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Is the negative interest rate policy effective?

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Abstract

This paper examines the effectiveness of the negative interest rate policy conducted by several central banks to stabilize economic growth and inflation expectations through the signaling channel. In doing so, we assess survey-based expectations data for up to 44 economies from 2002 to 2017 and analyze the impact of the adoption of a negative interest rate policy on expectations made by professionals based on a difference-in-differences approach. Our main findings are as follows: First, we show that the introduction of negative policy rates significantly reduces expectations regarding 3-month money market interest rates and also 10-year government bond yields. Second, we also provide evidence for a significantly positive effect of this unconventional monetary policy tool on GDP growth and inflation expectations. This implies that the negative interest rate policy appears to be effective in boosting economic growth and overcoming a deflationary spiral. Consequently, the effect of negative nominal interest rates on real interest rate expectations is also negative.

Keywords: Expectations, Inflation, Monetary policy, Negative interest rates, Survey data
JEL: E31, E43, E52

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1 Introduction

In the aftermath of the global financial crisis the world economy went into a great recession. As a result inflation rates in many industrial economies decreased substantially. Especially, in the Euro Area inflation was clearly below its target rate of 2% quite often between 2009 and 2016 and even went into the negative territory. To overcome the potential of a deflationary spiral, the European Central Bank (ECB) made use of unconventional monetary policy tools and as part of this strategy adopted a negative interest rate policy (NIRP) in June 2014 by setting its deposit facility rate below zero. The ECB intended to stimulate bank lending and therefore economic activity and stop the deflationary spiral by penalizing banks for holding overnight deposits at the central bank and not passing through liquidity they receive from the ECB to firms or households.[1] Several other central banks followed this policy introduced by the ECB as can be seen in Figure 1.[2] Denmark adopted a NIRP in September 2014, Switzerland in December 2014, Sweden in February 2015, Norway in September 2015, Bulgaria in January 2016, Japan in February 2016 and Hungary in March 2016.[3]

[1]Liquidity injected into the financial sector via long-term refinancing operations increased the deposit facility holdings at the ECB. Therefore, negative interest rates turned out to be essential to overcome this issue, complementing other unconventional monetary policy actions.

[2]Actually, negative interest rates have firstly been adopted by the Swiss National Bank (SNB) in the early 1970s to counter a currency appreciation and Denmark's Nationalbank also lowered its certificates of deposit rate below zero in July 2012 but raised it again into the positive territory in April 2014 before cutting it again below zero in September 2014. Therefore, it can be argued that the ECB started this new area of monetary policy.

[3]Norway and Hungary can be seen as special cases since both lowered their deposit facility rates below zero, however still maintained positive policy rates. The negative deposit rates had little or no influence on the money market rate in these economies (Jobst and Lin, 2016). Therefore, in the present study both economies are treated as special cases. See also Jobst and Lin (2016) and Bech and Malkhozov (2016) for excellent overviews of early experience with negative interest rates for the mentioned countries. It is also worth noting that previous literature distinguishes between negative official interest rates and negative effective interest rates. Studies such as Wu and Xia (2016) derive measures of a 'shadow rate' for the period where the official interest rate is zero by analyzing how the yield curve is affected by official interest rates. However, the present study focuses on negative official interest rates.

*** Insert Figure 1 about here ***

The conventional monetary policy transmission mechanism is distorted when the policy rate moves below zero due to the (near) zero lower bound of deposit rates offered by banks (Eggertsson *et al.*, 2019). In the negative interest rates environment the pass-through from the policy rate to the deposit rate is incomplete, i.e. banks cannot lower their deposit rates below zero in the same amount as the central bank since depositors have the option to substitute deposit for cash holdings.[4] Therefore, the transmission of monetary policy via the classical interest rate channel is weaker in a NIRP environment (Bernoth and Haas, 2018).[5] In addition, negative nominal interest rates are also associated with various financial stability concerns. For instance, negative interest rates and the inability of banks to pass these negative rates completely to depositors reduces the banks' ability to make profit (Eggertsson *et al.*, 2017, 2019; Altavilla *et al.*, 2018; Brunnermeier and Koby, 2018; Stráský and Hwang, 2019).[6] However, the latter is cru-

[4]Actually, it can be observed that household deposit rates have also decreased in the Euro Area over the recent years but are still positive (see e.g. Eisenschmidt and Smets, 2019). This shows that most banks have not (or not yet) passed on negative interest rates to household depositors, although first evidence of banks also passing through negative rates to corporate depositors are also observed (Altavilla *et al.*, 2019). This indicates the presence of the (near) zero lower bound of deposit rates offered by banks. We refer to a *near* zero lower bound since due to transport, storage, insurance and other costs that are associated with holding large amounts of cash, the effective lower bound on nominal interest rates is somewhere below zero (Bech and Malkhozov, 2016). In addition, the costs of avoiding negative interest by substituting cash for deposit holdings is lower for household depositors compared to large businesses and institutional investors (McAndrews, 2015).

[5]However, it should also be noted that there is no consensus among academics and policymakers when it comes to the question whether monetary policy can still be effective at the zero lower bound. For instance, Swanson (2018) argues that the US Federal Reserve has not been very constrained in its ability to influence medium- and longer-term interest rates at the zero lower bound. Other studies compare periods of negative interest rates with previous periods and find no evidence that the pass-through mechanism is affected by the NIRP. This has for example been illustrated by Turk (2016) for money market rates and bank loan interest rates in Sweden and Denmark and by De Rezende (2017) for Swedish government bond yields.

[6]In addition, the NIRP can also impact the risk-taking behavior of banks. However, currently the evidence of the NIRP effect on banks' risk-taking provided by the existing literature is mixed (Arce *et al.*, 2018; Neuenkirch and Nöckel, 2018; Demiralp *et al.*, 2019; Heider *et al.*, 2019; Tan, 2019; Bottero *et al.*, 2019).

cial not only for the sustainability of the banking system, but also for a sufficient and efficient credit supply to the whole economy. Moreover, inefficient credit provision can also arise from the fact that negative interest rates lower the cost of debt and therefore, delay the exit of non-viable firms. This also delays the efficient allocation of capital and labor and may result in a delayed and incomplete stimulus on economic activity (Kwon *et al.*, 2015; Jobst and Lin, 2016).

However, the NIRP does not solely weaken the classical transmission of monetary policy and provide threats to financial stability, but also offers a new transmission channel – the so-called signaling channel since households' spending and savings decisions depend not solely on the current interest rate but also on their expectations about future real interest rates. The fact that policy rates are negative today is a signal to investors that deposit rates will be zero for a longer period of time and this can stimulate investment and aggregate demand. The NIRP can be interpreted as tangible signal about future policy, which complements central bank announcements within the forward guidance policy conducted by several central banks in the recent years. The expected real interest rate is potentially reduced via the expectation that nominal interest rates remain low and the belief that inflation will increase. A key task is to prevent a situation of expected deflation in a zero or negative interest rate environment as experienced by Japan in the 1990s.

De Groot and Haas (2019) recently presented a New Keynesian model showing that the signaling channel of negative interest rates dominates any contractionary effects coming from the banking sector under two fairly reasonable conditions: First, policymakers are constrained to set policy in a time-consistent manner, which means that they cannot credibly commit to a desired future interest rate path that they know to be suboptimal ex-post since investors would expect this.[7] Second, central banks tend

[7]There is a large body of research on central bank credibility and time inconsistency following the

to change interest rates gradually (see also Bernoth and Haas, 2018).[8] Moreover, Bhattarai *et al.* (2015) also demonstrate the effectiveness of quantitative easing (QE) as another tangible signal about future policy to fight deflation and a negative output gap within a general equilibrium sticky-price closed economy model. They basically show that the QE policy lowers real long-term interest rates by decreasing expectation about real short-term interest rates.

Therefore, the present study contributes to the literature by analyzing the effectiveness of the NIRP conducted by several central banks to stabilize economic growth and inflation expectations through the signaling channel. In doing so, we assess a large survey-based expectations data set on a monthly basis provided by FX4casts for up to 44 economies for the sample period from 2002 to 2017. The impact of the adoption of a NIRP on expectations made by professionals (mostly banks) regarding short-term and long-term interest rates and especially regarding GDP growth and inflation is analyzed within a difference-in-differences (DiD) approach. The present data set enables us to apply a DiD regression approach since it includes expectations data for economies that have adopted negative interest rates as mentioned above and economies that have not and the sample includes the period prior and after the adoption of this policy tool around June 2014. Therefore, we are able to split up our data set into a treatment group (NIRP adopter countries) and a control group (NIRP non-adopter countries) and study the effect of the treatment (adoption of the NIRP). To the best of our knowledge this is the first paper, which empirically analyzes the effect of the NIRP on expectations through the signaling channel and therefore provides an empirical test for the most

seminal works by Kydland and Prescott (1977) and Barro and Gordon (1983).

[8]Eggertsson *et al.* (2017, 2019) also use a New Keynesian model, however, in contrast conclude that the total effect on aggregate output can be contractionary. In addition, Michail (2019) provides a counterfactual analysis of the NIRP impact for Denmark, Sweden and Switzerland and concludes that the NIRP has neither a significant effect on bank lending growth nor on observed inflation. On the other hand, Rognlie (2016), Porcellacchia (2018) and Altavilla *et al.* (2019) also argue in favor of a stabilizing effect of the NIRP on aggregate demand.

recent theoretical propositions.

The main findings of the present study are as follows: First, we show that the introduction of negative policy rates significantly reduces expectations regarding 3-month money market interest rates and also 10-year government bond yields. This shows that professionals consistently expect nominal interest rates to be lower in the short-run but also in the long-run. Especially, the latter confirms the presence of the signaling channel. Second, we also provide evidence for a significantly positive effect of this unconventional monetary policy tool on GDP growth and inflation expectations. This implies that professionals believe in the effectiveness of the negative interest rate policy in reducing real interest rates, boosting economic growth and overcoming a deflationary spiral.

The remainder of this paper is organized as follows. The next section introduces our data set and our empirical approach while Section 3 provides and interprets our empirical findings. Section 4 concludes.

2 Data and Empirical Methodology

This section presents our data set and provides a description of our empirical framework.

2.1 Data and NIRP

As already mentioned, we use survey-based expectations data provided by FX4casts. This data set provides monthly mean forecasts for the 3-month London Interbank Offered Rate (LIBOR), the 10-year government bond yield, the GDP growth rate and the inflation rate based on a consensus of 48 professional forecasters (mostly banks, see `FX4casts.com` for a completely list of contributors) and has already been used by Beckmann and Czudaj (2017) to approximate exchange rates expectations.[9] Table 1 provides all details regarding our data set and separates the four variables under observation into two financial and two real variables. Expectations regarding 3-month interest rates and 10-year government bond yields are measured as fixed horizon forecasts for three different forecast horizons (3-, 6- and 12-months). In contrast, expectations regarding GDP growth and inflation are provided as fixed event forecasts, which means that forecasts are queried by FX4casts for the current and the next year at each point in time. Therefore, the uncertainty regarding the current years forecast naturally decreases over time. To synchronize these two types of forecasts, we make use of the Patton and Timmermann (2011) approach to convert fixed event into fixed horizon forecasts based on a weighted average of forecasts for the current and the next year:

$$\hat{g}_{t,t-12} = w\hat{g}_{1,0} + (1-w)\hat{g}_{2,1}, \tag{1}$$

where $\hat{g}_{t,t-12}$ denotes the approximated 12-month fixed horizon forecast for GDP growth or inflation while $\hat{g}_{1,0}$ and $\hat{g}_{2,1}$ represent the corresponding fixed event forecasts for the current and the next year. w gives the weight for the current years forecast, which is set to $(24-t)/12$ for $t = 12, 13, \ldots, 23$ and therefore linearly decreases over time.

*** Insert Table 1 about here ***

Panel (a) of Table 1 provides expectations for NIRP adopter countries, which basically include Bulgaria, Denmark, Hungary, Japan, Norway, Sweden, Switzerland and Euro Area countries as already mentioned in the Introduction. Expectations regarding 3-month interest rates and 10-year government bond yields are solely available for

[9]The 3-month LIBOR and the 10-year government bond yield are both measured in nominal terms and are used as proxies for short-term and long-term interest rates in our study.

the Euro Area as a whole while GDP growth and inflation forecasts are considered for individual countries.[10] In contrast, Panel (b) gives our expectations data available for NIRP non-adopter countries. The sample period basically runs from October 2001 (February 2002) to December 2017 for 3-month interest rate and 10-year government bond yield (GDP growth and inflation) forecasts but starts later for a few economies according to Table 1. Therefore, our sample includes the period prior and after the adoption of the NIRP on June 2014 (and shortly after).

As a preliminary step, Table 2 reports descriptive statistics for expectations pooled across countries. Mean forecasts for short-term (long-term) interest rates lie around 4.5% (3%) and for GDP growth and inflation around 2.85% across all countries. The volatility measured by the standard deviation is unsurprisingly much higher for short-term than for long-term interest rate forecasts since for the latter data is only available for ten industrial economies. All variables are positively skewed, which indicates that upturns are on average steeper than downturns. Therefore, the null of Gaussianity can clearly be rejected according to the Jarque-Bera test.

*** Insert Table 2 about here ***

Moreover, Figure 2 shows inflation expectations for the main NIRP adopter countries and illustrates that these have increased shortly after the adoption of the NIRP by the ECB into the direction of the level of 2%. When keeping in mind that the other central banks introduced negative interest rates within the subsequent 1.5 years, this indicates that the NIRP might have been effective in stabilizing inflation expectations, which will

[10]The data set includes the following Euro Area countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain.

be examined in the following section.

*** Insert Figure 2 about here ***

2.2 Empirical Methodology

The introduction of negative interest rates by some but not all central banks has created a quasi-experiment, which subdivides the countries under observation into a treatment group (NIRP adopter countries) and a control group (NIRP non-adopter countries). The main benefit of this approach comprises the exploitation of the exogenous variation resulting from the policy change, which is the treatment in our study. We basically observe a panel of countries for a sample period that includes a pre-treatment and a post-treatment period and control for the treatment effect by considering treated and untreated countries. To measure the effect of the treatment, which in our case is the effect of the NIRP, we estimate the following difference-in-differences (DiD) regression:

$$Y_{it} = \beta_0 + \beta_1 N_t + \beta_2 A_i + \gamma N_t A_i + \varepsilon_{it}, \quad i = 1, \ldots, n, \quad t = 1, \ldots, T, \tag{2}$$

with

$$N_t = \begin{cases} 1, & \text{since June 2014} \\ 0, & \text{prior to June 2014} \end{cases}, \quad A_i = \begin{cases} 1, & \text{NIRP adopter country} \\ 0, & \text{NIRP non-adopter country} \end{cases},$$

where Y_{it} represents one of the four expectations measures (i.e. for short-term interest rates, long-term interest rates, GDP growth or inflation) and ε_{it} is a random error term.[11] We consider June 2014 as the start of the NIRP since the ECB firstly adopted

[11] Thornton and Vasilakis (2019) use a similar framework to examine the effect of the NIRP on exchange rate behavior. The underlying assumptions are basically the same as in the classical linear regression model, which are just added by the parallel trend assumption. The latter basically states that without the policy change expectations for both the treatment and the control group would have developed parallel to each other.

this policy on this date as illustrated in the Introduction. All other countries that also lowered interest rates below zero followed and therefore investors might have already expected the adoption of negative interest rates from this date.[12]

The DiD method basically compares the change of our dependent variable from the prior to the post NIRP period for the two different groups and the OLS estimate of γ in Eq. (2) gives the DiD estimator as the difference in the change of the treatment group to the change of the control group $\hat{\gamma} = (\overline{Y}_{\text{Treatment,Post}} - \overline{Y}_{\text{Treatment,Prior}}) - (\overline{Y}_{\text{Control,Post}} - \overline{Y}_{\text{Control,Prior}})$. The control group is important e.g. to account for other unconventional monetary policy tools conducted by central banks such as QE, which has also been excessively used by central banks that have not lowered their policy rates below zero such as the US Federal Reserve or the Bank of England. The beauty of our DiD approach is that it allows us to control for expectation effects stemming from QE actions since we have countries that adopted QE policies both within the treatment group (for example the Euro Area countries or Japan) and within the control group (for example the US or the UK). Therefore, the main difference between these two groups of countries is the adoption of negative interest rates and thus expectation effects observed in our study are due to the adoption of a NIRP and not due to QE actions. The next section provides a discussion of OLS estimations carried out for Eq. (2).

3 Empirical Results

In this section we discuss our empirical findings. We start by addressing the effect of the adoption of the NIRP on expectations regarding short-term and long-term nominal interest rates and then turn to its impact on GDP growth and inflation expectations.

[12] As already mentioned before, Denmark's Nationalbank already lowered its policy rate below zero in July 2012 but raised it again into the positive territory in April 2014. In addition, it is also worth noting that our results are not sensitive to variation of this date. In a robustness check, we also use March 2016 as starting date for the NIRP. This date is chosen due to the fact that since this date all eighth NIRP adopting central banks had negative deposit rates.

Finally, we also examine the NIRP effect on real interest rate expectations.

3.1 NIRP Effect on Nominal Interest Rate Expectations

First of all, Table 3 reports coefficient estimates for the DiD regression provided in Eq. (2) for 3-month money market interest rate expectations and for 10-year government bond yield expectations both over a 3-, 6- and 12-months horizon. Estimates for β_0 provide mean expectations regarding interest rates in NIRP non-adopter countries prior to June 2014 and are significantly positive around 5.7% for short-term interest rates and 4.2% for long-term interest rates. The significantly negative estimates for β_1 and β_2 account for the fact that interest rate expectations are generally lower in the NIRP period for all economies (β_1) and for the whole sample period for NIRP adopter countries (β_2). Although accounting for the latter, the effect of the NIRP on interest rates expectations is still significantly negative as shown by the estimates of the DiD coefficient γ. For 3-month interest rate forecasts this coefficient is highly significant (at the 1% level) for all three forecast horizons. For 10-year government bond yield forecasts it is also highly significant for the 12-month horizon, significant at the 5% level for the 6-month horizon and insignificant but still negative for the 3-month horizon. For both interest rates the magnitude of the effect gets stronger when the forecast horizon increases. The adjusted R^2 is much higher for long-term interest rate expectations simply due to the fact that in this case we only have data for ten industrial economies as shown in Table 1, which have a greater explanatory power due to a more stable path of monetary policy. However, the magnitude of the effect is much stronger for 3-month interest rates compared to 10-year government bond yields, which can be explained by the flattening of the term structure of interest rates. The latter increases with term to maturity but with a decreasing rate. Therefore, the effect of the NIRP might also be lower for long-term interest rates. This finding is fully in line with the study by Estrella and Hardouvelis (1991), which basically shows that a positive slope of the yield curve is associated with an expected increase in economic activity. The yield curve is proxied by Estrella and Hardouvelis (1991) as the interest rate spread between long-term and short-term interest rates. Therefore, the net NIRP effect on the spread between long-term and short-term interest rates expectations would be positive and would increase economic growth prospects as outlined by Estrella and Hardouvelis (1991).

*** Insert Table 3 about here ***

Overall, our findings show a significantly negative impact of the NIRP on short-term as well as long-term interest rate expectations. Especially, the latter confirms the presence of the signaling channel of the NIRP since the fact that policy rates are negative today lets professionals (i.e. bankers) believe that market rates will be low (i.e. around zero) for a longer period of time (i.e. 10 years). Theoretically, this stimulates investment and economic growth and therefore increases inflation expectations, which is tested explicitly in the following.

3.2 NIRP Effect on GDP Growth and Inflation Expectations

As a next step, we actually test this hypothesis of a positive effect of the NIRP on GDP growth and inflation expectations within the same framework. The empirical results are provided in Table 4. We also observe that expectations of professionals regarding GDP growth as well as inflation are on average lower for all economies in the NIRP period and for the NIRP adopter economies over the entire sample period. The former (latter) finding is displayed by significantly negative β_1 (β_2) coefficients for expectations regarding both macroeconomic variables. Again accounting for the latter, we find that the NIRP effect on GDP growth expectations is significantly positive, which indicates that professionals believe in the signaling channel of the NIRP as a new transmission mechanism of monetary policy and its stimulating effect on the economy. This finding generally confirms the theoretical evidence provided by De Groot and Haas (2019) and shows that professionals expect GDP growth to be on average more than 1 percentage point higher for NIRP adopter countries. The same effect is also significantly positive for inflation expectations at least at the 10% level with a p-value of 0.0506, although the magnitude is lower compared to the effect on GDP growth expectations (around 0.17 percentage points). This finding of a significantly positive effect on inflation expectations can be seen as evidence for the effectiveness of the NIRP in overcoming the potential of a deflationary spiral and implies that inflation expectations are anchored. The adjusted R^2 is nearly twice as high for GDP growth compared to inflation expectations.

*** Insert Table 4 about here ***

As already mentioned in the Introduction, Norway and Hungary can be seen as special cases since both lowered its deposit facility rates below zero, however still maintained positive policy rates. Therefore, as a robustness check we have also considered these two economies as NIRP non-adopters and have included them in the control group. The results turned out to be robust to this choice. Especially, the positive NIRP effect on GDP growth and inflation expectations has not changed remarkably and is significantly different from zero at the 1% level. As an additional robustness check, we have also repeated the whole analysis while considering March 2016 as the start of the NIRP. This choice is motivated by the fact that from this date all eighth NIRP adopting central banks had negative deposit rates. As can clearly be seen in Table 4 the corresponding coefficients are also significantly positive at the 1% level and even increase in magnitude. Moreover, we have also re-run this part of our analysis for a smaller group of countries excluding emerging economies from Asia and Latin America, which were in the control group for our main analysis and therefore might be responsible for overestimating the effect of the treatment group. The corresponding findings are reported in Table A.1 in the Appendix and clearly demonstrate that our results are remarkably robust to this variation. The NIRP effect on GDP growth prospects is a bit weaker in magnitude while the effect on inflation expectations is stronger in magnitude compared to the initial specification, but in all cases the NIRP effect is highly significant. This shows that the NIRP effect presented in our study is not driven by emerging economies within the control group. In addition, we have also considered a version of Eq. (2) including country and/or time fixed effects and the corresponding results also confirm our findings.[13]

3.3 NIRP Effect on Real Interest Rate Expectations

Finally, we also analyze the NIRP effect on real interest rate expectations, which need to be lowered by this monetary policy tool to stimulate investment and economic growth. Therefore, we have computed expectations regarding short-term and long-term real interest rates by using the data described in Section 2.1. Real interest rate expectations over a horizon of h months are constructed as follows

$$r_t^h = i_t^h - \pi_t^h, \tag{3}$$

where i_t^h denotes nominal interest rate expectations (either for 3-month interest rates or for 10-year government bond yields) and π_t^h represents inflation expectations. Short-

[13]The results are not reported but are available upon request.

term and long-term real interest rate expectations are solely considered for a horizon of 12 months (i.e. $h = 12$ in Eq. (3)) since inflation expectations are only available over this horizon.

We examine the impact of the NIRP on real interest rate expectations since investment decisions essentially depend on real instead of nominal interest rate expectations. Real interest rates are of even greater importance if the nominal interest rate has reached the zero lower bound. Such a scenario often occurs after a recession and in disinflationary or deflationary periods.[14] According to Eq. (3), an expected decrease of the inflation rate (potentially even into the negative territory) results in an increase of the expected real interest rate, if the expected nominal interest rate is zero. This would result in lowering production and prices even further. This phenomenon is often referred to as deflationary spiral. In contrast, an increase in inflation is still capable of reducing the real interest rate even if the nominal interest rate is expected to be constant. A NIRP is therefore able to reduce the expected real interest rate through both an increase in inflation expectation and a reduction of the expected nominal rate. These two mechanisms are closely related since negative interest rates reflect a strong commitment to an expansionary monetary policy path. If such a statement is deemed credible by markets, inflation expectations increase as shown in the previous subsection.

Figure 3 displays real short-run interest rate expectations for all eighth economies that have implemented a NIRP and is in line with studies arguing that the real equilibrium or natural interest rate consistent with stable inflation and output equating its long-term potential has fallen sharply after the global financial crisis and has stayed largely negative since then (Holston *et al.*, 2017; Belke and Klose, 2017; Brand *et al.*,

[14]Japan provides an infamous example of an extended deflationary period during the 1990s (Ahearne *et al.*, 2002) while several economies faced deflation fears in the aftermath of the global financial crisis since the cut in interest rates was unable to increase inflation via a boost in production.

2018).[15] Especially, the lowering of real interest rate expectations after the adoption of the NIRP indicates the effectiveness of this policy. However, to formally test this hypothesis, we also apply the same DiD approach considered before to check for the effect of the NIRP on expectations regarding short-term and long-term real interest rates. The corresponding results are reported in Table 5 and exhibit a significantly negative NIRP effect on short-term and long-term real interest rate expectations in all specifications. Overall, this confirms our finding that the NIRP appears to be effective in stimulating investment and economic growth.

*** Insert Figure 3 and Table 5 about here ***

4 Summary and Concluding Remarks

The present paper contributes to the existing literature by empirically examining the effectiveness of the NIRP and its signaling function of holding interest rates at a historical low level for a longer period of time to stimulate investment and therefore economic activity and stabilizing inflation expectations at a desirable level. Hence, we rely on a broad set of expectations data based on a survey of professional forecasters for up to 44 economies and we apply the difference-in-differences method to analyze the effect of the adoption of negative interest rates.

Our main findings are threefold: First, we show that the introduction of negative policy rates significantly reduces expectations regarding short-term money market interest rates and also long-term government bond yields, which confirms the signaling

[15]For the concept of the real equilibrium interest rate and its estimation techniques we also refer to Levy *et al.* (2003) and Beyer and Wieland (2019).

channel of the NIRP. Second, we also provide evidence for a significantly positive effect of this unconventional monetary policy tool on inflation and GDP growth expectations. This implies that the negative interest rate policy appears to be effective in overcoming a deflationary spiral and boosting economic growth. Finally, our results confirm that a cut of the nominal policy rate below zero lowers its real rate component and thus increases inflation expectations and boosts aggregate demand. In line with Swanson (2018), these findings suggest that monetary policy can still be effective at the zero lower bound.

The NIRP is a relatively new monetary policy tool. It has an impact on the classical transmission of monetary policy and comes with side effects regarding financial stability. However, through the signaling channel the NIRP appears to be an effective monetary policy tool in the current situation. In the upcoming years, it will be interesting to see when and how the central banks will exist from the NIRP. If interest rates are zero or even negative for a longer period of time, there is a risk for the occurrence of bubbles on real estate and equity markets and the scope of action of the central bank is limited. Therefore, the long-run consequences from this policy action are still debated among economists and offer the potential for future research. The present study provides novel evidence within this discussion.

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Figures and Tables

Figure 1: **Negative policy rates**

The plot shows monthly time series for policy rates of five central banks, which have adopted a negative interest rate policy (NIRP), for the period from January 1999 to August 2019. These include the Bulgarian National Bank's LEONIA rate (in cyan; negative since January 2016), the Danmarks Nationalbank's certificates of deposit rate (in red; negative from July 2012 to March 2014 and since September 2014), the European Central Bank (ECB) deposit facility rate (in black; negative since June 2014), the Central Bank of Hungary deposit facility rate (in orange; negative since March 2016), the Bank of Japan (BoJ) deposit facility rate (in violet, negative since February 2016), the Norges Bank's reserve rate (in dark green; negative from September 2015 to March 2019), the Sveriges Riksbank Repo rate (in blue; negative since February 2015), and the Swiss National Bank (SNB) policy rate (in green; negative since December 2014). The SNB publishes a policy rate since June 2019 and has published a range for the policy rate prior to June 2019. The plot shows the mean of the upper and the bottom value of this range. The data has been taken from the national central banks.

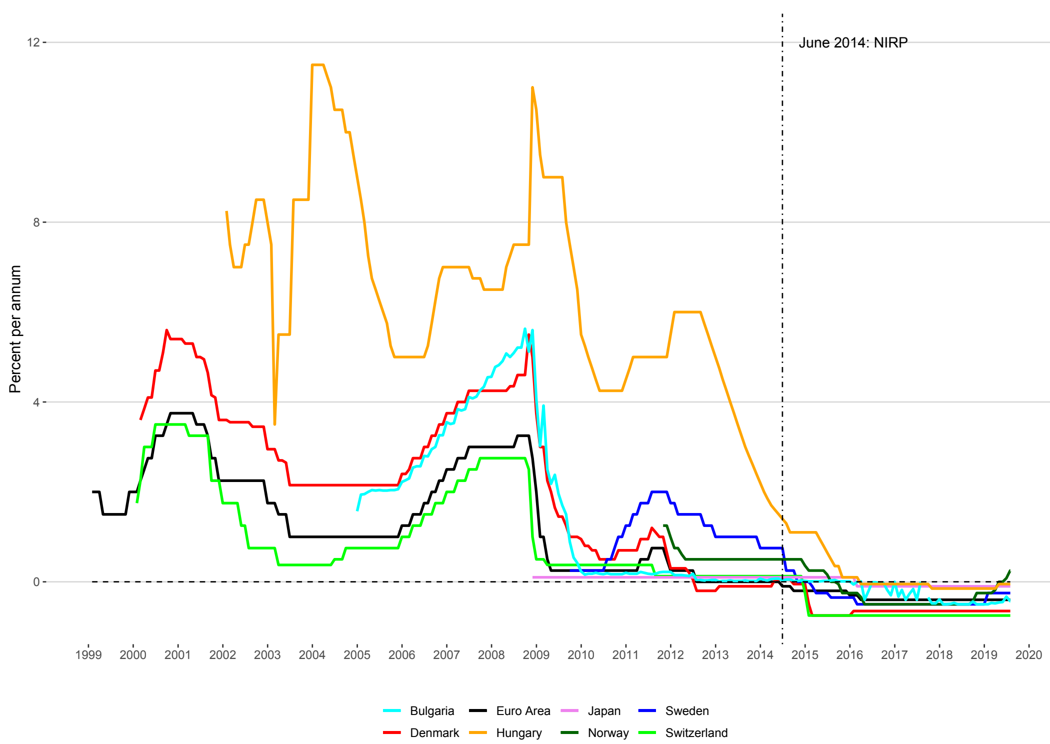

Figure 2: **Inflation expectations**

The plot shows monthly time series for 12-month inflation expectations for the period from February 2002 to December 2017 for Bulgaria (in cyan), Denmark (in red), the Euro Area (in black), Hungary (in orange), Japan (in violet), Norway (in dark green), Sweden (in blue), and Switzerland (in green). The data has been provided by FX4casts.

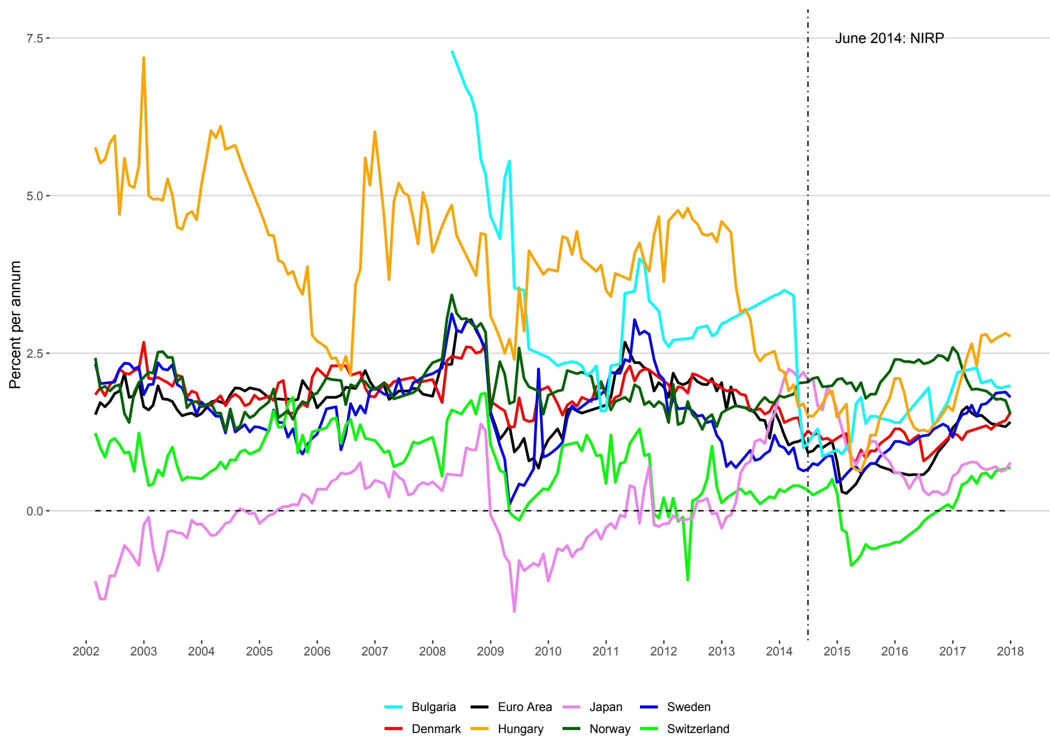

Figure 3: **Real interest rate expectations**

The plot shows monthly time series for expectations regarding the real 3-month interest rate for the period from February 2002 to December 2017 for Denmark (in red), the Euro Area (in black), Hungary (in orange), Japan (in violet), Norway (in dark green), Sweden (in blue), and Switzerland (in green). The data has been provided by FX4casts and real interest rate expectations are computed as difference between nominal interest rate and inflation expectations both observed over the 12-month horizon.

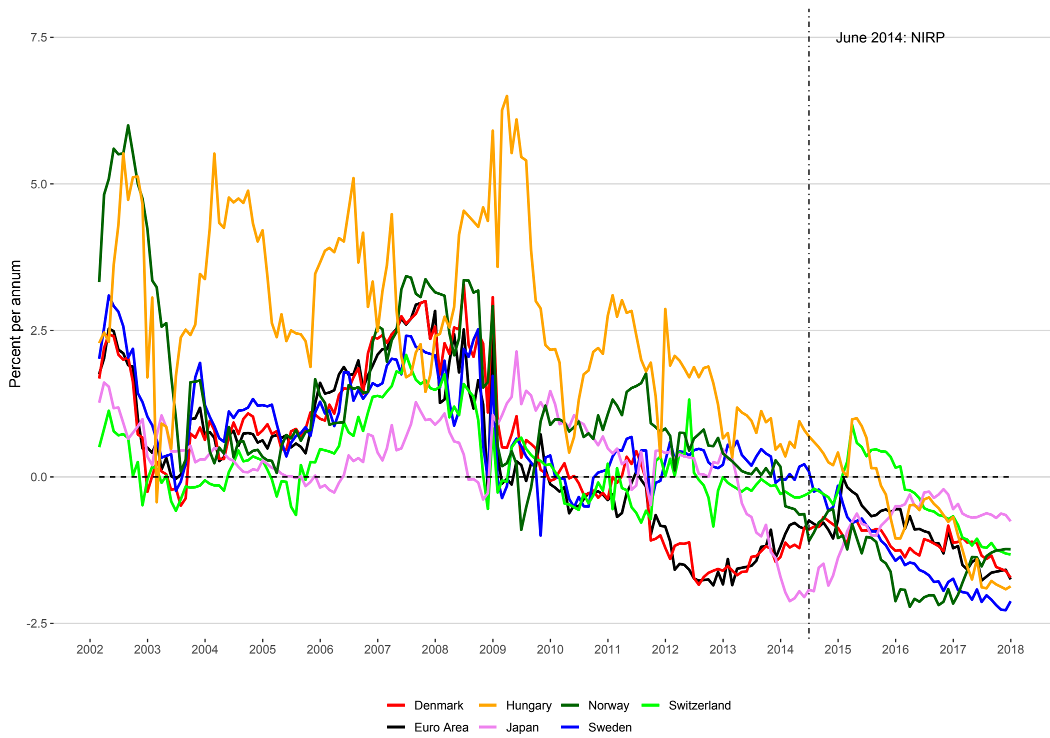

Table 1: **Expectations data sample**

Country	3m interest rate	10y gov. bond yield	Sample period	GDP growth	Inflation	Sample period
(a) NIRP adopter countries (treatment group):						
Austria			2001:10 - 2017:12	X	X	2002:02 - 2017:12
Belgium			2001:10 - 2017:12	X	X	2002:02 - 2017:12
Bulgaria			2001:10 - 2017:12	X	X	2008:04 - 2017:12
Denmark	X	X	2001:10 - 2017:12	X	X	2002:02 - 2017:12
Euro Area	X	X	2001:10 - 2017:12			2002:02 - 2017:12
Finland			2001:10 - 2017:12	X	X	2002:02 - 2017:12
France			2001:10 - 2017:12	X	X	2002:02 - 2017:12
Germany			2001:10 - 2017:12	X	X	2002:02 - 2017:12
Greece			2001:10 - 2017:12	X	X	2002:02 - 2017:12
Hungary	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Ireland			2001:10 - 2017:12	X	X	2002:02 - 2017:12
Italy			2001:10 - 2017:12	X	X	2002:02 - 2017:12
Japan	X	X	2001:10 - 2017:12	X	X	2002:02 - 2017:12
Netherlands			2001:10 - 2017:12	X	X	2002:02 - 2017:12
Norway	X	X	2001:10 - 2017:12*	X	X	2002:02 - 2017:12
Portugal			2001:10 - 2017:12	X	X	2002:02 - 2017:12
Spain			2001:10 - 2017:12	X	X	2002:02 - 2017:12
Sweden	X	X	2001:10 - 2017:12	X	X	2002:02 - 2017:12
Switzerland	X	X	2001:10 - 2017:12	X	X	2002:02 - 2017:12
(b) NIRP non-adopter countries (control group):						
Australia	X	X	2001:10 - 2017:12	X	X	2002:02 - 2017:12
Brazil	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Canada	X	X	2001:10 - 2017:12	X	X	2002:02 - 2017:12
Chile	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
China	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Colombia	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Czech Republic	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
India	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Indonesia	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Israel	X		2009:05 - 2017:12	X	X	2009:06 - 2017:12
Korea	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Malaysia	X		2008:12 - 2017:12	X	X	2002:02 - 2017:12
Mexico	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
New Zealand	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Peru			2001:10 - 2017:12	X	X	2008:04 - 2017:12
Philippines	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Poland	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Romania			2001:10 - 2017:12	X	X	2008:04 - 2017:12
Russia	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Singapore	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
South Africa	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Taiwan	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Thailand	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
Turkey	X		2001:10 - 2017:12	X	X	2002:02 - 2017:12
UK	X	X	2001:10 - 2017:12	X	X	2002:02 - 2017:12
USA	X	X	2001:10 - 2017:12	X	X	2002:02 - 2017:12

Note: The table reports the countries and sample periods for our expectations panel data set and the split into treatment group (NIRP adopter countries) and control group (NIRP non-adopter countries). We consider survey-based expectations made by professionals and provided by FX4casts for four variables: 3-month money market interest rates, 10-year government bond yields, GDP growth and inflation rates. *For Norway the time series for the 10-year government bond yield starts in 2008:06.

Table 2: **Descriptive statistics**

	3-month interest rate			10-year government bond yield			GDP	Inflation
	3M	6M	12M	3M	6M	12M	12M	12M
Mean	4.5740	4.5391	4.4987	2.8303	2.9419	3.0595	2.8283	2.8524
SD	4.7200	4.5120	4.1580	1.6062	1.6501	1.6718	2.0501	2.5823
Median	3.5000	3.5800	3.7000	2.7500	2.9400	3.0500	2.6750	2.2500
Min	-0.8200	-0.8000	-0.7000	-0.5500	-0.5100	-0.4200	-5.4000	-1.6000
Max	55.0000	55.0000	48.0000	6.8500	6.7500	6.9500	10.5000	45.3333
Skewness	3.2142	2.9937	2.6075	0.1153	0.0827	0.0686	0.1631	5.4032
Kurtosis	20.6866	18.8394	15.3949	-0.8502	-0.9031	-0.9265	1.2164	60.1553
JB**-stat**	114820.6857	95617.1472	64647.3552	60.1653	65.3326	68.0335	533.7032	1256066.0835
p**-value**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Countries	31	31	31	10	10	10	44	44
N	5868	5868	5868	1870	1869	1870	8063	8066

Note: The table reports descriptive statistics for survey-based expectations data measured in percent per annum and pooled across countries for the sample period from October 2001 to December 2017. Expectations are provided for 3-month money market interest rates (over a 3-, 6- and 12-months horizon), for 10-year government bond yields (over a 3-, 6- and 12-months horizon), for GDP growth (over a 12-months horizon), and for the inflation rate (over a 12-months horizon). SD denotes standard deviation, Kurtosis gives excess Kurtosis compared to the Gaussian, JB-stat represents the Jarque-Bera statistic testing the null of Gaussianity and the row below gives its corresponding p-value. N stands for the number of observations (number of cross-section units times the number of time periods).

Table 3: **NIRP effect on interest rate expectations**

	3-month interest rate			10-year government bond yield		
	3M	**6M**	**12M**	**3M**	**6M**	**12M**
γ	-0.5566	-0.6128	-0.7075	-0.0484	-0.2070	-0.2511
(se)	(0.1650)	(0.1601)	(0.1520)	(0.0896)	(0.0922)	(0.0942)
[p-value]	[0.0007]	[0.0001]	[0.0000]	[0.5889]	[0.0249]	[0.0078]
β_0	5.7748	5.7129	5.6220	4.1604	4.2397	4.3647
(se)	(0.0892)	(0.0844)	(0.0763)	(0.0501)	(0.0518)	(0.0523)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
β_1	-1.9766	-1.9148	-1.8167	-2.0597	-2.0057	-1.9722
(se)	(0.1402)	(0.1359)	(0.1286)	(0.0682)	(0.0696)	(0.0710)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
β_2	-3.1092	-3.0409	-2.8990	-1.4580	-1.3864	-1.4017
(se)	(0.1188)	(0.1139)	(0.1058)	(0.0658)	(0.0692)	(0.0704)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
N	5868	5868	5868	1870	1869	1870
Adj. R^2	0.1177	0.1241	0.1356	0.5116	0.4874	0.4794
Treatment group	7	7	7	6	6	6
Control group	24	24	24	4	4	4

Note: The table reports coefficient estimates, robust standard errors (se) with respect to heteroskedasticity and serial correlation according to Arellano (1987) and p-values for the difference-in-differences (DiD) regression provided in Eq. (2) for 3-month money market interest rates expectations (over a 3-, 6- and 12-months horizon) and for 10-year government bond yields expectations (over a 3-, 6- and 12-months horizon), respectively. N stands for the number of observations (number of cross-section units times the number of time periods) and Adj. R^2 provides the adjusted coefficient of determination. γ gives the NIRP effect.

Table 4: **NIRP effect on GDP growth and inflation expectations**

	GDP growth				Inflation			
	June 2014		**March 2016**		**June 2014**		**March 2016**	
	Full	**\HU+NO**	**Full**	**\HU+NO**	**Full**	**\HU+NO**	**Full**	**\HU+NO**
γ	1.0450	1.0330	1.1399	1.1300	0.1730	0.2206	0.3958	0.4249
(se)	(0.0749)	(0.0742)	(0.0930)	(0.0913)	(0.0884)	(0.0834)	(0.1031)	(0.0982)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0506]	[0.0081]	[0.0001]	[0.0000]
β_0	3.9445	3.8142	3.8548	3.7314	3.9066	3.8401	3.7847	3.7161
(se)	(0.0323)	(0.0313)	(0.0299)	(0.0289)	(0.0535)	(0.0499)	(0.0483)	(0.0452)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
β_1	-0.7956	-0.7373	-0.8188	-0.7580	-0.9660	-0.9711	-0.8859	-0.8746
(se)	(0.0614)	(0.0584)	(0.0784)	(0.0742)	(0.0813)	(0.0761)	(0.0923)	(0.0864)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
β_2	-2.4683	-2.4363	-2.3591	-2.3292	-2.0242	-2.1063	-2.0270	-2.1024
(se)	(0.0446)	(0.0452)	(0.0406)	(0.0410)	(0.0576)	(0.0537)	(0.0523)	(0.0489)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
N	8063	8063	8063	8063	8066	8066	8066	8066
Adj. R^2	0.3023	0.2826	0.2963	0.2770	0.1640	0.1682	0.1511	0.1554
Treatment group	18	16	18	16	18	16	18	16
Control group	26	28	26	28	26	28	26	28

Note: The table reports coefficient estimates, robust standard errors (se) with respect to heteroskedasticity and serial correlation according to Arellano (1987) and p-values for the difference-in-differences (DiD) regression provided in Eq. (2) for GDP growth expectations and inflation expectations, respectively. In both cases we also exclude Hungary (HU) and Norway (NO) from the treatment group as a robustness check since these countries solely apply negative deposit rates but their key policy rates are still positive. In both cases we run the entire analysis with two different starting dates of the NIRP: June 2014 (date at which the first central bank – the ECB – adopted this policy) and March 2016 (date since all eight central banks apply this policy). N stands for the number of observations (number of cross-section units times the number of time periods) and Adj. R^2 provides the adjusted coefficient of determination. γ gives the NIRP effect.

Table 5: **NIRP effect on real interest rate expectations**

	3-month interest rate				**10-year government bond yield**			
	June 2014		**March 2016**		**June 2014**		**March 2016**	
	Full	**\HU+NO**	**Full**	**\HU+NO**	**Full**	**\NO**	**Full**	**\NO**
γ	-1.0762	-0.4177	-1.1763	-0.5062	-0.3410	-0.2298	-0.1828	-0.2140
(se)	(0.0905)	(0.0862)	(0.1034)	(0.1023)	(0.0908)	(0.0905)	(0.0978)	(0.0947)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0002]	[0.0112]	[0.0616]	[0.0240]
β_0	1.6026	1.6418	1.5127	1.5330	2.1362	2.0540	1.9878	1.8684
(se)	(0.0414)	(0.0389)	(0.0377)	(0.0355)	(0.0516)	(0.0480)	(0.0483)	(0.0458)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
β_1	-0.8036	-0.9807	-0.8197	-1.0044	-1.5852	-1.6965	-1.8099	-1.8329
(se)	(0.0681)	(0.0652)	(0.0826)	(0.0805)	(0.0756)	(0.0724)	(0.0843)	(0.0800)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
β_2	-0.6609	-1.1598	-0.7644	-1.1918	-0.5020	-0.3950	-0.5723	-0.4073
(se)	(0.0608)	(0.0545)	(0.0566)	(0.0509)	(0.0631)	(0.0617)	(0.0608)	(0.0602)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
N	5751	5751	5751	5751	1834	1834	1834	1834
Adj. R^2	0.0791	0.0874	0.0614	0.0720	0.3826	0.3629	0.2740	0.2519
Treatment group	7	5	7	5	6	5	6	5
Control group	24	26	24	26	4	5	4	5

Note: The table reports coefficient estimates, robust standard errors (se) with respect to heteroskedasticity and serial correlation according to Arellano (1987) and p-values for the difference-in-differences (DiD) regression provided in Eq. (2) for expectations regarding real 3-month interest rates and real 10-year government bond yields, respectively. In both cases we also exclude Hungary (HU) and Norway (NO) from the treatment group as a robustness check since these countries solely apply negative deposit rates but their key policy rates are still positive. In the sample for real 10-year government bond yield expectations Hungary was not included due to data unavailability. In both cases we run the entire analysis with two different starting dates of the NIRP: June 2014 (date at which the first central bank – the ECB – adopted this policy) and March 2016 (date since all eight central banks apply this policy). N stands for the number of observations (number of cross-section units times the number of time periods) and Adj. R^2 provides the adjusted coefficient of determination. γ gives the NIRP effect.

Appendix

Table A.1: **NIRP effect on GDP growth and inflation expectations**

	GDP growth				**Inflation**			
	June 2014		**March 2016**		**June 2014**		**March 2016**	
	Full	**\HU+NO**	**Full**	**\HU+NO**	**Full**	**\HU+NO**	**Full**	**\HU+NO**
γ	0.8801	0.8421	0.8984	0.8703	0.5761	0.5739	0.6555	0.6404
(se)	(0.0910)	(0.0853)	(0.1040)	(0.0979)	(0.1403)	(0.1229)	(0.1566)	(0.1384)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
β_0	3.4856	3.3062	3.4049	3.2366	3.8274	3.7134	3.6388	3.5304
(se)	(0.0517)	(0.0467)	(0.0468)	(0.0422)	(0.0979)	(0.0848)	(0.0876)	(0.0761)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
β_1	-0.6307	-0.5464	-0.5774	-0.4984	-1.3691	-1.3245	-1.1456	-1.0901
(se)	(0.0803)	(0.0720)	(0.0912)	(0.0822)	(0.1359)	(0.1182)	(0.1497)	(0.1303)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
β_2	-2.0095	-1.9283	-1.9091	-1.8345	-1.9450	-1.9796	-1.8812	-1.9168
(se)	(0.0601)	(0.0570)	(0.0542)	(0.0512)	(0.1002)	(0.0871)	(0.0899)	(0.0783)
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
N	5685	5685	5685	5685	5685	5685	5685	5685
Adj. R^2	0.2216	0.2110	0.2175	0.2073	0.1343	0.1424	0.1161	0.1243
Treatment group	18	16	18	16	18	16	18	16
Control group	13	15	13	15	13	15	13	15

Note: This table provides the results of a robustness check excluding emerging economies from Asia, Africa and Latin America from the control group compared to Table 4. More precisely, we have excluded Brazil, Chile, Colombia, India, Indonesia, Malaysia, Mexico, Peru, Philippines, Singapore, South Africa, Taiwan and Thailand. The table reports coefficient estimates, robust standard errors (se) with respect to heteroskedasticity and serial correlation according to Arellano (1987) and p-values for the difference-in-differences (DiD) regression provided in Eq. (2) for GDP growth expectations and inflation expectations, respectively. In both cases we also exclude Hungary (HU) and Norway (NO) from the treatment group as a robustness check since these countries solely apply negative deposit rates but their key policy rates are still positive. In both cases we run the entire analysis with two different starting dates of the NIRP: June 2014 (date at which the first central bank – the ECB – adopted this policy) and March 2016 (date since all eight central banks apply this policy). N stands for the number of observations (number of cross-section units times the number of time periods) and Adj. R^2 provides the adjusted coefficient of determination. γ gives the NIRP effect.