset purchasing programs in England, Japan and the United States. Asset purchasing programs are just one piece of the puzzle, there is a clear necessity for broader and more rigorous analysis of other unconventional policies to ensure that policymakers can make informed decisions in future crises.

I.A.

The present paper aims to fill that void through analysis of the effects of negative interest rate policies on the term structure of government securities and assessing whether the implementation of negative rates can be transmitted through the term structure and lower long-term rates. Its goal is to first provide a foundation for future research regarding negative rates, similar to the initial policy research conducted regarding asset purchasing programs and to assess whether negative interest rates are an effective policy tool for Central Bankers by examining its effect on long rates and expectations. These

initial groundbreaking studies paved a path for researchers to use their findings in deeper and more rigorous study of its implications for other facets of the economy and markets. There is limited, if any, work that has been done studying the effects of negative interest rates, making this paper one of the first to use modern, high-frequency event-study methods to test if there is a significant reaction in the yield curve after the announcement of negative rates.

In one of the cases, there were statistically significant and sustained decreases in long rates while the reaction in the German yield curve moved against the long term trend, with a mute reaction in June and an upward movement in long rates in September, leading to interesting questions regarding the efficacy of such policies in lowering rates further up the yield curve.

II. Review of Relevant Literature

As mentioned previously, the amount of quantitative peer reviewed studies regarding unconventional monetary policy and its effects is sparse given its widespread use amongst global Central Banks and the implications these policies may have on economic health and societal wellbeing. While a currency "tax" had long been theorized as an option for central bankers to alleviate economic frictions when rates reached the Zero Lower Bound as early as the days of Irving Fisher, it wasn't articulated as a negative interest rate feasible in today's economy until much later (Goodfriend, 2000). Goodfriend suggested a variable carry tax that is functionally similar to the current strategy of taxing excess bank reserves, which should theoretically carry through to other rates.

For much of the late twentieth century, the rational expectations community that dominated macroeconomics insisted that persistent negative nominal rates were infeasible—investors would choose to hold their money in cash when faced with negative rates. Economists frequently bounded models and imposed conditions that kept nominal rates above zero. In the aftermath of the financial crisis, there was a renewed interest in Goodfriend, and also, Buitter's work, prompting many theoretical papers (Buitter and Panigirtzoglou 2003). These papers focused on possible methods for central banks to effectively implement negative nominal rates and relied upon theoretical models predicting efficiency gains from clearing a negative natural rate of interest (Buitter 2009). While these theoretical papers concerning negative rates may have opened the door for the policy in the first place, there is a clear lack of empirical work studying any of the effects of negative interest rates, either on financial markets, consumer and investor choice or systemic risk.

There is a great deal of literature on conventional monetary policy and subsequent market reaction, beginning with Cook and Hahn's (1989) seminal findings that there was a significant one day and lagged response in both short and long rates to FOMC rate decisions. While later studies showed smaller, but still significant results at the back end of the curve, there was evidence that increased FOMC transparency led to more gradual moves as decisions were expected and less of a shock (Roley and Sellon 1995, Radecki and Reinhart 1994).

The majority of quantitative post-financial crisis research on monetary policy has focused exclusively on the effects of LAPP's, which this paper follows in terms of methodology. The analysis of LAPP programs began with a seminal paper by Eggertson

and Woodford (2003), which harmonized previous literature regarding monetary policy at the Zero Lower Bound. They effectively list the benefits and negatives of numerous unconventional monetary policy and the channels through which their effects would flow through the economy. A large number of contemporary empirical literature regarding QE1, QE2 and other asset purchasing programs rely on the different channels identified by Eggertson and Woodford: macroeconomic news, portfolio rebalancing, duration risk, and liquidity. Gagnon provided one of the first empirical event studies regarding QE that was presented within a year of the program's announcement date and find statistically significant results regarding the effect of QE on long rates (Gagnon et al. 2010). Krishnamurthy and Vissig-Jorgensen (2011) apply similar techniques to QE and identify empirically how the program affected rates through each channel and is regarded as a model for empirical analysis of unconventional policies.

III. Methodology

III.A. Event Study Overview

Modern high-frequency event studies analyze changes in financial assets or returns in discrete, small windows around major announcements with the goal of analyzing the effect of those announcements. Eugene Fama is credited with the first modern event study while attempting to prove the EMH examining firm-level excess returns after split announcements (Fama et al., 1969). Fama et al. used monthly data to examine if there were price discrepancies, however there are flaws with using such wide windows for examining market reactions. Mackinlay provides an excellent survey of modifications and expansions upon Fama's work, including a pertinent discussion of

high-frequency event studies with small windows, which is the strategy that is used in this analysis (Mackinlay, 1997).

Similar to a recent empirical paper written by Swanson, the proceeding strategy hinges upon the assumption that negative interest rate announcements are discrete macroeconomic events, justifying the use of an event study to examine changes in the yield curve in France, Germany and Japan (Swanson, 2011). Jones, Lamont and Lumsdaine find that liquid safe asset markets adjust and encapsulate the change in expectations stemming from major macroeconomic announcements in a one to two trading day window (1998), further supporting the use of an event study and its results regarding the effectiveness of negative rates in lowering yields. The only major macroeconomic announcements on those days came from the respective Central Banks, justifying that the full effect of those events should be incorporated in the 1-2 day event window, as the rest of the macroeconomic outlook should remain constant ex-announcement. In liquid and highly traded markets, such as government debt and securities, these are reasonable assumptions, as easily exploitable trading opportunities should close extremely quickly (Flemming and Remolona, 1999). These past findings add to the robustness of event study statistical tests and validate that an event-study methodology can lead to conclusive results regarding the effectiveness of rates.

III.B. Two Test Cases: ECB and BOJ Announcements

The proceeding event-study analysis is centered around three 2 day event windows that are identified based on the June 5th and September 4th, 2014 ECB 10 basis point rate cut on overnight deposits and the January 29th, 2016 BOJ 10 basis point rate cut

on deposits as well. Both of these moves were unexpected in comparison to LAPP programs in those countries, which allows the event methodology to capture the effects of these policy changes. The press release from the ECB focused on the mechanics of the cut in the overnight deposit facility rate, specifying that not only were overnight deposits subject to the rate but also "banks' average reserve holdings in excess of the minimum reserve requirements", implying that the equivalent of the federal funds rate would truly be negative (ECB 2014). On September 10^{h} the ECB announced another similar, 10 basis point cut that was similarly unexpected and surprising as evident from analyst and market commentary at the time.[1]

During Mario Draghi's press conference on June 5th he alluded to an expansion of the previously unsuccessful LTRO program which could skew results, but due to the inconclusive details that were released ex-ante, the majority of the effect should be attributed to the unexpected nature of the rate cut.[2] The September cut also included more details regarding the LAPP and LTRO program, though at this point market expectations had settled and were expecting such an announcement, limiting the unexpected effects to the surprise rate cut itself.

Two years later, the Bank of Japan announced a similar cut on overnight deposits rather than an expansion of the LAPP programs that focused on government bonds and Japanese Exchange Traded Funds (JETF). A strong component of the announcement was the sheer unexpected nature of the announcement, given that Kuroda had signaled that

[1] A memo from Credit Agricole on announcement day highlights that the consensus at the time was that the ECB would hold rates steady and instead announce an Asset Purchasing program that was hinted at the previous announcement (Ducrozet 2014).

[2] Most of the news coverage around the event date focused on the negative rate announcement and not Draghi's hinting of a possible expansion of LTRO, implying that the negative rate announcement was the major component of a shift in macroeconomic expectations during the event window.

[3] John Cochrane and Monicka Piazzesi (2002) conducted an influential high-frequency VAR study involving target rate changes in

negative rates were not on the table as late as one week before the announcement (Kihara 2016). Facing uncertain risks regarding the possibility of deflation due to decreasing oil prices and falling growth in export partner countries, Kuroda stated: "The BOJ decided to adopt negative interest rates ... to forestall such risks from materializing". Kuroda also committed to possibly lowering rates even further in future policy meetings to combat the risk of another deflationary episode after two decades of sluggish price growth. This should amplify the effect of the rate decrease and further justify the use of a discrete event window. Structurally the mechanics of the negative rate policy are very similar to the ECB policy, allowing the two to be analyzed in a similar fashion.

III.C. Discussion of Methods

It's evident that the major change in expectations affecting risk-free assets in these windows stemmed from the announcement of negative interest rate policies. There are two distinct methodologies that were considered, one involving a structural Vector Auto Regression (VAR) framework using the change in rates as a shock and the other involving a simple event study testing for significant movements on announcement day. While the VAR framework has been used successfully in the past to analyze shocks in monetary policy and their implications for inflation and output, there is limited information that can be gleaned from a small sample of distinct events. Wright (2012) conducted a structural VAR analysis on Zero Bound monetary policy in the United States and reached similar conclusions to event studies by Swansson, Gagnon and

Krishnamurthy (2011) and Vissig-Jorgensen (2010) discussed above.[3] Given this reconciliation and similar results, the event study was chosen as a robust, yet simple method to test for significance.

After identifying the event windows, daily closing yield data for government securities was retrieved from the ECB statistical warehouse and BOJ websites. France and Germany were chosen to examine the ECB's rate cut to remove the risk of endogeneity by focusing on one country alone and are regarded as the two safest asset providers in the EMU and also happen to be the most liquid. This data was then differenced to estimate daily changes for maturities in the yield curve. As these were the first instances of negative interest rate policies in these countries, a two-day event window was chosen to capture the full shift in expectations. The null hypothesis for this event window is that negative rates should not cause a significant decrease or increase across the yield curve for these countries. The rationale behind this is based on the rational expectations theory and New-Keynesian theory that negative rates should not be able to effectively cross the Zero Lower Bound or cause longer-term rates to move down further. One could make the argument that under this theory, long rates represent a discounted average of future short rates and a decrease in short rates might move long rates in the opposite direction through increasing inflationary expectations or reducing central bank credibility in meeting its price target. However for this model, the alternative selected is that negative rates cause a significant change in the term structure of the yield

[3] John Cochrane and Monicka Piazzesi (2002) conducted an influential high-frequency VAR study involving target rate changes in the United States and European countries, but had a much larger sample size. Wright (2012) also relied on a larger sample size by focusing on all Fed announcements that took place after 2008.

curves.[4] Unconditional standard deviations were calculated for the previous trading year up until the day of the announcement and used in a two-sided t-test to test for significance. Even though the alternative hypothesis would suggest a one sided test, a two sided test was chosen for robustness reasons. The standard deviations for these windows are quite high historically, adding to the robustness of the results that are discussed below.

IV. The Response to Negative Rate Shocks

The results from these event studies are included in the tables below. The first panel of each table shows the yield changes for the two-day event window and the cumulative change over the two trading days and the asterisks denote statistical significance at the 10%, 5% and 1% levels with a two-sided test. The unconditional standard deviations are reported followed by the t-statistics and p-values relative to the specific time window that is in question. The analysis begins first with the Japanese rate cut, followed by the ECB rate cut, which has more interesting results. Data was obtained from the Bank of Japan and ECB Statistical Warehouse, respectively.

[4] This assumption is both based on economic intuition and basic financial theory regarding term structures. Long rates can be thought of some function of future short rates and thus a change in expected short rates should manifest itself as a change in longer-term rates as well and should not come as a surprise to readers. There should also be an impact flowing through the portfolio rebalancing and supply channels as negative deposit rates should force depositors to seek higher yielding risk-free assets, increasing equilibrium price and therefore decreasing yield to maturity (Eggertson and Woodford, 2003).

Table 1. Japanese Response to BOJ Rate Cut

	Maturity				
Date and Estimated Response	1 Year	5 Year	10 Year	20 Year	30 Year
1/29/16	-0.044***	-0.082***	-0.125***	-0.101***	-0.096***
2/1/16	-0.073***	-0.039***	-0.036*	-0.046**	-0.046*
Cumulative	-0.117***	-0.121***	-0.161***	-0.147***	-0.142***
Unconditional Standard Deviation					
1-Day	0.0069	0.0113	0.0209	0.0223	0.0241
2-Day	0.0098	0.0160	0.0296	0.0315	0.0341
T-Statistics					
1/29/16	6.362318841	7.24778761	5.97129187	4.52017937	3.94190871
2/1/16	10.56521739	3.44247788	1.71291866	2.05381166	1.86721992
Cumulative	11.97982358	7.5654168	5.44032394	4.6548554	4.13701478

Note: ∗p<0.1;∗∗p<0.05;∗∗∗p<0.01

Table 2. France Response to June ECB Rate Cut

	Maturity				
Date and Estimated Response	3 Month	1 Year	5 Year	10 Year	30 Year
1/29/16	-0.03***	-0.03**	-0.081*	-0.011	0.006
2/1/16	-0.02*	-0.01	-0.095**	-0.133***	-0.097***
Cumulative	-0.05***	-0.04**	-0.176***	-0.144***	-0.091**
Unconditional Standard Deviation					
1-Day	0.0115	0.0125	0.0409	0.0384	0.0313
2-Day	0.0163	0.0177	0.0578	0.0543	0.0443
T-Statistics					
1/29/16	2.6	2.384	1.95599022	0.26041667	0.22364217
2/1/16	1.73043478	0.784	2.29828851	3.4375	3.06709265
Cumulative	3.06822855	2.25142799	3.02551801	2.63323619	2.03321439

Note: ∗p<0.1;∗∗p<0.05;∗∗∗p<0.01

Table 3. France Response to September ECB Rate Cut

Date and Estimated Response	3 Month	1 Year	5 Year	10 Year	30 Year
9/4/16	-0.05***	-0.05***	-0.084**	-0.037	0.009
9/5/16	0	-0.01	-0.03	-0.04	-0.028
Cumulative	-0.05***	-0.06***	-0.114*	-0.077	-0.019
Unconditional Standard Deviation	0.0115	0.0125	0.0409	0.0384	0.0313
	0.01626346	0.01767767	0.05784133	0.0543058	0.04426488
T-Statistics					
9/4/16	4.33913043	3.984	2.02933985	0.9375	0.31948882
9/5/16	0.00869565	0.784	0.70904645	1.015625	0.86261981
Cumulative	3.06822855	3.38279884	1.9536202	1.39948217	0.40664288

Note: ∗p<0.1;∗∗p<0.05;∗∗∗p<0.01

Table 4. Germany Response to ECB Rate Cut

	Maturity					
Date and Estimated Response	6 Month	2 Year	5 year	10 Year	20 Year	30 Year
1/29/16	-0.01	0	0.01	0.03	0.05	0.04
2/1/16	0	-0.02	-0.05	-0.06	-0.02	0.01
Cumulative	-0.01	-0.02	-0.04	-0.03	0.03	0.05
Unconditional Standard Deviation						
1-Day	0.0101	0.0196	0.0331	0.0364	0.0317	0.0305
2-Day	0.0143	0.0277	0.0468	0.0515	0.0448	0.0431
T-Statistics						
1/29/16	1.00990	0.01531	0.32326	0.84341	1.58675	1.31475
2/1/16	0.01980	1.00510	1.48943	1.62912	0.62145	0.33115
Cumulative	0.71411	0.71071	0.83956	0.56918	0.67588	1.16151

Note: ∗p<0.1;∗∗p<0.05;∗∗∗p<0.01

Table 5. Germany Response to ECB Rate Cut

	Maturity					
Date and Estimated Response	6 Month	2 Year	5 year	10 Year	20 Year	30 Year
9/4/16	0.01	0	0.01	0.02	0.08**	0.1***
9/5/16	-0.05***	-0.05**	-0.03	0.07*	0.09***	0.07**
Cumulative	-0.04***	-0.05*	-0.02	0.09*	0.17***	0.17***
Unconditional Standard Deviation						
	0.0101	0.0196	0.0331	0.0364	0.0317	0.0305
	0.0143	0.0277	0.0468	0.0515	0.0448	0.0431
T-Statistics						
9/4/16	0.97030	0.01531	0.32326	0.56868	2.53312	3.28197
9/5/16	4.97030	2.55102	0.89728	1.94231	2.86120	2.31803
Cumulative	2.81443	1.79302	0.41230	1.76194	3.79875	3.94357

Note: $*p<0.1; **p<0.05; ***p<0.01$

IV.A. Discussion of Japanese Response

The movement in Japanese rates after the BOJ announcement was swift and profound, with nearly every maturity experiencing extremely statistically significant decreases in yields on each day and cumulatively. Long rates had slowly been creeping up in anticipation of a lackluster announcement from Kuroda, but short rates had remained steady in the days leading up to the announcement. Many of these movements had p-values that were 10^{-9} or smaller, which raises serious doubts over the null hypothesis that negative interest rates fail to flow through the yield curve. The most significant movements came in the short end of the curve, but the longer dated rates actually experienced a steeper absolute decline. This rate cut behaved very similarly to a rate cut in positive territory, implying that, at least in Japan, monetary policy can still function with similar effectiveness around the Zero Bound and that it might be possible for a central bank to use the entire yield curve as a tool to shape expectations and economic activity. This runs contrary to

If the rational expectations hypothesis regarding negative interest rates and the Zero Lower Bound was true, then Kuroda's statement also should not affect rates. In fact, all of the rates across the curve fell by more than the 10 basis point cut, signaling that, at least in this case specifically, negative interest rates were very effective in lowering long-term rates and expectations regarding rates in the future. While this study does not robustly decompose the effect of the initial rate cut and Kuroda's forward guidance to lower rates further into negative territory, the majority of the fall in long-rates and expectations for future short rates occurred on the first day, before Kuroda's announcement.

A key component of any monetary policy, especially when constrained by the ZLB, is communication of future policy (Bernanke, Reinhart and Sack 2004b). Kuroda's commitment to using negative rates until negative price pressures dissipated is an excellent example of this and market commentary at the time reflects this. While the BOJ has certainly had more experience with unconventional monetary policy given its long twenty-year history of conducting operations around the ZLB, empirical literature showed that the previous zero interest policy was ineffective in changing future expectations and thus lowering long rates.[5] Previous BOJ policy refrained from not only setting explicit price targets, such as the ECB and Federal Reserve's inflation target, but also from giving substantive forward guidance, which is critical to reducing uncertainty and effectively shaping market expectations. Thus it would be extremely useful to see if Kuroda's commitment to negative interest rates actually effected expectations regarding rates in the future, which is a slightly different question than what was posed earlier.

In the spirit of Okina and Shiratsuka (2004), an extension of the Nelson-Siegel (1987) model proposed by Svensson (1994) can be used to estimate the daily instantaneous forward yield curve. The fitted curve will provide an estimate of what the market is implying is the forward interest rate at each given period in the yield curve. Essentially this is the rate that is discounted for infinitesimally small periods at any point on the yield curve i.e. the estimated ten-year instantaneous forward rate (IFR) is the implied interest rate ten years in the future. While this model is simple and composed of smooth functional forms, it has been shown in practice to be flexible enough to model the general behavior of the yield curve while producing results that are robust enough to

[5] See Takeda and Yajima (2002) and Okina and Shiratsuka (2004) for further analysis of the Bank of Japan's zero interest policy commitment in 1999. Okina and Shiratsuka find that the average market participant only believed that the ZIRP would last between 1-3 years, severely hampering its ability to lower rates further up the curve.

detect a change in expectations (Okina and Shiratsuka 2004). The IFR for any period m, expressed as $r(m)$, is represented by the equation:

$$r(m) = \beta_0 + \beta_1 \exp\left(-\frac{m}{\tau_1}\right) + \beta_2 \left(\frac{m}{\tau_1}\right) \exp\left(-\frac{m}{\tau_1}\right) + \beta_3 \left(\frac{m}{\tau_2}\right) \exp\left(-\frac{m}{\tau_2}\right), \quad (1)$$

with $\beta_0, \beta_1, \beta_2, \beta_3, \tau_1, \tau_2$ as parameters that are estimated using the yield curve data. Using this model, the IFR curve can be estimated to proxy the market's expectations regarding rates in the distant future from the actual yield curve. While it's important to note that risk premia in highly liquid securities can be time varying, it can be inferred that within short windows that are heavily influenced by monetary policy guidance, fluctuations in interest rates on long dated securities can be attributed to changes in the expectations of short rates in the future.

Figure 2 plots the IFR curve on the day before the announcement, announcement day, and one month after announcement day. When comparing the curves in Figure 2, it can be verified visually that not only did the initial announcement reduce future expectations of rates, Kuroda's commitment to maintaining or even lowering rates further into negative territory was effective as well. By the end of the day, the ten-year IFR declined by more than 10 basis point, signaling that the broader market shifted their beliefs and expected interest rates to remain lower ten years out. The second curve, estimated from data at the end of February shows that the IFR curve had declined even further across the board.

While it may seem reasonable to believe that the end of month decline was entirely due to Kuroda's ability to control the curve and anchor expectations to his

statements, it's possible that part of the shift was due to a change in the risk premia structure of the yield curve. A change in inflationary or growth expectations, an increase in overall uncertainty or changes in liquidity or some confluence of all three could alter the entire rate structure of each security in the Yield Curve. Attempting to break this change down into its factor components is beyond the scope of this paper. However in Figure 3 the JGB VIX index, which is a measure of implied volatility on open options on JGB futures, is plotted from the beginning of 2016 until the end of February. Following the announcement there is a substantial increase in implied volatility and while this doesn't signal which direction market participants were hedging against, it does provide evidence that some of the decrease in rates may have come from investors searching for safer assets in a period of high uncertainty.

As the BOJ is faced with a dwindling supply of government bonds and a balance sheet that has swelled to over 90% of GDP, its use of negative interest rates will become an increasingly important tool in shaping expectations and battling asymmetric deflationary risks. It remains to be seen whether this policy is effective in shaping market expectations regarding prices, which is ultimately the goal of the BOJ's stimulatory activities. Even if the decline in expectations of future rates may be partially explained by an increase in uncertainty, there is reason to infer from the data that the rate cut into negative territory coupled with Kuroda's clear and strong communication of a commitment to this policy was a critical and effective factor in the decline of long rates.

IV. An Interesting Dichotomy: The German Conundrum

While mechanically the ECB and BOJ rate cuts functioned similarly and all three announcements were viewed to be unexpected, analysis of the effect of the ECB's rate cut leads to a striking dichotomy between the response in the Japanese and the German Yield Curves. Despite the unexpected nature of both ECB announcements, German yields failed to respond in similar fashion to other European Even in France, yields fell across the board cumulatively, and almost all the cumulative rate changes were statistically significant, both in June and in September. The heavily traded ten-year and five-year notes saw the largest and most statistically significant decreases during both periods, implying that the rate cut was effective in lowering rates up the yield curve in France. In June, yields plummeted across the Eurozone, with Italian 10 year yields falling almost 30 basis points in the two-day window, Spanish 10 year yields falling nearly 25 basis points and the more stable Dutch 10 year notes falling by 10 basis points. In fact, the ECB's composite yield curve estimates of all AAA bonds through out the Eurozone fell by 12 basis points in the two-day window, which includes the mute reaction from German Bunds which barely reacted.[6]

The German response yields a striking and puzzling contrast that at first glance seems to validate the rational expectations hypothesis and ZLB constraint: German rates barely reacted in June and coincidentally, long rates made statistically significant moves to the upside with the second announcement. This is especially surprising given the strong historical relationship between ECB rate changes and movement in German 10, 20 and 30 year Bunds. This relationship is tested through a simple event study regression in

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[6] Source: ECB TARGET zero-coupon yield curve estimates based on AAA government securities (see https://www.ecb.europa.eu/stats/money/yc/html/index.en.html for methodology) and ECB country specific yield curve data

which the two-day cumulative change in the par-yield for each maturity is regressed upon the change in the ECB's main policy rate, $\tilde{r}$, going back until 1999:

$$\Delta R_t(m) = \beta_0 + \beta_1 \Delta \tilde{r} + \varepsilon_t \quad (2)$$

Table 6. 2-Day Response to ECB Rate Changes

	Dependent variable:		
	X10Y	X20Y	X30Y
	(1)	(2)	(3)
Change	0.297***	0.418***	0.584***
	(0.069)	(0.081)	(0.098)
Constant	-0.008	-0.015	0.016
	(0.026)	(0.031)	(0.035)
Observations	40	40	33
R^2	0.326	0.410	0.535
Adjusted R^2	0.308	0.394	0.520
Residual Std. Error	0.163 (df = 38)	0.191 (df = 38)	0.192 (df = 31)
F Statistic	18.374*** (df = 1; 38)	26.353*** (df = 1; 38)	35.683*** (df = 1; 31)
Note:			*p<0.1; **p<0.05; ***p<0.01

All three coefficients presented in Table 6 are extremely statistically significant and display a very strong relationship that interestingly scales with the maturity—The 30-year Bund has the strongest correlation and largest expected change. Given a 100 basis point change in the ECB policy rate one could expect a 58 basis point move in the same

direction. If the change in the ECB rate is decomposed into an expected and unexpected component, similar to other studies conducted on monetary policy surprises (Hanson and Stein 2015, Kuttner 2001) one could expect an even larger relationship between the unexpected change and the change in yield. Given that the EONIA 1 month futures for June and September both declined by 10 basis points in the days following the announcement, both of these cuts would classify as surprises and should display a strong positive relationship with the cut.[7][8] There are several possible explanations for this deviation from historical trends that will be discussed below.

In the previous year, sluggish growth outlooks and deflationary risks plagued the entirety of the EMU while flare-ups in Greece and Spain highlighted an extremely uncertain period reminiscent of the 2011 European Sovereign Debt Crisis. In response, there was a flight to safety to German bunds, which skyrocketed due to excess demand, causing yields to fall sharply during the course of 2014. Around the time of the announcement, German two-year bonds were actually trading near negative territory, and were some 50-60 basis points lower than similar French dated securities, even though the two should have been trading in a much tighter spread given that they are two of the regional safe asset providers in the European Union. At this point, fears regarding France's fiscal situation that had boiled over during the debt crisis were receding and growth and inflationary pressures were actually higher in Germany than in France. It's possible that German Bunds were relatively overbought at the time given the flood of investor demand for safer assets. Upon hearing of a negative rate cut and a commitment

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7 Source: ICE Exchange Historical Data

8 The EONIA index is the Euro equivalent to the Eurodollar futures market and is an average of the overnight rate on Euro denominated deposits. Like the Eurodollar market, it can be used as a proxy for the markets expectation for the policy rate given an ECB decision. A fully expected rate cut would be evident if the EONIA future implied rate remained unchanged on announcement day. In both instances, there was a significant decrease of over 5 basis points on announcement day in the implied rate, meaning that the broader market believed that there was less than a 50% chance of a 10 basis point cut.

towards improving financial and price stability, investors then moved to other safe assets across the EMU, like French bonds, lowering yields through the portfolio rebalancing effect identified by Woodford (2003), and the negative price pressure on the German bund would have then canceled out the effect of the rate cut.

A more traditional explanation that is likely to be taken by followers of the New-Keynesian school of thought is that a decrease in rates may have changed the risk premia structure of German Bunds through increasing inflationary expectations. A decrease in rates below the natural rate of interest now will lead to higher price pressures, thereby necessitating the need for corrective monetary policy in the future, changing the path of future short rates. This explanation is less plausible than the portfolio rebalancing hypothesis as even if Germany were experiencing higher price pressures, the Eurozone as a whole would still be facing asymmetric deflationary risks. The ECB has a broad price target for the entire single market and policy is set to ensure price stability for all nations. Still, both of these theories seem to make Germany an exception rather than evidence for the alternative hypothesis. Though crude and incomplete, this similar reaction throughout the EMU highlights that the German response was unique and is likely an outlier and should not detract from the significant decline in rates shown in France, Italy, Spain and the Netherlands. The unique nature of the EMU should also be taken into account when evaluating the policy's effectiveness, with no barriers to capital, investors could easily move between different securities with similar maturities in short trading windows. Draghi's hints about an expansion of the LTRO program might have further reassured investors on the state of periphery EU countries, further amplifying the exodus from German debt into other debt through the portfolio rebalancing channel. However, the

steep fall in rates after the initial press release across the periphery and in France encompasses the effect of the negative rate cut itself, the LTRO announcement does not endanger the results or significance of the decrease.

It is important to note that despite the initial muted reaction in June and the sharp increase in long rates in September, German rates still ended lower by the end of the year. These results should not be taken without consideration of endogeineity, evidence of a long-term trend in rates, or a shift in the risk premia structure of the German Yield Curve unrelated to central bank policy. Figure 4 plots the path of several German Bund yields in 2014. There is a clear negative trend that is displayed in all four long maturities, suggesting that the decline in rates was independent of ECB policy and instead was a consequence of Germany's position as a regional safe asset provider during a period of heavy uncertainty. This reconciles with the possibility that the ECB cuts and reassurance actually worked to reverse this effect, leading to the short-term jump in rates in September and mute reaction in June.

V. Concluding Remarks and Thoughts for Future Research

The macroeconomic environment after the financial crisis has changed significantly, just twenty years ago it would have seemed infeasible to see major central banks implementing negative interest rate policies. Theoretical situations regarding the Zero Lower Bound that seemed to have no place in modern economic thought have now become important points of conversation for central bankers. The high frequency event-study examined above exemplifies promising results regarding the effect of negative interest rates on the longer end of the spectrum, hinting at their usefulness in the future

and justifying the initial remarks given by Bernanke. The analysis of implied forward rates in Japan show that there can be a significant decline in the expectation of future rates far up the curve while also stressing the importance of communication to maximize the potential shift in market beliefs. While there are a few caveats due to the uniqueness of the European Monetary Union and the results regarding Germany that were discussed above, these should be taken as opportunities for further empirical research, where a more robust VAR approach could be taken to measure the effect on key indicators other than long rates or an attempt to decompose the trend in the decline of the German Yield Curve and assess its attribution. An analysis of portfolio flows data might lead to a more robust conclusion explaining the observed "German Conundrum". While there may be consequences down the road as shown in studies published this year, it appears that this experiment in monetary policy will be a future tool in the powder keg for Central Bankers. This paper aims to set the foundation for further empirical research to improve the collective understanding of both its benefits and potential flaws in the future.

VI. Citations

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VII. Appendix

VII.A. Figures

Figure 1. JGB Yield Curve

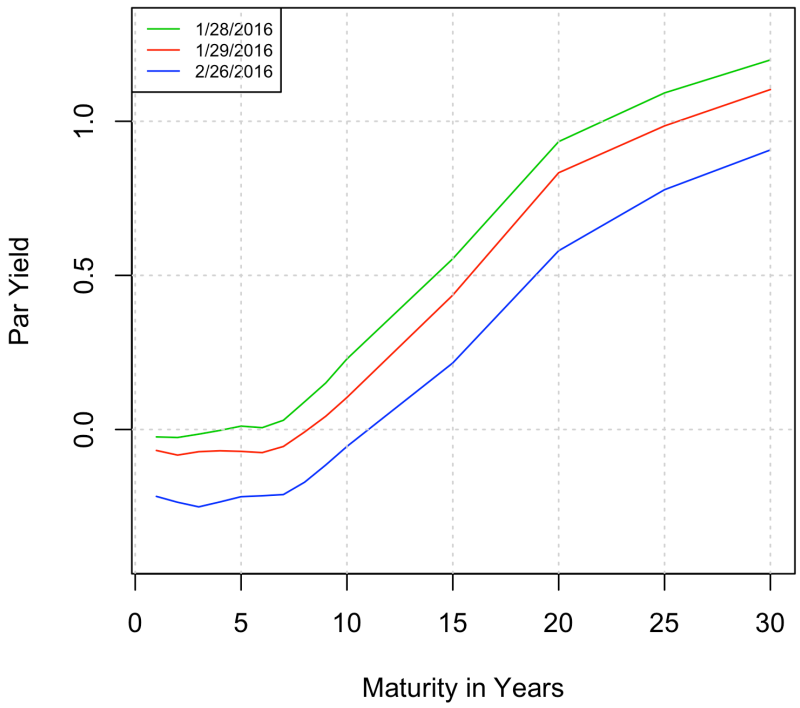

Figure 2. JGB IFR Curve

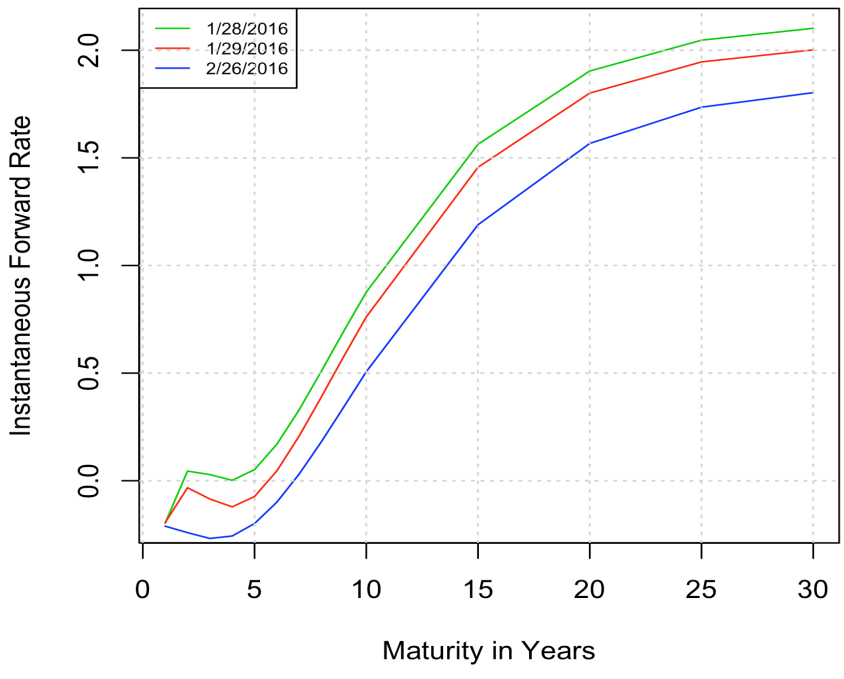

Figure 3. JGB VIX Index

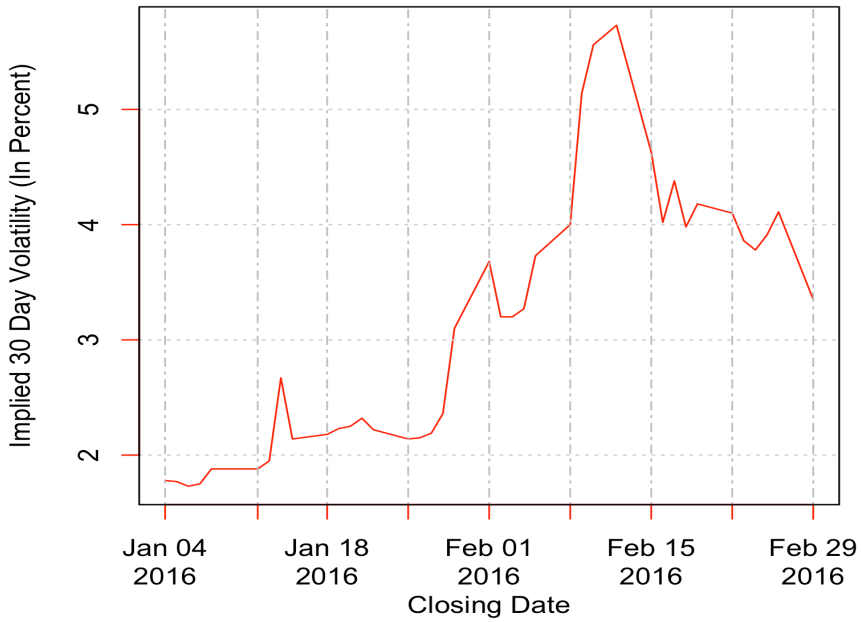

Figure 4. German Long Rates