

The channels of banks' response to negative interest rates*

Whelsy Boungou[†] and Paul Hubert[‡]

October 2021, WP #837

ABSTRACT

Faced with a potential zero lower bound on deposit interest rates, how do banks pass on the fall in net interest income due to negative interest rates? This paper aims to investigate the different channels of banks' responses to negative interest rates using a detailed breakdown of the profit and loss account of 3637 banks in 59 countries from 2011 to 2018. We find that the decrease in interest income due to negative interest rates is mitigated by an increase in non-interest income, but only partially. We find that banks respond to that shock by reducing the interest paid on non-customer deposit liabilities and their personnel expenses. We also show that banks' responses are not instantaneous and that they adjust their response as negative interest rates persist over time such that how long negative interest rates are implemented matters. Finally, our results suggest that large banks with higher deposits and higher leverage ratios are the most affected by the implementation of negative interest rates.

Keywords: Bank profitability, Interest flows, Non-interest flows, Deposits, Leverage.

JEL Classification: C2, E5, G2.

* We thank two anonymous referees as well as Christophe Blot and Jérôme Creel for helpful comments and discussions. Any remaining errors are ours. The views expressed in this paper do not necessarily reflect those of Banque de France.

[†] PSB Paris School of Business, boungouwhelsy@yahoo.com.

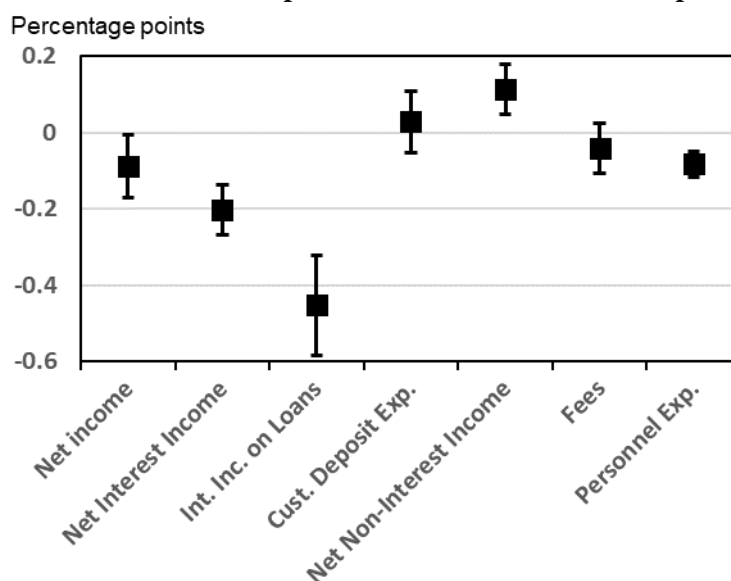
[‡] Banque de France & Sciences Po - OFCE, paul.hubert@banque-france.fr.

NON-TECHNICAL SUMMARY

Since 2012, several central banks in Europe and the Bank of Japan have introduced negative policy interest rates. The effectiveness of such policy depends crucially on the pass-through to the lending and deposit rates. However, it seems that the pass-through of negative interest rates to deposit rates is not perfect because of their downward rigidity. At least, two reasons can explain the reluctance of banks to introduce a negative deposit rate: (i) some legal constraints and (ii) the fear of a “cash rush”. Therefore, negative interest rate policies (NIRP) could negatively affect banks’ profitability by compressing net interest margins due to the lower bound for deposit rates.

In order to preserve their profitability and offset the fall in net interest margins, commercial banks face different options: (i) foster credit supply to mitigate the reduction in margins with an increase in volumes, (ii) redirect their income from interest products towards non-interest sources (such as fees and commissions), (iii) reduce their operating costs (such as salaries and employee benefits), by focusing more on digital banking for instance, or (iv) reduce the interest rate paid on non-customer deposit liabilities.

Effect of the NIRP adoption on banks revenues and expenses



Note: This figure shows the estimated effect of the NIRP adoption on net income, net interest income (then decomposed between the interest income on loans and customer deposit expenses) and net non-interest income (then decomposed between fees and personnel expenses). These variables are all normalized by total assets.

The analysis draws on yearly bank-level data for 3637 banks in 59 countries between 2011 and 2018. Our identification relies on the comparison between banks in the 25 countries that have adopted negative interest rates and those in the remaining countries that have not. We find that negative interest rates reduce banks’ net interest income by around 0.2 percentage points. Our results confirm evidence of the existence of a zero-lower bound on deposit interest rates: banks located in countries that have adopted NIRP are reluctant to charge a negative interest rate on customer deposits. We also find that banks increase their net non-interest income to offset the effects of negative interest rates on their net interest income. Our results indicate that the increase in banks’ net non-interest

income, in response to NIRP, is related to a reduction in non-interest expenses rather than to an increase in fees and commissions. We find a 0.1 percentage point reduction in personnel expenses following the NIRP implementation.

Les canaux de réponse des banques aux taux d'intérêts négatifs

RÉSUMÉ

Face à une potentielle borne inférieure à zéro des taux d'intérêt des dépôts, comment les banques répercutent-elles la baisse des revenus nets d'intérêts due aux taux d'intérêt négatifs ? Cet article vise à étudier les différents canaux de réponse des banques aux taux d'intérêt négatifs en utilisant une ventilation détaillée du compte de résultats de 3637 banques dans 59 pays de 2011 à 2018. Nous constatons que la diminution des revenus d'intérêts due aux taux d'intérêt négatifs est atténuée par une augmentation des revenus autres que d'intérêts, mais seulement partiellement. Nous constatons que les banques réagissent à ce choc en réduisant les intérêts payés sur les dépôts des entreprises et leurs dépenses de personnel. Nous montrons également que la réponse des banques n'est pas instantanée et qu'elles ajustent leur réponse au fur et à mesure que les taux d'intérêt négatifs persistent dans le temps, de sorte que la durée de mise en œuvre des taux d'intérêt négatifs compte. Enfin, nos résultats suggèrent que les grandes banques avec une part de dépôts plus élevée et des ratios de levier plus élevés sont les plus affectées par la mise en place de taux d'intérêt négatifs.

Mots-clés: Rentabilité bancaire, Marge d'intérêts, Marge hors intérêts, Dépôts, Levier.

Les Documents de travail reflètent les idées personnelles de leurs auteurs et n'expriment pas nécessairement la position de la Banque de France. Ils sont disponibles sur publications.banque-france.fr

1. Introduction

Since 2012, several central banks in Europe and the Bank of Japan have introduced negative policy interest rates. This policy aims to encourage commercial banks to increase their credit supply in order to support economic activity. The effectiveness of such policy depends crucially on the pass-through to the lending and deposit rates (Brunnermeier and Koby, 2018). However, it seems that the pass-through of negative interest rates to deposit rates is not perfect because of their downward rigidity (Hannoun, 2015, and Jobst and Lin, 2016). At least, two reasons can explain the reluctance of banks to introduce a negative deposit rate: (i) some legal constraints and (ii) the fear of a "cash rush" (Scheiber et al., 2016). Therefore, negative interest rate policies (NIRP) could negatively affect banks' profitability by compressing net interest margins due to the so-far observed zero lower bound for deposit rates. Some recent studies show that negative interest rates lead to a compression of net interest margins, although they have little or no effect on banks' overall profitability (Lopez et al., 2020, and Molyneux et al., 2019).

The question of how commercial banks cushion and offset the fall in net interest margins due to negative interest rates then arises. In order to preserve their profitability, commercial banks face different options: (i) foster credit supply to mitigate the reduction in margins with an increase in volumes, (ii) redirect their income from interest products towards non-interest sources (such as fees and commissions), (iii) reduce their operating costs (such as salaries and employee benefits), by focusing more on digital banking for instance, or (iv) reduce the interest rate paid on non-customer deposit liabilities. Against this backdrop, the main objectives of this paper are to: a) investigate empirically the channels through which banks respond to negative interest rates; b) assess how banks adjust their responses as negative rates persist over time; c) explore which bank characteristics influence banks' responses to negative rates. The analysis draws on yearly bank-level data for 3637 banks in 59 countries between 2011 and 2018. Our identification relies on the comparison between banks in the 25 countries that have adopted negative interest rates and those in the remaining countries that have not.

We complement the analysis of how banks respond to NIRP (from the perspective of their profit and loss accounts) with an investigation of which transmission channels from the central bank to commercial banks matters. The literature suggests that the effects of NIRP on banks would arise through three broad channels: (i) the improving economic outlook reducing loan defaults; (ii) a term structure effect implying securities valuation changes and additional margin compression; and (iii) the negative remuneration of central bank reserves. We investigate these three channels using our framework.

To explore these questions, we use a difference-in-differences (DiD) approach based on bank-level unconsolidated data (i.e. at the entity level) to compare the behavior of banks at a disaggregated level of their profit and loss account, before and after the introduction of NIRP. This methodology also enables us to examine whether banks' responses to NIRP depend on their characteristics. The key assumption of the DiD approach is that the control and treatment groups are comparable prior to the treatment. We therefore use the characteristics of the treated group to define the control group. As complementary analyses, we use the cross-sectional variation in measures of bank exposure to NIRP to identify the effects of this policy and the propensity-score matching approach to build a control group in order to cross-validate our results.

This paper differs from the existing literature in two respects. First, the granularity of our dataset enables us to precisely identify the channels of banks' response to the implementation of NIRP at a fine disaggregated level. We thus explore the dynamic of banks' response and assess whether keeping this policy for a prolonged period of time might have negative consequences for banks. It also assesses whether the channels of NIRP transmission to banks' balance sheet differ according to banks' characteristics (such as deposit reliance, size and leverage). Second, we use a large sample of banks located in several countries and covering a longer period of time. The inference in the empirical analysis relies on the time and cross-sectional variation of detailed balance sheet and profit and loss accounts of 3637 banks operating in 59 low-, middle-, and high-income countries during the period 2011-2018, consisting of around 20.000 observations. Our data cover the implementation of NIRP by all central banks in Europe (within and outside the euro area) and by the Bank of Japan.

The main empirical challenge of this paper is to identify a control group (banks unaffected by NIRP) that satisfies the common trend assumption with the treatment group (banks affected by NIRP) before the introduction of negative interest rates. To do so, we construct a control group by restricting the pool of banks unaffected by NIRP that match those treated using bank-specific characteristics (such as size and holdings of liquid assets) and the market concentration on which they operate (measured with the Herfindahl-Hirschman index, thereafter HHI). The control group closer to the treatment group is composed of banks with a size above the 80th percentile, with a share of liquid assets above the 10th percentile, and whose HHI is above the 40th percentile. For robustness, we construct alternative control groups based on various combinations of these thresholds allowing for different coverages of banks and countries. In addition, tests using the cross-sectional variation on bank exposure to NIRP are performed on the treated group only as a way to provide results independent of the construction of a control group.

The results of our analysis indicate that negative interest rates reduce banks' net interest income by around 9%. Our results confirm evidence of the existence of a zero-lower bound on deposit interest rates: banks located in countries that have adopted NIRP are reluctant to charge a negative interest rate on customer deposits. We find that the reduction in gross interest expenses does not come from the interest rate on customer deposits (possibly because of its downward rigidity, see Levieuge and Sahuc, 2021) but rather from the reduction in other interest expenses (the interest paid on non-customer deposit liabilities). We also find that banks increase their net non-interest income to offset the effects of negative interest rates on their net interest income. Our results indicate that the increase in banks' net non-interest income, in response to NIRP, is related to a reduction in non-interest expenses rather than to an increase in fees and commissions. We find a 6% reduction in personnel expenses following the NIRP implementation. Thus, NIRP could be seen as a trigger for accelerating a restructuring process with a view of lowering banks' costs. Overall, our results suggest that negative interest rates reduce banks' net interest income, but that banks' responses (through a reduction in interest paid on non-customer deposits and in their personnel expenses), over our sample period, are not sufficient to fully offset the reduction in net interest income.

While we show that the increase in net non-interest income mitigates in part the decrease in net interest income due to the NIRP implementation, an important question relates to the dynamic of these response and more precisely whether keeping this policy for a prolonged period of time might have negative consequences for banks. We aim to capture

empirically the effects of the so-called “negative-for-long” and how banks respond across time to NIRP. We find that how long NIRP is implemented matters. Indeed, we find that the magnitude of banks' responses increases as negative interest rates persist. We also highlight that at the end of our sample, banks start reducing customer deposit expenses and increasing net non-interest income to preserve their profits.

In addition, the investigation of the three broad transmission channels suggests that general equilibrium effects – through lower probability of loan defaults and less non-performing loans – and banks' exposure to negative remuneration of central bank reserves might be the more prominent one in affecting banks. This analysis thus suggests that the effects of NIRP on banks could be heterogenous and would depend on the bank business model, its structure and characteristics.

Finally, we therefore analyze whether these responses differ according to the characteristics of banks.¹ We find that banks' responses to negative interest rates depend on their size, share of deposits and leverage. Banks most affected by the introduction of negative interest rates are large banks with higher deposits and higher leverage ratios. We also find that these large banks are associated with larger reductions in personnel expenses after the implementation of NIRP. However, we find that smaller banks with lower deposit and leverage ratios appear to have more room to contain the effects of negative interest rates.

Overall, we do not find evidence that banks, whatever their characteristics, use fees to cushion the compression of their net interest margins and limit the increase in customer deposit expenses. But large banks, with higher deposits and higher leverage ratios, are more constrained because they are more dependent on deposits and therefore potentially more reluctant to charge negative interest rates on deposits. At the opposite, smaller banks that are less dependent on deposits are less constrained by the implementation of NIRP. The main message of this paper is that banks are able to adapt to NIRP by shifting revenue sources and compressing costs, and that large banks with higher deposits and higher leverage ratios are more constrained, especially in the early stages of negative interest rate implementation.

Our findings are robust in various respects. First, we build alternative control groups including one using propensity score matching techniques. Second, we use the nominal short-term policy interest rate as our variable of interest replacing the NIRP dummy. Using a continuous variable enables to circumvent the issue that the identification stems from a *time* dummy which could be correlated to other events happening at the same date. This also enables us to use the variability of the policy rate below zero (the deposit facility rate in the euro area, for instance) to obtain a more precise inference of the effect of negative interest rates. Third, we include a proxy for central bank balance sheet policies in our specification to control for the implementation of other unconventional monetary policies that happen at around the same time. Fourth, our dataset has an annual frequency but several central banks introduced the negative interest rate policy in the middle or end of a year - the European Central Bank (ECB), for instance, reduced its deposit facility rate from 0 to -0.10% in June 2014. We therefore redefine the NIRP dummy

¹ See the literature on the determinants of bank performance (see Molyneux and Thornton, 1992, Athanasoglou et al., 2008, Dietrich and Wanzenried, 2014).

such that it takes the value of one the year after the NIRP implementation – 2015 in the case of the ECB. These sensitivity analyses all confirm the baseline results.

This work relates to different contributions in the literature. First, our study extends the results of previous studies on the impact of negative interest rates on bank performance.² Lopez et al. (2020), using data from 5273 banks located in the European Union and Japan, show that negative interest rates have no effect on net income: they argue that banks compensate for the contraction in net interest income by increasing their net non-interest income. Molyneux et al. (2019) also document, using data on 7359 banks from 33 OECD countries, that banks respond by increasing their non-interest income (such as fees and commissions). In this paper, we explore the channels of NIRP transmission to banks and how they respond to this policy at a disaggregated level of their profit and loss account. We also introduce an identification approach using bank exposure to NIRP to cross-validate our results. Our analysis complements these papers in at least three respects: (i) we confirm evidence of banks' reluctance to charge negative interest rates on customer deposits; (ii) we do not find evidence that banks increase their fees in response to NIRP but instead find that banks' responses to negative interest rates came through a reduction in interest paid on non-customer deposits and non-interest expenses (such as personnel expenses); (iii) we show that bank responses to negative interest rates are not immediate and that banks adjust their responses as negative interest rates persist over time.

This paper also relates to the literature that examines the lending channel of monetary policy under negative interest rates. Arce et al. (2018), Heider et al. (2019), Molyneux et al. (2020) provide evidence that banks located in countries that have introduced negative interest rates have no incentive to increase the supply of credit. However, Boungou (2021), Demiralp et al. (2021) and Grandi and Guille (2020) find that banks highly dependent on deposits increase their lending activities under NIRP.³

2. The empirical strategy

2.1. Breakdown of interest and non-interest flows

The analysis of banks' responses to negative interest rates requires the most disaggregated profit and loss account data possible. For this purpose, we use the Fitch Solutions database. This commercial database is the most comprehensive one providing balance sheet and income statement information for thousands of banks around the world. We can then disaggregate banks' revenues and expenses into interest and non-interest flows.

In the interest flows category, we decompose net interest income between interest income and interest expenses. On the one hand, gross interest income is broken down into interest income on loans (related to loans, advances and leasing) and other interest income which refers to interest income generated from all non-loans assets (such as debt securities, trading book items, short-term funds and investment securities). On the other hand, gross interest expenses are broken down into customer deposits expenses (the interest paid on

² The relationship between low (but positive) interest rates and bank performance has been widely analyzed in the literature (see, among others, Genay and Podjasek, 2014, Borio et al., 2017, Claessens et al., 2018). Overall, this literature argues that low interest rates reduce bank profitability.

³ Bubeck et al. (2020) find that deposit-dependent banks hold riskier securities after the NIRP implementation.

customer deposits) and other interest expenses from all non-customer deposit liabilities (such as repurchase agreements, commercial paper, etc.).

We also decompose the non-interest flows between non-interest income and non-interest expenses. On the one hand, gross non-interest income refers to fees and commissions (not related to loans or insurance) and to other non-interest income, such as net gains (losses) on trading and derivatives, net gains (losses) on other securities, and net insurance income. On the other hand, gross non-interest expenses are broken down into personnel expenses (such as salaries and employee benefits) and other non-interest expenses (such as information technology costs, telecommunication services, amortization of intangibles, marketing, and other operating expenses of an administrative nature).

One advantage for our research question is that we do not limit our analysis to banks' profit margins (e.g., Bounie, 2019, Molyneux et al., 2019) and are able to consider total flows, which reveal information on both margins and quantities. This allows us to capture the overall banks' responses to negative interest rates on both margins and quantities.

2.2. The identification of the treatment

Since 2012, the Bank of Japan and seven central banks in Europe have moved their deposit (or reserve) interest rate in negative territory. In July 2012, the Danmarks Nationalbank was the first central bank to implement this policy by bringing its interest rate on certificates of deposit below zero. Although this rate has returned to positive territory for a few months in 2014 and stands at -0.60% in June 2021. Several other central banks have also implemented negative interest rates. The European Central Bank reduced its deposit facility rate below zero, to -0.10%, in June 2014 and it is at -0.50% in June 2021. In July 2014, the Sveriges Riksbank reduced its deposit rate to -0.50% and it stands at -0.10% in June 2021. The Swiss National Bank reduced its interest rate on sight deposits to below zero in January 2015, which is at -0.75% in June 2021. The Norges Bank reduced its reserve rate in September 2015 to -0.25%, which is at -1% in June 2021. The Bulgarian National Bank and the Bank of Japan implemented a negative deposit rate in January 2016, which stands at -0.68% and -0.10% respectively in 2020. The latest central bank to implement negative interest rates is the Magyar Nemzeti Bank, with an overnight deposit rate at -0.05% since March 2016. In our specifications, the NIRP dummy takes the value one from the year of introduction of negative interest rates. For instance, for Hungary, NIRP is equal to one from 2016 and zero before. Moreover, we assess the impact of when the policy as implemented within a year by setting the NIRP dummy equal to one the year after the policy was adopted.

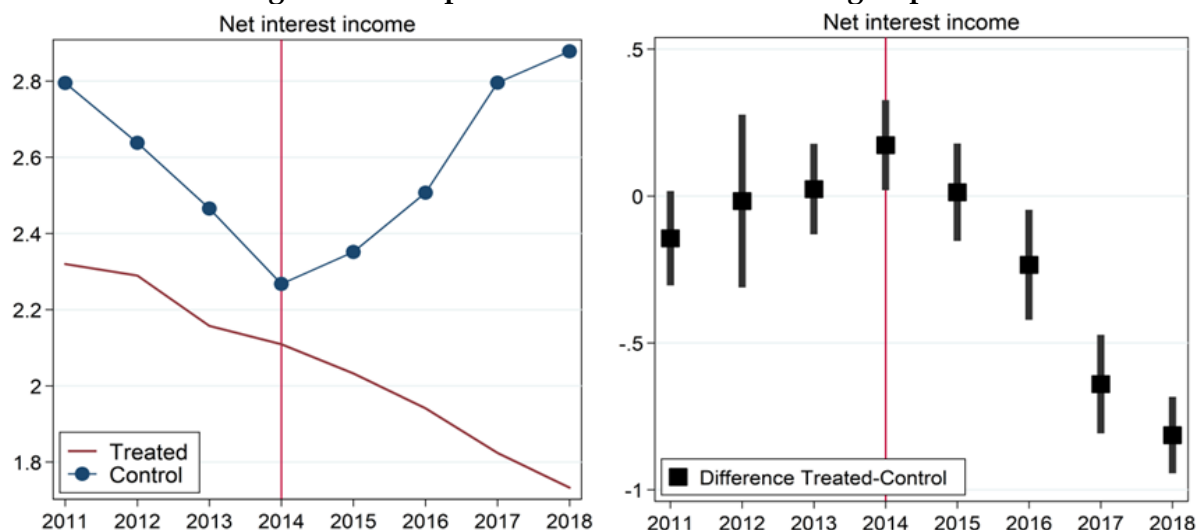
2.3. The identification of the control group

To analyze banks' responses to the implementation of negative interest rates, we use the differences-in-differences approach. This method is typically used to assess the effects of a treatment (i.e. a policy implementation) by comparing changes in an outcome variable between a group affected by the treatment and a group not affected by the treatment before and after the policy implementation. This approach was first introduced by Rubin (1974) and assumes that the outcome variables of interest in the treatment and control groups have a common trend prior to the introduction of the treatment. In this paper, the identification comes from comparing the profit and loss account variables of banks in countries that have adopted NIRP (the treated group) to a group of banks unaffected by

this policy (the control group). Given the large heterogeneity of banks, the main challenge of this paper is to determine a control group that satisfies the common trend assumption with the treatment group over the pre-treatment period.

We extract a dataset of 14894 banks located in 129 countries over the period 2011-2018 from the Fitch Solutions database. By using this type of unconsolidated data, we classify banks at the entity level, according to where they operate. We split this dataset into two groups according to the NIRP, treated and control groups. Our treated group consists of 7964 banks operating in seven countries (Bulgaria, Denmark, Hungary, Japan, Norway, Sweden and Switzerland) and the Economic and Monetary Union (EMU) excluding Estonia. The initial control group consists of 6930 banks located in 104 low-, middle-, and high-income countries that have not adopted negative interest rates. With such a heterogeneous database, it would be misleading to claim at this stage that our two groups evolved in a similar way before the introduction of negative interest rates.

Figure 1 - Comparison of treated and control groups



Note: The left panel plots the evolution of the average net interest income of the treated group and our control group. The right panel plots the centered difference between the two averages. For ease of reading, we consider 2014 as the year of the NIRP implementation.⁴

We therefore aim to define a control group that is as close as possible to our treated group before 2014. First, we clean our database by removing banks with missing observations and trim the sample at the 1st and 99th percentiles to ensure that outliers do not bias our comparisons. Second, we use bank-specific characteristics and the market concentration measure of the treated group as a guide to define the control group. Ultimately, the closest control group to the treated group is composed of banks whose size is above the 80th percentile of the bank size distribution), whose share of liquid assets is above the 10th percentile and whose HHI is above the 40th percentile. Table B in the Appendix summarizes the key descriptive statistics of the two groups over the pre-NIRP period. Figure 1 plots the evolution across our sample of the average net interest income of the treated group and our control group (on the left panel) and the centered difference

⁴ One common assumption in the literature is to consider 2014 as the year of implementation of negative interest rates (see Molyneux et al., 2019, 2020). This choice is motivated by the fact that most countries have introduced negative interest rates from 2014 onwards.

between the two averages (on the right panel). Both groups share a common trend before the NIRP implementation. The treated group consists of 3392 banks while our control group consists of 245 banks located in 34 low-, middle-, and high-income countries. The final database consists of an unbalanced panel dataset of 3637 banks operating in 59 low-, middle-, and high-income countries from 2011 to 2018, consisting of 19935 observations.⁵

We construct alternative control groups to assess the robustness of our findings to the baseline control group mentioned above. First, since most of the treated group comes from the euro area (3139 banks), we exclude low-income countries from the control group. Second, since the number of banks in the baseline control group is relatively small (245) compared to the treated group (3392), we relax the thresholds considered to identify the control group (size, liquidity and market structure) and define two other control groups with 587 and 784 banks respectively. Table B in the Appendix shows the key statistics for these groups (that also exclude low income countries). Finally, we also propose tests that abstract from the need for a control group using measures of bank exposure to NIRP in treated countries only.

2.4. The empirical model

To investigate the effects of NIRP on banks' financial statements, we use the difference-in-differences (DiD) framework, which is commonly used in the literature on negative interest rates.⁶ The DiD approach allows us to analyze the effect of the implementation of negative interest rates on a wide range of outcome variables and therefore to identify banks' responses to this policy. To this end, the model is specified as follows:

$$y_{i,j,t} = c + \alpha_1(Treated_{i,j} * NIRP_{j,t}) + \alpha_2 X_{i,j,t} + \theta_t + \lambda_i + \epsilon_{i,j,t} \quad (1)$$

where $y_{i,j,t}$ refers to a given financial statement variable of bank i in country j for the year t .⁷ $Treated_{i,t}$ is a dummy variable equal to 1 if a bank i is located in country j that has adopted NIRP, and 0 otherwise. $NIRP_{j,t}$ is the negative interest rate dummy variable and is equal to 1 if country j has a NIRP in place at year t , and 0 otherwise. The coefficient α_1 is the DiD estimator of the average difference in $y_{i,j,t}$ between treated and control groups before and after the NIRP implementation. $X_{i,j,t}$ is a vector that includes the interacted variables individually and both bank- and country-specific controls. The selection of our control variables is consistent with previous literature on the determinants of bank profitability (e.g., Molyneux and Thornton, 1992, Athanasoglou et al., 2008, Dietrich and Wanzenried, 2014). We include four bank-specific control variables: the logarithm of total assets (size), equity to assets ratio (capitalization)⁸, liquid assets to total assets (liquidity), deposits to total assets (funding).⁹ To account for the environment in which banks operate, we use the Herfindahl-Hirschman index (HHI) as a measure of the market structure of banks and the year-over-year change in the consumer price index (inflation),

⁵ Table A in the Appendix lists the different countries in the database.

⁶ See, among others, Heider et al. (2019), Molyneux et al. (2019, 2020), Boungou (2020) and Lopez et al. (2020).

⁷ All variables related to banks' income statement and balance sheet are scaled by total assets.

⁸ The equity to assets ratio is generally used in banking literature as a proxy for bank capitalization. The inverse of this ratio is also used as a proxy for leverage.

⁹ Using the variance inflation factor (VIF), we test for potential collinearity among the control variables. The outcome suggests that they are not highly correlated (see Table C in the Appendix).

and the real GDP growth rate (GDP).¹⁰ θ_t , λ_i and $\epsilon_{i,j,t}$ are respectively time (year) fixed-effects, bank fixed-effects, and an idiosyncratic error term. We compute robust standard errors clustered at bank level to control for heteroscedasticity and dependence between observations.

To ensure a robust identification of the effect of NIRP, we use measures of bank exposure to NIRP in a complementary specification. We use either triple interaction terms between bank exposure variables (described later), the treated dummy and the NIRP dummy, or double interaction terms between bank exposure variables and the NIRP dummy over the treated sample only. We also turn to the propensity score matching approach to define the control group and use a continuous variable (the policy rate) rather than a discrete variable to circumvent the issue that the identification stems from a *time* dummy which could be correlated to other events happening at the same date.

3. What are the channels through which banks respond to NIRP?

This section presents estimates of the effects of the NIRP implementation on banks' financial statements, obtained using the difference-in-differences methodology. We first examine the aggregate effect of negative interest rates on bank profitability, and then analyze the disaggregated banks' responses to this policy. We estimate various specifications of Equation (1) with different dependent variables. For sake of parsimony, the following tables only report our coefficient of interest α_1 , denoted as *DiD*.¹¹

Table 1 presents the estimates of the effects of the implementation of negative interest rates on some aggregate measures of bank profitability. The dependent variables considered are net income, net interest income and net non-interest income. We compare our estimates (labeled BH) to those of Molyneux et al. (2019) and Lopez et al. (2020) - two papers focusing on that issue specifically. Over the period under review, we find that negative interest rates have a negative effect on banks' overall profits: net income decreases by 0.089 percentage point (pp) on average following the NIRP implementation. This reduction represents approximately a 7% decrease in net income. This overall negative effect stems from a 0.204pp decrease in net interest income (corresponding to a 9% decrease), in part mitigated by a 0.115pp increase in net non-interest income (equivalent to a 10% increase).

Molyneux et al. (2019) find similar results. Focusing on 7359 banks from 33 OECD member countries over the period 2012-2016, the authors point out that negative interest rates have a negative impact on net income (-0.031pp) and net interest income (-0.164pp) and that the effects on overall profits are mitigated by an increase in non-interest income.¹² Lopez et al. (2020), analyzing 5200 banks from 27 advanced European and Asian countries over 2011-2016, find that NIRP compresses banks' net interest income (-0.078pp) but that this compression is exactly offset by a 0.075pp increase in net non-interest income, thus explaining the absence of a significant effect on net income.

¹⁰ The macroeconomic indicators are extracted from Datastream.

¹¹ Table D in the Appendix shows the parameter estimates for all control variables in Tables 1 to 3.

¹² Molyneux et al. (2019) focus on the response of (gross) non-interest income, not the net non-interest income, so we have not included their estimate in Table 1 for comparability purposes.

Table 1 - Aggregate effects

	Net Income			Net Interest Income			Net Non-Interest Inc	
	BH	MRX19	LRS20	BH	MRX19	LRS20	BH	LRS20
DiD	-0.089*	-0.031**	0.034	-0.204***	-0.164***	-0.078**	0.115***	0.075**
	(0.05)	(0.01)	(0.03)	(0.04)	(0.02)	(0.02)	(0.04)	(0.02)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	No	Yes	Yes	No	Yes	Yes	Yes
Country FE	No	Yes	No	No	Yes	No	No	No
Controls	Yes	Yes	No	Yes	Yes	No	Yes	No
R ²	0.03	0.57	0.01	0.26	0.51	0.13	0.05	0.05
Obs.	19935	17286	30686	19935	17271	30792	19935	30241
Nb. banks	3637	4612	5079	3637	4612	5078	3637	5041
Nb. countries	59	33	27	59	33	27	59	27
Sample	2011-18	2012-16	2011-16	2011-18	2012-16	2011-16	2011-18	2011-16

Note: BH refers to our results, estimated based on Equation (1). MRX19 indicates to the results of Molyneux, Reghezza and Xie (2019) and LRS20 to those of Lopez, Rose and Spiegel (2020). For the LRS20's results, the coefficients are taken from their table 1 and the R² and number of observations from their online appendix. DiD is our Difference-in-Differences estimator. It refers to the interaction between the dummy Treated and dummy NIRP. Our controls include natural logarithm of bank total assets, equity to assets ratio, liquid assets to total assets, customers deposits to total assets, Herfindahl-Hirschman Index, inflation rate, and real GDP growth rate. Robust standard errors clustered by banks in parenthesis. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

The R² of the equations for net income, net interest income and net non-interest income is 0.03, 0.26 and 0.05 respectively (see Table 1). The dichotomy between the variance explained for net interest and net non-interest income is also visible later on sub-component regressions. We think that one natural explanation for this different fit comes from the fact that NIRP – an interest rate policy – mechanically plays a larger role on the interest part than on the non-interest part of banks' profit and loss accounts. This is consistent with Lopez et al. (2020). They obtain a stronger R² for net interest income (0.13) than for net income (0.01) and net non-interest income (0.05). Although the level of the R² is higher in Molyneux et al. (2019), the same drop in fit appears between their regression on net interest margin (Table 3) and fees and commissions (Table 7).

In the following subsections, we aim to understand the channels through which banks respond to negative interest rates to cushion such a negative shock on their net interest income. We therefore look at the decomposition of interest and non-interest flows.

3.1. The responses of interest flows

We first assess the effects of the NIRP implementation on interest flows through the decomposition between gross interest income and gross interest expenses. We further decompose each item between interest income on loans and other interest income; and interest expenses on customer deposits and other interest expenses. We estimate Equation (1) on the same sample of observations to ensure that the results are not driven by changes in the composition of the sample considered. Table 2 shows the DiD estimated parameter – α_1 – for the various dependent variables mentioned above.

Table 2 – Breakdown of interest flows

	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.758*** (0.08)	-0.453*** (0.08)	-0.305*** (0.04)
R ²	0.57	0.35	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.553*** (0.07)	0.028 (0.05)	-0.581*** (0.04)
R ²	0.55	0.11	0.54

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3637 banks located in 59 countries over the period 2011-2018, consisting of 19935 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Our findings show that as a result of NIRP, banks' gross interest income declines (-0.758pp). Indeed, gross interest income is pulled down by interest income on loans and other interest income which fell by 0.453pp and 0.305pp, respectively. The NIRP implementation most certainly reduces the cost of credit (as suggested by the theoretical literature) but it also favors the reduction of other interest income. The results about gross interest expenses show that banks located in countries that have adopted NIRP reduces their gross interest expense by 0.553pp. This reduction in gross interest expenses is entirely explained by other interest expenses (-0.581pp), not customer deposit expenses. It is noteworthy that NIRP has no significant effect on interest expenses on customer deposits as it suggests that banks are reluctant to pass through the negative interest rates to deposits. This is confirmed by the R² of this regression (only 0.11) relative to the other variables considered in Table 2 (between 0.26 and 0.57). This is in line with Hannoun (2015) who states that: “*negative nominal deposit rates are presented as a tax imposed by the central bank on commercial banks (...), and not as a tax on the savers*”. In order to limit the effects of NIRP, banks instead reduce interest expenses on non-customer deposit liabilities. In the same vein, the analysis of Lopez et al. (2020) also supports the view that in the presence of NIRP affected banks are unable (or unwilling) to fully pass on losses to their depositors, thus justifying a decrease in banks' net interest income. Our results thus confirm the previous result in the literature that the pass-through of NIRP is not perfect as banks are reluctant to apply negative interest rates on savers' deposits.¹³

3.2. The responses of non-interest flows

We then consider the effects of the NIRP implementation on the non-interest flows and the decomposition between gross non-interest income and gross non-interest expenses. These categories of financial statements regroup fees and commissions and other non-interest income on one hand; and personnel expenses, and other non-interest expenses on the other hand. Table 3 shows the estimated parameters of Equation (1) with these dependent variables.

¹³ See, among others, Jobst and Lin (2016), Heider et al. (2019) and Boungou and Mawusi (2021).

Table 3 – Breakdown of non-interest flows

	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.026 (0.06)	-0.043 (0.04)	-0.010 (0.04)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.141*** (0.05)	-0.083*** (0.02)	-0.058 (0.04)
R ²	0.05	0.12	0.02

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3637 banks located in 59 countries over the period 2011-2018, consisting of 19935 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

We find no significant effect of NIRP on non-interest income, neither at the aggregate level, nor on the decomposition of into fees and other non-interest income. This result suggests that banks are not able to pass on the negative interest rates burden to their customer through this channel. Altavilla et al. (2019) find a similar result that banks did not increase their fees after the NIRP implementation. However, Bottero et al. (2019) and Heider et al. (2019) suggest that the effects of NIRP on fees depend on banks' reliance on deposits. These studies show that banks with a funding structure more oriented towards deposits increase fees on banking services after the NIRP implementation to compensate for the loss of income due to a squeeze on intermediation margins. In Section 5, we test whether the absence of a significant result might be due to some heterogeneity on that respect.

Conversely, our results on non-interest expenses indicate that banks located in NIRP-affected countries see their non-interest expenses decrease by 0.141pp compared to banks unaffected by NIRP. This reduction in non-interest expenses is driven by a reduction in personnel expenses (such as salaries and employee benefits) of 0.083pp. This corresponds to a 6% reduction in personnel expenses. Overall, it seems that negative interest rates act as a gas pedal in the restructuring process of banks (illustrated by the reduction in such expenses) started a few years ago in order to maintain their profits. This finding is consistent with the latest figures of the ECB structural banking indicators showing that the number of bank branches in the euro area decreased by 17.5% between 2015 and 2019 while the number of employees decreased by 7.3% over the same period.¹⁴

In order to respond to the decrease in net interest income, NIRP could be seen as a trigger for accelerating a restructuring process with a view of lowering banks' costs. Thus, banks reduce non-interest expenses (and more specifically personnel expenses) rather than increased fees and commissions. One must acknowledge that the trend in digitalization of banking services over the sample period may as well have contributed to reducing personnel expenses. However, this major challenge of banking sector is common to all countries not just those who experience negative interest rates. Our results suggest that NIRP may spur more restructuring and accelerate digital transformation of banking services compared to the control group. Another argument to explain the resilience of bank profitability relates to the increase in loan demand addressed to banks induced by

¹⁴ Figures updated on 08-06-2020. Source: Structural Indicators for the EU Banking Sector, section EU structural financial indicators, Table 1.

the decrease in interest rates. Nevertheless, Arce et al. (2018) and Heider et al. (2019) suggest that banks exposed to NIRP do not increase their credit supply. In this paper, by focusing on the profit and loss accounts, we encompass both the response of margins (prices) and credit volumes (quantities). The strong decrease in interest income on loans (shown in Table 2) suggests that the credit demand effect is not at work, at least not enough to offset the effect of the decreasing of loan interest rates.

3.3. Investigating the role of some potential biases

One potential concern with our baseline specification is that some structural changes, not captured by the comparison of control and treated groups, are in place over our sample and that are our time dummy measures that. For instance, due to the digitalization of the banking industry, banks are reducing their personnel expenses over the period. The difference-in-difference approach is supposed to circumvent this issue as long as this trend is common to both groups. However, we control further for this possibility by including controls for structural changes in banking sector structures. We augment the baseline specification with the share of interest income in total income, the share of other non-interest income (on trading and derivatives, other securities, and insurance income) to total income, the ratio of loans to customer deposits, and the ratio of personnel expenses to overhead costs. Table E in the Appendix shows the effect of the NIRP implementation when controlling for these bank specialization measures. The main findings presented in Tables 1 to 3 hold.

Because banks' propensity to apply negative rates may differ between retail and corporate deposits (the pass-through of negative rates to corporate deposits is higher), the distinction between the two types of deposits would matter for analyzing the channels through which banks adjust to the introduction of negative interest rates. However, the Fitch Solutions database provides a variable "interest expenses on customer deposits" that does not differentiate between retail and corporate deposits. In the absence of such information on the share of deposits from retail and corporate customers, we compute a proxy for this share. We use the information on mortgage loans (that represent a large share of household loans) and corporate loans to build a share of retail vs. corporate loans at the bank level. We do this with euro area data for data availability reasons. We then assume that banks granting relatively more credit to retail customers hold more retail deposits and vice versa. We define a dummy variable that equals one for high retail deposit banks with a share of mortgage loans relative to the sum of mortgage and corporate loans above the median of our sample. Based on this assumption, we are then able to compare the effects of NIRP on banks' profit and loss accounts using this proxy for high and low retail deposit banks augmenting Equation (1) with an interaction term between NIRP and this dummy variable. Estimates are reported in Table F in the Appendix. We find evidence that high retail deposit banks are reluctant to apply negative interest rates to customer deposits: their customer deposit expenses are significantly higher than those of low retail deposit banks after the NIRP implementation. Overall, high retail deposit banks experience a further compression of their net interest income by -0.047pp and of their net income by -0.063pp compared to low retail deposit banks as a result of the NIRP implementation.

In addition, Tables G to L in the Appendix shows the estimates of the effect of NIRP using alternative control groups or samples. In Table G (respectively H), the baseline control group excludes low-income countries (respectively low- and lower-middle-income

countries) based the World Bank classification. In Tables I and J, the thresholds defining the control group are relaxed and the control groups include 587 and 784 banks respectively. In Tables K and L, we present the descriptive statistics and estimates for a treated group subsample focusing on the euro area. The main findings presented in Tables 1 to 3 continue to hold.

Finally, we acknowledge that including banks located in countries where Islamic banking is prevalent (such as Bangladesh, Malaysia, Qatar, Egypt, and Turkey) in our control group may potentially introduce a bias since Islamic banks are prohibited from collecting and paying interest as such (IMF, 2015). Therefore, the interest income and expenses of these banks should inherently be lower and should not be affected by changes in interest rates set by the central bank in these countries. Based on this backdrop, we re-estimate Equation (1) by removing these countries from our control group. The results of this analysis (reported in Table M) support our baseline results.

3.4. Using bank exposure to NIRP for identification

As a complementary test to the baseline difference-in-difference approach, we use the cross-sectional variation in measures of bank exposure to NIRP to identify the effects of this policy, following Bottero et al. (2019) and Heider et al. (2019). We consider two measures of bank exposure to negative interest rates: a liquidity measure (securities divided by total assets) and a funding one (customer deposits divided by total assets). We modify Equation (1) to also include them through a triple interaction term between bank exposure variable, the treated dummy and the NIRP dummy.¹⁵ The identification now stems from the cross-sectional variation in bank exposure to NIRP when this policy is introduced in the treated countries.

Table 4 shows the estimates of the specification with the liquidity measure (Table N in the Appendix shows those for the funding measure). These results highlight that, in response to NIRP, banks with a high share of securities – more exposed to NIRP – manage to offset the reduction in net interest income (-0.595pp) by increasing their net non-interest income (0.496pp), through an increase in other non-interest income (0.248pp) and a reduction in personnel expenses (-0.152pp). The channels through which banks respond to NIRP are confirmed: interest income on loans decrease sharply but customer deposit expenses remains unaffected.

We also use a discrete measure of bank exposure to NIRP by simply defining a dummy variable that equals one when liquidity is above its sample median, and zero below. We then estimate the modified Equation (1) with a similar triple interaction term based on this exposure dummy. Estimates are presented in Table O in the Appendix and confirm the main results of this paper.

¹⁵ These measures were already proxied (liquidity, via the ratio of liquid assets to total assets) or considered as such (funding) in the vector of bank-specific characteristics, but only as controls.

Table 4 - Using bank exposure to NIRP for identification

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
Securities*DiD	-0.099 (0.07)	-0.595*** (0.04)	0.496*** (0.07)
R ²	0.04	0.35	0.06
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
Securities*DiD	-0.838*** (0.08)	-0.872*** (0.06)	0.034 (0.07)
R ²	0.61	0.40	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
Securities*DiD	-0.243*** (0.06)	0.029 (0.03)	-0.272*** (0.06)
R ²	0.55	0.12	0.54
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
Securities*DiD	0.050 (0.19)	-0.114 (0.20)	0.248* (0.13)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
Securities*DiD	-0.446** (0.21)	-0.152*** (0.04)	-0.294 (0.21)
R ²	0.05	0.10	0.02

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). It refers to the interaction between the dummy Treated and dummy NIRP. The variable Securities is the ratio of securities over total assets. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3604 banks located in 59 countries over the period 2011-2018, consisting of 19775 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Finally, we use the cross-sectional variation on bank exposure to NIRP on the treated group only, such that the identification arises from bank exposure to NIRP solely between banks exposed to NIRP. One benefit of these estimates is to be independent from the construction of a control group. Table P in the Appendix confirms the earlier findings.

3.5. The dynamic responses of banks to NIRP

While there is a consensus that NIRP *per se* does not hamper bank profitability (see Table 1 and Molyneux et al., 2019, or Lopez et al., 2020), an important question is whether keeping this policy for a prolonged period of time might have negative consequences for banks. In this subsection, we aim to capture empirically the effects of the so-called “negative-for-long” and how banks respond across time to NIRP.

We now estimate Equation (1) for different horizons after the NIRP implementation. For each regression, we restrict the sample to a given year (2014, 2015, ... or 2018) after the treatment and compare it to the years (2011 to 2013) before the treatment. Table 5 shows the estimated DiD parameters for all net and gross interest and non-interest variables for each of the five years after the NIRP implementation.

The main result is that the effect of NIRP is not immediate and that banks’ responses to it build up in time. For instance, the negative effect on gross interest income went monotonically from -0.184 in 2014 to -1.458 in 2018. The decrease in interest income from loans and the rest has followed similar trends. However, it is interesting to note that

customer deposit expenses even increase in the years just after the start of the treatment, but that they started decreasing at the very end of the sample in 2018. Banks might therefore be starting to pass lower rates to their customer to preserve their profits. Even if anecdotal, this is consistent with the decision of Commerzbank to apply negative interest rates on corporate deposit accounts.¹⁶ The response of the interest paid on non-customer deposit liabilities is strong and immediate, and continue to increase across years.

Table 5 – The dynamic bank responses to NIRP

	Net Inc.		Net Int. Inc.		Net Non-Int. Inc.	
DiD 2014	0.101	(0.08)	0.048	(0.04)	0.053	(0.07)
DiD 2015	-0.035	(0.07)	-0.084	(0.05)	0.049	(0.07)
DiD 2016	-0.066	(0.07)	-0.169***	(0.06)	0.103	(0.06)
DiD 2017	-0.121*	(0.07)	-0.231***	(0.07)	0.110*	(0.06)
DiD 2018	-0.156**	(0.07)	-0.384***	(0.06)	0.228***	(0.06)
Interest flows						
	Gross Int. Inc.		Int. Inc. on Loans		Oth. Int. Inc.	
DiD 2014	-0.184***	(0.07)	-0.109	(0.07)	-0.075	(0.05)
DiD 2015	-0.451***	(0.08)	-0.288***	(0.08)	-0.162***	(0.05)
DiD 2016	-0.552***	(0.11)	-0.334***	(0.11)	-0.218***	(0.06)
DiD 2017	-0.791***	(0.12)	-0.492***	(0.11)	-0.299***	(0.05)
DiD 2018	-1.458***	(0.12)	-0.989***	(0.12)	-0.469***	(0.06)
	Gross Int. Exp.		Cust. Dep. Exp.		Oth. Int. Exp.	
DiD 2014	-0.232***	(0.05)	0.038	(0.03)	-0.271***	(0.03)
DiD 2015	-0.366***	(0.07)	0.078*	(0.05)	-0.445***	(0.04)
DiD 2016	-0.383***	(0.09)	0.163**	(0.07)	-0.546***	(0.05)
DiD 2017	-0.560***	(0.10)	0.111	(0.08)	-0.671***	(0.05)
DiD 2018	-1.074***	(0.11)	-0.209**	(0.09)	-0.865***	(0.06)
Non-interest flows						
	Gross Non-Int. Inc.		Fees		Oth. Non-Int. Inc.	
DiD 2014	-0.165***	(0.05)	-0.127***	(0.05)	-0.035	(0.04)
DiD 2015	-0.120	(0.09)	-0.075*	(0.04)	-0.102	(0.07)
DiD 2016	-0.062	(0.10)	-0.072	(0.07)	-0.021	(0.05)
DiD 2017	-0.149	(0.10)	-0.038	(0.07)	-0.143**	(0.06)
DiD 2018	-0.045	(0.06)	0.040	(0.03)	-0.081	(0.05)
	Gross Non-Int. Exp.		Perso. Exp.		Oth. Non-Int. Exp.	
DiD 2014	-0.218***	(0.08)	-0.066**	(0.03)	-0.152***	(0.06)
DiD 2015	-0.169***	(0.05)	-0.074***	(0.02)	-0.095**	(0.04)
DiD 2016	-0.165**	(0.07)	-0.106***	(0.04)	-0.059	(0.04)
DiD 2017	-0.259***	(0.08)	-0.151***	(0.03)	-0.109*	(0.06)
DiD 2018	-0.273***	(0.06)	-0.147***	(0.03)	-0.126***	(0.05)

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1) for different years from 2014 to 2018. It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3637 banks located in 59 countries over the period 2011-2013 and the given year after the NIRP implementation. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

On the side of non-interest flows, while fees decrease during the first two years after the NIRP implementation, it appears that they start increasing at the very end of the sample in 2018 (although the associated coefficient is statistically not significant). Banks might therefore be starting to charge higher fees to their customer to preserve their profits in the

¹⁶ See <https://www.bloomberg.com/news/articles/2019-11-07/commerzbank-expands-effort-to-pass-on-negative-interest-rates> or <https://www.ft.com/content/74573de6-0a15-11ea-bb52-34c8d9dc6d84>.

years to come. The dynamic of non-interest expenses is worth noting: other non-interest expenses such as information technology, marketing and administrative costs decrease strongly in the first year of treatment, and these reductions are less pronounced in subsequent years before picking up again in the last two years, whereas personnel expenses start to decrease slowly but the trend continues over the five years of NIRP implementation.

These results confirm our previous results on how banks respond to the NIRP implementation and complement them by showing how customer deposit expenses and fees might evolve in the future to enable banks to preserve their profits if NIRP were to remain in place longer.

4. What are the transmission channels of NIRP to banks?

We complement our analysis of how banks respond to NIRP (from the perspective of banks' profit and loss accounts) with an investigation of which transmission channels matters, from the perspective of how the effect of this policy instrument transmit from the central bank to commercial banks. The literature suggests the effects of NIRP on banks would arise through three broad channels: (i) the economic outlook; (ii) a term structure effect; and (iii) excess reserves. We investigate these three channels using our framework.

Table 6 - Non-performing loans

	NPL
DiD	-0.578** (0.26)
R ²	0.08
Obs.	12255
Nb. banks	2649

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). DiD refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects, over the period 2011-2018. Robust standard errors clustered by banks in parentheses. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

First, the expansionary nature of NIRP should improve the economic outlook, leading to lower loan loss provisions and higher loan demand (see Ulate, 2021), which would in turn counter the margin compression. To test for this channel, we focus our attention on the share of non-performing loans (NPL) in banks' balance sheets. They should decline after a cut in policy rates as the growth outlook improves and loan defaults become less likely. We re-estimate Equation (1) with the ratio of non-performing loans to gross loans as the dependent variable. Table 6 reports the estimates. We find that the share of non-performing loans reduces by -0.578pp (equivalent to around -8%) after the NIRP implementation. This result is consistent with that of Boungou (2020) who also finds that NIRP favors a reduction of loss provisions.

Table 7 – Loans to total assets

	Net Income		Net Interest Income		Net Non-Int. Income	
	Low	High	Low	High	Low	High
DiD	-0.040 (0.07)	-0.119*** (0.04)	-0.364*** (0.03)	-0.373*** (0.02)	0.324*** (0.07)	0.254*** (0.04)
R ²	0.03	0.10	0.23	0.41	0.05	0.11
Obs.	8855	8980	8855	8980	8855	8980
Nb. banks	1538	1599	1538	1599	1538	1599

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). High correspond to banks with a ratio of gross loans to total assets greater than or equal to the median (59%). Low refers to banks with a ratio of gross loans to total assets less than 59%. DiD is our Difference-in-Differences estimator. It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects, over the period 2011-2018. Robust standard errors clustered by banks in parentheses. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Second, NIRP is supposed to flatten the term structure (see Lemke and Vladu, 2017), which leads to valuation gains on securities but also to margin compressions because interest rates on loans generally depend on the longer end of the yield curve. This should materialize in a differentiated impact on banks according to how many securities they hold and the size of their loan portfolio. In order to analyze this channel, we evaluate the effects of negative interest rates on the income statement of banks according to their securities holdings (see Table 4) and the size of their loan portfolio (see Table 7). Our results are somehow mixed. Estimates of Table 4 show that banks with large securities holdings have seen their net interest income more severely hit, but not their net income, whereas estimates of Table 7 suggest that banks with large loan portfolio experience a more pronounced reduction of their net income (-0.119pp) driven by a mix of lower interest income on loans and a lower compensation of non-interest income. The term structure effect therefore does not seem fully at work with the effects of the compression of long-term interest rates dominating the valuation effects.

Third, NIRP leads to a negative remuneration of central bank reserves, which should be further reduce banks' income for those with high excess reserves. Although we do not have access to data on banks' holdings of central bank reserves, we assume that banks holding more government securities (relative to total assets) before NIRP should be more affected by the introduction of negative interest rates. On this basis, we define two subsets of banks: banks with a ratio of government securities to total assets greater than or equal to the median (2.4%) and banks with a ratio of government securities to total assets less than 2.4%. The results of this analysis are reported in Table 8. We find that following the implementation of NIRP banks holding more government securities in their portfolio experience a reduction in net income of -0.216pp. Furthermore, banks with a high retail deposit share could be more affected by this channel because banks' other liabilities reprice more easily (see Basten and Mariathasan, 2018, and Demiralp et al., 2021). When analyzing the effects of NIRP according to a proxy of their share of retail deposits (see Section 3.3 and Table F), we find that banks more exposed to retail deposits are the most affected by the implementation of negative interest rates. Both sets of estimates suggest that the channel via the negative remuneration of central bank reserves seems at work.

Table 8 - Government securities

	Net Income		Net Interest Income		Net Non-Int. Income	
	Low	High	Low	High	Low	High
DiD	-0.065 (0.05)	-0.216*** (0.04)	-0.413*** (0.03)	-0.405*** (0.03)	0.348*** (0.06)	0.189*** (0.04)
R ²	0.07	0.13	0.51	0.39	0.07	0.15
Obs.	8429	7525	8429	7525	8429	7525
Nb. banks	1347	1340	1347	1340	1347	1340

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). High correspond to banks with a ratio of government securities to total assets greater than or equal to the median (2.41%). Low refers to banks with a ratio of government securities to total assets less than 2.41%. DiD is our Difference-in-Differences estimator. It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects, over the period 2011-2018. Robust standard errors clustered by banks in parentheses. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Overall, the investigation of these three transmission channels suggests that the channel of general equilibrium effects and the one going through the negative remuneration of central bank reserves might be the more prominent one in affecting banks. This analysis also suggests that the effects of NIRP on banks could be heterogenous and depend closely on the bank business model, its structure and characteristics. We explore some of these dimensions in the next section.

5. Exploring the determinants of banks' response to NIRP

In this section, we assess which bank characteristics drive the impact of negative interest rates on banks' financial statements. Our database provides balance sheet information that allows us to explore which type of banks is most impacted by negative interest rates. We focus on three important characteristics of banks: the share of the deposits in their balance sheet, their size and their leverage ratio, and estimate the impact of negative interest rates on different subsamples according to these criteria.¹⁷

5.1. Deposits

We analyze the effects of NIRP on banks' financial statements according to the share of deposits held by banks.¹⁸ We divide the overall sample in two subsamples, above and below the median of the ratio of deposits to total assets (75%). Since banks are reluctant to apply negative interest rates on customer deposits, the negative effect of NIRP on banks is likely to be greater for banks that are highly dependent on deposits. As a result, the reaction of deposit-dependent banks should be stronger compared to those that are less dependent on deposits.

Table 9 shows the subsample estimates. We find that the reduction in the net interest income is stronger for high-deposit banks (-0.453pp) compared to banks with a low share of deposits (-0.310pp). This pattern is consistent with the result that banks highly dependent on deposits are reluctant to apply negative interest rates on deposits because they may fear losing their core funding base: the effect on customer deposit expenses is negative for low-deposit banks and positive for high-deposit banks. However, the effects

¹⁷ Previous studies have analyzed the effects of NIRP according to the competitive environment and the holding of liquid assets (see Bottero et al., 2019, Boungou 2019, Molyneux et al., 2019).

¹⁸ We focus on customer deposits overall not on the distinction between retail and corporate deposits since we do not have this information in the Fitch database. See section 3.3 for a discussion of the distinction.

of NIRP on fees at banks remain null for both banks with high deposit shares and those with low deposit. In addition, we find that high-deposit banks reduce much more their non-interest expenses than low-deposit banks. This is especially true for personnel expenses (such as salaries and employee benefits) and other non-interest expense (that include overhead costs). Our results suggest that high-deposit banks are the most affected by NIRP and thus increase their non-interest income after NIRP implementation. However, this increase in non-interest income is not sufficient to fully offset the decline in net interest income.

Table 9 - Deposits

	Net Income		Net Interest Income		Net Non-Int. Income	
	Low	High	Low	High	Low	High
DiD	-0.072	-0.148***	-0.310***	-0.453***	0.238***	0.305***
	(0.07)	(0.04)	(0.03)	(0.02)	(0.07)	(0.04)
R ²	0.03	0.15	0.18	0.48	0.06	0.14
Interest flows						
	Gross Int. Inc.		Int. Inc. on Loans		Oth. Int. Inc.	
	Low	High	Low	High	Low	High
DiD	-0.959***	-1.087***	-0.747***	-0.602***	-0.213***	-0.485***
	(0.06)	(0.03)	(0.04)	(0.03)	(0.05)	(0.04)
R ²	0.48	0.79	0.34	0.52	0.15	0.55
	Gross Int. Exp.		Cust. Dep. Exp.		Oth. Int. Exp.	
	Low	High	Low	High	Low	High
DiD	-0.649***	-0.633***	-0.102***	0.037**	-0.547***	-0.671***
	(0.05)	(0.02)	(0.02)	(0.02)	(0.05)	(0.03)
R ²	0.02	0.79	0.21	0.22	0.42	0.78
Non-Interest flows						
	Gross Non-Int. Inc.		Fees		Oth. Non-Int. Inc.	
	Low	High	Low	High	Low	High
DiD	0.315*	0.071	0.121	0.034	0.239	0.032
	(0.19)	(0.06)	(0.09)	(0.04)	(0.18)	(0.04)
R ²	0.03	0.10	0.02	0.12	0.02	0.02
	Gross Non-Int. Exp.		Perso. Exp.		Oth. Non-Int. Exp.	
	Low	High	Low	High	Low	High
DiD	0.077	-0.235***	-0.047	-0.158***	0.124	-0.076***
	(0.18)	(0.04)	(0.05)	(0.03)	(0.16)	(0.02)
R ²	0.05	0.19	0.11	0.24	0.02	0.08
Obs.	9427	9526	9427	9526	9427	9526
Nb. banks	1822	1570	1822	1570	1822	1570

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). High correspond to banks with a ratio of deposits to total assets greater than or equal to the median (75%). Low refers to banks with a ratio of deposits to total assets less than 75%. DiD is our Difference-in-Differences estimator. It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects, over the period 2011-2018. Robust standard errors clustered by banks in parentheses. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Other papers also point out that the level of deposits can affect the transmission of monetary policy in an environment of negative interest rates. Heider et al. (2019) examine the effects of NIRP on syndicated lending activity in the euro area and find that banks with more deposits reduce their lending activity but lend more to risky firms. Bubeck et al. (2020) found similar results.

5.2. Bank size

We next investigate the effects of NIRP according to the size of banks. We divide our sample in two subsets above and below the median of the natural logarithm of total assets (6.02). According to the literature (see e.g., Bottero et al., 2019, Molyneux et al., 2019, Bounou, 2020, Lopez et al., 2020), the effects of NIRP are expected to be greater on small banks, as they face more difficulties in diversifying their sources of funding and income.

Table 10 – Bank size

	Net Income		Net Interest Income		Net Non-Int. Income	
	Small	Large	Small	Large	Small	Large
DiD	0.031 (0.08)	-0.168*** (0.04)	-0.350*** (0.03)	-0.355*** (0.02)	0.381*** (0.08)	0.186*** (0.04)
R ²	0.04	0.09	0.26	0.34	0.07	0.08
Interest flows						
	Gross Int. Inc.		Int. Inc. on Loans		Oth. Int. Inc.	
	Small	Large	Small	Large	Small	Large
DiD	-1.017*** (0.05)	-0.971*** (0.05)	-0.581*** (0.04)	-0.798*** (0.03)	-0.437*** (0.04)	-0.173*** (0.04)
R ²	0.64	0.59	0.32	0.48	0.47	0.17
	Gross Int. Exp.		Cust. Dep. Exp.		Oth. Int. Exp.	
	Small	Large	Small	Large	Small	Large
DiD	-0.667*** (0.03)	-0.616*** (0.04)	-0.031** (0.02)	-0.061*** (0.02)	-0.636*** (0.03)	-0.554*** (0.04)
R ²	0.73	0.53	0.26	0.21	0.71	0.48
Non-Interest flows						
	Gross Non-Int. Inc.		Fees		Oth. Non-Int. Inc.	
	Small	Large	Small	Large	Small	Large
DiD	0.408 (0.28)	0.110 (0.09)	0.120 (0.09)	0.071 (0.07)	0.415 (0.30)	0.040 (0.04)
R ²	0.05	0.03	0.06	0.01	0.02	0.05
	Gross Non-Int. Exp.		Perso. Exp.		Oth. Non-Int. Exp.	
	Small	Large	Small	Large	Small	Large
DiD	0.027 (0.27)	-0.076 (0.07)	-0.087 (0.06)	-0.081*** (0.02)	0.114 (0.24)	0.005 (0.05)
R ²	0.10	0.03	0.12	0.24	0.05	0.01
Obs.	9523	9430	9523	9430	9523	9430
Nb. banks	1696	1696	1696	1696	1696	1696

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). Large correspond to banks with a natural logarithm of assets greater than or equal to the median (6.02). Small refers to banks with a natural logarithm of assets less than 6.02. DiD is our Difference-in-Differences estimator. It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects, over the period 2011-2018. Robust standard errors clustered by banks in parentheses. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

While Molyneux et al. (2019) and Lopez et al. (2020) find that small banks are the most exposed to losses in the event of negative interest rates. Table 9 indicates a somehow more mixed picture. We find that net interest income for small and large banks reacts almost similarly to the implementation of NIRP (-0.350pp vs. -0.355pp). Furthermore, our results show that the increase in net non-interest income is greater for small banks than for large banks. We also find that the reduction in the interest income on loans is greater for large banks (-0.798pp vs. -0.581pp). At the opposite, small banks have lost more than large banks from other interest income (-0.437pp vs. -0.173pp). Moreover, we find that NIRP serves as an amplifier in the restructuring of large banks by reducing personnel expenses to maintain their profits. Overall, NIRP reduces net interest income for both small and large banks. Nevertheless, it appears that small banks are able to totally offset this reduction by increasing net non-interest income (while large banks only partially offset it).

5.3. Leverage

Finally, we analyze the effects of NIRP as a function of the leverage ratio. Following Baker (1973)'s argument that "it is desirable to include leverage in equations explaining profitability", we assess how banks' responses to negative interest rates evolve according to the level of leverage ratio. To measure leverage, we use the equity to assets ratio. A bank is considered to have a low leverage ratio if its equity to assets ratio is above the median of the distribution of equity to assets (9.12%) and conversely bank is considered as highly-leveraged if its equity to assets ratio is below 9.12%. Some previous studies have analyzed the relationship between the level of capital and the performance of banks in an environment of low positive interest rates (see Demircug-Kunt and Huizinga, 2010, and Berger and Bouwman, 2013). They highlight the existence of a positive relationship between leverage and bank performance. We test the hypothesis that highly-leveraged banks - benefiting from the interest rate decrease - are less impacted by negative interest rates compared to low-leverage banks.

Table 11 - Leverage

	Net Income		Net Interest Income		Net Non-Int. Income	
	Low	High	Low	High	Low	High
DiD	-0.050	-0.196***	-0.354***	-0.401***	0.304***	0.205***
	(0.07)	(0.03)	(0.03)	(0.02)	(0.07)	(0.03)
R ²	0.03	0.08	0.24	0.38	0.05	0.13
Interest flows						
	Gross Int. Inc.		Int. Inc. on Loans		Oth. Int. Inc.	
	Low	High	Low	High	Low	High
DiD	-0.983***	-1.074***	-0.582***	-0.749***	-0.401***	-0.325***
	(0.04)	(0.05)	(0.04)	(0.03)	(0.03)	(0.05)
R ²	0.62	0.60	0.33	0.47	0.35	0.24
	Gross Int. Exp.		Cust. Dep. Exp.		Oth. Int. Exp.	
	Low	High	Low	High	Low	High
DiD	-0.629***	-0.673***	-0.054***	-0.021	-0.575***	-0.653***
	(0.02)	(0.05)	(0.02)	(0.02)	(0.02)	(0.05)
R ²	0.73	0.53	0.25	0.19	0.68	0.50
Non-Interest flows						
	Gross Non-Int. Inc.		Fees		Oth. Non-Int. Inc.	
	Low	High	Low	High	Low	High
DiD	0.509**	-0.007	0.213**	0.034	0.403*	-0.051
	(0.23)	(0.05)	(0.10)	(0.02)	(0.24)	(0.04)
R ²	0.04	0.09	0.03	0.09	0.02	0.05
	Gross Non-Int. Exp.		Perso. Exp.		Oth. Non-Int. Exp.	
	Low	High	Low	High	Low	High
DiD	0.205	-0.212***	-0.019	-0.135***	0.224	-0.077***
	(0.22)	(0.04)	(0.05)	(0.02)	(0.20)	(0.02)
R ²	0.06	0.19	0.12	0.22	0.02	0.08
Obs.	9640	9313	9640	9313	9640	9313
Nb. banks	1701	1691	1701	1691	1701	1691

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). Low correspond to banks with a equity to assets ratio greater than the median (9.12%). High refers to banks with a equity to assets ratio less than or equal to 9.12%. DiD is our Difference-in-Differences estimator. It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects, over the period 2011-2018. Robust standard errors clustered by banks in parentheses. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 11 presents our estimates. We reject our null hypothesis and find that the effects of NIRP on net income are greater for banks with high leverage (-0.196pp) compared to

banks with low leverage (the effect is not significant). Contrary to high-leverage banks, low-leverage banks are able to pass on the reduction in interest rates to customer deposits (-0.054pp). This might be due to the lower opportunity cost of funding of low-leverage banks that could turn relatively more easily to wholesale markets if losing their customer deposits. It is interesting to note that the level of leverage also influences the banks' responses in terms of non-interest flows. Indeed, our results show that low-leverage banks tend to increase non-interest income (via an increase in fees of 0.213pp and other non-interest income of 0.403pp) and high-leverage banks tend to reduce non-interest expenses (through a reduction in personnel expenses by -0.135pp and other non-interest expenses by -0.077pp), in order to preserve their profitability. It seems then that the responses chosen by low leverage banks allow them to fully compensate for the reduction in net interest margins, as evidenced by net income, while high-leverage banks only partially compensated. This result is consistent with Bubeck et al. (2020) who also note that banks with less capital (and thus high-leverage) are most affected by the introduction of negative interest rates.

Overall, our results highlight that banks' response channels to negative interest rates are influenced by their specific characteristics (i.e., deposit dependence, size and leverage). Indeed, we find that large banks with higher deposits and higher leverage ratios are the most affected by negative interest rates. Indeed, we show that following the introduction of negative interest rates these banks (large banks with higher deposits and higher leverage ratios) experience a reduction in net income compared to other banks. This reduction comes from a reduction in net interest income which is only partially compensated by an increase in net non-interest income (resulting from a reduction in personnel expenses and other non-interest expenses).

6. Sensitivity analysis

We test the robustness of our baseline results in several ways. First, based on Rosenbaum and Rubin (1983), we combine difference-in-differences with propensity score matching (PSM) to further check the robustness of our control group. Although our control group has a similar trend and characteristics to our treated group before the introduction of negative interest rates (see Section 2.3), PSM allows us to control for potential factors that could affect the trend of our treated and control groups over time. We use the Kernel Matching method (Beheja and Wahba, 1999, Becker and Ichino, 2002). We run a probit model to generate the propensity scores (these scores are available upon request).¹⁹ Table Q in the Appendix shows similar results to the baseline case.

As a second test, we re-estimate Equation (1) by replacing our DiD estimator with the nominal short-term policy interest rate and using a standard OLS model with fixed effects. The rationale for this test is to use the variability of the policy rate below zero to obtain a more precise inference of the effect of negative interest rates. For instance, we use the ECB deposit facility rate for euro area banks. The results are similar to our previous results and are presented in Table R in the Appendix.

Third, we include the growth rate of the monetary base ($M0$) in Equation (1) in order to disentangle the effects of negative interest rates from the effects of other unconventional

¹⁹ Our results are similar if using logit model.

monetary policies since these different policies are implemented over the same time span. The monetary base captures central bank reserves so the various balance sheet policies. Taking this into consideration, we find similar results to our baseline (see Table S in the Appendix).

Finally, we acknowledge that several central banks in our treated group introduced negative interest rates in the middle and even at the end of the year. As a result, during this year, banks are affected by positive and negative interest rates. We redefine our dummy variable for the implementation of the negative interest rate policy such that $NIRP_{j,t}$ equals 1 the year following the introduction of negative interest rates, and 0 before. For example, for euro area banks, the NIRP dummy equals 1 from 2015 and 0 before, as the ECB introduced negative interest rates for the first time in June 2014. The results are reported in Table T in the Appendix. Overall, these sets of results provide support for our main findings about the channels of banks' responses to negative interest rates.

7. Conclusion

This paper uses a large database of disaggregated profit and loss account data from 3637 banks operating in 59 countries over the period 2011 to 2018 to study the channels of banks' responses to negative interest rates. We find that the negative interest rate policy yields a decrease in net interest income that is only in part mitigated by an increase in net non-interest income. We provide evidence that this negative impact comes from the interest rate on deposits because of its downward rigidity due to the reluctance of banks to charge a negative interest rate on customer deposits. Banks respond to that shock by reducing the interest paid on non-customer deposit liabilities and their personnel expenses. Thus, NIRP could be seen as a trigger for accelerating a restructuring process with a view of lowering banks' costs. We also show that banks' responses are not instantaneous and that banks adjust their response as negative interest rates persist over time. Banks start reducing customer deposit expenses and increasing fees at the very end of our sample.

Our results are important for future monetary policy decisions in at least two respects. They provide an understanding of the mechanisms of monetary policy transmission to banks under negative interest rates, and second, they highlight the potential side effects of maintaining negative interest rates for a prolonged period of time.

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APPENDIX

Table A - Countries in the sample

Treated group (25 countries)		
Austria	Hungary	Norway
Belgium	Ireland	Portugal
Bulgaria	Italy	Slovakia
Cyprus	Japan	Slovenia
Denmark	Latvia	Spain
Finland	Lithuania	Sweden
France	Luxembourg	Switzerland
Germany	Malta	
Greece	Netherlands	
Control group (34 countries)		
Angola	India	Russia
Australia	Kazakhstan	Singapore
Bangladesh	Korea	South Africa
Brunei Darussalam	Libya	Thailand
Canada	Malaysia	Togo
Croatia	Mauritius	Turkey
Czech Republic	Morocco	Ukraine
Egypt	New Zealand	United Kingdom
Ethiopia	Nigeria	United States
Guatemala	Peru	Venezuela
Hong Kong	Qatar	
Iceland	Romania	

Note: The treated group includes 7 countries outside the EMU.

Table B - Pre-NIRP descriptive statistics

Treated group					
Variable	Obs.	Mean	Std. Dev.	Min	Max
Size	7634	6.16	1.88	-0.95	14.59
Capitalization	7634	0.10	0.06	0	0.99
Liquidity	7634	0.18	0.16	0	0.99
Funding	7634	0.67	0.19	0	0.97
Control group 1 - Baseline					
Variable	Obs.	Mean	Std. Dev.	Min	Max
Size	347	10.67	1.74	8.50	19.33
Capitalization	347	0.09	0.03	0.03	0.27
Liquidity	347	0.16	0.10	0.04	0.93
Funding	347	0.63	0.16	0.01	0.90
Control group 2					
Variable	Obs.	Mean	Std. Dev.	Min	Max
Size	881	8.93	1.98	6.22	19.33
Capitalization	881	0.11	0.05	0.01	0.44
Liquidity	881	0.18	0.14	0.04	0.94
Funding	881	0.63	0.20	0	0.91
Control group 3					
Variable	Obs.	Mean	Std. Dev.	Min	Max
Size	1144	8.15	2.26	4.75	19.33
Capitalization	1144	0.12	0.07	0.01	0.77
Liquidity	1144	0.19	0.14	0.04	0.95
Funding	1144	0.62	0.22	0	0.91

Note: This Table presents the descriptive statistics of bank-specific variables for treated and control groups before the pre-NIRP period (2011-2013). Size refers to the natural logarithm of the total assets. Capitalization denotes the equity to assets ratio. Liquidity measures liquid assets to total assets. Funding refers to deposits to total assets. The control group 1 is the baseline one, over high, middle and low-income countries, the control group 2 is defined with $Size > p(50)$, $HHI > p(25)$ and $Liquidity > p(10)$ over high and middle-income countries, and the control group 3 is defined with $Size > p(25)$, $HHI > p(25)$ and $Liquidity > p(10)$ over high and middle-income countries.

Table C - Correlation matrix

	Size	Cap.	Liquidity	Funding	HHI	GDP	Inflation
Size	1						
Cap.	-0.22	1					
Liquidity	-0.11	0.14	1				
Funding	-0.34	-0.26	0.03	1			
HHI	0.10	0.10	0.01	0.00	1		
GDP	0.12	-0.01	0.06	0.17	0.06	1	
Inflation	0.04	0.02	0.04	-0.03	0.04	-0.05	1

Note: Size refers to the natural logarithm of bank total assets. Capitalization (Cap) is computed as the equity to assets ratio. Liquidity measures liquid assets to total assets. Funding is the ratio of customer deposits to total assets. HHI is the Herfindahl-Hirschmann index. GDP is real GDP growth rate. Inflation is yearly change of consumer price index.

Table D - Including controls

	Net Income	Net Int. Inc.	Net Non-Int. Inc.	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.089* (0.05)	-0.204*** (0.04)	0.115*** (0.04)	-0.758*** (0.08)	-0.453*** (0.08)	-0.305*** (0.04)	-0.553*** (0.07)	0.028 (0.05)	-0.581*** (0.04)	-0.026 (0.06)	-0.043 (0.04)	-0.010 (0.04)	-0.141*** (0.05)	-0.083*** (0.02)	-0.058 (0.04)
NIRP	-0.037 [0.06]	-0.123*** [0.05]	0.086 [0.05]	-0.188** [0.09]	-0.146* [0.09]	-0.042 [0.05]	-0.065 [0.08]	-0.107* [0.06]	0.042 [0.05]	0.164 [0.13]	0.116 [0.07]	0.134 [0.11]	0.078 [0.11]	-0.014 [0.03]	0.092 [0.10]
Size	-0.071 (0.08)	-0.220*** (0.04)	0.149* (0.08)	-0.342*** (0.10)	-0.231*** (0.06)	-0.111 (0.09)	-0.122 (0.08)	-0.014 (0.02)	-0.107 (0.08)	-1.015*** (0.34)	-0.587*** (0.16)	-0.634* (0.36)	-1.163*** (0.31)	-0.427*** (0.07)	-0.737*** (0.28)
Cap.	0.262 (2.00)	2.984*** (0.70)	-2.722 (1.91)	1.760* (0.97)	0.358 (0.66)	1.402* (0.74)	-1.224** (0.50)	0.351** (0.15)	-1.575*** (0.49)	3.921 (3.78)	5.331*** (1.94)	-1.731 (3.19)	6.643 (4.23)	4.912*** (1.83)	1.731 (3.23)
Liquidity	0.261 (0.35)	-0.423*** (0.11)	0.685* (0.36)	-0.342 (0.21)	-0.254* (0.15)	-0.089 (0.18)	0.081 (0.17)	-0.094* (0.05)	0.174 (0.16)	0.286 (0.49)	0.269 (0.43)	-0.198 (0.26)	-0.398 (0.50)	-0.190 (0.24)	-0.209 (0.36)
Deposits	-0.450* (0.25)	0.547*** (0.12)	-0.996*** (0.24)	0.152 (0.27)	0.178 (0.15)	-0.026 (0.27)	-0.394 (0.25)	0.172*** (0.06)	-0.566** (0.26)	-0.761* (0.39)	-0.272 (0.37)	-0.535** (0.22)	0.236 (0.40)	0.230 (0.21)	0.005 (0.27)
HHI	-1.648*** (0.53)	1.463*** (0.29)	-3.111*** (0.53)	2.161*** (0.48)	1.369*** (0.45)	0.792* (0.48)	0.698* (0.38)	-2.830*** (0.34)	3.528*** (0.35)	-1.543* (0.83)	0.289 (0.61)	-0.577 (1.21)	1.568* (0.84)	0.937*** (0.28)	0.631 (0.68)
GDP	-0.006 (0.00)	-0.015*** (0.00)	0.009** (0.00)	-0.027*** (0.01)	0.013** (0.01)	-0.040*** (0.01)	-0.012* (0.01)	-0.011* (0.01)	-0.001 (0.00)	0.023*** (0.01)	0.014** (0.01)	0.007 (0.00)	0.014* (0.01)	-0.000 (0.00)	0.014* (0.01)
Inflation	-0.000 (0.00)	0.004 (0.00)	-0.004 (0.00)	0.010 (0.01)	0.004*** (0.00)	0.006 (0.01)	0.006* (0.00)	-0.000 (0.00)	0.006** (0.00)	-0.005 (0.01)	-0.001 (0.00)	-0.002 (0.00)	-0.001 (0.00)	0.000 (0.00)	-0.001 (0.00)
Constant	1.987*** [0.61]	2.863*** [0.33]	-0.877 [0.62]	5.132*** [0.74]	3.457*** [0.44]	1.675** [0.68]	2.269*** [0.65]	0.543*** [0.16]	1.726*** [0.62]	8.296*** [2.65]	4.449*** [1.32]	5.133* [2.70]	9.172*** [2.45]	3.412*** [0.53]	5.760*** [2.19]
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.03	0.26	0.05	0.57	0.35	0.26	0.55	0.11	0.54	0.03	0.02	0.01	0.05	0.12	0.02

Note: DiD is the Differences-in-Differences parameter, estimated from Equation (1). It refers to the interaction between the dummy 'Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3637 banks located in 59 countries over the period 2011-2018, consisting of 19935 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table E – Including additional controls about bank specialization

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.095*	-0.179***	0.084**
	(0.05)	(0.04)	(0.04)
R ²	0.11	0.30	0.21
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.733***	-0.344***	-0.389***
	(0.08)	(0.07)	(0.03)
R ²	0.58	0.57	0.46
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.554***	0.039	-0.593***
	(0.07)	(0.05)	(0.04)
R ²	0.56	0.13	0.55
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.088*	-0.048	-0.069***
	(0.05)	(0.04)	(0.02)
R ²	0.07	0.03	0.25
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.172***	-0.071***	-0.101***
	(0.05)	(0.02)	(0.04)
R ²	0.06	0.23	0.04

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. We augment the baseline specification with the share of interest income in total income, the share of other non-interest income to total income, the ratio of loans to customer deposits and the ratio of personnel expenses to overhead costs. Robust standard errors clustered by banks in parentheses. Annual data from 3613 banks located in 59 countries over the period 2011-2018, consisting of 19856 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table F - Using a proxy for the retail deposit share

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
D_HighRetail*NIRP	-0.063*	-0.047***	-0.016
	(0.03)	(0.01)	(0.03)
R ²	0.03	0.26	0.05
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
D_HighRetail*NIRP	-0.170***	-0.296***	0.126***
	(0.02)	(0.02)	(0.02)
R ²	0.58	0.35	0.27
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
D_HighRetail*NIRP	-0.123***	0.032***	-0.155***
	(0.02)	(0.01)	(0.02)
R ²	0.55	0.08	0.57
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
D_HighRetail*NIRP	-0.046	-0.024	-0.023
	(0.03)	(0.03)	(0.02)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
D_HighRetail*NIRP	-0.03	-0.021	-0.009
	(0.04)	(0.02)	(0.03)
R ²	0.05	0.12	0.02

Note: D_HighRetail refers to banks with a ratio of mortgage loans to the sum of mortgage and corporate loans greater than or equal to the median (91%). All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3382 banks located in 18 euro area countries over the period 2011-2018, consisting of 18815 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table G - Restricting the control group to high and middle-income countries

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.085*	-0.200***	0.115***
	(0.05)	(0.04)	(0.04)
R ²	0.03	0.258	0.048
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.748***	-0.449***	-0.299***
	(0.08)	(0.08)	(0.04)
R ²	0.58	0.35	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.548***	0.026	-0.574***
	(0.07)	(0.05)	(0.04)
R ²	0.55	0.11	0.54
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.024	-0.045	-0.012
	(0.06)	(0.04)	(0.04)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.139***	-0.082***	-0.057
	(0.05)	(0.02)	(0.04)
R ²	0.05	0.12	0.02

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3635 banks located in 57 countries over the period 2011-2018, consisting of 19927 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table H - Restricting the control group to high and upper-middle-income countries

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.035	-0.162***	0.127***
	(0.05)	(0.04)	(0.04)
R ²	0.03	0.26	0.05
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.652***	-0.408***	-0.244***
	(0.08)	(0.09)	(0.04)
R ²	0.58	0.35	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.490***	0.077	-0.567***
	(0.07)	(0.05)	(0.04)
R ²	0.56	0.13	0.55
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.018	-0.059	-0.004
	(0.06)	(0.04)	(0.04)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.146***	-0.090***	-0.056
	(0.05)	(0.02)	(0.04)
R ²	0.05	0.12	0.02

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3591 banks located in 50 countries over the period 2011-2018, consisting of 19829 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table I - Using the alternative control group 2

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.113** (0.05)	-0.208*** (0.04)	0.096** (0.04)
R ²	0.03	0.22	0.04
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.824*** (0.07)	-0.466*** (0.07)	-0.358*** (0.06)
R ²	0.49	0.27	0.20
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.616*** (0.05)	-0.067 (0.05)	-0.549*** (0.04)
R ²	0.47	0.05	0.50
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.096 (0.06)	-0.050 (0.04)	-0.063 (0.05)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.192*** (0.07)	-0.063*** (0.02)	-0.129** (0.06)
R ²	0.05	0.12	0.02

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3979 banks located in 80 countries over the period 2011-2018, consisting of 21408 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table J - Using the alternative control group 3

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.129*** (0.04)	-0.189*** (0.04)	0.061 (0.04)
R ²	0.03	0.20	0.04
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.779*** (0.07)	-0.468*** (0.07)	-0.311*** (0.05)
R ²	0.45	0.23	0.18
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.590*** (0.05)	-0.109** (0.05)	-0.481*** (0.04)
R ²	0.43	0.05	0.45
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.059 (0.07)	-0.030 (0.04)	-0.041 (0.06)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.119 (0.08)	-0.037* (0.02)	-0.083 (0.07)
R ²	0.05	0.12	0.02

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 4176 banks located in 83 countries over the period 2011-2018, consisting of 22068 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table K - Pre-NIRP descriptive statistics for a euro area subsample test

Treated group					
Variable	Obs.	Mean	Std. Dev.	Min	Max
Size	7151	6.22	1.86	-0.95	14.59
Capitalizatio	7151	0.09	0.06	0	0.99
Liquidity	7151	0.18	0.15	0	0.99
Funding	7151	0.67	0.20	0	0.97
Control group					
Variable	Obs.	Mean	Std. Dev.	Min	Max
Size	344	10.68	1.75	8.5	19.33
Capitalizatio	344	0.09	0.03	0.03	0.27
Liquidity	344	0.16	0.1	0.04	0.93
Funding	344	0.63	0.16	0.01	0.9

Note: This Table presents the descriptive statistics of bank-specific variables for treated and control groups. Size refers to the natural logarithm of the total assets. Capitalization denotes the equity to assets ratio. To measure the liquidity of banks, we use the ratio liqui assets to total assets. Funding refers to deposits to total assets. Pre-NIRP period corresponds to 2011-2013.

Table L - The effect of NIRP for a euro area subsample test

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.094* (0.05)	-0.203*** (0.04)	0.109** (0.04)
R ²	0.03	0.26	0.05
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.731*** (0.08)	-0.420*** (0.08)	-0.312*** (0.04)
R ²	0.59	0.34	0.27
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.528*** (0.07)	0.073 (0.05)	-0.601*** (0.04)
R ²	0.56	0.08	0.58
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.023 (0.06)	-0.047 (0.04)	-0.008 (0.04)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.132*** (0.05)	-0.083*** (0.02)	-0.049 (0.04)
R ²	0.05	0.12	0.02

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3382 banks located in 50 countries over the period 2011-2018, consisting of 18815 observations. The control group only includes high and middle income countries. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table M - Removing the countries where Islamic Banking is prevalent

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.137**	-0.214***	0.076
	(0.07)	(0.06)	(0.06)
R ²	0.03	0.26	0.05
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.439***	-0.176	-0.263***
	(0.11)	(0.11)	(0.05)
R ²	0.59	0.37	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.225***	0.271***	-0.496***
	(0.08)	(0.06)	(0.04)
R ²	0.58	0.16	0.55
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.101	-0.048	-0.054
	(0.08)	(0.06)	(0.05)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.178***	-0.121***	-0.057
	(0.06)	(0.02)	(0.05)
R ²	0.05	0.12	0.02

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. We augment the baseline specification with the share of interest income in total income, the share of other non-interest income to total income, the ration of loans to customer deposits and the ratio of personnel expenses to overhead costs. Robust standard errors clustered by banks in parentheses. Annual data from 3575 banks located in 54 countries over the period 2011-2018, consisting of 19614 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table N - Using a funding measure for bank exposure to NIRP

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
Deposits*DiD	-0.267*** (0.08)	-0.171*** (0.05)	-0.095 (0.08)
R ²	0.03	0.26	0.05
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
Deposits*DiD	-0.514*** (0.11)	-0.184** (0.07)	-0.330*** (0.09)
R ²	0.57	0.34	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
Deposits*DiD	-0.343*** (0.09)	0.089** (0.04)	-0.432*** (0.07)
R ²	0.55	0.12	0.54
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
Deposits*DiD	-0.166 (0.14)	0.039 (0.12)	-0.212** (0.09)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
Deposits*DiD	-0.070 (0.12)	-0.093* (0.05)	0.023 (0.10)
R ²	0.05	0.12	0.02

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3637 banks located in 59 countries over the period 2011-2018, consisting of 19935 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table O - Using a discrete measure of liquidity for the exposure to NIRP

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DSecurities*DiD	-0.029*	-0.135***	0.106***
	(0.02)	(0.01)	(0.02)
R ²	0.03	0.26	0.05
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DSecurities*DiD	-0.209***	-0.253***	0.044**
	(0.02)	(0.02)	(0.02)
R ²	0.569	0.359	0.254
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DSecurities*DiD	-0.074***	0.014*	-0.089***
	(0.02)	(0.01)	(0.01)
R ²	0.54	0.11	0.53
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DSecurities*DiD	0.043	0.017	0.057
	(0.03)	(0.02)	(0.05)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DSecurities*DiD	-0.063**	-0.024**	-0.039*
	(0.03)	(0.01)	(0.02)
R ²	0.05	0.12	0.02

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). It refers to the interaction between dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3637 banks located in 59 countries over the period 2011-2018, consisting of 19935 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table P - Using exposure to NIRP only on the treated group

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
Securities*NIRP	-0.092 (0.08)	-0.544*** (0.04)	0.452*** (0.08)
R ²	0.04	0.38	0.07
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
Securities*NIRP	-0.630*** (0.07)	-0.871*** (0.06)	0.242*** (0.07)
R ²	0.65	0.46	0.29
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
Securities*NIRP	-0.086 (0.06)	-0.010 (0.02)	-0.076 (0.06)
R ²	0.60	0.20	0.57
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
Securities*NIRP	-0.019 (0.21)	-0.135 (0.22)	0.241 (0.16)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
Securities*NIRP	-0.472** (0.23)	-0.134*** (0.05)	-0.337 (0.23)
R ²	0.05	0.10	0.02

Note: All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3359 banks located in 59 countries over the period 2011-2018, consisting of 18793 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table Q – Propensity Score Matching

	Net Inc.	Net Int. Inc.	Net Non-Int. Inc.
DiD (PSM)	-0.176*** (0.00)	-0.412*** (0.02)	0.237*** (0.05)
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD (PSM)	-1.242*** (0.04)	-0.773*** (0.06)	-0.469*** (0.00)
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD (PSM)	-0.830*** (0.01)	-0.239*** (0.01)	-0.591*** (0.01)
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD (PSM)	0.084 (0.09)	0.013 (0.02)	0.104*** (0.01)
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD (PSM)	-0.152** (0.08)	-0.109** (0.05)	-0.043 (0.06)

Note: This table presents the results of our estimates by combining Difference-in-Differences and Propensity Score Matching (PSM). All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets). Bootstrapped standard errors are in parentheses. Annual data from 3637 banks located in 59 countries over the period 2011-2018, consisting of 19935 observations. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels respectively.

Table R – Nominal interest rate

	Net Inc.	Net Int. Inc.	Net Non-Int. Inc.
Nom. int. rate	0.114*** (0.02)	0.101*** (0.02)	0.013 (0.01)
R ²	0.04	0.27	0.05
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
Nom. int. rate	0.471*** (0.03)	0.171*** (0.02)	0.300*** (0.03)
R ²	0.63	0.36	0.31
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
Nom. int. rate	0.370*** (0.02)	0.158*** (0.02)	0.212*** (0.02)
R ²	0.62	0.22	0.56
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
Nom. int. rate	-0.080*** (0.02)	-0.069*** (0.01)	-0.016 (0.01)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
Nom. int. rate	-0.093*** (0.01)	-0.009 (0.01)	-0.084*** (0.01)
R ²	0.05	0.12	0.02

Note: nom. int. rate refers to the nominal policy short-term interest rate. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3624 banks located in 59 countries over the period 2011-2018, consisting of 19902 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table S - Controlling for other unconventional monetary policies

	Net Inc.	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.089*	-0.181***	0.092**
	(0.05)	(0.04)	(0.04)
R ²	0.03	0.26	0.05
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.702***	-0.449***	-0.253***
	(0.08)	(0.08)	(0.05)
R ²	0.58	0.35	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.521***	0.022	-0.543***
	(0.07)	(0.05)	(0.04)
R ²	0.56	0.11	0.55
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.055	-0.049	-0.016
	(0.06)	(0.04)	(0.04)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.147***	-0.081***	-0.066*
	(0.05)	(0.02)	(0.04)
R ²	0.05	0.12	0.02

Note: DiD is our Difference-in-Differences estimator. It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include the growth rate of M0 together with bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3632 banks located in 59 countries over the period 2011-2018, consisting of 19914 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table T - Treatment year

	Net Inc.	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.148*** [0.05]	-0.226*** [0.04]	0.077* [0.04]
R ²	0.03	0.26	0.05
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.777*** [0.08]	-0.456*** [0.08]	-0.320*** [0.04]
R ²	0.59	0.35	0.29
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.551*** [0.07]	0.005 [0.05]	-0.556*** [0.04]
R ²	0.57	0.12	0.55
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.053 [0.06]	-0.012 [0.04]	-0.052 [0.04]
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.130*** [0.05]	-0.088*** [0.02]	-0.042 [0.03]
R ²	0.05	0.12	0.02

Note: DiD is our Difference-in-Differences estimator. It refers to the interaction between the dummy Treated and dummy NIRP. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, deposits to total assets) and country-specific controls (i.e., Herfindahl-Hirschman index, inflation rate, real GDP growth rate), year and bank fixed effects. Robust standard errors clustered by banks in parentheses. Annual data from 3637 banks located in 59 countries over the period 2011-2018, consisting of 19935 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.