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Pre- and post- analysis of Bank of Japan's policy implementation of negative interest rates

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Abstract. *This paper analyzes the effect of Bank of Japan's implementation of negative interest rate policy on various macroeconomic indicators – the Nikkei Stock, unemployment rate, foreign exchange rate, gross domestic product (GDP), and inflation rate – in a pre-and-post analysis. The implementation of negative interest rates was in response to conventional monetary policy having little to no effect after the financial crisis of 2008. The Bank of Japan was not the first central bank to implement negative interest rates; however, it is only one of six central banks to do so. For this reason, literature in unconventional monetary policy, specifically negative interest rates, is limited. In this paper, we find evidence that movements in the Nikkei 225 Stock, the exchange rate, unemployment, and GDP coincide with movements expected under conventional monetary policy. We also find evidence of statistically significant impact on GDP and unemployment. However, we could not find evidence it had an effect on the inflation rate. Overall, this paper finds that the unconventional monetary policy of negative interest rates followed similar movements as that of conventional monetary policy.*

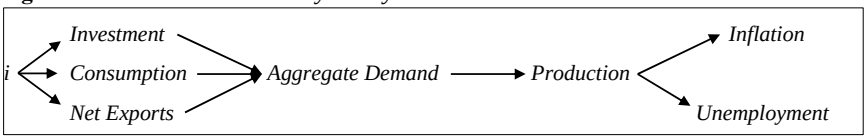
Keywords: GDP, monetary policy, unemployment, inflation rate, 2008 financial crisis, exchange rate, policy analysis.

JEL Classification: E520, E580, E200.

Introduction

Under conventional monetary policy, central banks make decisions regarding interest rate policy in an attempt to accomplish specific goals intended to stimulate economic growth through a variety of channels. There are two common goals central banks worldwide tend to focus heavily on: a targeted inflation rate (i.e., price stability) and full employment (Piffer, 2011; IMF, 2017). The mechanism in which setting interest rate policy results in achieving a central bank's goals, and ultimately the desired outcome of positively influencing economic activity, is illustrated below in Figure 1 where *i* represents the interest rate policy.

Figure 1. *Conventional Monetary Policy Mechanism*



As seen from Figure 1, adjusting the interest rate results in influencing investment, consumption, and net exports, and these in turn provide further change within an economy until eventually affecting the goals set by the central banks (e.g. targeted inflation rate and full employment) (Claus et al., 2018). The impact adjusting interest rate policy has on the progression illustrated in Figure 1 is that it has an inverse effect on investment, consumption, net export, aggregate demand, production, and inflation while it has a positive effect on unemployment. For example, if an arbitrary country's economy (e.g. country A) is contracting, policy makers would decide to lower interest rates as one approach to boost the economy. In doing so, theoretically, reducing interest rates would lower borrowing costs thereby increasing the amount of borrowing allowing investments to increase. With consumption, lowered interest rates would prompt an increase in spending today rather than saving for the future thereby increasing consumption. Regarding net exports, lowered interest rates trigger a country A's currency to depreciate, upon which outside countries begin to view country A's goods as cheaper thereby country A would increase its exports and decrease its imports, resulting in an increase in net exports. In turn, the increases experienced would lead to an increase in aggregate demand on the basis that investment, consumption, and net exports are its primary components (Kira, 2013). As a result, there would be an increase in a country's production which would theoretically lead to increasing inflation and decreasing unemployment (Dell'Ariccia et al., 2018). On the contrary, if a central bank determines its economy is expanding too quickly such that there is a threat of hyperinflation, raising interest rates would be the course of action to counterbalance the impending threat of hyperinflation. In this case, theoretically, the opposite progression of lowering interest rate ensues.

When the 2008 global financial crisis occurred, however, countries worldwide struggled to boost their economies despite conducting conventional monetary policy. The desired results of growth in investment, consumption, and net exports did not occur even though central banks lowered interest rates to near-zero (Claus et al., 2018); a result contradicting what conventional monetary policy theory states. There are various explanations why

lowering interest rates to near-zero did not produce the desired results: the decline in global growth in the midst of the crisis increased savings rather than increasing investment or consumption, populations were pessimistic about the future thereby also increasing savings, aging and declining population growth increased savings (and thus decreased investments and consumption), and distribution of income provoked those with high income to save more and spend less whereas those with low income could not invest properly (Jurkšas, 2017). Overall, lowering interest rates to near-zero failed to encourage growth in investments, consumption, and net exports resulting in ineffectiveness from the conventional monetary policy mechanism.

To address this issue, various central banks began implementing unconventional monetary policy through utilizing a strategy known as quantitative easing (QE). QE policies implemented in conjunction with near-zero interest rates utilized by major central banks were unconventional means to stimulate economic growth, and a resolution to the global financial crisis (Aizenman et al., 2016). Central banks that implemented QE include the United States' Federal Reserve, the Bank of England, the European Central Bank, and the Bank of Japan (BOJ) (Cecchetti and Schoenholtz, 2015; Fawley and Neely, 2013). Generally, QE is the process of central banks buying back securities (e.g. government bonds) to improve economic growth by injecting money into the economy in hopes of encouraging investment and consumption, an objective lowering interest rates to near-zero could not achieve (Dell'Ariccia et al., 2018). Conceptually, the securities purchased by central banks expand reserves held by commercial banks upon which can then be immediately accessed and lent out, thus potentially stimulating investment and consumption (Cecchetti and Schoenholtz, 2015). However, QE struggled to increase investment and consumption despite the large volumes of securities purchased by central banks due to commercial banks withholding increased excess reserves rather than lending (Fawley and Neely, 2013).

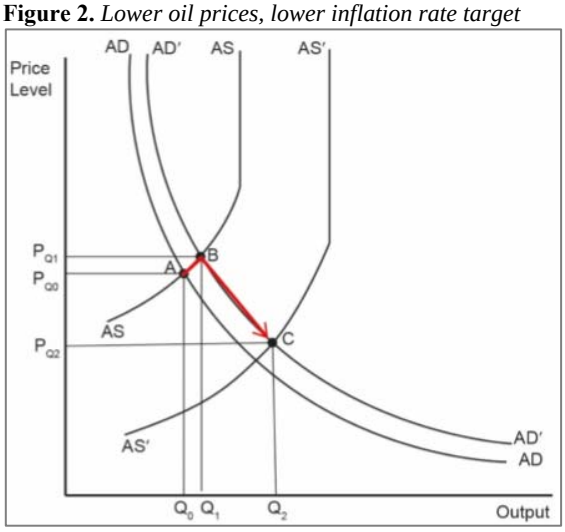
In addition to near-zero interest rate policy and QE, negative interest rate policy (NIRP) was another unconventional monetary policy tool six central banks imposed to further stimulate economic growth. The six central banks were the European Central Bank in June 2014, the Swiss National Bank in December 2014, the Swedish Riskbank in February 2015, the Danmarks Nationalbank in July 2012, the BOJ in January 2016, and the Central Bank of Hungary in March 2016 (Arteta et al., 2016; Aizenman et al., 2016; Jurkšas, 2017). Specific objectives NIRP implementation were expected to accomplish that were set by central banks includes price stability (i.e., European Central Bank, Swedish Riskbank, Swiss National Bank, BOJ, and Central Bank of Hungary) and exchange rate stability (i.e., Danmarks Nationalbank, Swiss National Bank, and the Central Bank of Hungary); completing these objectives in turn would aid in stimulating the country's economy (Angrick and Nemoto, 2017). The underlying general concept of NIRP is that commercial banks will pay interest on their deposits of excess reserves to the central bank instead of the central bank paying interest to commercial banks. Arteta et al. (2016) refers to NIRP as "taxing" commercial banks for excess reserves held requiring them to pay interest which is contrary to the norm. Central banks introduced NIRP with aspiration that it would

achieve their goals in a similar theoretical manner to conventional monetary policy (Jurkšas, 2017). NIRP is unknown territory central banks have not ventured into prior to Danmarks Nationalbank's implementation in 2012, therefore research is limited regarding its long-term impact on central banks' objectives and various economic indicators. This paper will primarily focus on the BOJ's NIRP implementation, where there is a lack of research due to only having three years of data available to study.

Japan

As mentioned earlier, the implementation of negative interest rates was not the first unconventional monetary policy the BOJ utilized. In 2013, the BOJ implemented quantitative and qualitative monetary easing (QQE) as a way to achieve an inflation target rate of 2% set intentionally to overcome deflation and sluggish economic growth resulting from the 2008 financial crisis that magnified existent problems dating back to the 1990's (Dell'Ariccia et al., 2018). Under QQE, the BOJ purchased trillions of yen in long term Japanese government bonds which resulted in a short-term increase in inflation; however, sustained inflation growth failed due to a decrease in oil prices the following year in 2014. The decline in oil prices had a negative impact on inflation due to oil products being substantial components of Japanese imports. Yoshino et al. (2017) provided the following figure to illustrate the impact of oil prices on Japan's inflation rate.

Figure 2. *Lower oil prices, lower inflation rate target*



AD = aggregate demand; AS = aggregate supply.
Source: Yoshino et al. (2017).

From Figure 2, it can be observed aggregate supply (AS) increases when oil prices drop because oil is often used as an input, thus lower oil prices signifies cheaper inputs. Moreover, fundamental economics states input costs is one determinant of supply: the lower an input cost, then the cheaper it is to utilize the input thereby increasing the supply. In Figure 2, this is evident by the rightward shift from AS to AS' and from point B to point C. Additionally, aggregate demand (AD) increases from reduced oil prices because it is

now cheaper to consume oil and oil products; hence, the rightward shift from AD to AD' in Figure 2. The movements from the two curves results in the price level decreasing from P_{Q1} to P_{Q2}. Amid declining oil prices, the BOJ kept the target inflation rate at 2%, and introduced a second round of QQE by purchasing more securities in late 2014. However, despite two rounds of QQE, Japan continued to experience persistently low inflation thus adopting NIRP in January of 2016 in conjunction with continued utilization of QQE (Dell'Ariccia et al., 2018; Arteta et al., 2017; Angrick and Nemoto, 2017; Yoshino et al., 2017).

The BOJ implemented NIRP as a three-tier system: current accounts at the BOJ (i.e., commercial bank reserves) were divided into three strata each with an assigned specific interest rate (Angrick and Nemoto, 2017; Jurkšas, 2017; Arteta et al., 2017; Yoshino et al., 2017). The first-tier is designated the "positive" rate upon which an interest rate of 0.1% was assigned. The second-tier was subjected to an interest rate of 0% designated as the "Macro Add-On" rate. Tier three, the "Policy-Rate", was designated the negative interest rate at -0.1% (Angrick and Nemoto, 2017; Wall Street Journal (Online), 2016). According to a transcript of an interview between the Wall Street Journal and BOJ Governor Haruhiko Kuroda (2016), Mr. Kuroda stated the third-tier accounts for less than 10% of total reserves suggesting NIRP's overall impact might be marginal. The initial amounts each tier's specific interest rate was applied to, as stated by the announcement BOJ delivered in 2016, were 210 trillion yen in the first tier, 40 trillion yen in the second tier, and 10 trillion yen in the third tier. Configuration of the initial amounts within each tier was based on a series of mathematical equations. First, the BOJ subtracted the required reserves amount (i.e., the amount financial institutions are required to hold in reserves) from the average outstanding balance of current accounts at the BOJ to produce the amount for the first tier. To calculate the second tier, the BOJ added the required reserve amount together with the BOJ total amount of credit supplied from various programs. The third-tier amount was configured from subtracting the first and second tier amount from total current accounts. Furthermore, the amounts within each tier would steadily increase at the discretion of the BOJ based on the pace of increase observed in total current accounts (Key Points of Today's Policy Decisions, 2016). Based on the configuration of the three-tier system in addition to Mr. Kuroda's statement, there is an early indication NIRP's impact might be marginal.

When the BOJ began QQE and included NIRP in its unconventional monetary policy, their objective was to achieve the 2% inflation target rate in addition to stimulating economic growth after the global financial crisis of 2008. Due to NIRP's recent implementation (i.e., 2016) there is a lack of research regarding its effectiveness, specifically on various economic indicators. Therefore, the purpose of this research is to analyze how the NIRP has affected Japan's economy drawing comparisons before and after its implementation. This research will analyze its effect on important factors of economic growth that are generally affected when central banks make decisions regarding changes in interest rate policy: Nikkei Stock, unemployment rate, foreign exchange rate, gross domestic product (GDP), and inflation rate.

Data set

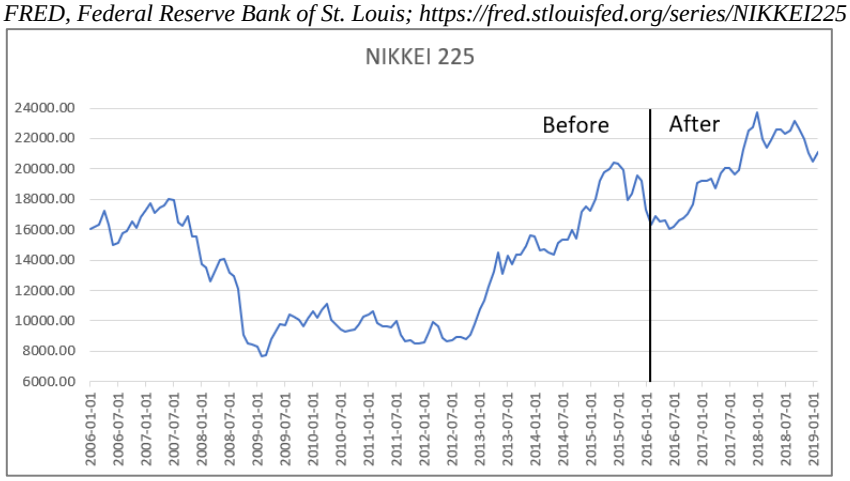
The data obtained for the Nikkei Stock, unemployment rate, foreign exchange rate, GDP, and inflation rate begins from January 2006 and concludes with the most recent data available. The data set was utilized in two ways to conduct the analysis of NIRP. First, graphical representations are used to observe any significant variations. Each variable's graph was obtained from the Federal Reserve Bank of St. Louis website (FRED). Additionally, Nikkei Stock, unemployment rate, foreign exchange rate, and inflation rate data were measured monthly; GDP was measured quarterly. Second, regression analysis was conducted on specific variables (i.e., inflation rate, unemployment rate, and GDP) to further determine if NIRP had a statistically significant impact.

To conduct regression analysis, additional variables needed to be obtained, specifically consumption, investment, and net exports, as these are components of GDP (Wolla, 2013). In theory, monetary policy affects consumption, investment, and net exports (see Figure 1) whereas fiscal policy affects government expenditure. Based on this, GDP was broken down into its components to better capture the effect NIRP has on GDP, and data on these variables were obtained from the FRED. Consumption was broken down into real consumption of households and final private consumption. Investment was divided into real private residential investment and real private non-residential investment. Net export data includes real net exports of goods and services. Furthermore, the variables of interest were converted to percent change from a year ago, and data was collected quarterly to provide a common unit of measure. Additionally, a dummy variable was created representing interest rate policy that takes on a value of 1 if the interest rate is negative and 0 otherwise.

Results

Nikkei 225 Stock Average

Figure 3. *Nikkei Industry Research Institute, Nikkei Stock Average, Nikkei 225 [NIKKEI225], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/NIKKEI225*



Prior to the financial crisis of 2008, the Nikkei Stock fluctuated between about 16,000 and 18,000, even reaching an index as high as about 18,000. Once the financial crisis occurred, the stock plummeted to just below 8,000 yen, and never fully recovered close to what it was prior the financial crisis (about 16,000 yen). The recovery phase did not take place until about five years later in 2013 when it reached close to 16,000 yen. The steep increase observed from Figure 3 in 2013 and 2014 could be attributed to the two rounds of QQE the BOJ implemented, which coincides with the findings of Dell'Ariccia et al. (2018).

In Figure 3, when NIRP is implemented (as evident by the split in the graph), there is an increase in stock prices coinciding with the theory that stock prices increase when interest rates decrease. However, the increase is minimal at the onset of the unconventional monetary policy, an observation corresponding with Jurkšas (2017) who found slight increases in stock indices across four countries with NIRP including Japan. The immediate slight increase could be attributed to the markets' uncertainty of using negative interest rates. Additionally, there may not have been a drastic change in stock price due to markets adjusting prior to its implementation. In theory, markets typically adjust to policy changes prior to their implementation based on news and discussions presented beforehand.

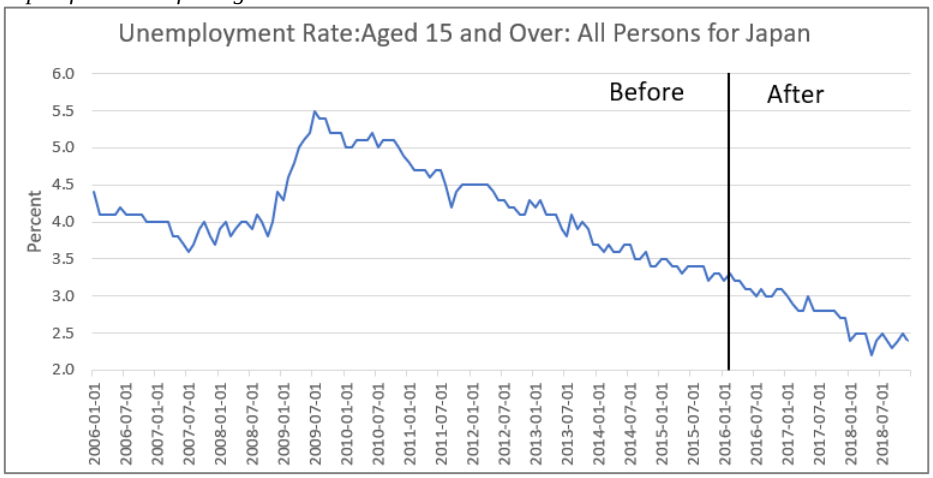
The idea of NIRP had been discussed by the BOJ prior to its official announcement, and as the likelihood of its implementation increased, the markets began to make adjustments. This could be a reason why there is a decline right before its implementation.

Outside of the immediate minimal increase observed from Figure 3 after NIRP implementation, the stock price has been rising with some fluctuation overtime. The Nikkei 225 index increased from just above 16,000 at the onset of NIRP to about 21,000 as of January 2019, with a high of close to an index of 24,000 yen in 2018. This rise could be due to external factors in addition to markets becoming more comfortable to NIRP.

Overall, ten years prior NIRP, the Nikkei 225 didn't surpass an index of 18,000 until 2015; in the three years since NIRP, the Nikkei 225 surpassed 18,000 in 2017. This could be indicative of how impactful NIRP was compared to earlier implementations of unconventional monetary policy (i.e. QQE). However, further statistical analysis is warranted to accurately compare the two unconventional monetary policies' level of impact on the Nikkei 225 Stock. Nevertheless, as mentioned earlier, the increase observed post NIRP is consistent with conventional monetary policy theory that stock prices increase as interest rates decrease.

Unemployment rate:

Figure 4. *Organization for Economic Co-operation and Development, Unemployment Rate: Aged 15 and Over: All Persons for Japan [LRUNTTTTJPM156S], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/LRUNTTTTJPM156S*



From Figure 4 above, Japan's unemployment rate can be observed decreasing from the beginning of 2006 until about mid-2007 when it begins to fluctuate, between about 3.5% and just above 4%, to late-2008 when it drastically increases, reaching a peak of 5.5% around mid-2009: this sharp increase in unemployment rate has often been attributed to the global financial crisis, and has since been observed in other countries ("The Recession of 2007-2009", 2012; Restrepo-Echavarria, 2017). Since the peak in mid-2009, and when central banks began to adapt unconventional monetary policy, the level has seen almost a constant decreasing trend. During this time, the BOJ began to lower its interest rate policy from its peak of 0.5% in 2008 to 0.3% in late 2008, and then to 0.1% in the beginning of 2009, followed by another decrease to 0% in late-2010; changes that, according to conventional monetary policy mechanism, played an important factor in unemployment rates observed decrease. The unemployment rate not only returned to levels previously seen before the crisis but has steadily decreased further to its current position to just below 2.5%. When the NIRP was implemented in 2016, unemployment for January was 3.2%. After the NIRP, the unemployment rate has only increased or decreased by 0.1 percentage points, except in May 2017 when it increased by 0.2 percentage points (due to new participants in the labor force), and January 2018 when it decreased 0.3 percentage points from December 2017.

As shown in Figure 4, since the NIRP implementation in 2016, the unemployment rate appears to have consistently decreased at about the same rate as before its implementation. However, unemployment is not affected instantaneously when a new interest rate policy is put into effect; rather, it takes time for movements in unemployment to be reflective of a change in the interest rate. Furthermore, two rounds of QQE were implemented during this time that could have aided in unemployment's decline. Therefore, it is difficult to conclude NIRP is having a significant effect on unemployment rate based solely on Figure 4 as it

shows a steady decrease seven years before its implementation. Furthermore, NIRP may only be aiding the driving force behind the decrease in unemployment rate. Thus, regression analysis was conducted to further examine its impact.

Regression analysis: The independent variables included in the regression were net exports (netexp), real private residential investment (realresinv), real private non-residential investment (nonresinv), real consumption of households (hhcon), private final consumption (pfcon), 3-month LIBOR rate (libor) based on the yen, and the interest rate dummy variable (irdummy). The results from the regression are shown in Table 1. Additionally, Table 2 contains the results from a joint significant test on the determinants of GDP (netexp, realresinv, nonresinv, hhcon, and pfcon) to determine if they are jointly statistically significant. The determinants of GDP were tested for joint statistical significance based on GDP's (i.e., aggregate demand) influence on the unemployment rate (see Fig. 1). As stated previously, quarterly data was utilized from January 2006 to the most recent date.

Table 1. *Unemployment Regression*

VARIABLES	unemp
pfcon	0.0806
	(1.335)
hhcon	0.685
	(0.509)
nonresinv	-1.680***
	(0.180)
realresinv	-0.0818
	(0.0962)
netexp	-0.000385
	(0.000910)
libor	-0.00389
	(0.00448)
irdummy	-7.829**
	(3.007)
Constant	-1.642*
	(0.920)
Observations	45
R-squared	0.815

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

pfcon = private consumption, hhcon = household consumption, nonresinv = real private non-residential investment, realresinv = real private residential investment, netexp = net exports, libor = 3-month LIBOR rate, irdummy = interest rate dummy variable that takes a value of 1 if the interest rate is negative and 0 otherwise

Table 2

Joint Significant Test
Variables
pfcon = 0
hhcon = 0
nonresinv = 0
realresinv = 0
netexp = 0
F(5, 37) = 29.88
Prob > F = 0.0000

H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$

H_A: at least one $\beta \neq 0$

Observing Table 1, the coefficient estimate on irdummy is negative and statistically significant at the 5% level or greater indicating negative interest rate has a decreasing influence on the unemployment rate. The 3-month LIBOR rate did not show to have a significant impact on unemployment rate over the time period. Similarly, the rest of the variables, apart from nonresinv, were found not to be individually statistically significant, implying they do not influence unemployment rate. However, a joint significance test was

conducted for selected variables (see Table 2) which produced an F-statistic of 29.88 with a p-value of 0.0000. With this result, it is concluded that we reject the null hypothesis suggesting the determinants of GDP are jointly statistically different from zero. Thus, the declining trend in unemployment rate is jointly influenced by the pfcon, hhcon, nonresinv, realresinv, and netexp, in addition to the NIRP statistically individually assisting in this movement.

It should be noted, however, that despite the regression indicating NIRP has a statistically significant impact on unemployment rate, the magnitude of its impact is unclear. Combining the regression results with the findings from Figure 4, it is inconclusive to state the effectiveness of negative interest rates on unemployment rate. As mentioned when discussing Figure 4, the regression results in Table 1 might be indicating NIRP as supporting the already established decline in unemployment rate. Prior to its implementation, the BOJ engaged in two rounds of QQE in addition to lowering interest rates numerous times. These actions could have initiated and sustained unemployment rate's reduction, with NIRP helping to sustain that decline. Further research would benefit from isolating each actions' impact on unemployment rate. Overall though, based on the regression results displayed in Table 1, the unconventional monetary policy of negative interest rates produced the same results on unemployment that conventional monetary policy does: that is, as interest rates are lowered, the unemployment rate decreases.

Foreign exchange rate

Figure 5. *Board of Governors of the Federal Reserve System (US), Japan/US Foreign Exchange Rate [DEXJPUS], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/DEXJPUS*

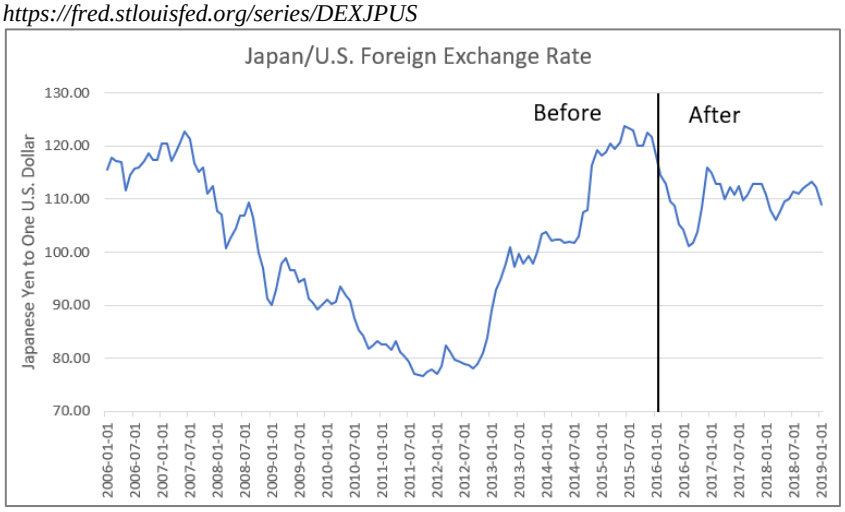


Figure 5 displays the exchange rate fluctuated between values of about 110 and 120 Yen/1 USD from 2006 until the financial crisis occurred. When the global financial crisis occurred, the currency began to depreciate (with periods of appreciation although there is an overall slight declining trend) until it reached an overall low of 76.64 Yen/1 USD about October 2011. The yen then began to recover and appreciate, with slight decreases in various years, to reach a high of 123.72 Yen/1 USD in June 2015 following the introduction

of QQE in 2013 and its expansion in 2014. In conventional monetary policy theory, a significant increase in money supply, which the two QQE policies sought to achieve, should influence a country's currency to depreciate. However, this was not the case.

Further observations from Figure 5 after NIRP in 2016 indicates the yen maintained its depreciation it began in November 2015 until it reached a value of 101.24 Yen/1 USD in August 2016 where it began to appreciate once more. The depreciation it began to experience in November 2015 could be attributed to the foreign exchange market making adjustments to news regarding NIRP. Once the policy went into effect, the currency's depreciation was maintained. Then in December 2017, the yen depreciated to a value of 106.5 Yen/1 USD (with minor fluctuations in-between), followed by it appreciating towards the end of 2018 upon which it has begun to depreciate once more to its current value of 108 Yen/1 USD (as of January 2019). Although NIRP is unconventional, Figure 5 displays some evidence the exchange rate followed its theoretical conventional monetary policy movement: a decrease in interest rate depreciates a country's currency. While there is this evidence NIRP had an effect on the exchange rate, previous research has found NIRP's effect on the exchange rate to be inconclusive (Aizenman et al., 2016, p. 4; Hameed and Rose, 2017, p. 41).

GDP

Figure 6. *Cabinet Office, Gross Domestic Product for Japan [JPNNGDP], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/JPNNGDP*

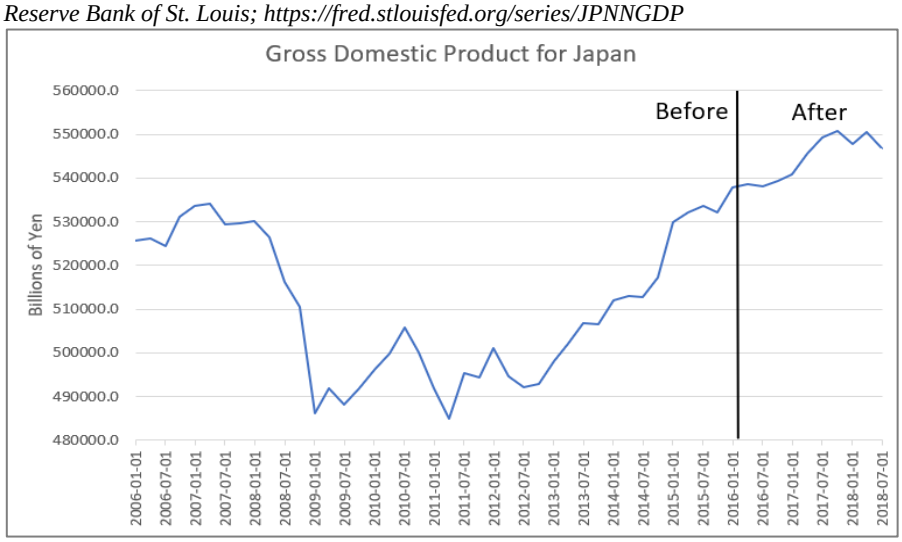


Figure 6 displays Japan's GDP maintained levels between ¥520,000 billion and ¥540,000 billion from the 1st Quarter of 2006 until the financial crisis in 2008 when it decreased steeply to low levels it has not experienced before at ¥486,125.5 billion in the 1st Quarter of 2009. Japan GDP then experienced an increase until the 3rd Quarter of 2010 when it decreased again to about ¥485,000 billion in the 2nd quarter of 2011. From that point until the 4th Quarter of 2012, GDP experienced slight increases and decreases. As it can be observed from Figure 6, when QQE was implemented in 2013 and renewed in 2014, GDP's growth became stable and began to trend upward with less fluctuations than prior QQE.

After the NIRP was implemented, GDP did experience a slight dip from Quarter 2 to Quarter 3 in 2016, however GDP has continued its growth despite that minor dip. In fact, GDP is now at levels above what Japan had experienced prior to the financial crisis reaching a value as high of about ¥550,000 billion in the 4th Quarter of 2017. Overall, it would appear from Figure 6 the unconventional monetary policy of negative interest rates produced the same results as conventional monetary policy: Japan's GDP grew from about ¥53,800 billion at the onset of NIRP to a value of about ¥54,700 billion (as of July 2018), hence lowering the interest rate into negative territory did increase GDP as it would have under conventional monetary policy. Although GDP's growth trend was maintained after putting into effect NIRP, Figure 6 is unable to provide conclusive evidence to determine exactly if NIRP's impact is significant. Therefore, additional analysis was conducted using a regression model.

Regression analysis: Table 3 reports the results from regressing Japan's GDP on pfcon, hhcon, nonresinv, realresinv, netexp, and the interest rate dummy variable. From the output, the only variables to have an effect on Japan's GDP are hhcon, nonresinv, and realresinv as they are individually statistically significant. Accordingly, a joint significance test was conducted on pfcon, hhcon, nonresinv, realresinv, and netexp similar to the joint significant test conducted for unemployment rate. From Table 4, it was found that these variables are jointly statistically significant as the p-value is 0.0000 thereby indicating they jointly influence Japan's GDP. The coefficient on the variable of interest, irdummy, is positive thereby indicating GDP increases as the interest rate takes on a negative value. This is suggestive of lowering interest rates into negative territory proceeding in a similar manner as conventional monetary policy. However, the interest rate dummy variable is not statistically significant indicating there is no evidence of an impact on Japan's GDP. It should be noted the level of statistical significance could be affected based on the limited number of observations present. To investigate this, an additional regression of GDP was conducted converting quarterly data into monthly data. Yearly data was averaged, and then used to fill in missing monthly data. Table 5 reports the results, and Table 6 reports the results from a joint significant test conducted on the same variables as Table 4.

As a result from converting the data from quarterly to monthly, the coefficient on the interest rate dummy variable maintained its positive effect as before suggesting a negative interest rate positively influences GDP. However, contrary to the previous results in Table 3, the interest rate dummy variable using monthly data is now statistically significant at less than the 0.1% level or greater. This is indicating that there is evidence NIRP has an impact on GDP monthly rather than quarterly. Three other variables also experienced increases in statistical significance – hhcon (from 5% to less than 0.1% or greater), realresinv (from 1% to less than 0.1% level or greater), and netexp (from not statistically significant to less than 0.1% level or greater). Each variable maintained its positive/negative effect on Japan's GDP. Additionally, the joint significance test results in Table 6 mirror the results in Table 4 indicating there is evidence the variables – pfcon, hhcon, nonresinv, realresinv, and netexp – are jointly statistically significant, and jointly influence GDP utilizing monthly data.

Table 3

GDP Regression	
VARIABLES	gdp
pfcon	0.203
	(0.434)
hhcon	0.361**
	(0.165)
nonresinv	0.375***
	(0.0578)
realresinv	-0.0598*
	(0.0312)
netexp	0.000257
	(0.000295)
irdummy	1.530
	(0.945)
Constant	-0.325
	(0.292)
Observations	45
R-squared	0.672

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4

Joint Significance Test
Variables
pfcon = 0
hhcon = 0
nonresinv = 0
realresinv = 0
netexp = 0
F(5,38) = 15.48
Prob > F = 0.0000

H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$
H_A: at least one $\neq 0$

Table 5

GDP Monthly Regression	
VARIABLES	gdp
pfcon	0.125
	(0.326)
hhcon	0.465***
	(0.0923)
nonresinv	0.390***
	(0.0300)
realresinv	-0.0657***
	(0.0203)
netexp	0.000608***
	(0.000216)
irdummy	1.150***
	(0.337)
Constant	-0.345**
	(0.167)
Observations	144
R-squared	0.708

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6

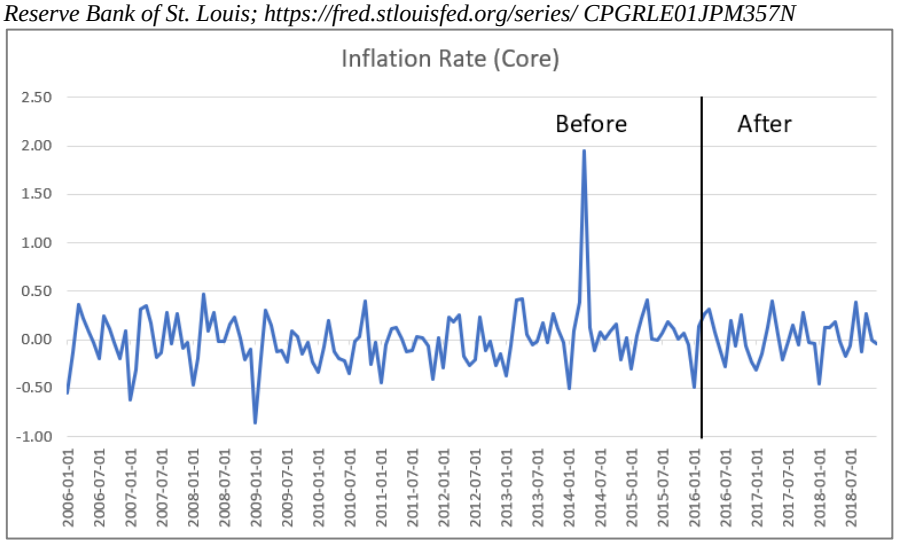
Joint Significance Test: GDP Monthly Regression
Variables
pfcon = 0
hhcon = 0
nonresinv = 0
realresinv = 0
netexp = 0
F(5, 137) = 63.88
Prob > F = 0.0000

H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$
HA: at least one $\neq 0$

Overall, Figure 6 did not display a significant fluctuation that could have be utilized to signify NIRP's effect, however there is some evidence of negative interest rate's impact displayed by the continued growth GDP has been experiencing since its implementation. Furthermore, the regression output provided deeper analysis indicating NIRP has a positive effect on GDP growth after 2016, however it was not statistically significant when utilizing quarterly data. Upon converting the data from quarterly to monthly, NIRP was found to have a statistically significant impact on GDP. Despite these findings, it is difficult to accurately conclude NIRP as the sole factor in GDP's growth since 2016 due to the two rounds of QQE that were implemented in 2013 and 2014 in addition to the lowering of interest rates beforehand. GDP growth was already experiencing an upward trend when QQE was introduced in 2013, and again in 2014. Altogether, NIRP appears to have maintained the steady growth GDP was already experiencing prior to its implementation, thereby acting in a manner similar to conventional monetary policy when interest rates are lowered (i.e., GDP increases).

Inflation rate:

Figure 7. *Organization for Economic Co-operation and Development, Consumer Price Index: OECD Groups: All Items Non-Food and Non-Energy for Japan [CPGRLE01JPM357N], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/ CPGRLE01JPM357N*



Before NIRP and the financial crisis, the inflation rate fluctuated between a rate of -0.5% and 0.5% (see Figure 7). When the financial crisis occurred, inflation rate reached a low of close to -1% around the beginning of 2009. Inflation rate recovered to return within the range of -0.5% and 0.5% by mid-2009 and continued to fluctuate. To overcome the fluctuation and low inflation, the BOJ's targeted inflation rate was set at 2% in 2013 (Yoshino et al., 2017; Dell'Ariccia et al., 2018). To achieve this goal, the first round of QQE was implemented in the beginning of 2013 where there is a noticeable increase in inflation rate. However, this increase was minimal as the inflation rate did not exceed 0.5% at that time and resumed the fluctuation it had been accustomed to experience. In 2014, inflation did reach the 2% target rate (as seen in Figure 7) when there was an expansion of QQE in addition to prices of oil and energy increasing. Despite reaching its goal, the inflation rate sharply decreased again below 0.5% within the same year once oil prices began to significantly decline (Yoshino et al., 2017).

Since the sharp decline from 2% inflation rate in 2014, the BOJ has been unable to reach its 2% target inflation rate, let alone climb outside 0.5% with it fluctuating between -0.5% and 0.5% once again. Even after NIRP implementation, Figure 7 shows that inflation rate has yet to increase above 0.5%. Theoretically, under conventional monetary policy, the inflation rate should increase as a result of interest rates decreasing: Figure 7 shows the expected response has not yet been produced. This observation is in conjunction with findings from Aizenman et al. (2016) and Arteta et al. (2016) who both presented results which stated NIRP did not influence inflation. However, it should be noted there is a length of time before inflation rate begins to show signs of it being affected by changes in interest rate policy. Therefore, we cannot conclude NIRP will not affect inflation in the future.

Based on the inconclusiveness from the Figure 7, regression analysis was conducted to further analyze the impact of NIRP on inflation rate.

Regression analysis: Table 7 contains the results from regressing inflation on net exports, real private residential investment, real private non-residential investment, real consumption of households, private final consumption, 3-month LIBOR rate based on the yen, and the interest rate dummy variable. Based on the results, all the independent variables are not individually statistically significant, indicating there is no evidence they individually influence inflation rate. Table 8 reports the results from a joint significant test on consumption, investment and net exports that produced a p-value of 0.6862 indicating these variables are not jointly statistically significant. In addition to the variable of interest – irdummy – not being statistically significant, its coefficient estimate would indicate NIRP has the opposite effect on inflation rate contrary to conventional monetary policy. That is, rather than increasing inflation rate as a result of lowering interest rates, inflation rate decreases when interest rates were lowered into negative territory. However, taking into account the effect converting quarterly data into monthly data had on GDP, the process was repeated for inflation rate.

Table 7

Inflation Regression	
VARIABLES	inflation
pfcon	7.504
	(91.20)
hhcon	-32.00
	(34.77)
nonresinv	-10.88
	(12.27)
realresinv	0.299
	(6.572)
netexp	-0.000159
	(0.0622)
libor	0.219
	(0.306)
irdummy	-32.49
	(205.4)
Constant	-53.70
	(62.86)
Observations	45
R-squared	0.084

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8

Joint Significance Test on Inflation Regression
Variables
pfcon = 0
hhcon = 0
nonresinv = 0
realresinv = 0
netexp = 0
F(5, 37) = 0.62
Prob > F = 0.6862

H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$
H_A: at least one $\neq 0$

Table 9

Inflation Regression – Monthly	
VARIABLES	inflation
pfcon	-34.64
	(265.9)
hhcon	3.900
	(76.39)
nonresinv	-15.06
	(26.12)
realresinv	4.034
	(17.65)
netexp	0.0493
	(0.175)
libor	0.0142
	(0.545)
irdummy	1,219***
	(396.9)
Constant	-33.42
	(137.2)
Observations	133
R-squared	0.108

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

After converting the data from quarterly to monthly, irdummy is now considered statistically significant at less than 0.1% level or greater (see Table 9). This suggests there is evidence NIRP influences the inflation rate at the monthly level. Furthermore, the coefficient on irdummy is positive thereby indicating interest rates in negative territory increase inflation rate: a finding opposite the results in Table 7 and in conjunction with conventional monetary policy.

The lack of consistency regarding the statistical significance of irdummy results between quarterly and monthly regressions is not surprising, as inflation has continued to fluctuate

within the same range of -0.5% to 0.5% as before the NIRP went into effect, and even before the two rounds of QQE were implemented. The inconclusive findings and uncertainty regarding NIRP's impact presented in this paper also coincide with previous research on inflation rate and negative interest rates. Jurkšas (2017) stated inflation expectations hadn't recovered in the euro area, and there is uncertainty in the impact on short-term and long-term inflation based on negative interest rates complex transmission mechanism. Dell'Ariccia et al. (2018) determined the two rounds of QQE did not sustain inflation growth, and negative interest rates' impact on inflation was difficult to identify. In a study conducted on multiple countries that implemented NIRP, Arteta et al. (2017) discovered inflation expectations decreased in most of these countries. Yoshino et al. (2017) additionally found failure in achieving the 2% inflation target rate. Overall, the BOJ implemented QQE and negative interest rates to reach the targeted inflation rate of 2% but have yet to have significant impact on inflation rate outside of a short spike in 2014.

Conclusion

NIRP falls into the category of unconventional monetary policy, with QE (or QQE utilized by Japan), as only six central banks have implemented this policy as a means to promote price stability and economic growth after the 2008 global financial crisis. There has been limited research regarding this unconventional mechanism based on the fact it has not been implemented before: the first central bank established NIRP in 2014. Central banks were hesitant in implementing the policy due to the uncertainty surrounding whether lowering interest rates into negative territory would produce similar results as that of conventional monetary policy. This paper focused on Japan's implementation of NIRP, and whether the unconventional mechanism replicated what conventional monetary policy theory states should occur when interest rates are lowered.

Based on observations derived from each figure, and from the output's produced by the regression analysis, there is evidence NIRP has followed conventional monetary policy to an extent. Movements in the Nikkei 225 Stock and the exchange rate coincide with movements expected under conventional monetary policy: that is, when interest rates were lowered, the stock exchange increased, and the exchange rate depreciated as it would under conventional monetary policy. Economic growth has occurred post-NIRP implementation as indicated by sustained decrease in unemployment rate and continued growth in GDP. Furthermore, lowering interest rates into negative territory was found to have a statistically significant impact on GDP and unemployment, in addition to decreasing unemployment and increasing GDP as would have occurred under conventional monetary policy. However, NIRP has yet to increase the inflation rate as would be expected under conventional monetary policy being that the rate is still well below the target rate of 2%.

Overall, it would appear the unconventional monetary policy of lowering interest rates into negative territory produced similar results as that of conventional monetary policy regarding GDP, unemployment, stock market, and the foreign exchange rate: inflation rate has yet to be affected in the same manner. Additional research is warranted to provide conclusive findings on NIRP's impact on inflation rate. Furthermore, additional research

should isolate NIRP's effect from other unconventional monetary policies implemented (such as quantitative easing) to further clarify the magnitude of NIRP's effect. Based on potential results produced from future negative interest rate research, central banks may be less apprehensive to solely implement negative interest rates rather than in conjunction with other unconventional monetary policy tools in the event of another financial crisis whether it occurs globally (e.g. the 2008 financial crisis) or domestically.

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