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POUR OBTENIR LE GRADE DE
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L'UNIVERSITÉ DE BORDEAUX**

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SPÉCIALITÉ SCIENCES ÉCONOMIQUES

Par Whelsy BOUNGOU

**ESSAYS ON BANKING INTERMEDIATION
AND NEGATIVE INTEREST RATE ENVIRONMENT**

Sous la direction de Sophie BRANA, Professeure des universités

Soutenue le 25 juin 2021

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L'Université de Bordeaux n'entend donner aucune approbation ou désapprobation aux opinions exprimées dans cette thèse. Ces opinions doivent être considérées comme propres à l'auteur.

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Notice

With the exception of the general introduction, the different chapters of this thesis are derived from research articles (published and in working papers) and have an autonomous structure. Therefore, terms such as "chapter" or "article" or "paper" are used to refer to them, and some information, especially literature, is sometimes repeated from one chapter to another.

Note

A l'exception de l'introduction générale, les différents chapitres de cette thèse sont issus d'articles de recherche (publiés et en documents de travail) et ont une structure autonome. Par conséquent, des termes tels que "chapitre", "article" ou "document" sont utilisés pour s'y référer, et certaines informations, notamment la littérature, sont parfois répétées d'un chapitre à l'autre.

Résumé

Depuis 2012, sept banques centrales en Europe (Bulgarie, Danemark, Hongrie, Norvège, Suède, Suisse et la Banque centrale européenne) et la Banque du Japon ont introduit l'un de leurs principaux taux directeurs en territoire négatif, visant à stimuler les économies caractérisées (au lendemain de la crise financière mondiale de 2008-2009) par de faibles niveaux de croissance économique et d'inflation. Cette mesure de politique monétaire a soulevé plusieurs interrogations, notamment auprès des décideurs politiques et du monde académique, quant à ses potentiels effets sur l'intermédiation bancaire. A ce jour, seulement quelques études empiriques se sont intéressées à cette question. Cette thèse vise donc à contribuer au débat en étudiant empiriquement les effets de l'introduction des taux d'intérêt négatifs sur le comportement des banques. Notre analyse s'articule autour de deux grandes parties comprenant chacune deux chapitres. La première partie vise à identifier les effets des taux d'intérêt négatifs sur les marges d'intermédiation des banques et sur l'offre de crédit, tandis que la deuxième partie identifie les différents canaux de réponses (y compris les incitations à la prise de risque) des banques à l'introduction de cette mesure de politique monétaire.

Dans le premier chapitre, nous analysons les effets des taux d'intérêt négatifs sur les marges nettes d'intérêt des banques (et leur décomposition). Nous montrons que les taux d'intérêt négatifs ont réduit les marges nettes d'intérêt des banques. En décomposant celles-ci, nous observons que la réduction des marges bancaires provient du taux d'intérêt sur les dépôts des particuliers qui se réduit moins vite que le taux d'intérêt sur les prêts, suite au passage du taux d'intérêt directeur en dessous de zéro. Il semble alors que les banques affectées par les taux d'intérêt négatifs soient réticentes à réduire, voire à appliquer, un taux d'intérêt négatif sur les dépôts des épargnants. Nous trouvons également que ces banques ont augmenté l'offre de crédit en réponse à l'introduction des taux d'intérêt négatifs. Dans le deuxième chapitre, nous analysons la relation entre le comportement à prêter des banques et les taux d'intérêt négatifs. Pour mesurer le comportement de prêts des banques, nous

considérons le coût, le volume et la maturité du crédit. Ces trois éléments permettent d'identifier comment a évolué les décisions de prêts des banques lorsque les taux d'intérêt passent en dessous de zéro. Nos résultats soulignent que les taux d'intérêt négatifs, en favorisant une réduction du coût de financement des emprunteurs, ont permis aux banques d'ajuster leur comportement de prêts en augmentant le volume de crédit à l'économie et en priorisant les prêts avec des durées plus longues. Par ailleurs, cette augmentation du volume de crédit en réponse à l'introduction des taux d'intérêt négatifs pourrait poser des questions pour la stabilité financière, notamment si les banques prêtent principalement à des agents moins solvables. Autrement dit, est-ce que la réduction des marges des banques, liée aux taux d'intérêt négatifs, pourrait inciter les banques à prendre plus de risques ?

Le troisième chapitre de cette thèse vise à apporter des éléments de réponse à cette question en évaluant comment la compression des marges nettes d'intérêt, due aux taux d'intérêt négatifs, influence la prise de risque des banques. Les résultats de notre analyse soutiennent que malgré une réduction des marges nettes d'intérêt liée aux taux d'intérêt négatifs, les banques n'ont pas pour autant été incitées à prendre plus de risques. Autrement dit, le profil risque des banques semble être resté inchangé en réponse à l'introduction des taux d'intérêt négatifs. Une question se pose alors: Comment les banques ont-elles réussi à compenser la compression des marges sans prendre plus de risque? L'objet du quatrième chapitre est donc d'examiner les canaux de réponses des banques aux taux d'intérêt négatifs, en utilisant une ventilation détaillée du compte de résultats des banques. Nos résultats confirment l'existence d'un seuil minimum sur les taux d'intérêt des dépôts des particuliers. De plus, nous trouvons que la diminution des revenus nets d'intérêt des banques (due aux taux d'intérêt négatifs) n'a été atténuée que partiellement, par une diminution des frais de personnel et des intérêts payés sur les dépôts autres que ceux des particuliers. Nos résultats mettent également en lumière que les réponses des banques ne sont pas instantanées et qu'elles les ajustent à mesure que les taux d'intérêt négatifs persistent dans le temps.

Abstract

Since 2012, seven central banks in Europe (Bulgaria, Denmark, Hungary, Norway, Sweden, Switzerland, and the European Central Bank) and the Bank of Japan have introduced one of their main policy rates in negative territory, aiming to stimulate economies characterized (in the aftermath of the 2008-2009 global financial crisis) by low levels of economic growth and inflation. This monetary policy measure has raised several questions, particularly among policymakers and academics, about its potential effects on bank intermediation. To date, only a few empirical studies have addressed this issue. This thesis therefore aims to contribute to the debate by empirically studying the effects of the introduction of negative interest rates on the behavior of banks. Our analysis is structured around two main parts, each comprising two chapters. The first part aims to identify the effects of negative interest rates on banks' intermediation margins and on the supply of credit, while the second part identifies the different channels of response (including risk-taking incentives) of banks to the introduction of this monetary policy measure.

In the first chapter, we analyze the effects of negative interest rates on banks' net interest margins (and their decomposition). We show that negative interest rates have reduced banks' net interest margins. By decomposing these margins, we observe that the reduction in bank margins comes from the interest rate on retail deposit which is reduced less quickly than the interest rate on loans, following the passage of the key interest rate below zero. It seems then that banks affected by negative interest rates are reluctant to reduce, or even charge, a negative interest rate on savers' deposits. We also find that these banks increased the supply of credit in response to the introduction of negative interest rates. In the second chapter, we analyze the relationship between the lending behavior of banks and negative interest rates. To measure the lending behavior of banks, we consider the cost, volume and maturity of credit. These three elements allow us to identify how banks' lending decisions changed when interest rates fell below zero. Our results highlight that negative interest rates, by promoting a reduction in the cost of financing for

borrowers, allowed banks to adjust their lending behavior by increasing the volume of credit to the economy and prioritizing loans with longer maturities. On the other hand, this increase in the volume of credit in response to the introduction of negative interest rates could raise questions for financial stability, especially if banks lend mainly to less creditworthy agents. In other words, could the reduction in bank margins, linked to negative interest rates, encourage banks to take more risks?

The third chapter of this thesis aims to provide some answers to this question by assessing how the reduction in net interest margins, due to negative interest rates, affects banks' risk-taking. The results of our analysis argue that despite a reduction in net interest margins due to negative interest rates, banks have not been encouraged to take more risk. In other words, the risk profile of banks seems to have remained unchanged in response to the introduction of negative interest rates. One question then arises: How did banks manage to compensate for the margin squeeze without taking more risk? The purpose of the fourth chapter is therefore to examine the channels through which banks responded to negative interest rates, using a detailed breakdown of banks' income statements. Our results confirm the existence of a minimum threshold on retail deposit interest rates. Furthermore, we find that the decrease in banks' net interest income (due to negative interest rates) was only partially mitigated by a decrease in personnel costs and interest paid on non-retail deposits. Our results also highlight that banks' responses are not instantaneous and that they adjust them as negative interest rates persist over time.

To my parents and MR

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General Introduction

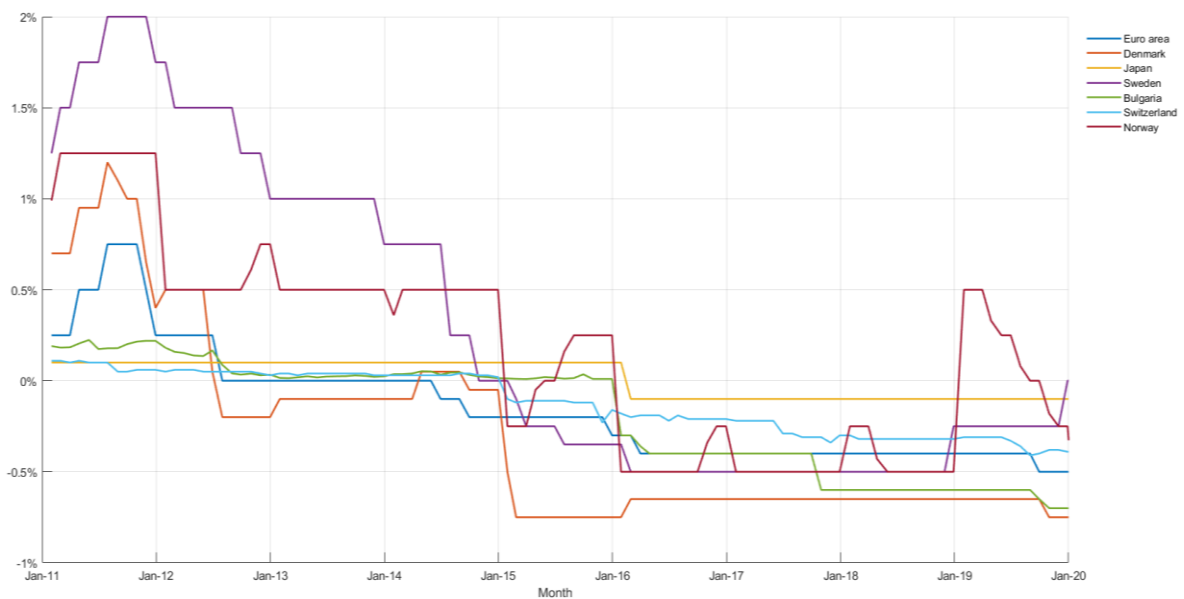
The global financial crisis of 2008-2009 highlighted the importance of banks in the transmission of monetary policy and therefore their key role in financing the economy. The traditional activity of banks is to collect funds from households and grant loans to firms, and is commonly referred to as “banking intermediation”. In other words, banks transform short-term resources (deposits) into longer-term resources (loans). In addition, by assuming the role of intermediary, the banks require in return the payment of interest to credit applicants, which constitutes the cost of the credit. In this way, the banks act as intermediaries to facilitate the matching of supply and demand for capital. This maturity transformation activity generates the main source of income of banks: the intermediation margins. The intermediation margins are the difference between the interest received from borrowers (related to the granting of credit) and the interest paid by banks on customer deposits. By influencing the ability of economic agents to save, and to obtain financing for their projects banks are at the heart of economic activity. Moreover, elements external to banks, such as changes in key monetary policy interest rates (e.g. the introduction of negative interest rate policy) and elements internal to banks, such as the structure of their balance sheets, can significantly influence the intermediation process. **By considering the structure of banks' balance sheets, this thesis then aims to understand how bank intermediation evolves in response to the implementation of negative interest rate policy.**

More specifically, this thesis consists of four empirical essays studying current issues on the effects of negative interest rates on banks, covering diverse topics that include: (i) the effects of negative interest rates on bank margin intermediation; (ii) the adjustment of banks' lending behavior in a negative interest rate environment; (iii) the influence of a negative interest rate shock on bank margins on banks' risk-taking; (iv) banks' response channels to the implementation of negative interest rates. Since banks are an essential part of the economy in general and of the transmission of

monetary policy, it is therefore important in our view to understand how banks react to the implementation of negative interest rate policy (NIRP).

Since NIRP is an unprecedented monetary policy tool, the literature on this topic is burgeoning. Indeed, until the global financial crisis of 2008-2009, no central bank had introduced a nominal interest rate below zero. NIRP is considered as a complementary tool to the unconventional monetary policies already in place (such as asset purchase programs and forward guidance) to further stimulate the economy in the face of low growth and inflation. Although the European Central Bank (ECB) is the major central bank to have introduced negative interest rates (including reducing its deposit facility rate below zero to -0.10% in June 2014 and at -0.50% since September 2019), while the Danish central bank was the first to implement negative interest rates in July 2012. Several other central banks in Europe (Bulgaria, Hungary, Norway, Switzerland, and Sweden) and the Bank of Japan followed suit, introducing also a negative interest rate policy. Figure 1 illustrates the shift of central bank policy rates below zero.

Figure 1. Central bank policy rates



Source: Central banks

Although negative interest rates (and other unconventional monetary policy measures) were introduced by central banks (in pursuit of their mandates) to address the global financial crisis and its aftermath, a number of observers have raised concerns about their impact on the behavior of economic agents, the resilience of financial intermediaries, and ultimately financial stability (Coeuré, 2016). The introduction of negative interest rates has raised concerns about their effects on banks' interest margins and their perception of risk. First, the falling of interest rates below zero could compress banks' net interest margins, as the interest rate on retail deposits is rigidly downward (Jobst and Lin, 2016). This downward rigidity in the retail deposit rate is explained by the reluctance of banks to apply a negative interest rate on customer deposits (Brunnermeier and Koby, 2018). This reluctance is mainly explained by legal constraints (requiring a minimum level of remuneration on deposits) and by the fear of losing customers to other banks (Scheiber et al. 2016). Therefore, by refusing to pass on negative interest rates to customer deposits, banks' profits from maturity transformation will be negatively affected (Hannoun, 2015). From this perspective, margin compression could then incentivize banks to take more risk by seeking more profitable assets (Jensen and Meckling, 1976; Keeley,

1990). This risk-taking incentive could materialize through a portfolio rebalancing towards riskier assets when returns on safe assets are low or through a greater concentration of loans to (historically risky) small and medium-sized enterprises (Maddaloni and Peydró, 2011; Borio and Zhu, 2012). In order to increase returns, banks could potentially increase their exposure to lower quality counterparties (Coeuré, 2016).

Although the literature on negative interest rates is growing, most papers on the effects of monetary policy interest rate changes on bank behavior focus predominantly on the period when interest rates are low but positive. These studies indicate that periods of low interest rates are indeed associated with a reduction in banks' net interest margins (among others, Genay and Podjasek, 2014; Busch and Memmel, 2017; Bikker and Vervliet, 2018; Claessens et al. 2018), and with a loosening of bank lending standards, inducing greater risk-taking (Gambacorta, 2009; Delis and Kouretas, 2011; Maddaloni and Peydró, 2011; Borio and Zhu, 2012; Dell'Ariccia et al. 2017). This thesis then aims to understand whether the implementation of negative interest rates can also lead to an increase in risk-taking by banks and thus undermine financial stability. The results of this thesis provide new insights into the understanding of monetary policy transmission and contribute to scientific banking research.

This thesis has two objectives: (i) analyze how bank intermediation evolves in the presence of negative interest rates; (ii) identify banks' responses to a negative shock on intermediation margins. Understanding the influence of interest rate changes on bank intermediation—and the associated responses — is important and policy-relevant. Indeed, albeit it is essential for a bank to determine its vulnerability to changes in interest rates, the monetary authority must be able to assess the risks (associated with its decisions) to the banking system that could affect the economy as a whole.

In the first part of this thesis, we study how negative interest rates impact the net interest margins and lending behavior of banks. Specifically, we aim to answer the following questions: (i) what is the impact of negative interest rates on bank margins

(and their decomposition)? (ii) How do banks adjust their lending behavior (through the cost, volume and maturity of loans) in the presence of negative interest rates? In the second part (divided into two chapters, chapters 3 and 4, respectively), we specifically discuss banks' reactions to negative interest rates. While chapter 3 aims to identify the influence of changes in net interest margins on banks' risk-taking in the presence of negative interest rates, chapter 4 focuses on analyzing the different channels through which banks respond to the reduction in net interest margins associated with negative interest rates.

The first chapter of this thesis aims to evaluate the effects of the introduction of negative interest rates on banks' net interest margins. Recent empirical evidence on the relationship between negative interest rates and bank performance highlight that negative interest rates would negatively affect bank performance (among others, Molyneux et al. 2019; Lopez et al. 2020). Indeed, these studies show that the implementation of negative interest rates would reduce banks' net interest margins and ultimately their overall profitability. We complement this previous literature by analyzing: (i) how negative interest rates affect banks' net interest margins and their decomposition (considering separately the interest rate on loans and the interest rate on retail deposits); (ii) whether bank-specific characteristics influence the impact of negative interest rates on bank margins; (iii) how banks with a larger effect on net interest margins (especially those highly dependent on deposits) adjust the supply of credit to the economy. To achieve this, we mobilize a large database of 9638 banks located in 41 countries over the period from 2009 to 2018. The results of our analysis support that negative interest rates have reduced banks' net interest margins. We also show that this reduction in bank margins is consistent with the claim that rates on loans adjust faster than rates on deposits (Brunnermeier and Koby, 2018; Leveuge and Sahuc, 2020). Put differently, our results seem to confirm the downward rigidity of the rate on deposits and thus the reluctance of banks to reduce or even apply a negative interest rate on retail deposits in response to the introduction of negative interest rates. Furthermore, when considering bank-specific characteristics, we find that the effects of negative interest rates were not the same across banks. Our results indicate that bank-specific characteristics influence the transmission of negative

interest rates and in particular banks that are highly dependent on deposits were most affected by negative interest rates. We also find that these highly deposit-dependent banks were more likely to increase the supply of credit.

This last point highlights that the implementation of negative interest rates would also influence the lending behavior of banks affected by this policy. Indeed, the implementation of unconventional monetary policies in general encourages banks to lend to the real economy in order to support growth and the return of inflation to its target level compatible with the price stability objective of central banks (Schwaab, 2017). As a result, the objective of the following chapter (chapter 2) is then to further explore this point by analyzing how banks adjust their lending decisions in the presence of negative interest rates. To date, there is no consensus in the literature on this topic. Although some studies claim that negative interest rates would promote an increase in credit (among others, Basten and Mariathan, 2018; Hong and Kandrac, 2018; Bottero et al. 2019), other studies support the opposite (Arce et al. 2018; Eggertsson et al. 2019; Heider et al. 2019, among others).

In chapter 2, we contribute to the debate by shedding additional light on the relationship between negative interest rates and banks' lending behavior. Specifically, we investigate how negative interest rates affect the cost of credit, the volume of credit, and loans with different maturities (including loans less than three months, between three months and twelve months, and above five years). Using data from 4072 banks operating in 54 countries over the period 2009-2018, the results of chapter 2 support the existence of the monetary policy lending channel under negative interest rates. Indeed, our results claim that negative interest rates by reducing the cost of credit would have promoted an increase in the volume of credit. We also show that negative interest rates had a significant effect on the maturity of loans by favoring, in particular, an expansion of long-term loans. In addition, our results support that the effectiveness of negative interest rate pass-through depends on bank characteristics such as size and deposit dependence. Put otherwise, large and deposit-dependent banks reacted more strongly to negative interest rates by adjusting their lending activity. Overall, the results of this chapter 2 provide some

insights into a more general question of whether the monetary policy lending channel operates under negative interest rates.

The third chapter of this thesis aims to assess the effects of the reduction in net interest margins (related to negative interest rates) on the risk-taking of banks located in the eurozone. In other words, we investigate the indirect effect of negative interest rates on banks' risk taking through bank margins. To do so, our analysis is structured as follows: (i) we estimate the effects of negative interest rates on net interest margins; (ii) we recover the predicted values of bank margins via the previous estimation, which we then use to analyze the influence of the reduction in margins on banks' risk taking. As noted above, negative interest rates reduce the net interest margins of banks because of the downwardly rigid deposit rate. In line with traditional theory (Jensen and Meckling, 1976; Keeley, 1990; Demsetz et al. 1996), this reduction in margins could induce greater risk-taking by banks, prompting them to find alternative sources of income. Put another way, faced with shrinking net interest margins, banks respond by softening their lending standards, which increases the level of risky assets on their balance sheets and increases the risk of failure (Delis and Kouretas, 2011; Maddaloni and Peydró, 2011). Indeed, low interest rates are an important source of distortion for the financial sector by making risk-free assets less attractive and can lead to a “*search-for-yield*” by financial intermediaries (Rajan, 2005).

Using data from 962 banks located in 18 countries of the eurozone over the period 2011-2017, the results of the chapter 3 confirm that the shift of the policy rate into negative territory was accompanied by a reduction in banks' net interest margins. In line with the analysis of Ciccarelli et al. (2013), we analyze whether this effect differs between the core and the periphery of the eurozone. We observe that the reduction in margins was more important for banks located in the core countries of the euro area. Moreover, we find that despite the reduction in net interest margins (NIRP-related), eurozone banks have not been encouraged to take more risk. This result is in line with the analysis of Arce et al. (2018) as well as Boungou (2020) who support that negative interest rates have not led to an increase in risk-taking by banks. One

question then arises, how did banks compensate for the reduction in net interest margins without changing their risk profile?

In chapter 4, we therefore aim to analyze how banks respond to the reduction in net interest margins and the persistence of negative interest rates in order to preserve their overall profitability. Given the persistence of negative interest rates, banks may have to rethink their business models in order to continue to generate profit. The reinterpretation of their business model could be done by (i) offering commission-based products to their customer portfolio instead of interest-based products; (ii) further improving management efficiency and cost control (e.g. by focusing more on digital banking). Using disaggregated balance sheet and income statement data from 3645 banks located in 59 countries over an eight-year period from 2011 to 2018, we: (i) analyze the channels of bank responses to interest rates; (ii) assess how these responses change as negative interest rates persist over time; and (iii) investigate whether bank-specific characteristics (such as size, deposit dependence, and leverage) influence these responses.

In doing so, we provide additional empirical evidence of the existence of a lower bound on retail deposit interest rates. In other words, we show that banks affected by negative interest rates are reluctant (to reduce or even) charge a negative rate on retail deposits. Our results also show that the increase in net non-interest income comes from a reduction in payroll costs rather than from an increase in fees. We also try to capture the effects of the so-called “*negative-for-long*” by assessing how banks respond as negative interest rates persist over time. We find that banks' responses to negative interest rates are not immediate. In fact, the magnitude of bank responses increases as negative interest rates remain in place for a longer period of time. Finally, we find that bank-specific characteristics influence bank responses to negative interest rates. Our results support that the banks most affected by negative interest rates are those that are deposit dependent, large, and highly leveraged.

Part 1 Bank Margins and Lending Behavior in Negative Interest Rate World

Chapter 1 Bank lending margins in a negative interest rate environment¹

Abstract

Following the 2008 Global Financial Crisis, the central banks of many advanced economies resorted to unconventional monetary policies including, the adoption of a negative interest rate policy, aimed at spurring economic recovery and growth. The effectiveness of this policy remains an ongoing debate and largely limited to theoretical assertions. Using a dataset of 9638 banks from 41 countries over the period 2009–2018, and a Difference-in-Differences estimator, this paper examines whether the adoption of a negative interest rate policy has any effect on bank lending margins. We find that bank margins have contracted in countries where negative rates have been implemented. Our results suggest that, in a negative interest rate environment, the rate on loans declines faster than the rate on retail deposits. Moreover, we show that the effects of NIRP on bank lending margins were stronger for smaller, less capitalized, deposit-dependent banks. Finally, our findings indicate that banks reliant on retail deposits increased lending in response to NIRP.

JEL code: E43, E51, E52, F34, G21.

Keywords: Negative interest rates, Bank margins, Loan rate, Deposit rate, Difference-in-Differences estimation.

¹ This chapter is co-authored with Charles Mawusi and has been published in [International Journal of Finance and Economics](#), 2021, 1-16.

1. Introduction

Unconventional monetary policy has become a common feature of many advanced economies following the Global Financial Crisis in 2008. Since 2012, central banks in Bulgaria, Denmark, Hungary, Japan, Norway, Sweden, Switzerland, and the European Central Bank have implemented a negative interest rate policy (NIRP), aimed at stimulating post-crisis economies characterized by low levels of growth and inflation. However, the potential effects of NIRP on bank lending margins have raised questions about its effectiveness as a policy instrument.

There is general agreement that negative interest rates could reduce banks' lending margins. This negative effect on interest margins stems from the incomplete transmission of NIRP to deposit rate. Indeed, negative interest rates could have a limited pass-through effect since banks are reluctant to charge negative rates on retail deposits because of legal constraints or fear of losing their core funding base (see Eggertsson et al. 2019, Heider et al. 2019). Thus, bank lending margins (defined as the difference between the interest rate on loans and the interest rate on customer deposits) contract as lending rates falls while deposit rates remain rigidly downward. This reduction in the margin is more significant for banks that are highly reliant on retail deposits (see IMF, 2016, Scheiber et al. 2016). The reduction in bank lending margins could also reduce banks' incentives to lend to the real economy, and as a consequence, undermine the NIRP target (Hannoun, 2015).

Against this background, this paper analyzes the effects of negative interest rates on bank lending margins (NIM thereafter). First, we investigate the effects of negative interest rates on NIM and its decomposition (i.e. loans rate and customer deposit rate). Next, we assess whether bank characteristics (such as size, capital, and deposits) influence the impact of NIRP on NIM (and its decomposition). Finally, we examine if the effects of negative interest rates on banks' incentives to lend depend on retail deposits.

We contribute to the previous literature (reviewed in section 2) in several ways. First, we use the NIM decomposition to better identify the pass-through effects of NIRP on bank lending margins. This decomposition allows us to examine how banks adjust

their balance sheets in the face of a NIRP. Second, we analyze how the lending activities of banks that are highly reliant on deposits evolve in the presence of negative interest rates. Finally, we use a large database of 9638 banks located in 41 countries over the period 2009-2018, consisting of 71785 observations. This large cross-country panel allows us to capture the heterogeneities among banks, countries, and across time.

Using the Difference-in-Differences method, our results show that negative interest rates reduced the NIM of banks located in countries that have adopted NIRP. Our results also show that this reduction in bank lending margins results from a faster reduction in the loan rate relative to the deposit rate. This result supports the idea that banks are reluctant to charge a negative rate on retail deposits. Moreover, we show that bank characteristics influence the transmission of negative interest rates. Specifically, we find that the NIRP effects were stronger for smaller, less capitalized and high deposit-dependent banks. Our results remain valid even after several robustness tests, for example by combining Difference-in-Differences with Propensity Score Matching.

By analyzing the effects of negative interest rates on banks' lending activity, we find an expansion in credit activity for banks located in NIRP-affected countries. Our results highlight that the increase in the supply of credit is driven by banks highly reliant on retail deposits. This result is consistent with the work of Heider et al. (2019) and Demiralp et al. (2019), which suggest that negative interest rates in the euro area favored an increase in the credit supply of deposit-dependent banks. Our analysis thus highlights the presence of a monetary policy lending channel under negative interest rates (Boungou, 2020b).

The remainder of the paper is organized as follows. Section 2 briefly reviews the related literature on interest rates and bank profitability. Section 3 describes our data and empirical approach. Section 4 documents the effects of NIRP on bank lending margin and lending activity, including several robustness checks. Section 5 concludes.

2. Related literature

The recent adoption of unconventional monetary policies by many advanced economies has drawn attention to the side effects of a negative interest rate policy. Indeed, several papers have discussed plausible transmission channels through which negative interest rates can affect banks' net interest margins and profitability (see, Jobst and Lin, 2016, Blot and Hubert, 2016). However, empirical support remains limited. Our study draws from the empirical literature that: (i) examines the effect of low interest rates on bank profitability; (ii) analyzes bank profitability within a negative interest rate environment.

2.1. Low interest rates and bank profitability

In line with the monetary policy debate, a number of multi-country studies have analyzed the effects of changes in the level of interest rates on bank margins and profitability. For example, using data of 109 major international banks, spanning 1995–2012, Borio et al. (2017) find a positive relationship between the level of interest rate and bank profitability. Bank profits contract at lower levels of interest rate and can be eroded in extremely low interest cases, whereas, profits increase at high interest levels. The decline in profits at low interest rates reflects among other things, the reduction in bank lending margins. This often stems from legal constraints that prevent the transmission of unusually low policy rates to deposit rates or a deliberate effort by banks to keep deposit rates above policy rates in order to maintain their primary source of funding (Heider et al. 2019). In a similar study, Claessens et al. (2018) sample 385 banks from 47 countries between 2005 and 2013, and find evidence in support of the low interest rates low banks' net interest margins and profit hypothesis. Accordingly, a 1 percentage point decrease in interest rates implies an 8 basis point drop in the net interest margins. In contrast to the preceding studies, Bikker and Vervliet (2018) argue that banks can maintain profits in a low interest environment by lowering loan loss provisions as observed in commercial and savings banks in America.

The effects of low interest rates at the country level have also received notable attention in the literature. Most of the studies are in general agreement that lower interest rates affect net interest margins (see, Genay and Podjasek, 2014, Busch and Memmel, 2017, Weistroffer, 2013), but, its effects on the overall profitability of banks remain contentious. Indeed, Genay and Podjasek (2014) indicate that bank profitability decreases in a persistently low interest rate environment. Conversely, banks can preserve profits when rates are low by shifting portfolios towards securities and non-interest incomes as evidenced in the study by Weistroffer (2013). Moreover, Brei et al. (2019) highlight that low interest rates induce banks to shift their activities from interest-generating to fee-related and trading activities.

2.2. Negative interest rates and bank profitability

The current empirical literature on negative interest rate policy has emphasized the role of negative interest rates in influencing bank lending (Heider et al. 2019, Eggertsson et al. 2019), bank risk-taking (Nucera et al. 2017, Boungou, 2020a, Bubeck et al. 2020), and exchange rate (Thornton and Vasilakis, 2019). Relatively little empirical research exists on the link between a negative interest rate policy and bank net interest margins. To our knowledge, the study by Molyneux et al. (2019) is the first to analyze the relationship between NIRP and bank margins (and profit). In their study, they analyze the effect of a negative interest rate policy on bank profit and margins, using 7359 banks from 33 OECD countries over the period 2012-2016. The authors find that banks' net interest margins and profits were lower in countries that have implemented a negative interest rate policy than those that have not. Our paper differs from that of Molyneux et al. (2019) on at least one point. Aside using a relatively larger dataset, and examining the effect of NIRP on the NIM decomposition, our paper examines how banks affected by negative interest rates (especially those dependent on retail deposits) adjust their lending activities.

Nonetheless, the degree of financial burden presented by low and negative interest rates can vary depending on bank-specific characteristics. For instance, the effect of a negative interest rate policy on bank profitability will depend to some extent on the bank size, the level of diversification, and the funding structure. Small deposit-

dependent banks face more profit burdens in a negative interest rate environment as lending rates are expected to fall more than deposit rates, because deposit funded banks are reluctant to pass negative rates on to deposit rates for fear of losing their core clientele, and thus, funds (see, Eggertsson et al. 2019, Heider et al. 2019). Large low-deposit-funded banks, on the other hand, can mitigate the effects of a negative interest rate policy on net interest margins and profits by expanding outside their core markets, trading derivatives, and investing in non-interest income activities (Weistroffer, 2013, Altavilla et al. 2018). Other bank-specific and macroeconomic characteristics that may influence the relationship between a negative interest rate policy and bank profitability include bank capitalization (Borio et al. 2017); market concentration (García-Herrero et al. 2009, Athanasoglou et al. 2008); real GDP (Athanasoglou et al. 2008); and inflation (Molyneux et al. 2019).

Our proposed study contributes to the literature in two ways. First, this study examines the different adjustment process and strategies adopted by banks in the presence of a NIRP. Some of the aforementioned studies argue that banks are reluctant to pass on negative rates on deposits, consequently putting pressure on net interest margins. Thus, we examine the effect of NIRP on the different composition of the NIM. Moreover, and unlike the previous studies, we consider the pass-through effect of negative rates on the lending activities of banks.

3. Data and empirical methodology

3.1. Data

Our data set consists of an unbalanced panel of bank-specific and country-specific variables that capture information on individual bank's balance sheets and income statements as well as the economic environment in which they operate between 2009 and 2018. The data begins five years (2009-2013) prior to adoption of a negative interest rates and includes, countries that have ever adopted a negative interest rate

policy (Bulgaria, Denmark, EMU countries², Hungary, Japan, Norway, Sweden, and Switzerland) and those with similar characteristics that have not adopted the policy (Argentina, Australia, Bolivia, Brazil, Canada, Chile, China, Iceland, India, Indonesia, Korea, Mexico, New Zealand, Poland, Russia, Thailand, Turkey, The United Kingdom, and The United States). While the first group of countries is used as the treatment group (affected by NIRP), the second refers to the control group (unaffected by NIRP).

We organize our initial sample (consisting of more than 16000 banks located in 59 countries) by selecting banks with similar characteristics to confirm the requirement for a parallel trend between our two groups, treated and control, before the implementation of the treatment. To do so, we consider the size and the share of customer deposits as the selection criteria. After several tests, we find that banks with similar characteristics prior to the implementation of the treatment are those with size greater than or equal to the 50th percentile and share of deposits greater than or equal to the 90th percentile of our sample. Figure 1.1 illustrates that the evolution of lending margins of the banks in our final sample. The figure shows that the bank lending margins of both the treated and control groups moved in the same direction before the implementation of negative interest rates.

Information on the bank balance sheet comes from the Fitch Connect database. Following the strategy of Claessens et al. (2018), we extract consolidated data from the Fitch Connect database and, when not available, we retrieve non-consolidated data. This approach was also used by Molyneux et al. (2019), to avoid reporting banks that operate in both the treated group and the control group. Also, we winsorize the data at the 1st and 99th percentile levels to ensure that outliers do not bias our estimates. The data on macroeconomic variables are obtained from central banks, Datastream, and the OECD database.

² Austria, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, and Spain.

Overall, our final sample is made up of 9638 banks from 41 countries³ spanning 2009-2018, resulting in a total of 71785 observations⁴. Contrary to what has been used in the extant literature, this data provides an extensive country sample and time frame, allowing us to capture the heterogeneities in monetary systems as well as the evolution of negative interest rates.

Table 1.A1 reports the descriptive statistics for variables in our two groups before and after the introduction of negative interest rates. While the pre-NIRP period corresponds to 2009-2013, the post-NIRP period refers to 2015-2018. We consider 2014 to be the year of the implementation of NIRP because the majority of the countries in our sample have adopted this policy in this period. To measure bank lending margins, we use net interest margins to total assets (NIM). Net interest margins refer to the spread between the loan rate and deposit rate. While we measure the loan rate using interest income relating to loans, the deposit rate is measured using interest paid on customer deposits. These two components of bank lending margins are scaled by total assets. We deviate slightly from the previous empirical works by capturing not just the effect of NIRP on the NIM but also, the effect on the different compositions of the NIM.

The bank-specific controls. Following the previous banking literature, we use four bank-specific characteristics that can affect banks' lending margins and influence the transmission of monetary policy. First, we use the ratio of liquid assets to total assets (Liquidity) as a proxy for bank liquidity. Second, we use the equity to assets ratio (Capitalization) to measure the level of capitalization of banks. Third, we use customer deposits to total assets (Deposits), as a proxy for the bank funding. Finally, we measure the size of banks using the natural logarithm of total assets (Size).

The country-specific controls. Table 1.A1 displays the country-specific variables. We employ the Herfindahl-Hirschman Index (HHI)⁵ to measure the concentration of the

³ Table 1.A6 shows the distribution of banks across countries.

⁴ The data is available through the Fitch Solutions commercial database.

⁵ We performed similar tests using the Boone index and the Lerner index. The results (not reported but available on request) are similar to those including Herfindahl-Hirschman Index.

banking system. Bank concentration is assumed to influence the transmission of monetary policy (Brunnermeier and Koby, 2018). To account for macroeconomic heterogeneities between countries, we include the growth rate of the yearly consumer price index (Inflation), and the real GDP growth rate (GDP) as macroeconomic determinants of bank profitability. We also include the spread (Yield curve) between the yield on 10-year government bonds and the short-term interest rate, to account for other unconventional monetary policies that may have been implemented in parallel with the NIRP.

3.2. Empirical methodology

To analyze the effects of the introduction of NIRP on bank lending margins (and its decomposition), we use a Difference-in-Differences (DiD) framework. This methodology has been widely used in recent literature, which analyzes the effects of negative interest rates (e.g., Boungou, 2020a, Heider et al. 2019, Molyneux et al. 2020, Thornton and Vasilakis, 2019). This method allows us to compare the effects of negative interest rates on banks' lending margins using a treatment group of banks affected by NIRP, and a control group of banks unaffected by NIRP. The DiD approach is ideal for our study in that it allows for causal inferences, and also controls for potential biases resulting from omitted variables. Equation (1) summarizes our baseline model:

$$Margins_{i,k,t} = c + \alpha_1(Treated_{i,k} * Post_{k,t}) + \alpha_2 Y_{i,k,t} + \theta_t + \lambda_i + \varepsilon_{i,k,t} \quad (1)$$

where $Margins_{i,k,t}$ is the banks' lending margins (and its decomposition) measures for the bank i in country k at year t . $Treated_{i,k}$ is a dummy variable equal to 1 if bank i in country k is affected by NIRP, and 0 otherwise. $Post_{k,t}$ is a dummy variable equal to 1 in the years following the implementation of interest rates by country k in year t , and 0 otherwise. The coefficient α_1 is our DiD estimator which represents the average difference in bank's $Margins_{i,k,t}$ between the treated and the control group. Using the Variance Inflation Factor (VIF), we test the control variables for multicollinearity. A mean VIF of 1.26 suggests that our control variables are not highly correlated (see Table 1.A2 for the correlation matrix). $Y_{i,k,t}$ refers to both bank-specific and country-specific controls. The selection of these controls is based on the literature on the

determinants of bank performance, which underlines the importance of these bank-specific and country-specific controls to the transmission of monetary policy (e.g., Athanasoglou et al. 2008, Dietrich and Wanzenried, 2011, Molyneux and Thornton, 1992). θ_t , λ_i and $\varepsilon_{i,k,t}$ are respectively time fixed-effect, bank fixed-effects⁶, and idiosyncratic error. As suggested by Bertrand et al. (2004), we use robust standard errors clustered at the bank-level to control for heteroscedasticity and, more importantly, for dependence. In addition, based on the analysis of Rosenbaum and Rubin (1983), we check the robustness of our results by combining DiD and Propensity Score Matching (the results are presented in section 4.3).

4. Empirical Findings

In this section, we present the results of our analysis on the effects of NIRP on NIM (and its decomposition). We complement this analysis by checking whether bank-specific characteristics such as size, capital and deposits influence the impact of NIRP on the NIM decomposition. We conclude our analysis by looking at whether reliance on customer deposits induces banks to lend more in a negative interest rate environment.

4.1. Baseline results

The results from estimating Equation (1) are presented in Table 1.1. Standard errors are robust and clustered at the bank level and all the estimates include bank and time fixed effects. To make our results easier to interpret, we multiply the coefficients by 100. Our baseline results are presented in the first column of Table 1.1, where the dependent variable is NIM. The second and third columns of Table 1.1 present the results of the decomposition of the NIM into loan rate and deposit rate, respectively. Our variable of interest is $Treated_{i,k} * Post_{k,t}$, precisely the coefficient α_1 . The coefficient α_1 is our DiD estimator (denoted in Tables as the NIRP-Effect), which is the average difference in the change of $Margins_{i,k,t}$ between countries affected by NIRP and countries that have not adopted NIRP.

⁶ When considering country-year fixed effects, we find similar results (available on request).

In column 1 of Table 1.1, the coefficient associated with our DiD estimator is negative and statistically significant at the 1% level, indicating that NIM has been reduced following the introduction of NIRP. Specifically, NIM decreased by 0.112 percentage points (pp), in countries affected by NIRP compared to countries unaffected by this policy. This result is consistent with the findings of Molyneux et al. (2019), who focused his study on 33 OECD countries. The study finds that bank margins have been reduced by 0.16 pp in countries affected by negative rates⁷. To further understand which part of the banks' lending margins was most affected by NIRP, we decompose the NIM into loan rate and deposit rate. The results of the decomposition are presented in columns 2 and 3. We find that the loan and deposit rates have reduced by 0.728 pp and 0.619 pp respectively, in response to the introduction of NIRP. This result highlights the compression of banks' NIM due to the imperfect pass-through of negative interest rates. As pointed out by Jobst and Lin (2016), the reduction in loan rate is faster than the reduction in deposit rate resulting from a rigid downward rate on retail deposits. The result is also consistent with the notion that banks are reluctant to charge negative rates on customer deposits.

The coefficients associated with our specific control variables are consistent with previous studies on the determinants of bank profitability. The results seem to suggest liquid assets and consumer deposits as important determinants of bank lending margins. Specifically, we find a negative relationship between liquid assets, loan rate, and deposit rate, and a positive relationship between deposits and bank lending margins. The results imply that increasing banks' liquid assets would reduce their interest income relating to loans. By holding onto large amounts of liquid assets, banks increase their opportunity cost of supplying loanable funds, thus, limiting their potential interest income. In addition, banks with sufficient liquid assets would have less incentive to attract more deposits by increasing their interest paid on customer deposits. Finally, the positive effect of deposits on bank lending margins is consistent with standard bank intermediation activity. Banks collect large deposits

⁷ By analyzing the effects of negative rates on banks located in the European Union, Boungou (2019) also finds similar results.

that are transformed into credit, consequently increasing their interest income relating to loans (i.e. maturity transformation).

4.2. NIRP and bank-specific characteristics

In this subsection, we assess whether bank characteristics such as size, capital, and deposits influence the impact of negative interest rates on bank lending margins.

Bank size. To assess the effects of negative rates according to size, we divide our sample around the median of the logarithm of total assets (6.66). We consider banks to be small, if assets are below 6.66 (median) and, conversely, large when assets are above 6.66. The results of the effects of negative rates according to bank size are reported in Panels A and B of Table 1.2. Our findings show that the effects of negative interest rates were stronger among small banks (Panel A) than large banks (Panel B). One explanation for this result is that smaller banks are generally dependent on deposits and therefore more reluctant to apply a negative rate on their main source of funding. Previous work also indicates that smaller banks have been more strongly impacted by NIRP (among others, Bottero et al. 2019, Boungou 2020a).

Bank capitalization. We also test whether the effects of negative rates differ according to the banks' capital holdings. To do this, we divide our sample between less capitalized banks and more capitalized banks, using the median of equity to assets as a reference point (12.45%). The results of this sub-sample analysis are reported in Panels C and D of Table 1.2. The results highlight that the reduction in bank lending margins, related to NIRP, was higher for less capitalized banks (Panel D) compared to more capitalized banks (Panel C). In response to this reduction, we then assume that banks with less capital will have an incentive to seek more profitable assets. Indeed, Boungou (2020a) finds that less capitalized banks take more risk in response to negative interest rates.

Customers deposits. Finally, we check whether dependence on customer deposits influences the transmission of negative interest rates. We proceed in the same way as above using the median deposits of 61%. The results are reported in Table 1.2 to Panel E for banks with low deposits and in Panel F for banks with high deposits. Our

results indicate that banks dependent on customer deposits were more affected by NIRP. Demiralp et al. (2019) show that deposit-dependent banks increase the supply of credit to the real economy, in response to NIRP. In section 4.4, we compare and contrast the lending activity of deposit-dependent and less deposit-dependent banks in a negative interest rate environment.

4.3. Further Robustness Checks

In this subsection, we check the robustness of our baseline results by performing four tests. First, as discussed in section 3.2, following Rosenbaum and Rubin's (1983) analysis, we check the robustness of our results by combining Difference-in-Differences with Propensity Score Matching. Precisely, we use the Nearest Neighbor matching method (Behejia and Wahba, 1999; Leuven and Sianesi, 2003). The results of these estimates are reported in Table 1.A3. We find results similar to our baseline results. The results of the Probit model are presented in Table 1.A7. Our results remain unchanged even when using the Logit model (not reported).

Second, we conduct sub-sample analyses by modifying our country sample in three ways to see if the results are confirmed. First, we focus on a sample composed only of European countries. The treated and control groups include only European countries. Second, we focus only on OECD member countries. Third, we eliminate countries that have implemented negative interest rates after 2014, namely Hungary (adopted in March 2016), Bulgaria (January 2016), Japan (January 2016), Norway (September 2015), Sweden (February 2015), and Switzerland (January 2015)⁸. The results of these sub-analyses are presented in Table 1.A4 and are similar to our baseline.

Third, we include the real interest rate in our regression and estimate it separately using a standard OLS with fixed effects. Indeed, as indicated by Jobst and Lin (2016), the decline in the nominal interest rate could also reduce its real component, which would allow inflation expectations to rise and stimulate aggregate demand. The results are reported in Table 1.A5. These results are robust to the previous ones and

⁸ We rely on Jobst and Lin (2016) to date the implementation of NIRP.

show the existence of a positive and significant relationship between the real interest rate and the bank lending margins. In other words, a reduction in the real interest rate leads to a reduction in the bank lending margins.

Finally, we distinguish between the effects of low and negative interest rates by including the level of the interest rate as an additional explanatory variable to our baseline estimates. Our results did not change qualitatively even after including the nominal interest rate (see Table 1.A8).

4.4. NIRP and lending activities (low and high deposits)

In the last sub-section, we analyze the effects of negative interest rates on the credit supply according to customer deposit holdings. In other words, we investigate if in the presence of NIRP the reliance on customer deposits induces an increase in the banks' credit supply. Economic theory suggests that the compression of interest margins due to NIRP reduces banks' incentives to lend (Hannoun, 2015). However, the empirical literature indicates that the effects of NIRP on banks' credit supply depend on banks' reliance on deposits (see, Heider et al. 2019, Eggertsson et al. 2019). For example, Demiralp et al. (2019) find that euro area banks that are most dependent on retail deposits have significantly increased their lending activities in response to the implementation of NIRP.

Consistent with our previous results, which suggest that the reduction of NIM has been stronger for high-deposit banks, we test whether high-deposit banks adjusted their balance sheets by increasing their lending activities. To capture the change in bank lending activity, we use the loan growth rate, measured as the logarithm of net loans. Thus, we re-estimate Equation (1) by considering in this case the logarithm of net loans as the dependent variable. We apply the same strategy as in section 4.2 to distinguish between low and high deposit banks.

The results of our estimates are reported in Table 1.3. Column I of Table 1.3 presents the results of NIRP effects on credit supply considering all banks. Columns II and III of Table 1.3 report the results of the effects of negative rates on the credit supply of low and high deposit banks, respectively. The results in column I show that banks

located in countries that have adopted NIRP increased their credit offers by 0.338 percentage compared to banks not affected by NIRP. This result underlines bank lending as a plausible channel through which interest rates are transmitted to the real economy. The literature also points to the presence of a lending channel in monetary policy under NIRP (see, Basten and Mariathasan, 2018, Schelling and Towbin, 2018, Bottero et al. 2019, Boungou, 2020b). They find that the introduction of negative interest rates has led to an increase in the supply of loans by banks.

Concerning the effects of NIRP on the lending activities according to the reliance on customer deposits, we do not find any significant effect of NIRP on the credit offer of low deposit banks (see column II of Table 1.3). This result is expected because, as we have shown previously, low deposit banks were less impacted by NIRP. On the other hand, we find that high deposit banks increased their credit supply in response to negative interest rates by 0.369 percentage (column III). This result is consistent with the idea that negative interest rates reduce the margins of banks dependent on customer deposits, thereby, inducing high deposit banks to boost their credit supply in order to support economic activity (see Demiralp et al. 2019, Heider et al. 2019).

5. Conclusion

Since 2012, central banks in several countries have implemented negative interest rates policy. This new monetary policy is at the heart of the debate among policy-makers and researchers interested in the effects of monetary policy. With this paper, we contribute to the debate by examining how negative interest rates impact bank lending margins.

Using the Difference-in-Differences method and a new data set covering 9638 banks located in 41 countries over the period 2009–2018, we find that negative rates induce a reduction in banks' net interest margins located in countries affected by NIRP. We also find that NIM compression stems from the reluctance of banks to apply a negative rate on retail deposits. However, we highlight that the pass-through of negative policy rates on NIM and its decomposition depends on the banks' specific characteristics, namely size, capital, and deposits. In addition, smaller, less

capitalized and deposit-dependent banks have been more strongly impacted by the implementation of NIRP. Finally, we emphasize that banks highly reliant on retail deposits have adjusted their balance sheets by lending more to the real economy.

These results corroborate previous studies on the effects of a low (or even negative) interest rate environment on banks' profitability and lending-behavior. One of the policy implications of this paper, in terms of monetary policy, is for policy-makers to take into account the environment in which banks operate when designing monetary policies. These monetary policies can have heterogeneous effects across banks.

In summary, our study analyzes the effects of negative interest rates on bank lending margins, considering only interest income related to loans and interest paid on customer deposits. We recommend future studies to consider other transmission channels of negative interest rates to banks' income and expense-related activities. For example, examining the effect of NIRP on the interest income from interbank exposures and bond holdings as well as, fees and commissions, and securities holdings will prove useful to the prevailing literature on negative interest rates and bank income activities.

Table 1.1. Negative interest rates and banks' lending margins

	NIM	Decomposition of NIM:	
		Loan rate	Deposit rate
NIRP-Effect	-0.112*** (0.03)	-0.728*** (0.06)	-0.619*** (0.04)
Liquidity	-1.915*** (0.14)	-3.912*** (1.07)	-0.194* (1.04)
Capitalization	0.043*** (0.00)	0.019 (0.01)	-0.023* (0.01)
Deposits	1.117*** (0.14)	1.657*** (0.50)	0.535 (0.46)
Size	-0.282*** (0.08)	-0.183 (0.34)	0.072 (0.31)
HHI	0.004 (0.66)	1.662** (0.8)	1.642** -64
Yield curve	0.006*** (0.00)	-0.004 (0.00)	-0.010*** (0.00)
Inflation	0.048*** (0.00)	0.092*** (0.02)	0.044** (0.02)
GDP	-0.029*** (0.00)	-0.075*** (0.01)	-0.045*** (0.00)
Constant	3.678*** (0.62)	4.946** (2.39)	1.457 (2.16)
Observations	71785	71785	71785
Number of banks	9638	9638	9638
R-squared (within)	0.081	0.023	0.014
Bank FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Note: NIRP-Effect is our Difference-in-Differences estimator. NIM refers to net interest margins to total assets. The loan rate is interest income relating to loans. The deposit rate is interest paid on customer deposits. Liquidity is the ratio of bank liquid assets to total assets. Capitalization is the ratio of bank equity to total assets. Deposits is the ratio of customers' deposits to total assets. Size is the natural logarithm of bank total assets. HHI is the Herfindahl-Hirschman Index. The yield curve is the spread between the yield on 10-year government bonds and the short-term interest rate. Inflation is (the growth rate of) the yearly consumer price index. GDP is the real GDP growth rate. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Table 1.2. Negative interest rates and banks' lending margins according to bank characteristics

	NIM	Decomposition of NIM:	
		Loan rate	Deposit rate
Panel A. Small banks			
NIRP-Effect	-0.187*** (0.05)	-0.875*** (0.06)	-0.701*** (0.04)
Observations	41076	41076	41076
Number of banks	6206	6206	6206
R-squared (within)	0.091	0.020	0.014
Panel B. Large banks			
NIRP-Effect	0.011 (0.04)	-0.461*** (0.07)	-0.478*** (0.04)
Observations	30709	30709	30709
Number of banks	4384	4384	4384
R-squared (within)	0.064	0.129	0.149
Panel C. Less capitalized			
NIRP-Effect	-0.147*** (0.03)	-0.639*** (0.06)	-0.497*** (0.04)
Observations	52440	52440	52440
Number of banks	7868	7868	7868
R-squared (within)	0.060	0.046	0.030
Panel D. More capitalized			
NIRP-Effect	-0.087 (0.09)	-0.654*** (0.19)	-0.586*** (0.17)
Observations	19345	19345	19345
Number of banks	3970	3970	3970
R-squared (within)	0.081	0.021	0.019
Panel E. Low deposits			
NIRP-Effect	-0.125 (0.10)	-1.013*** (0.25)	-0.916*** (0.21)
Observations	24865	24865	24865
Number of banks	4442	4442	4442
R-squared (within)	0.095	0.021	0.018
Panel F. High deposits			
NIRP-Effect	-0.101*** (0.02)	-0.359*** (0.03)	-0.259*** (0.02)
Observations	46920	46920	46920
Number of banks	7072	7072	7072
R-squared (within)	0.078	0.087	0.058

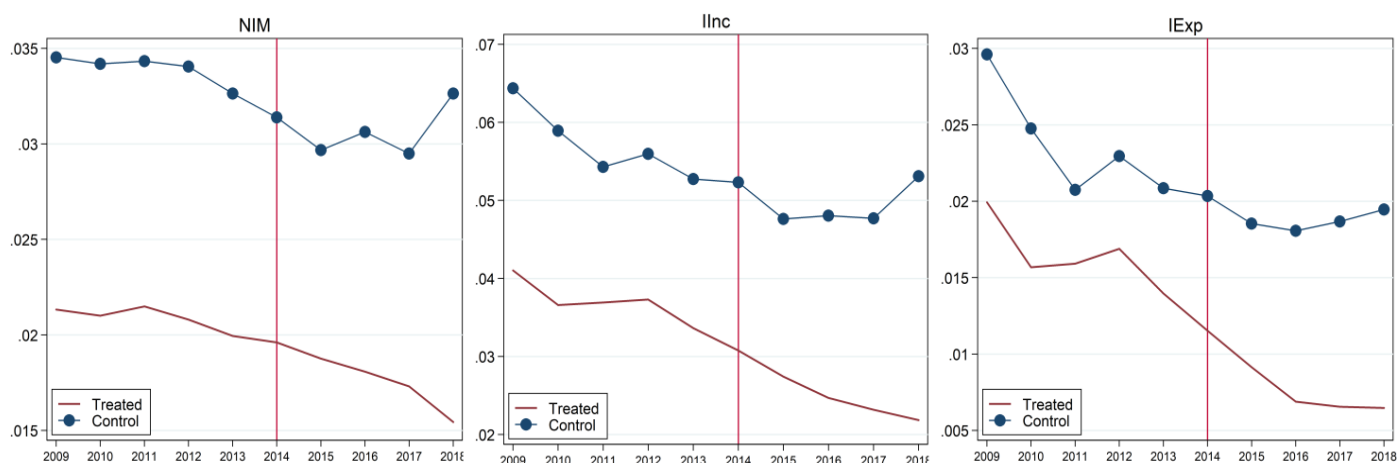
Note: NIRP-Effect is our Difference-in-Differences estimator. NIM refers to net interest margins to total assets. The loan rate is interest income relating to loans. The deposit rate is interest paid on customer deposits. All regressions include year and bank fixed effects, and bank-specific and country-specific controls. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Table 1.3. Negative interest rates and lending activities (low and high deposits)

	Growth rate of loans		
	All banks	Low deposits	High deposits
	(I)	(II)	(III)
NIRP-Effect	0.338*** (0.07)	0.312 (0.26)	0.369*** (0.06)
Liquidity	-18.065*** (0.52)	-21.995*** (0.91)	-15.663*** (0.62)
Capitalization	-0.042*** (0.01)	-0.036** (0.01)	-0.057*** (0.02)
Deposits	1.584*** (0.40)	2.614** (1.03)	1.109** (0.42)
Size	10.303*** (0.15)	10.037*** (0.29)	10.387*** (0.17)
HHI	-2.910* (1.534)	-7.897 (8.14)	-2.211 (1.37)
Yield curve	0.001 (0.00)	-0.001 (0.00)	0.003 (0.00)
Inflation	0.081*** (0.01)	0.017 (0.04)	0.093*** (0.01)
GDP	0.010 (0.01)	-0.034 (0.04)	0.017* (0.01)
Constant	-6.153*** (1.22)	-4.164* (2.40)	-6.561*** (1.36)
Observations	70979	15849	55130
Number of banks	9537	2483	7054
R-squared (within)	0.654	0.604	0.697
Bank FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Note: NIRP-Effect is our Difference-in-Differences estimator. The growth rate of loan is the logarithm of net loans. Liquidity is the ratio of bank liquid assets to total assets. Capitalization is the ratio of bank equity to total assets. Deposits is the ratio of customer's deposits to total assets. Size is the natural logarithm of bank total assets. HHI is the Herfindahl-Hirschman Index. The yield curve is the spread between the yield on 10-year government bonds and the short-term interest rate. Inflation is (the growth rate of) the yearly consumer price index. GDP is the real GDP growth rate. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Figure 1.1. The evolution of banks' net interest margins and their breakdown.



Note : Average of net interest margins (NIM), interest income relating to loans (Ilnc), and interest paid on customer deposits (IExp) among treated banks (red line) and control banks (blue line) from 2009-2018.

Appendix

Table 1.A1. Descriptive statistics

Country with NIRP										
Variable	Pre-NIRP period					Post-NIRP period				
	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max
NIM	23337	.021	.017	.014	.697	20886	.018	.0154	.007	.525
Loan rate	23337	.036	.089	.015	.984	20886	.026	.048	.004	5.898
Deposit rate	23337	.016	.085	.012	.973	20886	.007	.045	.002	5.807
Liquidity	23337	.197	.186	.126	1	20886	.196	.191	.145	1
Capitalization	23337	9.729	9.704	.050	99.45	20886	11.058	10.575	0	100
Deposits	23337	.632	.244	.011	.989	20886	.662	.243	.038	.985
Size	23337	6.581	1.975	-3.673	14.766	20886	6.728	2.016	-3.692	14.714
HHI	23337	.082	.049	.040	.652	20886	.063	.050	.023	.377
Yield curve	23337	2.497	.713	-.130	3.43	20886	1.368	.558	-.12	3.32
Inflation	23337	1.508	1.154	-1.676	5.08	20886	.804	.790	-1.42	3.718
GDP	23337	.245	3.040	-14.814	7.597	20886	1.858	1.286	-.632	25.007

Country without NIRP										
Variable	Pre-NIRP period					Post-NIRP period				
	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max
NIM	13194	.042	.0301	.006	.579	14288	.039	.035	.007	.996
Loan rate	13194	.068	.042	.033	.610	14288	.066	.056	.024	3.556
Deposit rate	13194	.025	.022	.006	.544	14288	.026	.041	.002	3.484
Liquidity	13194	.241	.199	0	1	14288	.203	.188	0	1.124
Capitalization	13194	16.149	14.450	.010	99.97	14288	15.376	14.181	.091	100
Deposits	13,194	.523	.335	.112	.994	14288	.614	.299	.090	.984
Size	13194	6.302	3.308	-3.061	20.413	14288	7.047	3.549	-2.606	20.983
HHI	13194	.158	.101	.051	.326	14288	.137	.079	.053	.288
Yield curve	13194	.279	11.852	-62.91	75.68	14288	.333	11.073	-58.01	93.37
Inflation	13194	5.355	3.650	-.848	17.1	14288	4.122	3.825	-.946	16.221
GDP	13194	1.933	3.743	-7.889	11.11	14288	2.193	2.766	-3.536	8.17

Note: NIM is the net interest margin measured as net interest margins to total assets. The loan rate is interest income relating to loans. The deposit rate is interest paid on customer deposits. Liquidity is the ratio of bank liquid assets to total assets. Capitalization is the ratio of bank equity to total assets. Deposits is the ratio of customers' deposits to total assets. Size is the natural logarithm of bank total assets. HHI is the Herfindahl-Hirschman Index. The yield curve is the spread between the yield on 10-year government bonds and the short-term interest rate. Inflation is (the growth rate of) the yearly consumer price index. GDP is the real GDP growth rate.

Table 1.A2. Correlation matrix

	L1.	L2.	L3.	L4.	L5.	L6.	L7.	L8.
L1. Liquidity	1							
L2. Capitalization	0.242*	1						
L3. Deposits	-0.191*	-0.448*	1					
L4. Size	-0.119*	-0.306*	0.063*	1				
L5. HHI	-0.034*	-0.124*	0.089*	-0.013*	1			
L6. Yield curve	-0.001	-0.021*	-0.003	0.001	0.072*	1		
L7. Inflation	0.185*	0.301*	-0.450*	-0.183*	-0.348*	-0.125*	1	
L8. GDP	0.040*	0.006	0.079*	0.203*	-0.137*	-0.005	-0.004	1

Note: This table represents the correlation matrix among the variables used in the baseline regression. Correlations that are significant at least at 5% level are reported using star (*). Liquidity is the ratio of bank liquid assets to total assets. Capitalization is the ratio of bank equity to total assets. Deposits is the ratio of customers' deposits to total assets. Size is the natural logarithm of bank total assets. HHI is the Herfindahl-Hirschman Index. The yield curve is the spread between the yield on 10-year government bonds and the short-term interest rate. Inflation is (the growth rate of) the yearly consumer price index. GDP is the real GDP growth rate.

Table 1.A3. Propensity Score Matching (PSM) - Difference-in-Differences results

	NIM	Decomposition of NIM:	
		Loan rate	Deposit rate
	(I)	(II)	(III)
NIRP-Effect (PSM)	-0.524*** (0.18)	-0.771*** (0.22)	-0.226*** (0.09)
Observations	35174	35174	35174
Bank FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Note: NIRP-Effect (PSM) refers to the combination of Difference-in-Differences and Propensity Score Matching (PSM). NIM refers to net interest margins to total assets. The loan rate is interest income relating to loans. The deposit rate is interest paid on customer deposits. ***, ** and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Table 1.A4. NIRP results based on country sub-sample analyses

	NIM	Decomposition of NIM:	
		Loan rate	Deposit rate
Panel A. European countries			
NIRP-Effect	-0.253*** (0.06)	-1.294*** (0.13)	-1.045*** (0.11)
Observations	51223	51223	51223
Number of banks	7189	7189	7189
R-squared (within)	0.110	0.040	0.018
Panel B. OECD countries			
NIRP-Effect	-0.168*** (0.03)	-0.481*** (0.07)	-0.318*** (0.06)
Observations	54920	54920	54920
Number of banks	7460	7460	7460
R-squared (within)	0.049	0.033	0.022
Panel C. Removing countries that have implemented negative rates after 2014			
NIRP-Effect	-0.178*** (0.04)	-1.083*** (0.11)	-0.916*** (0.10)
Observations	62322	62322	62322
Number of banks	8713	8713	8713
R-squared (within)	0.093	0.039	0.019

Note: NIRP-Effect is our Difference-in-Differences estimator. NIM refers to net interest margins to total assets. The loan rate is interest income relating to loans. The deposit rate is interest paid on customer deposits. All regressions include year and bank fixed effects, and bank-specific and country-specific controls. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Table 1.A5. Real interest rates and banks' lending margins

	NIM		Decomposition of NIM:			
	(I)	(II)	(III)	(IV)	(V)	(VI)
NIRP-Effect	-0.059*		-0.644***		-0.596***	
	(0.03)		(0.05)		(0.04)	
ireal	0.033***	0.033***	0.061***	0.069***	0.029***	0.036***
	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
Observations	67911	67911	67911	67911	67911	67911
Number of banks	9332	9332	9332	9332	9332	9332
R-squared (within)	0.086	0.087	0.026	0.025	0.017	0.015

Note: NIRP-Effect is our Difference-in-Differences estimator. ireal is the real interest rate. NIM refers to net interest margins to total assets. The loan rate is interest income relating to loans. The deposit rate is interest paid on customer deposits. All regressions include year and bank fixed effects, and bank-specific and country-specific controls. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Table 1.A6. The distribution of banks across countries

Country	Number of banks	Country	Number of banks
Treated group:		Control group:	
1. Austria	731	23. Argentina	22
2. Bulgaria	16	24. Australia	115
3. Denmark	71	25. Bolivia	18
4. Estonia	11	26. Brazil	143
5. Finland	186	27. Canada	120
6. France	407	28. Chile	27
7. Germany	2085	29. China	200
8. Greece	31	30. Iceland	7
9. Hungary	113	31. India	300
10. Ireland	43	32. Indonesia	238
11. Italy	735	33. Korea	109
12. Japan	318	34. Mexico	81
13. Latvia	22	35. New Zealand	28
14. Lithuania	12	36. Poland	177
15. Luxembourg	131	37. Russia	1079
16. Malta	25	38. Thailand	38
17. Netherlands	65	39. Turkey	46
18. Norway	86	40. United Kingdom	250
19. Portugal	130	41. United States	791
20. Spain	226	<i>Total</i>	<i>3789</i>
21. Sweden	57		
22. Switzerland	348		
<i>Total</i>	<i>5849</i>		

Table 1.A7. Propensity score matching estimation: Probit model

	NIM	Decomposition of NIM:	
		Loan rate	Deposit rate
Liquidity	-33.898*** (5.15)	-33.898*** (5.15)	-33.898*** (5.15)
Capitalization	-1.425*** (0.11)	-1.425*** (0.11)	-1.425*** (0.11)
Deposits	-145.336*** (5.37)	-145.336*** (5.37)	-145.336*** (5.37)
Size	-6.747*** (0.44)	-6.747*** (0.44)	-6.747*** (0.44)
HHI	1974.045 (26.85)	1974.045 (26.85)	1974.045 (26.85)
Yield curve	-0.204 (0.15)	-0.204 (0.15)	-0.204 (0.15)
Inflation	-72.612*** (1.29)	-72.612*** (1.29)	-72.612*** (1.29)
GDP	-7.043*** (0.58)	-7.043*** (0.58)	-7.043*** (0.58)
Constant	289.271*** (7.60)	289.271*** (7.60)	289.271*** (7.60)
Observations	35174	35174	35174
Pseudo R2	0.527	0.528	0.528
Log Likelihood	-11399.275	-11399.275	-11399.275
LR (Chi2)	25459.78	25459.78	25459.78

Note: NIM refers to net interest margins to total assets. The loan rate is interest income relating to loans. The deposit rate is interest paid on customer deposits. Liquidity is the ratio of bank liquid assets to total assets. Capitalization is the ratio of bank equity to total assets. Deposits is the ratio of customers' deposits to total assets. Size is the natural logarithm of bank total assets. HHI is the Herfindahl-Hirschman Index. The yield curve is the spread between the yield on 10-year government bonds and the short-term interest rate. Inflation is (the growth rate of) the yearly consumer price index. GDP is the real GDP growth rate. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Table 1.A8. Nominal interest rates and banks' lending margins

	NIM	Decomposition of NIM:	
		Loan rate	Deposit rate
	(I)	(III)	(V)
Nominal	0.150*** (0.02)	0.377*** (0.02)	0.227*** (0.02)
NIRP-Effect	-0.058** (0.03)	-0.571*** (0.02)	-0.523*** (0.04)
Observations	70914	70914	70914
Number of banks	9601	9601	9601
R-squared (within)	0.084	0.025	0.015

Note: NIRP-Effect is our Difference-in-Differences estimator. Nominal is the nominal interest rate. NIM refers to net interest margins to total assets. The loan rate is interest income relating to loans. The deposit rate is interest paid on customer deposits. All regressions include year and bank fixed effects, and bank-specific and country-specific controls. Annual data from 9601 banks located in 41 countries over the period 2009-2018, consisting of 70914 observations. Robust standard errors clustered by banks in parenthesis. ***, ** and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Chapter 2 Empirical Evidence of the Lending Channel of Monetary Policy under Negative Interest Rates⁹

Abstract

Does the lending channel of monetary policy operate under a negative interest rate policy (NIRP)? The purpose of this study is to shed light on the existence of a lending channel of monetary policy under NIRP. To do so, we aim to provide an in-depth analysis of the relationship between NIRP and bank-lending behavior. To achieve this, we employ a large panel dataset of 4072 banks operating in 54 countries over the period 2009-2018 and a Difference-in-Differences methodology. We find that banks located in countries affected by negative interest rates have adjusted their bank-lending behavior by increasing lending activities. Our findings suggest that in response to negative interest rates, banks have reduced their lending cost, and increased lending supply, particularly loans with maturities ranging from 3 to 12 months and those over 5 years. Finally, we also find that the transmission of monetary policy under negative interest rates to the real economy depends on banks' specific characteristics such as reliance on retail deposits and size.

JEL codes: E43, E51, E52, F34, G21.

Keywords: Negative interest rates, Lending cost, Lending supply, Lending maturity, Difference-in-Differences estimation.

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*« The use of interest rates [...] has been quite efficient
in order to lower the financing costs. [...] We are still seeing credit expansion. »
(Christine Lagarde)¹⁰*

1. Introduction

In response to the Great Financial Crisis of 2007-2009, several central banks have implemented unprecedented monetary policy measures, so-called unconventional monetary policies (UMP). These new measures, mainly focused on banks, aim to stimulate post-crisis economies characterized by low growth and low inflation.

Since 2012, in addition to existing UMP measures, seven central banks in Europe as well as the Bank of Japan have moved one of their main policy rates into negative territory.¹¹ The introduction of a negative interest rate policy (NIRP) aims to tax banks' excess reserves so that they can be used to increase the lending supply. Indeed, NIRP has been implemented to improve banks' funding and liquidity conditions, and ultimately increase the supply and demand for credit. Moreover, Schwaab (2017) argues that this accommodative monetary policy gives banks an incentive to lend to the real sector, and as a result support growth and a return of inflation to levels that are consistent with the central banks' objective of price stability. A crucial question then arises: Does the lending channel of monetary policy operate under a negative interest rate policy? In other words, how do banks change their lending-behavior in a negative interest rate environment?

The conventional view is that in normal times the central bank remunerates banks' excess reserves in order to regulate the liquidity in circulation, in line with its objective of price stability. However, in times characterized by low economic growth and low inflation, the central bank takes decisions to support economic activity, for instance, through the bank lending channel. To this end, the taxation of

¹⁰ ECB Press Conference at Frankfurt am Main on 12 December 2019.

¹¹ Bulgaria (in January 2016), Denmark (July 2012), Euro area (June 2014), Hungary (March 2016), Japan (January 2016), Norway (September 2015), Sweden (February 2015), Switzerland (January 2015).

reserves aims to increase the cost of holding reserves with the central bank, and thus encourages an increase in the supply of credit by reducing both bank and borrower financing costs (Coeuré, 2016). However, credit expansion depends on the transmission of negative interest rates to the lending rate and the retail deposit rate (Brunnermeier and Koby, 2018). Indeed, if the transmission of negative interest rate is not perfect, it would squeeze banks' interest margins (Boungou, 2019; Lopez et al. 2020; Molyneux et al. 2019; Boungou and Mawusi, 2021) and thus potentially reduce their incentive to lend to the real economy (Hannoun, 2015).

The assumption that NIRP could reduce the banks' interest margins (NIM) is based on the fact that the increase in the lending supply, linked to excess reserves, is not accompanied by a reduction in both the rate on loans and the rate on retail deposits. Indeed, as noted by Jobst and Lin (2016), banks' NIM compresses as rates on new loans decline and existing (variable rate) loans are reduced, while deposit rates remain downward sticky. In fact, several empirical studies argue that negative interest rates reduce banks' net interest margins. Using data of 7359 banks from 33 OECD countries over the period 2012-2016, Molyneux et al. (2019) find that negative interest rates have reduced the NIM of banks located in countries that have adopted this policy.¹²

According to Scheiber et al. (2016), there are at least two reasons why banks are reluctant to lower deposit rates below zero: (i) legal constraints; (ii) the risk of substitution of savings deposits by banknotes ("*rush to cash*"). Through the lending channel, banks can mitigate the compression of net interest margins due to NIRP in several ways: (i) increase (or reduce) the cost of lending; (ii) increase the supply of credit (if the demand is strong); (iii) if banks decide to increase the supply of credit, they would adjust their portfolio by shifting from short-term to long-term loans (see Black and Rosen, 2016; Ortiz-Molina and Penas, 2008).¹³ Taking this body of work

¹² Based on 5200 banks operating in the 27 advanced European and Asian countries over the period 2010-2017, Lopez et al. (2020) find similar results.

¹³ Other studies indicate that in order to maintain profitability, banks can also: (i) increase fees and commissions (Lopez et al. 2020; Molyneux et al. 2019); reduce personnel expenses (Boungou and Hubert, 2020); (iii) invest more in risky securities (Bubeck et al. 2020).

one step further, we analyze empirically how banks' lending behavior has changed in the presence of negative interest rates.

Using the Difference-in-Differences method, we conduct an in-depth analysis of the effects of negative interest rates on bank-lending behavior. We capture banks' lending behavior through changes in the cost, volume and maturity of loans. In addition, we examine how bank-specific characteristics can amplify or weaken the lending channel of monetary policy under negative interest rates. In other words, we investigate whether the effects of NIRP differ across bank-specific characteristics. Indeed, the transmission of monetary policy to the real economy through the lending channel under negative interest rates may differ according to bank-specific characteristics such as size and deposits (see Schelling and Towbin, 2018; Heider et al. 2019; Molyneux et al. 2020).

Our main contribution is the growing literature on how negative interest rates influence bank behavior. Despite a several number of empirical studies on this topic, there is no paper that provides cross-country evidence. To our knowledge, this is the second paper (after Molyneux et al. 2020) that provides cross-country evidence on how negative policy rates affect the lending behavior using a large sample of banks operating in 54 countries over the period 2009-2018. This goes beyond existing analysis on bank-lending behavior which typically look at single countries in domestic context (Arce et al. 2018; Basten and Mariathasan, 2018; Schelling and Towbin, 2018; Bottero et al. 2019; Eggertsson et al. 2019; Gunji, 2018; Heider et al. 2019; Hong and Kandrac, 2018). This undoubtedly explains the divergence of results found in this literature. Indeed, two results generally emerge from this literature. On the one hand, some studies support the presence of a lending channel for monetary policy under negative interest rates (Basten and Mariathasan, 2018; Schelling and Towbin, 2018; Bottero et al. 2019; Gunji, 2018; Hong and Kandrac, 2018). On the other hand, analyses suggest that negative interest rates have not encouraged banks to lend more (Arce et al. 2018; Eggertsson et al. 2019; Heider et al. 2019).

Besides, while some studies have focused only on the effects of NIRP on the volume of credit (among others, Molyneux et al. 2020; Bottero et al. 2019; Basten and Mariathan, 2018; Hong and Kandrac, 2018) or on a specific type of loans, such as syndicated loans (Heider et al. 2019), we complement these studies by conducting an in-depth analysis of the effects of NIRP on bank-lending behavior, namely on cost, supply, and maturity of lending. Therefore, this paper is the first to show how the maturity of loans influences the transmission of monetary policy in the context of negative interest rates.

To measure bank-lending behavior, we use three proxies: (i) lending cost; (ii) lending supply; (iii) lending maturity. While lending cost refers to interest income on loans, lending supply is measured as the total of gross loans. Lending maturity refers to the volume of credit with different maturities, i.e. loans with a maturity of less than 3 months, those between 3 and 12 months and finally those with a maturity above 5 years. One of the advantages of analyzing the effects on loan maturities is that it allows us to investigate how banks manage their credit risk in the presence of negative interest rates. Indeed, we assume that the increase in loans with longer maturities reflects better credit risk management by banks and shorter maturities reflect higher credit risk (Ortiz-Molina and Penas, 2008). Employing a large panel dataset of 4072 banks operating in 54 countries over the period from 2009 to 2018 and the Difference-in-Differences methodology, we show that banks located in NIRP-affected countries have reduced the cost of credit, thereby increasing the supply of credit. Our findings also highlight that negative interest rates have had a significant effect on lending maturity by favoring, notably, an expansion of loans with maturities of more than 3 months for banks located in NIRP-affected countries, compared to those that did not adopt this policy. Overall, these results support the presence of a lending channel of monetary policy under negative interest rates, and stresses above all that short-term loans become less attractive than others in an environment of low or even negative interest rates.

These conclusions remain valid even when we combine the Difference-in-Differences methodology with Propensity Score Matching, and when we consider

the other unconventional monetary policies that were conducted in conjunction with the introduction of NIRP. Finally, we show that the effectiveness of this monetary policy transmission channel depends on bank-specific characteristics such as size and deposits. Specifically, we find that large and high-deposits banks reacted more strongly to negative interest rates by adjusting their lending activity.

The remainder of the paper is organized as follows. Section 2 briefly reviews the related literature on negative interest rates and bank-lending behavior. Section 3 describes our data and empirical approach. Section 4 documents the effects of NIRP on bank-lending behavior, including several robustness checks. Section 5 concludes.

2. Related literature

Since 2012, several banks have introduced a new unconventional monetary policy tool: negative policy interest rates. By introducing negative interest rates, central banks want banks to use their excess reserves to lend to the real economy and thus support economic activity. Central banks then support the presence of a lending channel for monetary policy under negative interest rates to boost economic activity. In doing so, a question emerges: Does this lending channel operate under negative interest rates? To answer that, we analyze in depth the effects of NIRP on bank-lending behavior, considering the cost, volume and maturity of loans. In this context, we provide a first cross-country evidence of the role played by loan maturity in the transmission of negative interest rates.

The recent literature has tried to provide some answers to this question by analyzing the relationship between negative interest rates and bank-lending behavior. Meanwhile, there is no consensus on the effects of negative interest rates on lending activities. Indeed, this lack of consensus is undoubtedly linked to: (i) the samples used (mostly focused on single countries), ignoring the cross-country dimension¹⁴; (ii) the difference between the characteristics of the banks (i.e. size and

¹⁴ Euro area (Arce et al. 2018; Heider et al. 2019); Italy (Bottero et al. 2019); Japan (Gunji, 2018; Hong and Kandrac, 2018); Spain (Arce et al. 2018); Sweden (Eggertsson et al. 2019); Switzerland (Schelling and Towbin, 2018; Basten and Mariathan, 2018).

reliance on deposits); (iii) the failure to take into account the maturity of the loans (Ortiz-Molina and Penas, 2008; Black and Rosen, 2016). As a result, two results are highlighted in this literature.

On the one hand, some studies show that the introduction of negative interest rates has led to an increase in the supply of credit by banks. Schelling and Towbin (2018) have provided empirical evidence by analyzing the effects of the introduction of negative interest rates by the Swiss National Bank (SNB) on individual Swiss corporate loans. Using a Difference-in-Differences approach, they find that banks, with a lot of deposits, try to offset their relatively higher funding costs by offering more generous lending terms and thereby capturing market shares. Also analyzing the Swiss banking market, Basten and Mariathasan (2018) find similar results. They show that the introduction of negative interest rates by the SNB has led to an increase in the supply of loans by Swiss banks. In particular, they find an expansion of banks' activities in the mortgage market. In the same vein, Hong and Kandrac (2018) investigate how negative interest rate policy introduced in January 2016 by the Bank of Japan affected Japanese banks' lending behavior. They highlight that credit supply increased more for banks that were more affected by NIRP. Similarly, using the experience in Japan, Gunji (2018) find that the loan rates of banks to which negative interest rates were levied declined compared to those of the banks that were not subject to NIRP. Another study, Bottero et al. (2019), examines the transmission of negative interest rates through the Italian banking system. They note an increase in the growth rate of total bank credit after the introduction of NIRP.

On the other hand, other studies examining the effects of NIRP find that negative interest rates did not encourage an increase in the supply of bank loans. Using a Difference-in-Differences framework, Heider et al. (2019) estimate the effects of the introduction of negative interest rates by the European Central Bank on the credit supply of euro area banks.¹⁵ Heider et al. (2019) show that in response to negative

¹⁵ Other evidence in the euro area (and Spain) shows that negative interest rate had no significant impact on banks' credit standards, which suggests that banks did not expand their loan supply (Arce et al. 2018).

interest rates, euro area banks have on the whole lent less to the real economy. They also find that these effects depend on the reliance on deposits. Indeed, their results suggest that banks with high deposits lend more to risky firms, which could pose a risk to financial stability. Focusing on the Swedish banking system, Eggertsson et al. (2019) also show that once the policy rate turns negative, the usual transmission mechanism of monetary policy through the bank sector breaks down in Sweden. They find that Swedish banks that rely more heavily on deposit financing also have lower credit growth in a negative interest rate environment. Based on data from 6675 banks in 33 OECD countries over 2012-2016 and a Difference-in-Differences method, Molyneux et al. (2020) find similar results. Indeed, the authors show that after the introduction of negative interest rates bank lending was weaker in NIRP-adopter countries than in countries that did not adopt the policy.

To date, Molyneux et al. (2020) is the only study that analyses the effects of negative interest rates on the volume of credit by considering several countries. However, our approach differs from that of Molyneux et al. (2020) on three respects. First, Molyneux et al. (2020) study the relationship between negative interest rates and loan volume, we go even further by considering the cost of credit and the volume of loans with different maturities. Second, we provide additional insights into the relationship between NIRP implementation and banks' credit risk through loan maturities. Third, while the study by Molyneux et al. (2020) covers 33 OECD countries and the period 2012-2016, we go further by analyzing the effects of NIRP on the lending behavior of 4072 banks located in 54 countries over a 10-year period from 2009 to 2018. In doing so, we complement the previous literature by detailing how banks' lending behavior evolves in the presence of negative interest rates.

3. Data and empirical methodology

3.1. Data

To assess the effects of negative interest rates on bank-lending behavior, we extract data from 5454 banks located in 122 countries around the world over a ten-year

period from 2009 to 2018. The data used for our estimates come from Fitch Connect, IMF, Datastream, and central banks. Our main source is the Fitch Connect database, which contains detailed information on the composition of banks assets and liabilities.¹⁶ Using the Difference-in-Differences method, we ensure that banks unaffected by NIRP (control group) have a similar trend before the implementation of NIRP with banks affected by this policy (treated group), in order to respect the requirement of a parallel trend between our two groups, at least prior the treatment. To do so, we use the holdings of liquid assets and market structure (measured with the Herfindahl-Hirschman Index) as a selection criterion to determine the control group that is as close as possible to the treated group. This shows that banks unaffected by NIRP, with similar lending behavior to the group treated before NIRP was set up, are those with a ratio of liquid assets to total assets above the 90th percentile and with a HHI index above the 40th percentile. Figure 1 illustrates this parallel evolution between our two groups before the introduction of negative interest rates.

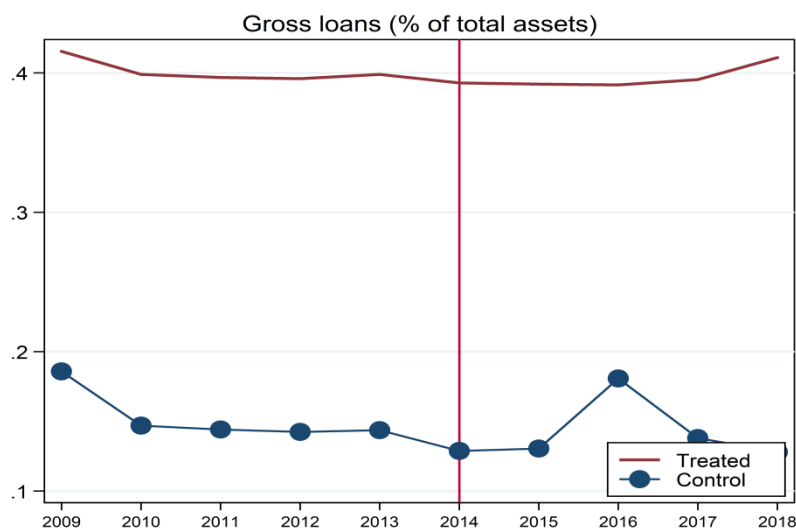


Figure 1. Average of gross loans (% of total assets) among treated banks (red line) and control banks (blue line) from 2009-2018. Following Molyneux et al. (2019, 2020), we consider 2014 as the year of implementation of NIRP to facilitate graphic reading.

¹⁶ Fitch Connect is a commercial database.

We have sorted our database by winsorizing the data at the 1st and 99th percentile level to ensure that outliers do not bias our estimates (e.g., when assets are less than zero or customer deposits are below zero). Our final database includes a large unbalanced dataset of 4072 banks in 54 low-, middle-, and high-income countries over the period 2009-2018, consisting of 25175 annual observations. While the treatment group consists of 3128 banks operating in 23 countries adopting NIRP¹⁷, the control group consists of 944 banks located in 31 countries not affected by negative interest rates.¹⁸

Table A1 displays the descriptive statistics of bank-specific control prior to the implementation of negative interest rates for the treated and control groups. We measure bank-lending behavior ($Lending_{i,k,t}$) using lending cost, lending supply, and lending maturity. As a proxy for lending cost, we use interest income on loans to gross loans (Int_inc). We use the gross loans to total assets as a proxy of lending supply (Lend_ta).¹⁹ To measure lending maturity, we use loans of different maturities (scaled by total assets) such as loans less than 3 months (Three_months), loans between 3 months and 12 months (Twelve_months), and loans above 5 years (Five_years).²⁰

The bank-specific controls ($\beta_{i,k,t}$). According to the previously mentioned literature, we use four specific characteristics of banks' balance sheets that can influence bank-lending behavior. First, we use the ratio of liquid assets to total assets (Liquidity) as proxy for bank liquidity. Second, we include capitalization, defined as equity to assets ratio (Capitalization). Third, we use customer deposits to total assets (Deposits), as a proxy for the bank funding. Finally, we proxy bank size with the logarithm of the bank's total assets (Size).

¹⁷ Denmark, ¹⁸ EMU member countries (without Estonia), Hungary, Japan, Sweden, Switzerland.

¹⁸ Argentina, Australia, Belarus, Bosnia and Herzegovina, Brazil, Canada, Croatia, Czech Republic, Egypt, El Salvador, Iceland, Indonesia, Kazakhstan, Korea (South), Kyrgyzstan, Malaysia, Mauritius, Morocco, New Zealand, Panama, Peru, Poland, Romania, Russia, Singapore, South Africa, Thailand, Tunisia, Turkey, Ukraine, United Kingdom.

¹⁹ The advantage of considering gross loans is that it takes into account the entire lending activity of banks and not just one type of loan. In their analysis, Heider et al. (2019), for example, considered only syndicated loans, which is only a fraction of what all banks do. Moreover, only the large banks are generally involved in syndicated loans.

²⁰ It might have been interesting to also examine the effects of NIRP on the supply of loans with maturities between 1 and 5 years. Unfortunately, we do not have this information in our database.

The country-specific controls ($Y_{k,t}$). In our empirical exercises we also consider country-specific controls. We employ the Herfindahl-Hirschman Index (HHI) to reflect the market concentration. It can take values between 0 (perfect competition) and 1 (monopoly). In addition, to account for macroeconomic heterogeneities between countries and for the demand of credit, we include inflation rate, unemployment rate, fiscal policy²¹, and real GDP growth rate.

3.2. Empirical methodology

To examine the effect of negative interest rates on bank-lending behavior, we use the Difference-in-Differences (DiD) methodology. DiD allows us to compare the effects of negative interest rates on bank-lending behavior for a treatment group of banks (Treated) with a control group of banks (Control) unaffected by NIRP.²² The empirical strategy is based on a series of panel regressions. Equation (1) summarizes our baseline model:

$$Lending_{i,k,t} = c + \alpha_1(Treated_{i,t} * Post_{k,t}) + \alpha_2\beta_{i,k,t} + \alpha_3Y_{k,t} + \theta_t + \lambda_i + \varepsilon_{i,k,t} \quad (1)$$

where $Lending_{i,k,t}$ is the bank-lending behavior (proxy with lending cost, lending supply, and lending maturity) for the bank i in country k at year t . $Treated_{i,t}$ is a dummy variable equal to 1 if bank i in country k is affected by NIRP, and 0 otherwise. $Post_{k,t}$ is a dummy variable equal to 1 in years following implementation of NIRP by country k and 0 before. The coefficient of α_1 is our DiD estimator in average of $Lending_{i,k,t}$ between Treated and Control groups. Using the Variance Inflation Factor (VIF), we test the control variables for multicollinearity. A mean VIF of 1.26 suggests that our control variables are not highly correlated (see Table A2 for the correlation matrix). In addition, the descriptive statistics in Table A1 display that the bank-specifics of the two groups are close prior to the

²¹ General government structural balance as a percentage of potential GDP.

²² Following Jobst and Lin (2016), we use the real interest rate as a robustness test. Indeed, a decline in the nominal interest rate could also reduce its real component, allowing inflation expectations to strengthen and boost aggregate demand. We find similar results to our baseline (not reported, but available on request).

implementation of treatment.²³ While $\beta_{i,k,t}$ refers to bank-specific controls, $Y_{k,t}$ refers to country-specific controls. θ_t , λ_i and $\varepsilon_{i,k,t}$ are respectively time fixed-effects, bank fixed-effects, and idiosyncratic error.²⁴ As suggested by Bertrand et al. (2004), we use robust and clustered standard errors at the bank level to control for heteroscedasticity and dependence between observations.

The Difference-in-Differences method is widely used in the literature analyzing the effects of negative interest rates on bank behavior (among others, Basten and Mariathan 2018; Heider et al. 2019; Lopez et al. 2020; Molyneux et al. 2019; Bounou 2020). As noted by Molyneux et al. (2019), the advantage of using this method is that it reduces potential endogeneity bias by controlling for omitted variable bias and reverse causality. Indeed, the objective of NIRP is to support economic activity and notably through the lending channel. The taxation of banks excess reserves by the central bank is intended to encourage banks to take up such liquidity to improve the supply of loans. Therefore, this new policy should impact bank-lending behavior (to a lesser extent at least) and not vice versa.

4. Empirical findings

4.1. Baseline results

Table 1 presents the results of the effects of negative interest rates on lending cost (column I), and on lending supply (column II) based on Equation (1). While interest income on loans (Int_inc) is our proxy for lending cost, gross loans to total assets is the proxy of lending supply (Lend_ta). Estimations are performed with fixed effects and standard errors are robust and clustered at bank level.

Looking at column I of Table 2.1, negative interest rates (denoted in Tables as NIRP-Effect) have the expected sign and magnitude. In the year following the

²³ Although our two groups have close characteristics prior to treatment (see Figure 1), we use the Propensity Score Matching in robustness to build our treatment and control groups. We obtain similar results to our baseline (see Section 4.3).

²⁴ Although previous studies on negative interest rates also include bank fixed effects in their estimates (e.g. Bounou, 2020; Lopez et al. 2020), we re-estimate Equation (1) by including country fixed effects. Our main results do not change even when considering country fixed effects (not reported but available on request).

introduction of negative interest rates, banks reduced the lending cost by 0.344 percentage points (pp). This result argues that the transfer of excess reserves from the central bank to the banks was accompanied by a reduction in the lending cost due to a large supply of liquidity. In the same vein, previous studies also find similar results, focusing on individual countries, namely Italy (Bottero et al. 2019) and Japan (Gunji, 2018).²⁵ Indeed, they also find that credit supply has increased for banks affected by negative interest rates, compared to those unaffected by NIRP. This result is consistent with the NIRP's objective of bringing inflation closer to its target. Indeed, by taxing excess bank reserves, central banks aim to increase the share of liquidity held by banks and thus reduce both bank and borrower financing costs (Coeuré, 2016). Estimates of bank-specific and country-specific controls are also in line with standard results (see Hong and Kandrac, 2018; Abuka et al. 2019).

Column II of Table 2.1 reports the results for the lending supply. The coefficient estimate on NIRP-Effect indicates a 0.022pp expansion of lending supply in countries affected by negative interest rates.²⁶ This result validates the presence of a monetary policy lending channel under negative interest rates (Gunji 2018; Basten and Mariathan, 2018; Bottero et al. 2019). Conversely, Arce et al. (2018) and Molyneux et al. (2020) find different effects of negative interest rates on the supply of loans (reduced or no effect). These different effects may stem from bank-specific characteristics (see Bottero et al. 2019; Heider et al. 2019) or the duration of the loans (Ortiz-Molina and Penas, 2008; Black and Rosen, 2016).

Finally, we analyze whether the effects of interest rates on credit volume differ according to the maturity of the loans to the real economy. To test this channel, we proxy lending maturity by using credit volumes with different maturities: loans with a maturity of less than 3 months (*Three_months*), loans with a maturity of between 3 and 12 months (*Twelve_months*) and finally loans with a maturity of

²⁵ Bounou and Mawusi (2021) also find a reduction in the cost of lending in countries affected by negative interest rates.

²⁶ Using the experience in Japan, Hong and Kandrac (2018) find that credit supply increased more for banks that were more affected by NIRP.

more than 5 years (Five_years). Table 2.2 details the results based on lending maturity.

Table 2.1. Negative interest rate policy, lending cost and lending supply

	Int_inc	Lend_ta
	(I)	(II)
NIRP-Effect	-0.344** (0.15)	0.022** (0.01)
Liquidity	0.042*** (0.01)	-0.003*** (0.00)
Capitalization	-0.026 (0.02)	-0.000 (0.00)
Deposits	-0.379 (0.99)	0.026 (0.02)
Size	-0.142 (0.30)	0.007 (0.01)
HHI	3.044 (2.08)	-0.027 (0.09)
Inflation	0.008 (0.02)	0.000 (0.00)
Unemployment	0.089** (0.04)	-0.005*** (0.00)
Fiscal	-0.116*** (0.03)	0.004 (0.00)
GDP	-0.002 (0.02)	-0.002 (0.00)
Constant	4.764** (2.33)	0.406*** (0.05)
Observations	25175	25175
Number of banks	4072	4072
R2 (within)	0.157	0.008
Year FE	Yes	Yes
Bank FE	Yes	Yes

Note: NIRP-Effect is our Difference-in-Differences estimator. It takes the value 1 for bank i , the year after country k implements NIRP and 0 before. Liquidity is the ratio of bank liquid assets to total assets. Capitalization is the ratio of bank equity to total assets. Deposits is the ratio of customer deposits to total assets. Size is the natural logarithm of bank total assets. HHI is the Herfindahl-Hirschman Index. Inflation is the yearly Consumer Price Index in percentage. Unemployment is the unemployment rate. Fiscal is the fiscal policy measured as general government structural balance as a percentage of potential GDP. GDP is the real GDP growth rate. Robust standard errors clustered by banks in parenthesis. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Column I of Table 2.2 presents the results of the estimates when the dependent variable is the total credits of less than 3 months duration. Our DiD estimator has the expected sign but the effect is statistically non-significant. We find that negative interest rates did not favor an increase in the supply of very short-term credit. One explanation for this would be that central banks, by introducing negative interest rates, would like banks to move toward a supply of credit of a longer duration, which has a greater effect on the real economy. This result also points to a lower credit risk during the NIRP implementation period, as loans with shorter maturities can be assimilated to a higher credit risk (Ortiz-Molina and Penas, 2008). Indeed, earlier studies have argued that an accommodative monetary policy encourage banks to shift short-term loans with long-term loans (among others, Berger et al. 2005; Black and Rosen, 2016). Columns II and III of Table 2.2 report the results for loans with maturities between 3 and 12 months and over 5 years, respectively. The results show that banks located in countries that adopted negative interest rates increased the volume of loans with terms between 3 and 12 months by 0.023 percentages. These results corroborate the previous ones by highlighting the effectiveness of the transmission of monetary policy to the real economy under negative interest rates. For loans over 5 years, the coefficient associated with our DiD estimator is positive and significant at 5% level. To sum up, these results show that negative interest rates have favored the increase in the supply of credit, precisely loans with maturities of more than 3 months.

Our previous results highlight the importance of the maturity of loans contracted in the transmission of monetary policy under negative interest rates. We can then assume that bank-specific characteristics would influence the impact of NIRP on lending activity. The coefficients associated with bank-specific and country-specific controls are consistent with the banking literature, which analyzes the relationship between monetary policy and lending channel.

4.2. The issue of bank heterogeneity

Our previous results highlight the presence of a lending channel of monetary policy under negative interest rates. Indeed, we show that in response to the introduction of NIRP, banks have reduced the cost of credit and increased the volume of loans, especially loans with terms between 3 months and 12 months and those over 5 years. It seems important to understand whether the increase in lending activity is homogeneous across all banks or whether the increase has been greater for some banks. If we consider that the composition of banks' balance sheets provides an essential piece of information on lending decisions, then one would expect that individual bank characteristics would have a significant impact on the performance of the lending channel. For instance, banks depending on their size and dependence on retail deposits potentially face different changes in their investment opportunities (Heider et al. 2019).

Table 2.2. Negative interest policy and lending maturity

	Lending maturity:		
	Three_months	Twelve_months	Five_years
	(I)	(II)	(III)
NIRP-Effect	-0.009 (0.01)	0.023*** (0.01)	0.008** (0.00)
Liquidity	-0.001 (0.00)	-0.001*** (0.00)	-0.001*** (0.00)
Capitalization	0.000 (0.00)	-0.001*** (0.00)	0.001* (0.00)
Deposits	0.002 (0.01)	0.011 (0.01)	0.013 (0.01)
Size	-0.007* (0.00)	0.000 (0.00)	0.014*** (0.00)
HHI	0.207** (0.09)	-0.079*** (0.02)	-0.155*** (0.04)
Inflation	0.000 (0.00)	-0.001* (0.00)	0.001*** (0.00)
Unemployment	-0.004*** (0.00)	-0.001* (0.00)	0.001 (0.00)
Fiscal	0.006*** (0.00)	0.001 (0.00)	-0.003*** (0.00)
GDP	-0.001 (0.00)	-0.002* (0.00)	0.000 (0.00)
Constant	0.149*** (0.04)	0.082*** (0.03)	0.175*** (0.04)
Observations	25175	25175	25175
Number of banks	4072	4072	4072
R2 (within)	0.005	0.003	0.080
Year FE	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes

Note: NIRP-Effect is our Difference-in-Differences estimator. It takes the value 1 for bank i , the year after country k implements NIRP and 0 before. Liquidity is the ratio of bank liquid assets to total assets. Capitalization is the ratio of bank equity to total assets. Deposits is the ratio of customer deposits to total assets. Size is the natural logarithm of bank total assets. HHI is the Herfindahl-Hirschman Index. Inflation is the yearly Consumer Price Index in percentage. Unemployment is the unemployment rate. Fiscal is the fiscal policy measured as general government structural balance as a percentage of potential GDP. GDP is the real GDP growth rate. Robust standard errors clustered by banks in parenthesis. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Therefore, in this section we focus on two key characteristics of banks: size and deposits, which are important for the following reasons. First, small banks with lower deposits tend to be more limited in terms of expanding the supply of credit. In addition, larger banks with higher deposits would respond more strongly to the introduction of NIRP by increasing their lending activity (Heider et al., 2019). Second, analyzing the effects of negative interest rates as a function of bank characteristics allows us to better document the relationship between NIRP and

banks' lending behavior, but more importantly, to define the channel that guides our results (Bottero et al. 2019). In doing so, we create a smaller number of peer groups using the median. For example, for size, a bank is considered small if its logarithm of total assets is below the median (6.30) and conversely it is large if its assets exceed the median.²⁷ Tables 2.3 shows the results of the impact of negative interest rates on bank-lending behavior across different type of banks.

In Table 2.3, columns I and II present the results according to bank size (small and large, respectively) and columns III and IV present results based on the reliance on deposits (low- and high-deposits, respectively). The results reported in Table 2.3 show that the reduction in the cost of lending was greater for large banks (-1.566pp) and for high-deposits (-1.493pp) compared to other banks affected by NIRP. However, we find that the increase in the supply of credit differs according to the characteristics of the banks. Indeed, our results highlight that small and low-deposit banks reduced the supply of credit in the year following the implementation of interest rates by 0.015pp and 0.011pp, respectively. In addition, we show that the characteristics of banks influence the supply of credit with different maturities. Indeed, while small and low-deposit banks have reduced the share of loans with maturities of less than 3 months, large and high-deposit banks have rather increased the share of loans with maturities of more than 5 years. Overall, banks affected by negative interest rates increased their lending activity to the economy, focusing more on long-term loans rather than on the supply of short-term loans. These results underline the importance of loan maturity in the transmission of monetary policy. In particular, the effectiveness of the transmission of monetary policy through the lending channel varies according to the maturity of the loans (see, Black and Rosen, 2016).

Table 2.3. Negative interest rate policy, lending and bank-specific characteristics

²⁷ We proceed in the same way for deposits (73%).

Int_Inc				
	Small	Large	Low-deposits	High-deposits
NIRP-Effect	-1.062*** (0.24)	-1.566*** (0.29)	-1.273*** (0.45)	-1.493*** (0.15)
R2(within)	0.191	0.256	0.134	0.310
Lend_ta				
	Small	Large	Low-deposits	High-deposits
NIRP-Effect	-0.015** (0.01)	-0.004 (0.01)	-0.011* (0.01)	-0.015 (0.03)
R2(within)	0.198	0.005	0.232	0.007
Three_months				
	Small	Large	Low-deposits	High-deposits
NIRP-Effect	-0.036*** (0.01)	-0.030** (0.01)	-0.030*** (0.01)	-0.042 (0.03)
R2(within)	0.179	0.005	0.126	0.007
Twelve_months				
	Small	Large	Low-deposits	High-deposits
NIRP-Effect	0.001 (0.00)	0.001 (0.00)	0.001 (0.00)	0.001 (0.00)
R2(within)	0.062	0.063	0.082	0.052
Five_years				
	Small	Large	Low-deposits	High-deposits
NIRP-Effect	0.021*** (0.00)	0.025*** (0.00)	0.018*** (0.00)	0.026*** (0.00)
R2(within)	0.071	0.129	0.107	0.098
Observations	9144	11288	6786	13646
Nbr.of banks	1498	1607	1251	1854

Note: NIRP-Effect is our Difference-in-Differences estimator. It takes the value 1 for bank i , the year after country k implements NIRP and 0 before. All estimates include bank-specific controls (i.e. liquid assets to total assets, equity to total assets, customer deposits to total assets, is the natural logarithm of bank total assets), country-specific controls (i.e., Herfindahl-Hirschman Index, yearly Consumer Price Index, unemployment rate, fiscal policy, real GDP growth rate), year- and bank-fixed effects. Robust standard errors clustered by banks in parenthesis. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

4.3. Further robustness checks

In this sub-section, we establish three robustness tests to our baseline results. First, based on the analysis of Rosenbaum and Rubin (1983), we check the robustness of our baseline results by combining Difference-in-Differences and Propensity Score Matching (PSM). Precisely, we use the Kernel Matching algorithm (Behejia and Wahba, 1999; Becker and Ichino, 2002). The results of this first robustness test are reported in Tables 2.A3.²⁸ As a second robustness check, we perform sub-sample analysis, assessing the effects of NIRP in OECD member countries (see Table 2.A4). Indeed, the Treated and Control groups are made up solely of banks located in OECD member countries. Finally, as we know, negative interest rates were implemented as a complement to other unconventional monetary policies, with the aim of providing more stimulus to economic growth. Therefore, to dissociate the effects of other monetary policy tools on bank-lending behavior, we (alternatively) use the three monetary aggregates (M1, M2, M3). These aggregates allow us to capture the evolution of other monetary policy tools, such as the various asset purchase programmes that boost the real economy through the (mostly) lending channel. The results of this last robustness test are reported in Tables 2.A5 and 2.A6. In summary, our main results remain robust after a series of tests, even taking into account the other monetary policy tools.

5. Conclusion

Since 2012, several central banks have introduced negative interest rates to reduce financing costs and thus promote credit expansion, with a view to boosting economic activity. This article documents how negative interest rates can impact bank-lending behavior. To this end, using Difference-in-Differences framework, we exploit balance sheet data from 4072 banks located in 54 countries over the period 2009-2018. To get better understanding about how negative interest rate policy

²⁸ We use a probit model to generate propensity scores (not reported, but available on request).

affects bank-lending behavior, we empirically assess the effects of negative interest rates on banks': (i) lending cost; (ii) lending supply; (iii) lending maturity.

Our results highlight that negative interest rates have favored a reduction in the lending cost of banks located in countries affected by negative interest rates. This reduction in financing costs has been accompanied by an increase in the lending supply in the year following the introduction of negative interest rates. Moreover, our findings provide further evidence of the link between negative interest rates and bank lending maturity. Negative interest rates have fostered an increase in the supply of credit, particularly loans with maturities ranging from 3 to 12 months and those over 5 years. We also find that these results depend on bank-specific characteristics such as reliance on retail deposits and size. In addition, large and high-deposits banks reacted more strongly to negative interest rates by adjusting their lending behavior. Our results are consistent with previous studies analyzing the effects of negative interest rates on the bank lending channel. Finally, these results remain robust by: (i) combining the Difference-in-Differences methodology and Propensity Score Matching; (ii) controlling the effects of other unconventional monetary policies; (iii) conducting sub-sample analysis.

The findings of this study show that negative interest rates have a significant impact on bank-lending behavior. They also indicate that the transmission of monetary policy under negative interest rates to the real economy depends on banks' specific characteristics. We believe that our study contains interesting insights for monetary policy, which might be useful when considering the effectiveness of negative interest rates.

Appendix

Table 2.A1. Descriptive statistics before NIRP

Variable	Obs.	Mean	Std. Dev.	Min	Max
Treated group					
Liquidity	10538	18.82	16.95	.51	98.45
Capitalization	10538	10.94	9.47	.02	98.77
Deposits	10538	61.53	15.26	1	98.02
Size	10538	6.44	1.79	-2.21	14.49
Control group					
Liquidity	2287	19.01	13.83	.08	96.17
Capitalization	2287	11.22	7.66	.01	92.85
Deposits	2287	59.06	35.28	0.4	95.93
Size	2287	8.30	2.88	.29	20.13

Note: Liquidity is the ratio of bank liquid assets to total assets. Capitalization is the ratio of bank equity to total assets. Deposits is the ratio of customer deposits to total assets. Size is the natural logarithm of bank total assets.

Table 2.A2. Correlation matrix

	L1.	L2.	L3.	L4.	L5.	L6.	L7.	L8.	L9.
L1.Liquidity	1								
L2. Capitalization	0.1787*	1							
L3.Deposits	-0.1008*	-0.3288*	1						
L4.Size	0.0698*	-0.1196*	-0.1956*	1					
L5.HHI	0.0792*	0.0100	0.0646*	-0.0546*	1				
L6.Inflation	0.0820*	0.1799*	-0.1315*	0.1123*	-0.0099	1			
L7.Unemployment	0.0838*	0.0761*	-0.2388*	0.0778*	0.0614*	0.082*	1		
L8.Fiscal	-0.1397*	-0.0892*	0.3279*	-0.2133*	-0.0614*	-0.258*	-0.522*	1	
L9.GDP	0.0298*	0.0859*	0.0266*	0.1621*	-0.0183*	0.018*	-0.180*	-0.005	1

Note: This table represents the correlation matrix among the variables used in the baseline regression. Correlations that are significant at least at 5% level are reported using star (*).

Table 2.A3. Difference-in-Differences and PSM results

	Int_inc	Lend_ta	Lending maturity:		
			Three months	Twelve months	Five years
	(I)	(II)	(III)	(IV)	(V)
NIRP-Effect (PSM)	-2.245*** (0.16)	0.065*** (0.01)	-0.019*** (0.00)	-0.060*** (0.00)	0.143*** (0.00)
Observations	25175	25175	25175	25175	25175

Note: This table presents the results by combining the Difference-in-Differences with Propensity Score Matching (PSM). NIRP-Effect is our Difference-in-Differences estimator. It takes the value 1 for bank i the year after country k implements NIRP and 0 before. All estimates include fixed effects and bootstrapped standard errors are in parentheses. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Table 2.A4. NIRP and lending behavior: Evidence from OECD member countries

	Int_inc	Lend_ta	Lending maturity:		
			Three_months	Twelve_months	Five_years
			(I)	(II)	(III)
NIRP-Effect	-0.653*** (0.17)	0.010 (0.01)	-0.001 (0.01)	0.008** (0.00)	0.002 (0.01)
Liquidity	0.043*** (0.02)	-0.003*** (0.00)	-0.001 (0.00)	-0.001*** (0.00)	-0.002*** (0.00)
Capitalization	-0.020 (0.03)	-0.000 (0.00)	0.000 (0.00)	-0.001** (0.00)	0.000 (0.00)
Deposits	-0.732 (1.11)	0.037 (0.02)	0.018 (0.02)	0.016* (0.01)	0.002 (0.02)
Size	-0.195 (0.38)	-0.002 (0.01)	-0.007 (0.01)	-0.005* (0.00)	0.010 (0.01)
HHI	-0.921 (1.25)	0.001 (0.13)	0.267** (0.13)	-0.064*** (0.02)	-0.202*** (0.05)
Inflation	0.081* (0.04)	0.007* (0.00)	0.007* (0.00)	0.001 (0.00)	-0.001 (0.00)
Unemployment	0.153*** (0.05)	-0.005*** (0.00)	-0.005*** (0.00)	-0.001* (0.00)	0.000 (0.00)
Fiscal	-0.109*** (0.03)	0.005 (0.00)	0.012*** (0.00)	-0.002*** (0.00)	-0.006*** (0.00)
GDP	0.015 (0.02)	0.001 (0.00)	0.002 (0.00)	-0.001*** (0.00)	-0.000 (0.00)
Constant	4.538* (2.74)	0.450*** (0.06)	0.088* (0.05)	0.100*** (0.02)	0.261*** (0.05)
Observations	21639	21639	21639	21639	21639
Number of banks	3329	3329	3329	3329	3329
R2 (within)	0.181	0.011	0.006	0.049	0.088
Year FE	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes

Note: NIRP-Effect is our Difference-in-Differences estimator. It takes the value 1 for bank i , the year after country k implements NIRP and 0 before. Liquidity is the ratio of bank liquid assets to total assets. Capitalization is the ratio of bank equity to total assets. Deposits is the ratio of customer deposits to total assets. Size is the natural logarithm of bank total assets. HHI is the Herfindahl-Hirschman Index. Inflation is the yearly Consumer Price Index in percentage. Unemployment is the unemployment rate. Fiscal is the fiscal policy measured as general government structural balance as a percentage of potential GDP. GDP is the real GDP growth rate. Robust standard errors clustered by banks in parenthesis. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Table 2.A5. NIRP, lending cost, and supply and unconventional monetary policies (UMPs)

	int_inc			Lend_ta		
	(I)	(II)	(III)	(IV)	(V)	(VI)
NIRP-Effect	-0.359**	-0.548***	-0.491***	0.022**	0.018**	0.020**
	(0.16)	(0.16)	(0.16)	(0.01)	(0.01)	(0.01)
M1	-0.006**			-0.001		
	(0.00)			(0.00)		
M2		0.013**			-0.000	
		(0.01)			(0.00)	
M3			0.033***			0.000
			(0.01)			(0.00)
Observations	25008	23784	24677	25008	23784	24677
Number of banks	4030	3773	3969	4030	3773	3969
R2 (within)	0.158	0.191	0.159	0.009	0.012	0.008
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Note: NIRP-Effect is our Difference-in-Differences estimator. It takes the value 1 for bank i , the year after country k implements NIRP and 0 before. Controls include bank-specific characteristics (the ratio of bank liquid assets to total assets, the ratio of bank equity to total assets, the ratio of customer deposits to total assets and the natural logarithm of bank total assets) and country-specific characteristics (the Herfindahl-Hirschman Index, the yearly Consumer Price Index in percentage, the unemployment rate, the fiscal policy measured as general government structural balance as a percentage of potential GDP and the real GDP growth rate). ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Table 2.A6. NIRP, lending maturity and unconventional monetary policies (UMPs)

	Three_months			Twelve_months			Five_years		
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)
NIRP-Effect	-0.009 (0.01)	-0.007 (0.01)	-0.011 (0.01)	0.023*** (0.01)	0.016*** (0.00)	0.022*** (0.01)	0.008** (0.00)	0.009* (0.00)	0.009** (0.00)
M1	0.001* (0.00)			-0.001*** (0.00)			-0.001*** (0.00)		
M2		0.000 (0.00)			-0.000 (0.00)			-0.000*** (0.00)	
M3			0.001* (0.00)			0.000 (0.00)			-0.001*** (0.00)
Observations	25008	23784	24677	25008	23784	24677	25008	23784	24677
Number of banks	4030	3773	3969	4030	3773	3969	4030	3773	3969
R2 (within)	0.005	0.005	0.005	0.004	0.059	0.003	0.083	0.087	0.084
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: NIRP-Effect is our Difference-in-Differences estimator. It takes the value 1 for bank i , the year after country k implements NIRP and 0 before. Controls include bank-specific characteristics (the ratio of bank liquid assets to total assets, the ratio of bank equity to total assets, the ratio of customer deposits to total assets and the natural logarithm of bank total assets) and country-specific characteristics (the Herfindahl-Hirschman Index, the yearly Consumer Price Index in percentage, the unemployment rate, the fiscal policy measured as general government structural balance as a percentage of potential GDP and the real GDP growth rate). ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Part 2 Bank Reactions to the Implementation of Negative Interest Rates

Chapter 3 Bank Margins and Risk-Taking in a Negative Interest Rate Environment: An Empirical Analysis of the Euro Area²⁹

Abstract

Recent evidence highlights that the implementation of negative interest rate policy (NIRP) reduces banks' net interest margins (NIM) because of the downwardly rigid customer deposit rate. This raises at least one question: Would the reduction of NIM (related to NIRP) encourage banks to take more risk? Using a panel dataset of 962 banks located in the euro area countries over the period 2011-2017, this paper aims to investigate the indirect effect of NIRP on banks' risk-taking through net interest margins. Our results confirm this assertion that negative interest rates reduce banks' NIM. We also highlight that the reduction in NIM due to NIRP did not induce banks to take more risk. Finally, we find that these effects were stronger for banks located in the core countries of the euro area.

JEL: E43, E52, E58, G21.

Keywords: Negative Interest Rates, Bank Margins, Bank Risk-Taking, Euro Area.

²⁹ This chapter is based on the paper "[OFCE Working Paper, N°10/2019](#)".

« *The NIRP had a negligible effect on bank profitability over the period from 2014 to 2019.* »
(Isabel Schnabel, 2020)³⁰

« *Negative rates will not provoke the collapse of the financial system.* »
(Mario Draghi, 2019)³¹

1. Introduction

Since the 2008-2009 Global Financial Crisis, many central banks have implemented a range of unconventional monetary instruments (including large scale asset purchases and forward guidance) to address low inflation and economic growth. Since 2012, several central banks (including the European Central Bank) have gradually introduced a negative interest rate policy (NIRP). According to Cœuré (2016a), the implementation of negative rates, by the European Central Bank (ECB)³², intended to increase the supply of credit by taxing banks' excess reserves at the central bank. This should lead to an increase in the supply and demand for loans thanks to a reduction in financing costs for both banks and borrowers. All of these effects should eventually promote economic growth and – with a time lag – lift inflation (Blot and Hubert, 2016; Jobst and Lin, 2016; Scheiber et al. 2016).

This unprecedented non-standard monetary policy measure raised at least two concerns: whether NIRP would contribute to reduce banks' net interest margins (NIM) and whether the potential effects on NIM would influence risk-taking. First, the introduction of negative interest rates could hinder the transmission of monetary policy if NIRP compress banks' net interest margins. This is because banks' lending rates fall in a linear fashion, but their funding costs are non-linear - interest rates on customer deposits are sticky - reducing net interest margins and ultimately impact

³⁰ Speech by Isabel Schnabel, Member of the Executive Board of the ECB, at the Roundtable on Monetary Policy, Low Interest Rates and Risk Taking at the 35th Congress of the European Economic Association:

<https://www.ecb.europa.eu/press/key/date/2020/html/ecb.sp200826~77ce66626c.en.html>

³¹ ECB Press Conference at Frankfurt am Main on 12 September 2019.

³² The ECB reduced its deposit facility rate to negative territory in June 2014 and it is currently at -0.5%.

banks profitability (Coeuré, 2016b). Second, in response to the reduction on bank margins related to NIRP, banks may have incentives to take more risk to compensate for this reduction (Heider et al. 2019; Bubeck et al. 2020), in line with traditional predictions of firm financing models (Jensen and Meckling, 1976; Keeley, 1990; Demsetz et al. 1996). In doing so, ultra-low even negative interest rates would promote the *search-for-yield*, encouraging investors to move away from government bonds to riskier assets (Rajan, 2005; Hannoun, 2015). However, recent empirical analyses point out that banks' risk incentives seem to be weaker in an environment of negative interest rates (Scheiber et al. 2016; Nucera et al. 2017; Arce et al. 2018; Bounou, 2020). Indeed, with negative interest rates, loan loss provisions (which represent the risks posed by non-performing loans) generally decline after interest rates fall, because the probability of loan defaults decreases as interest rates fall and growth prospects improve (Scheiber et al. 2016). This would then have a positive effect on bank profitability.

Based on this backdrop, the main purpose of this paper is to analyze the impact of the net interest margins of euro area banks on risk-taking in the presence of negative interest rates. In other words, we analyze the indirect effect of NIRP on risk-taking through banks' net interest margins. We then contribute to the understanding of the effects of negative interest rates by providing the first empirical evidence on this issue. The empirical literature has mainly focused on the effects of NIRP on banks': (i) interest margins and hence profitability (among others, Molyneux et al. 2019; Lopez et al. 2020; Bounou and Mawusi, 2021); (ii) risk-taking (among others, Nucera et al. 2017; Arce et al. 2018; Bounou, 2020; Bubeck et al. 2020), putting aside the fact that the impact of negative interest rates on bank margins could also influence banks' risk-taking. Using data from 962 banks located in 18 eurozone countries over the period from 2011 to 2017, this analysis then aims to fill this gap. In accordance with the analysis of Ciccarelli et al. (2013) we also assess whether the results of this analysis are the same between banks located in the core euro area countries and those located in the periphery of the euro area.

This paper begins by analyzing the effects of the implementation of NIRP by the ECB on banks' net interest margins (NIM). On the basis of this first analysis, we then investigate the effects of the change in NIM (related to NIRP) on the risk-taking of banks in the euro area countries. Finally, at each step of the analysis, we check whether these effects are homogeneous between the core and the periphery of the euro area countries.

Our analysis gives the following main results. First, our results support the hypothesis that negative interest rates reduce banks' net interest margins. Second, we find that the reduction in bank margins was stronger for banks operating in the core countries of the euro area. Third, we find that the reduction in bank margins (NIRP-related) has not led to an increase in risk-taking. Finally, our results remain unchanged, even after performing several robustness analyses.

This study is related to the empirical literature that examines: (i) the relationship between negative interest rates and banks, in terms of profitability and risk-taking (among others, Nucera et al. 2017, Molyneux et al. 2019, Boungou, 2020; Boungou and Mawusi, 2020; Bubeck et al. 2020); (ii) the relationship between banks' profitability and risk-taking (among others, Godlewski, 2005; Tan, 2016; Paroush and Schreiber, 2019; Xu et al. 2019; Martynova et al. 2020; Pessarossi et al. 2020). However, to the best of our knowledge, this is the first study that analyzes the relationship between banks' risk-taking and NIRP through the channel of the net interest margins. In addition, we shed additional light on the heterogeneous transmission of monetary policy among euro area countries.

The remainder of this paper is organized as follows. The second part describes the related literature. The third part presents the data and the empirical model. The fourth one presents and comments the empirical results. The last section concludes.

2. Related literature

Our research question focuses on the relationship between bank margins and risk-taking in a negative interest rate environment. It is therefore related both to the

literature that studies the effects of negative interest rates on banks in terms interest margins (and hence profitability) and risk-taking, and to the literature that studies the relationship between banks' profitability and risk-taking.

The literature on the relationship between monetary policy and bank performance points out that changes in the policy interest rate would impact banks' net interest margins (Altavilla et al. 2018; Claessens et al. 2018; Bikker and Vervliet, 2018; Molyneux et al. 2019; Lopez et al. 2020, Boungou and Mawusi, 2021). Indeed, this literature supports that reducing the monetary policy interest rate would squeeze bank margins and thus compromise the effectiveness of monetary policy transmission. However, the effectiveness of the transmission of changes in the policy interest rate depends on the sensitivity and speed of adjustment of the lending and deposit rates (Brei et al. 2020). Indeed, it seems that the lending rate would adjust faster than the deposit rate, leading to a compression of banks' net interest margins (Jobst and Lin, 2016; Boungou and Mawusi, 2021). The downward rigidity of the interest rate paid on deposits results from banks' reluctance to reduce or even apply a negative interest rate on customers' deposits due to legal constraints and fear of losing customers (Scheiber et al. 2016). Therefore, by refusing to pass on negative interest rates on customer deposits, banks' profits from maturity transformation will be negatively affected (Hannoun, 2015).

Recent studies provide empirical evidence of the compression of bank margins related to the environment of ultra-low (but positive) interest rates. Claesens et al. (2018) using data from 3385 banks in 47 countries over the period 2005-2013 analyze the effects of persistent low interest rates on bank margins and profitability. They find that low interest rates reduce bank margins because the interest rate paid on deposits declines less quickly than the interest rate on credit. The authors also show that the longer rates are low, the more the banks' NIM is affected. Focusing on euro area banks, Altavilla et al. (2018) also find that a prolonged period of low interest rates would reduce banks' net interest income. Bikker and Verviliet (2018) find similar evidence by focusing on the US banking sector.

In the same vein, Molyneux et al. (2019) analyze the influence of negative interest rates on the margins and profitability of 7359 banks operating in 33 OECD member countries over the period 2012-2016. They find that bank margins and profits fell in NIRP-adopter countries compared to countries that did not adopt the policy. Bounboua and Mawusi (2021) also find similar evidence. By decomposing the net interest margins of 9638 banks located in 41 countries over the period 2009-2018, Bounboua and Mawusi (2021) find that negative interest rates have compressed the bank NIM because the interest rate on deposits is downwardly rigid. In general, the results of the work on the relationship between the level of interest rate (ultra-low or negative) and banks' margins highlight that the reduction of the interest rates compresses banks' net interest margins. As a result, this reduction could negatively impact banks' profitability, reduce their equity capital, and jeopardize their financial stability (Zimmermann, 2017). In other words, the compression of bank margins related to changes in monetary policy rates could encourage banks to search for more profitable assets (*search-for-yield*) and thus potentially undermine financial stability.

We contribute to this literature by analyzing the relationship between bank margins and risk-taking in a negative interest rate environment, a relationship that has not been explored to date. Specifically, we analyze the effect of NIRP on banks risk-taking through the channel of net interest margins. In doing so, we provide the first empirical evidence of the relationship between banks' net interest margins and risk-taking in an environment of negative interest rates. Indeed, the traditional predictions of firm financing models indicate that the more banks' profitability increases, the less incentive there is for banks to take more risk (among others, Jensen and Meckling, 1976; Keeley, 1990; Demsetz et al. 1996). According to Martynova et al. (2020), this relationship seems to have been reversed since the 2008 Global Financial Crisis. Indeed, the authors argue that the most profitable banks are those that take the most risk, in particular because of the loosening of borrowing constraints favored by their status as profitable banks. Several empirical studies also challenge the idea that bank profitability should be encouraged to promote bank stability (among others; Bolt et al. 2012; Tan, 2016; Pessarossi et al. 2020). Using data from 266 banks in 26 European countries over the period from June 2001 to December 2014, Pessarossi

et al. (2020) find no evidence of a negative relationship between bank profitability and risk-taking³³.

In addition, previous work on negative interest rates highlights that banks' incentives to take risk would depend on the effects of negative interest rates on banks' overall profitability and thus on the adjustment of their activities to compensate for the reduction in bank margins (Scheiber et al. 2016; Molyneux et al. 2019, Boungou and Hubert, 2020; Lopez et al. 2020). These studies indicate that the effects of negative interest rates on bank profitability have been benign and thus limit incentives to take risk. Lopez et al. (2020), using data from 5200 banks from 27 advanced European and Asian countries over the period 2010-2017, show that banks compensated for the reduction in net interest margins by increasing their non-interest income activities, thus preserving overall bank profitability. Other analyses also show that banks' profitability has been spared from the negative effects of NIRP through increased fees and commissions (Molyneux et al. 2019) and reduced operating costs (Boungou and Hubert, 2020). Therefore, the risk profile of banks would not necessarily change in response to the implementation of negative interest rates.

Moreover, Scheiber et al. (2016) points out that the probability of default on loans decreases as interest rates fall and growth prospects improve, and this has a positive effect on banks' overall profitability. Furthermore, work on the relationship between negative interest rates and bank risk-taking shows that banks affected by the implementation of negative interest rates took less risk. Boungou (2020) investigating the effects of NIRP implementation on risk-taking of 9421 banks operating in 59 countries from 2009 to 2018, shows that banks' risk-taking was lower in countries affected by NIRP compared to banks located in countries that did not adopt this policy³⁴. Focusing on the Spanish banking sector, Arce et al. (2018) also find that the banks most affected by NIRP did not change their risk-taking behavior.

³³ Other studies find a negative relationship between bank profitability and risk taking (among others, Godlewski, 2005; Athanoglou et al. 2008; Paroush and Schreiber, 2019, Xu et al. 2019).

³⁴ Nucera et al. (2017) also find a reduction in banks' risk-taking in the euro area in response to the introduction of negative interest rates.

3. Data and empirical model

3.1. Data

Using panel data from 962 banks over the period 2011-2017, this study aims at analyzing the effects of the implementation of negative interest rate policy (NIRP) by the European Central Bank (ECB) on banks operating in euro area countries (without Estonia). We have sorted our database by deleting missing bank data and winsorizing the data at the 1st and 99th percentile level to ensure that outliers do not bias our estimates (for example, when bank total assets are less than zero or customer deposits are below zero). Although not including the latest modification in the rate of the ECB's deposit facilities in September 2019 (notably the change in the deposit facility rate from -0.4% to -0.5%), our sample takes into account all previous changes in the deposit facility rate and allows us to assess the effects of the implementation of negative interest rates on banks' net interest margins (NIM) and their effects on risk-taking.

Negative interest rate measures. In the context of a slump in economic growth and increasing risks of deflation, and with limited support from fiscal and structural policies, the ECB (and other central banks) decided, in addition to existing unconventional monetary policy measures, to go into the negative territory and therefore provide additional support (Arteta et al. 2018). Following Claessens et al. (2018), we use the annual average of the ECB deposit facility rate (id) to take into account the passage of the interest rate in negative territory. Furthermore to take into account the change of id , we introduce two other variables, in particular to capture the period of negative interest rates. First, we use a dummy variable (D_{NIRP}) that captures periods when the deposit facility rate is negative. This variable is equal to 1 from 2014 (as negative interest rates have been in place since June 2014 in the euro area) and 0 before. Second, we introduce an interaction term ($id * D_{NIRP}$) between nominal interest rate (id) and negative interest rate dummy variable (D_{NIRP}). This interaction variable allows us to capture the effects of additional reductions in negative interest rates.

Bank margin measure. We use the banks' net interest margins (NIM) to first validate the claim that negative interest rates would reduce the banks' NIM, and second to analyze how these effects would influence risk-taking by euro area banks. We measure the banks' NIM by using net interest income divided by total assets. Net interest income refers to the difference between the interest rate on credit and the interest rate paid on customer deposits. Previous empirical work points out that the introduction of negative interest rates would compress banks' net interest margins (among others Molyneux et al. 2019; Lopez et al. 2020; Bounou and Mawusi, 2021). This compression of margins would come from the customer deposit rate, which is downwardly rigid because banks would be reluctant to apply a negative rate on customer deposits (Jobst and Lin, 2016; Scheiber et al. 2016; Heider et al. 2019; Bounou and Hubert, 2020). We then expect to observe a negative and significant relationship between net interest margins and the implementation of NIRP.

Bank risk-taking measures. The main question of this paper is to assess how the reduction of margins due to negative interest rates would influence banks' risk-taking. Specifically, we evaluate the indirect effect of NIRP on banks' risk-taking through net interest margins. To measure banks' risk-taking, we use two complementary and widely used measures. First, we use the natural logarithm of the Z-score as a measure of banks' individual risk-taking³⁵. Z-score is defined as $(\text{ETA} + \text{ROA}) / \sigma_{\text{ROA}}$, where ETA is the equity to assets ratio, ROA is the return on assets and σ_{ROA} is the standard deviation of ROA³⁶. A higher Z-score implies a lower probability of risk-taking and, conversely, a higher probability of risk-taking. Second, as another measure of banks' risk-taking, we use risk weighted assets to total assets (RWA). RWA provides a measure of asset risk and its year-over-year change indicates the change in the risk profile of the banks' asset portfolio. Therefore, any changes in the RWA should - at least in part - reflect changes in the new business and thus capture the risk-taking of the banks in our sample.

³⁵ Thereafter, we use Z-score to refer to the natural logarithm of the Z-score.

³⁶ As Beck et al. (2013), we use a three-year rolling time window, rather than the full sample period, to compute the standard deviation of ROA to allow for time variation in the denominator of the z-score.

Given that net interest margins are an important source of income for banks, the squeeze on NIM could provide an incentive for banks to find new sources of income and thus potentially take more risk (Jobst and Lin, 2016; Scheiber et al. 2016), in line with: (i) the risk-taking channel of monetary policy (Borio and Zhu, 2012); (ii) the traditional theory that stipulates that the least profitable banks are those that take the most risk (Jensen and Meckling, 1976; Keeley, 1990). However, Schnabel (2020) mentions that over the 2014-2019 period, negative interest rates have had negligible effects on the overall profitability of euro area banks. In other words, euro area banks would have succeeded in compensating for the reduction in interest margins (allowing them to preserve their profitability) and thus limiting the recourse to riskier positions. Indeed, recent studies support that in response to the introduction of negative interest rates, and in order to preserve their profitability, banks would have increased their non-interest income (Lopez et al. 2020), reduced their expense costs (Scheiber et al. 2016; Boungou and Hubert, 2020), thus justifying less risk-taking (Nucera et al. 2017; Arce et al. 2018; Boungou, 2020). Furthermore, Martynova et al. (2020) point out that banks with less profit take less risk compared to those that are more profitable. In doing so, we expect to observe a positive non-significant relationship between net interest margins (NIRP-related) and banks' risk-taking. In other words, we assume that the reduction in net interest margins (related to NIRP) would not necessarily induce banks to take more risk³⁷.

Bank-specific controls. As determinants of bank margins, according to the banking literature, we use liquidity, capitalization, efficiency, deposits and size, respectively. As a liquidity of banks proxy, we take liquid assets to total assets. The banks have to hold a percentage of liquid assets in order to meet these short-term obligations in the case of a bank rush. As a result, a higher liquid asset ratio makes the bank more liquid and less vulnerable in the event of a bankruptcy. As other bank-specific characteristics, we use equity to assets ratio as a measure of bank capitalization. To capture the effect of efficiency, we include a bank's specific control, namely efficiency measured as the cost to income ratio. This ratio is typically used as an indicator of

³⁷ For more details on what banks can do to offset the negative effects of NIRP see Jobst and Lin (2016).

management's ability to control expenses (Kosmidou et al. 2008). We also include in our estimates the ratio customer deposits to total assets. In order to take into account the possible "too-big-to-fail" theory, bank size is included in our regressions, defined as the natural logarithm of banks' total assets.

Country-specific controls. The banking literature suggests that the environment in which banks operate may have effects on their behavior. As a result, the structure of the banking industry and the country's economic situation can affect banks' margins and risk-taking. We consider the real GDP growth rate (GDP) as a control of the business cycle. The growth rate of the yearly consumer price index (inflation) is used as a measure of the macroeconomic conditions. Finally, we use the Herfindhal-Hirschman Index (HHI) as a measure of banking market structure. This index is commonly accepted as a measure of concentration and it is calculated by squaring the market shares of each competing bank on the market. HHI ranges between 0 (perfect competition) and 1 (monopoly).

While our bank-specific data comes from Orbis Bank Focus³⁸, the country-specific control variables are extracted from Datastream. The descriptive statistics of the variables used in this study are displayed in Table 3.A.

3.2. Empirical model

Based on the analysis of Altavilla et al. (2018), we use OLS estimators with fixed effects to examine the effects of negative interest rates on the NIM of euro area banks and their effects on risk-taking. Our analysis is structured as follows: (i) we analyze the effects of NIRP on banks' net interest margins; (ii) we investigate how these effects (on NIM) influence banks' risk-taking decisions. As a result, the following equation (1) describes a bank net interest margins as a function of policy interest rate and other determinants of bank margins:

$$NIM_{i,k,t} = c + \alpha_1(id_{k,t} * Dnirp_t) + \alpha_2 X_{i,k,t-1} + \alpha_3 Y_{k,t} + \omega_i + \theta_t + \varepsilon_{i,k,t} \quad (1)$$

³⁸ Orbis Bank Focus is a global database of banks' financial statements and ownership structures maintained by Bureau van Dijk and Moody's Investors Service.

$NIM_{i,k,t}$ refers to net interest margins of bank i located in country k of the euro area at time t . While $id_{k,t}$ is the nominal interest rate of the ECB's deposit facility, $Dnirp_t$ is the dummy variable that takes the value 1 from 2014 (year of introduction of negative interest rates by the ECB) and 0 before. α_1 is our coefficient of interest that captures the effects of further reductions in negative interest rates. Bank-specific controls are captured by $X_{i,k,t-1}$, the country-specific controls is represented with $Y_{k,t}$. The choice of these control variables is based on the literature on the determinants of bank profitability (among others, Athanasoglou et al. 2008, Kosmidou et al. 2008; Garcia-Herrero et al. 2009). ω_i , θ_t and $\varepsilon_{i,k,t}$ are respectively bank fixed effects, time (year) fixed effects and idiosyncratic error. Table 3.B presents the correlation matrix of the control variables included in all our regressions.

Based on the estimation results of equation (1), we then want to determine the influence of NIM reduction (due to NIRP) on banks' risk-taking. To do this, we use equation (1) to determine the predicted values of NIM. These predicted values are then fed into the equation (2) on banks' risk-taking. The regression model then becomes the following:

$$Risk_{i,k,t} = c + \beta_1 \widehat{NIM}_{i,k,t} + \beta_2 X_{i,k,t-1} + \beta_3 Y_{k,t} + \theta_t + \varepsilon_{i,k,t} \quad (2.1)$$

where $Risk_{i,k,t}$ is the risk-taking measures (alternatively, Z-score and RWA) for bank i operating in country k of the euro area at time t . $\widehat{NIM}_{i,k,t}$ is the predicted values of net interest margins by negative interest rates from equation (1) of the bank i in the euro area country k at time t . This predicted variable allows us to assess the effects of the compression of net interest margins caused by negative interest rates on banks' risk-taking.

Another specification of equation (2) is to combine the banks' NIM with the negative interest rate dummy variable ($Dnirp_t$). This interaction term also allows us to capture the changes in the NIM (in a negative interest rate environment) on risk-taking by euro area banks. We expect to obtain similar results considering both equation (2.1) and equation (2.2) specifications. Robust standard errors are clustered at the bank level in all estimates.

$$Risk_{i,k,t} = c + \beta_1(NIM_{k,t} * Dnirp_t) + \beta_2X_{i,k,t-1} + \beta_3Y_{k,t} + \omega_i + \theta_t + \varepsilon_{i,k,t} \quad (2.2)$$

4. Empirical results

This section presents and comments the results of the study. In the first subsection, we assess the effects of negative interest rate on banks net interest margins (Table 3.1) and whether these effects are similar between the core and periphery of the euro area countries (Table 3.2). We then analyze whether the effects of NIRP on NIM would influence banks' risk-taking (Table 3.3) and how these effects evolve between the core and the periphery of the euro area (Table 3.4).

4.1. The effects of negative interest rates on bank margins

In this subsection, we present the results of the effects of negative interest rates on banks' net interest margins. The results are reported in Table 3.1.

Table 3.1. NIRP and bank margins

	NIM		
	(I)	(II)	(III)
id	0.232*** (0.03)		
Dnirp		-0.028*** (0.00)	
id*Dnirp			0.233*** (0.04)
Bank FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Observations	3098	3098	3098
Banks	962	962	962
R2 (within)	0.459	0.459	0.459

Note: Note: id is the ECB's deposit facility rate. Dnirp is NIRP-dummy equals to 1 from 2014 and 0 before. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, cost to income ratio, customer deposits to total assets), 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. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Column I of Table 3.1 presents results using only the ECB deposit facility rate as the independent variable of interest. The results show that the reduction in the deposit facility rate by 1 percentage point (pp) implies a reduction in the NIM of 0.23 pp. This result is consistent with previous analyses on the effects of low (but positive) monetary policy interest rates on bank profitability and margins (among others, Bikker and Vervliet, 2018; Claessens et al. 2018; Brei et al. 2020). For instance, by analyzing the US banking sector, Bikker and Vervliet (2018) show that the low interest rate environment compresses banks' net interest margins.

In addition, by assessing the changes in the NIM during the period of negative interest rates (column II), we find that during the NIRP implementation period ($Dnirp_t$), euro area banks experienced a deterioration in NIM (-0.03pp). The results presented in column III of Table 3.1 support our previous results by highlighting that the additional reductions in the deposit facility rate over the period 2014-2017 have compressed the NIM of banks operating in the euro area by an average of 0.23pp. This result supports the assumption that negative interest rates reduce banks' net interest margins (see, Molyneux et al. 2019; Lopez et al. 2020; Boungou and Mawusi, 2021). Using data from 7359 banks in the 33 OECD member countries over the period 2012-2016, Molyneux et al. (2019) also show that bank margins have decreased in countries that have adopted negative interest rates compared with countries that have not adopted this policy.

Table 3.2. NIRP and bank margins: Core vs. periphery

	NIM					
	Core			Periphery		
	(I)	(II)	(III)	(IV)	(V)	(VI)
id	0.295*** (0.05)			-0.010 (0.07)		
Dnirp		-0.042*** (0.01)			-0.204*** (0.01)	
id*Dnirp			0.343*** (0.09)			-0.131 (0.14)
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1461	1461	1461	1637	1637	1637
Banks	556	556	556	406	406	406
R2 (within)	0.470	0.470	0.470	0.486	0.486	0.486

Note: id is the ECB's deposit facility rate. Dnirp is NIRP-dummy equals to 1 from 2014 and 0 before. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, cost to income ratio, customer deposits to total assets), 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. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

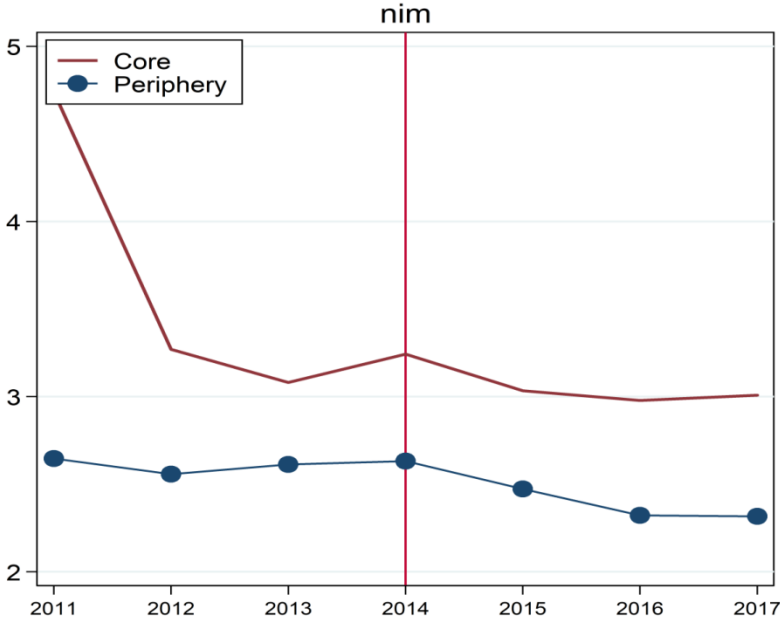
In general, our results point out that reductions in the ECB deposit facility rate reduce the net interest margins of banks located in the euro area countries. Based on previous work on the heterogeneous transmission of monetary policy within euro area countries (Ciccarelli et al. 2013), we then assess whether banks located in euro area countries (particularly in the core and periphery) have been similarly impacted by the implementation of NIRP (results reported in Table 3.2). To do so, we organize our sample of euro area countries into two groups, consisting of 9 countries for the core (Austria, Belgium, Finland, France, Germany, Latvia, Lithuania, the Netherlands and Slovakia) and 9 others for the periphery (Cyprus, Greece, Ireland, Italy, Luxembourg, Malta, Portugal, Slovenia and Spain)³⁹. Figure 3.1 shows the evolution of the NIM of banks located in the core and those located in the periphery of the euro area, before and after the implementation of NIRP.

The results in Table 3.2 (columns II and V) show that the negative interest rate environment has affected both core and periphery banks in the euro area. However, the reduction of the deposit facility rate over the period 2014-2017 by 1pp further

³⁹ The number of banks per country in the core and periphery of the euro area countries is presented in Table 3.C.

compressed the NIM of core banks by 0.34pp (column III) and with no significant effect for the periphery (column VI). These results suggest that banks located in the core countries of the euro area are more sensitive to interest rate changes by the European Central Bank compared to banks located in the periphery of the euro area. Thus, these results highlight that the results in Table 3.1 are potentially explained by the core countries of the euro area. Overall, this result sheds additional light on the heterogeneous transmission of monetary policy in the euro area countries.

Figure 3.1. The evolution of banks' net interest margins.



Note: Average NIM of banks located in the core countries of the euro area (red line) and banks located in countries on the periphery of the euro area (blue line) from 2011-2017. NIM is the yearly difference between interest rate on credit and interest rate on customer deposits divided by total assets. 2014 is the year of implementation of negative interest rates by the ECB.

4.2. The effects of the reduction in NIRP-related margins on banks' risk taking

In this section, we now analyze the effect of NIRP on banks' risk-taking through the channel of the net interest margins. Specially, we investigate whether, in response to the squeeze in net interest margins due to NIRP, banks in the euro area countries have been encouraged to take more risk. To do so, we use the two specifications of equation (2), namely to define the predicted values of the NIM using equation (2.1) and to use an interaction variable between the NIM and the negative interest rate dummy variable (equation 2.2). These two specifications allow us to assess how

changes in banks' net interest margins in a negative interest rate environment influence their risk-taking. The results of this analysis are reported in Table 3.3. Indeed, considering either of the two specifications in equation (2), we find that the reduction in margins associated with NIRP had no significant effect on risk-taking by euro area banks, measured using the Z-score and RWA. In other words, the reduction in net interest margins did not increase banks' incentives to take more risk. Unsurprisingly, we do not find a significant effect in distinguishing between the core and the periphery countries of the euro area (see, Table 3.4). In addition, this result undoubtedly echoes Benoît Coeuré's speech (2016b) where he notes that many banks have been able to do more to offset the decline in interest income by increasing loan volumes, lowering interest expenses, reducing risk provisions and capital gains.

Table 3.3. Bank margins (NIRP-related) and risk-taking

	Z-score		RWA	
	(I)	(II)	(III)	(IV)
\widehat{NIM}	-3.022 (46.19)		4.740 (7.80)	
NIM*Dnirp		-24.656 (19.94)		5.640 (5.80)
Bank FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	2962	3098	2962	3098
Banks	920	962	920	962
R2 (within)	0.015	0.015	0.422	0.446

Note: \widehat{NIM} is the predicted values of net interest margins by negative interest rates from equation (1). NIM refers to net interest margins. Dnirp is NIRP-dummy equals to 1 from 2014 and 0 before. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, cost to income ratio, customer deposits to total assets), 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. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Therefore, despite a reduction in NIM related to NIRP, euro area banks would have taken less risk. Based on the detailed loan-level information for Spain, Arce et al. (2018) also find that there is no differences in risk-taking among banks whose net interest income was affected by negative interest rates compared to those not affected by this policy. Our result is also consistent with Martynova et al. (2020) who supports

that a low level of profitability does not imply an increase in risk-taking. In the same vein, analyzing the Chinese banking industry over the period 2003-2011, Tan (2016) also finds no significant effect of bank margins on risk-taking. Previous work on the relationship between risk-taking and negative interest rates also points out that risk-taking has been lower in NIRP countries (Nucera et al. 2017, Boungou, 2020). For instance, Boungou (2020) shows that bank risk-taking was lower in countries affected by negative interest rates compared to those unaffected by NIRP. However, the lack of effect on risk-taking, despite a reduction in net interest margins, may be related to the banks' response channels to NIRP to preserve their profitability, thus reducing incentives to take risk. Indeed, in response to the introduction of negative interest rates, banks would have diversified their sources of income (Molyneux et al. 2019; Lopez et al. 2020), reduced their costs (Boungou and Hubert, 2020), thus making it possible to compensate for the reduction in net interest margins (Lopez et al. 2020) and thus justifying a smaller effect or no effect on banks' overall profitability (Molyneux et al. 2019).

Overall, the results of our research show that despite a reduction in net interest margins, caused by the shift of interest rates into negative territory by the ECB, banks seem to have managed to compensate for the decline in bank margins and thus limit their recourse to riskier positions. In addition, Schnabel (2020) pointed out that the negative effects from lower net interest income and the charge on excess reserves were broadly compensated by a reduction in loan-loss provisions.

Table 3.4. Bank margins (NIRP-related) and risk-taking: Core vs. periphery

	Z-score				RWA			
	Core		Periphery		Core		Periphery	
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
\widehat{NIM}	-206.256 (158.42)		80.535 (91.82)		-8.901 (10.34)		32.572** (13.50)	
NIM*Dnirp		4.177 (28.22)		-1.099 (40.92)		-5.770 (5.40)		-8.840 (10.40)
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1379	1461	1583	1637	1379	1461	1583	1637
Banks	527	556	393	406	527	556	393	406
R2 (within)	0.186	0.180	0.015	0.016	0.172	0.192	0.015	0.555

Note: \widehat{NIM} is the predicted values of net interest margins by negative interest rates from equation (1). NIM refers to net interest margins. Dnirp is NIRP-dummy equals to 1 from 2014 and 0 before. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, cost to income ratio, customer deposits to total assets), 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. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

4.3. Further robustness checks

In order to check the robustness of our results, we perform three tests by: (i) controlling for potential endogeneity bias; (ii) using alternative risk-taking measures; (iii) controlling for other unconventional monetary policy measures.

Previous studies on the relationship between monetary policy and bank (in terms of profitability and risk-taking) point out that this relationship can be endogenous (among others, Athanasoglou et al. 2008; Garcia-Herrero et al. 2009; Maddaloni and Peydró, 2011; Martynova et al. 2020). Indeed, these studies show that central banks make monetary policy decisions based on the observed behavior of banks and vice versa. Consequently, this potential endogeneity bias can be linked either to the existence of a reverse causality between monetary policy and bank profitability (risk-taking), and/or to the bias of omitted variables. To overcome this potential endogeneity bias, a lagged dependent variable is included and dynamic panel estimates are used. More precisely, we apply the two-step system generalized method of moments (system GMM) developed by Arellano and Bond (1991) and further advanced by Arellano and Bover (1995) and Blundell and Bond (1998) that

provides consistent estimation in dynamic model with lags of dependent variable. Tables 3.D and 3.E show the results using dynamic estimators. The results we obtain (using the system GMM) do not differ from those found using OLS estimators with fixed effects. In other words, although identifying potential endogeneity bias, we find similar results to our main results.

Second, we analyze that our results on banks' risk-taking in the euro area are not influenced by how we measure risk-taking. Therefore, we use two alternative measures of banks' risk-taking, namely the share of non-performing loans in total loans (NPLS) and loan loss provisions on total loans (Provision). These two alternative measures, although related, provide us with information on the lending activity of banks, particularly the risks associated with non-performing loans. As Scheiber et al. (2016) suggest low or even negative interest rates would reduce loan loss provisions (and thus the associated risks) because the probability of default on loans decreases as interest rates fall and growth prospects improve. In addition, the compression of net interest margins should be accompanied by a reduction in NPLS and provisions, which would improve banks' profitability. Therefore, the reduction in NIM related to NIRP is also not expected to result in an increase in NPLS and provisions. The results of this analysis are reported in Table 3.F. Even considering these two alternative measures of bank risk-taking, our overall results remain unchanged.

Finally, we test the robustness of our main results by controlling for other unconventional monetary policies (UMPs). Indeed, the ECB has brought its deposit facility rate into negative territory in addition to other unconventional monetary policy measures, such as securities purchase programs limited to covered bonds and asset-backed securities. On March 9, 2015, the ECB expanded its securities purchase programs to include public sector bonds (PSPP). The effects of these other UMPs measures should then be decoupled from the introduction of negative interest rate policy (in place since June 2014). To do this, we include in our estimates the monetary aggregate M3, in order to take into account the developments in the ECB's balance sheet. Our results (reported in Tables 3.G and 3.H) underline that the effects

of negative interest rates on banks' net interest margins (and their effects on risk-taking) remain unchanged even when controlling for other unconventional monetary policies.

5. Conclusion

Since 2012, seven central banks in Europe and Bank of Japan have implemented negative interest rate policy, which aimed at stimulating economic growth by avoiding deflationary risk and domestic currency appreciation. This unconventional monetary policy tool is still at the heart of the political and academic debate regarding its potential effects on banks' profitability and risk-taking.

In this paper, we analyze the impact of the introduction of negative policy interest rates (NIRP) by the European Central Bank on the net interest margins of euro area banks and how these effects influence risk-taking. To do so, we use a panel dataset from 962 banks operating in 18 euro area countries over a seven-year period from 2011 to 2017. We complete our analysis by assessing whether the effects of NIRP on bank margins (and their effects on risk-taking) are similar between banks located in core euro area countries and those located in the periphery of the euro area.

The assumption that negative interest rates reduce banks' net interest margins is confirmed by this study. Indeed, our results highlight that negative interest rates have reduced the NIM of banks operating in the euro area. We also find that the reduction in margins was stronger for banks located in the core countries of the euro area. Finally, our results show that despite the reduction in net interest margins (due to NIRP), banks were not encouraged to take more risk. These results hold controlling for potential endogeneity bias, risk measures and other unconventional monetary policies.

The main implication of this study is that the reduction in banks' net interest margins associated with NIRP does not necessarily imply the use of riskier positions by banks. This may reflect the fact that banks have adjusted their business activities in

order to compensate (at least partially) for possible losses related to the negative interest rate environment. While there is a consensus that NIRP per se does not in itself hamper bank profitability, one avenue for further research could be to determine whether maintaining this policy for an extended period of time could, on the contrary, negatively affect the banks' profitability.

Appendix

Table 3.A. Descriptive statistics

Variable	Definition	Observation	Mean	Std. Dev.	Min	Max
NIM	Net interest income to total assets	3098	0.022	0.006	-0.004	0.077
id	ECB's deposit facility rate	3098	-0.157	0.208	-0.4	0.25
Dnirp	Dummy NIRP equals to 1 from 2014 and 0 before.	3098	0.609	0.488	0	1
Z-score	The natural logarithm of Z-score	3098	2.284	3.565	-4.331	37.652
RWA	Risk weighted assets to total assets	3098	0.570	0.145	0.038	0.978
Size	Natural logarithm of total bank assets.	3098	6.884	2.103	2.798	14.447
Capitalization	Equity to asset ratio	3098	0.094	0.035	0.009	0.550
Liquidity	Liquid assets to total assets	3098	0.117	0.102	0	0.930
Efficiency	Cost to income ratio	3098	0.650	0.120	0.046	1
Deposits	Customer deposits to total assets	3098	0.612	0.180	0	0.972
HHI	Herfindahl-Hirschman index	3098	0.085	0.040	0.037	0.524
GDP	Real GDP growth rate	3098	0.767	1.722	-9.2	10.818
Inflation	Growth rate of the yearly consumer price index	3098	1.210	1.103	-3.165	4.222

Table 3.B. Correlation matrix

	Size	Capitalization	Liquidity	Efficiency	Deposits	HHI	GDP	Inflation
Size	1							
Capitalization	-0.391	1						
Liquidity	0.146	0.004	1					
Efficiency	-0.170	-0.101	0.056	1				
Deposits	-0.290	-0.005	0.056	0.300	1			
HHI	0.168	0.041	0.140	-0.109	-0.073	1		
GDP	0.051	-0.041	0.132	0.160	0.411	-0.003	1	
Inflation	-0.060	0.007	-0.027	0.149	-0.147	-0.082	-0.238	1

Note: This table represents the correlation matrix among the variables used in the regressions. Size is the natural logarithm of bank total assets. Capitalization is the ratio of bank equity to total assets. Liquidity is the ratio of bank liquid assets to total assets. Efficiency is the cost to income ratio. Deposits is the ratio of customers' deposits to total assets. HHI is the Herfindahl-Hirschman Index. GDP is the real GDP growth rate. Inflation is (the growth rate of) the yearly consumer price index.

Table 3.C. The number of banks per euro area country

Core		Periphery	
Austria	12	Cyprus	9
Belgium	9	Greece	4
Finland	5	Ireland	1
France	23	Italy	327
Germany	491	Luxembourg	3
Latvia	6	Malta	6
Lithuania	4	Portugal	34
Netherlands	5	Slovenia	9
Slovakia	1	Spain	13
<i>Total</i>	<i>556</i>	<i>Total</i>	<i>406</i>

Table 3.D. NIRP and bank margins: Dynamic results

	NIM		
	(I)	(II)	(III)
NIM_t-1	0.982*** (0.09)	0.726*** (0.26)	0.857*** (0.21)
id	0.050* (0.03)		
Dnirp		0.018 (0.02)	
id*Dnirp			0.080** (0.04)
Bank FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Observations	2549	2549	2549
Banks	913	913	913
Instruments	19	23	29
Hansen (p-value)	0.150	0.208	0.442
AR(1)	0.000	0.006	0.000
AR(2)	0.210	0.117	0.403

Note: The estimations are based on system GMM estimator (Blundell and Bond, 1998). id is the ECB's deposit facility rate. Dnirp is NIRP-dummy equals to 1 from 2014 and 0 before. All estimates include one year lagged bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, cost to income ratio, customer deposits to total assets), 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. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 3.E. Bank margins and risk-taking: Dynamic results

	Z-score		RWA	
	(I)	(II)	(III)	(IV)
Risk_t-1	0.848*** (0.13)	0.886*** (0.11)	0.791*** (0.15)	0.781*** (0.08)
\widehat{NIM}	-0.262 (1.85)		-0.373 (0.70)	
NIM*Dnirp		-8.827 (22.11)		0.555*** (0.18)
Bank FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	2462	2549	2462	2549
Banks	881	913	881	913
Instruments	18	20	23	18
Hansen (p-value)	0.215	0.545	0.268	0.504
AR(1)	0.037	0.042	0.000	0.000
AR(2)	0.100	0.100	0.818	0.712

Note: The estimations are based on system GMM estimator (Blundell and Bond, 1998). \widehat{NIM} is the predicted values of net interest margins by negative interest rates from equation (1). NIM refers to net interest margins. Dnirp is NIRP-dummy equals to 1 from 2014 and 0 before. All estimates include one year lagged bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, cost to income ratio, customer deposits to total assets), 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. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 3.F. Bank margins (NIRP-related) and other risk-taking measures

	NPLS		Provision	
	(I)	(II)	(III)	(IV)
\widehat{NIM}	0.507 (0.55)		-0.167 (0.11)	
NIM*Dnirp		-0.160 (0.30)		0.014 (0.07)
Bank FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	2962	3098	2962	3098
Banks	920	962	920	962
R2 (within)	0.448	0.445	0.331	0.333

Note: \widehat{NIM} is the predicted values of net interest margins by negative interest rates from equation (1). NIM refers to net interest margins. Dnirp is NIRP-dummy equals to 1 from 2014 and 0 before. All estimates include one year lagged bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, cost to income ratio, customer deposits to total assets), 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. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 3.G. NIRP and bank margins (controlling for other UMPs)

	NIM		
	(I)	(II)	(III)
id	0.023*** (0.00)		
Dnirp		-0.022*** (0.00)	
id*Dnirp			0.036*** (0.01)
M3	0.005*** (0.00)	0.005*** (0.00)	0.005*** (0.00)
Bank FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Observations	3098	3098	3098
Banks	962	962	962
R2 (within)	0.459	0.459	0.459

Note: id is the ECB's deposit facility rate. Dnirp is NIRP-dummy equals to 1 from 2014 and 0 before. M3 is the monetary aggregate M3. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, cost to income ratio, customer deposits to total assets), 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. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 3.H. Bank margins and risk-taking (controlling for other UMPs)

	Z-score		RWA	
	(I)	(II)	(III)	(IV)
\widehat{NIM}	0.388 (5.94)		-0.061 (0.10)	
NIM*Dnirp		-24.655 (19.93)		-0.564 (0.58)
M3	-1.052 (1.25)	-1.231 (1.32)	0.001 (0.02)	-0.023 (0.02)
Bank FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	2962	3098	2962	3098
Banks	920	962	920	962
R2 (within)	0.015	0.015	0.422	0.446

Note: \widehat{NIM} is the predicted values of net interest margins by negative interest rates from equation (1). NIM refers to net interest margins. Dnirp is NIRP-dummy equals to 1 from 2014 and 0 before. M3 is the monetary aggregate M3. All estimates include bank-specific (i.e., natural logarithm of total assets, equity to assets ratio, liquid assets to total assets, cost to income ratio, customer deposits to total assets), 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. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Chapter 4 Channels of Banks' Responses to Negative Interest Rates⁴⁰

Abstract

Facing a potential zero lower bound on retail 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 3645 banks in 59 countries from 2011 to 2018. We find that the decrease in interest income due to negative interest rates has been mitigated only partially by an increase in non-interest income. We show that banks responded 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 banks 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 have been able to better respond through an increase of net non-interest income.

JEL codes: C2, E5, G2.

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

⁴⁰ This chapter is co-authored with Paul Hubert and has been published in [Journal of Economic Dynamics and Control](#), 2021, Volume 131, 104228.

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 retail deposit rates (Brunnermeier and Koby, 2018). However, it seems that the pass-through of negative interest rates to deposit rates is not full 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 retail deposit rate: (i) some legal constraints and (ii) the fear of a "cash rush" (Scheiber et al. 2016). Consequently, the negative interest rate policy (NIRP) could negatively affect banks' profitability by compressing net interest margins due to a potential threshold effect around the zero lower bound on deposit rates. Some recent studies show that negative interest rates have led to a compression of net interest income, although they have had little or no effect on banks' overall profitability (see Lopez et al. 2020, Molyneux et al. 2019).

This question of how commercial banks have been able to cushion and offset the fall in net interest margins due to negative interest rates then arises. In order to preserve their profitability, commercial banks faced different options: (i) foster credit supply to mitigate the reduction in price with an increase in volumes, (ii) redirect their income from interest products towards non-interest sources (such as fees and commissions), (iii) develop other sources of income unrelated to the lending activity, (iv) reduce their operating costs (such as salaries and employee benefits) by focusing more on digital banking for instance, or (v) reduce the interest rate paid on non-customer deposit liabilities. Against this backdrop, the objective of this paper is to investigate empirically the channels through which banks have responded to negative interest rates. We also aim at exploring which bank characteristics influence the banks' response to negative interest rates. The analysis draws on yearly bank-

level data for 3645 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.

To explore this question, we use a difference-in-differences (DiD) approach based on bank-level data 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 allows us to examine whether banks' responses to NIRP depend on their characteristics. The key assumption is that the control and treatment groups are comparable prior to the treatment. We pay a special attention to identify and construct a control group of banks that is as close as possible to our treatment 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 cross-validate our results.

This paper differs from the existing literature in three 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 to NIRP and assess whether keeping this policy for a prolonged period of time might have negative consequences for banks. It also assess whether these channel responses to NIRP differ according to banks' balance sheet characteristics. Second, we pay special attention to the identification of a control group that experiences similar dynamics to the treatment group. Using only a dummy for when the NIRP was implemented might lead to unreliable conclusions if the treated and control groups were already having differentiated dynamics before the implementation of NIRP. Third, 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 3645 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). The control group closer to the treatment group is composed of the largest banks (with a size above the 80th percentile), a share of liquid assets greater than the 10th percentile, and whose HHI index is greater than the 40th percentile.⁴¹ For robustness, we construct alternative control groups based on various combinations of these thresholds allowing for different coverage 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.

Our results confirm evidence of the existence of a zero lower bound on retail deposit interest rates. Our results highlight that banks located in countries that have adopted NIRP have been 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 (because of its downward rigidity, see Leveuge and Sahuc, 2020) but rather from the reduction in other interest expenses (the interest paid on non-customer deposit liabilities). We also find that banks increased 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 (such as personnel expenses) rather than to an increase in fees and commissions. Overall, our results suggest that negative interest rates have reduced banks' net interest income,

⁴¹ Our results are robust to using propensity score matching to build the control group.

but that banks responded to this shock by reducing the interest paid on non-customer deposit liabilities and their personnel expenses.⁴²

While we show that the increase in net non-interest income has mitigated 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 “low-for-long” and how banks respond across time to NIRP. We find that how long NIRP is implemented matters: at the very end of our sample in 2018, banks start reducing customer deposit expenses and increasing fees to preserve their profits.

After having established the banks’ response to negative interest rates, we analyze whether these responses differ according to the characteristics of banks.⁴³ We find that the 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 deposit-dependent, large and with high leverage. However, we also find that these banks (larger, with higher deposits and leverage ratios) are associated with higher non-interest income after the NIRP implementation. This is mainly driven by a reduction in personnel expenses and other non-interest expenses (that include overhead costs).

Overall, banks, whatever their characteristics, have not responded through fees to cushion the compression of their net interest margin as they try to limit the increase in customer deposit expenses. They have adjusted their profit and loss account to offset the negative effects on net interest income. But large banks with higher deposits and higher leverage ratios would better resist to negative interest rates because of more room for adaptation. At the opposite, small banks that were

⁴² Another channel for mitigating the decrease in net interest margins is the lower probability of default on loans due to lower interest rates (see Boungou, 2019, for the effect of NIRP on non-performing loans).

⁴³ See the literature on the determinants of bank performance (see Molyneux and Thornton, 1992, Athanasoglou et al., 2008, Dietrich and Wanzenried, 2014).

potentially more efficient in their cost structure, but were relying relatively more on interest income than on non-interest income, are more severely hit by the NIRP implementation, because more constrained. The main message of this paper is that banks have been able to adapt to NIRP by shifting revenue sources and compressing costs and that large banks with higher deposits and higher leverage ratios have been more effective in doing so.

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 happened 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 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, notably Lopez et al. (2020) and Molyneux et al. (2019).⁴⁴ Lopez et al. (2020), using data from 5273 banks located in the European Union and Japan, show that negative interest rates had little effect on bank performance despite a contraction

⁴⁴ 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). In general, this literature argues that low interest rates reduce bank profitability.

in net interest income. They argue that banks compensated for losses in interest margins by increasing their net non-interest income. Molyneux et al. (2019) also document, using data on 7359 banks from 33 OECD countries, that banks responded by increasing their non-interest income (such as fees and commissions). Our analysis contrasts with these previous studies in at least two respects: (i) whereas Lopez et al. (2020) find that banks affected by NIRP increased their interest rate on retail deposits, we confirm evidence of banks' reluctance to charge negative interest rates on customer deposits; (ii) we highlight that banks' responses to negative interest rates went through a reduction in the interest paid on non-customer deposit liabilities and in non-interest expenses such as personnel expenses through an increase in fees (Altavilla et al. 2019, and Molyneux et al. 2019).

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 had no incentive to increase the supply of credit. However, Demiralp et al. (2019) and Grandi and Guille (2020) find that banks highly dependent on deposits increased their lending activities under NIRP.⁴⁵

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.

⁴⁵ Bubeck et al. (2020) find that deposit-dependent banks hold riskier securities after the NIRP implementation.

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 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., Boungou, 2019, Molyneux et al. 2019) but we 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 prices 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, it currently stands at -0.60%. 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 currently at -0.50%. In July 2014, the Sveriges Riksbank reduced its deposit rate to -0.50% and it currently stands at -0.10%. The Swiss National Bank reduced its interest rate on sight deposits to below zero in January 2015 and is at -0.75% in 2020. The Norges Bank reduced its reserve rate in September 2015 to -0.25% and is now at -1%. 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 was 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 the 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.

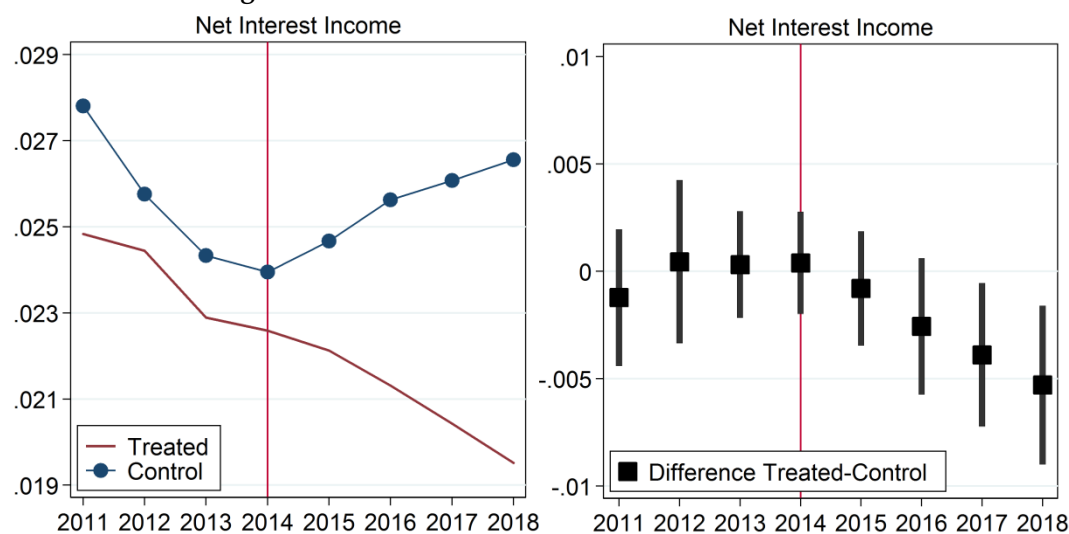
We initially extract from Fitch Solutions a dataset of 14894 banks located in 129 countries over the period 2011-2018. We split this dataset into two groups according

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.

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 with the largest banks (with a size greater than the 80th percentile of the distribution of bank size), a share of liquid assets greater than its 10th percentile and whose HHI index is greater than its 40th percentile. Table 4.B in the Appendix summarizes the key descriptive statistics of the two groups over the pre-NIRP period. Figure 4.1 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 between the two averages (on the right panel). Both groups share a common trend before the NIRP implementation. The treated group consists of 3399 banks while our control group consists of 246 banks located in 34 low-, middle-, and high-income countries. The final database consists of an unbalanced panel dataset of 3645 banks operating in 59 low-, middle-, and high-income countries from 2011 to 2018, consisting of 19996 observations.⁴⁶

⁴⁶ Table 4.A in the Appendix lists the different countries in the database.

Figure 4.1. The evolution of net interest income



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.⁴⁷

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 (3146 banks), we exclude low-income countries from the control group. Second, since the number of banks in the baseline control group is relatively small (246) compared to the treated group (3399), we relax the thresholds considered to identify the control group (size, liquidity and market concentration) and define two other control groups with 589 and 787 banks respectively. Table 4.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.⁴⁸ The DiD approach allows us to analyze the effect of the

⁴⁷ 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.

⁴⁸ See, among others, Heider et al. (2019), Molyneux et al. (2019, 2020), Boungou (2020) and Lopez et al. (2020).

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 the bank i in country j for the year t .⁴⁹ $Treated_{i,t}$ 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 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)⁵⁰, liquid assets to total assets (liquidity), deposits to total assets (funding).⁵¹ 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), and the real GDP growth rate (GDP).⁵² 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 the 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

⁴⁹ All variables related to the banks' income statement and balance sheet are scaled by total assets.

⁵⁰ The equity to assets ratio is generally used in the banking literature as a proxy for bank capitalization. The inverse of this ratio is also used as a proxy for leverage.

⁵¹ 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 4.C in the Appendix).

⁵² The macroeconomic indicators are extracted from Datastream.

terms between the bank exposure variables (described later), the treated dummy and the NIRP dummy, or double interaction terms between the 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*.⁵³

Table 4.1 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. We find that negative interest rates have a negative effect on banks' overall profits: net income has decreased by 0.107 percentage point (pp) on average following the NIRP implementation. This overall negative effect stems from a 0.202pp decrease in net interest income, in part mitigated by a 0.095pp increase in net non-interest income.

⁵³ Table 4.D in the Appendix shows the parameter estimates for all control variables in Tables 4.1 to 4.3.

Table 4.1. Aggregate effects

	Net Income			Net Interest Income			Net Non-Interest Inc.	
	BH	MRX19	LRS20	BH	MRX19	LRS20	BH	LRS20
DiD	-0.107** (0.05)	-0.031** (0.01)	0.034 (0.03)	-0.202*** (0.04)	-0.164*** (0.02)	-0.078** (0.02)	0.095** (0.05)	0.075** (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	0.15	0.51	0.13	0.02	0.05
Obs.	19996	17286	30686	19996	17271	30792	19996	30241
Nb. banks	3645	4612	5079	3645	4612	5078	3645	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.

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 have been mitigated by an increase in non-interest income.⁵⁴ Lopez et al. (2020), analyzing 5200 banks from 27 advanced European and Asian countries over 2011-2016, find that NIRP compressed 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.

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.

⁵⁴ 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 4.1 for comparability purposes.

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 4.2 shows the DiD estimated parameter - α_1 - for the various dependent variables mentioned above.

Table 4.2. Breakdown of interest flows

	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.760*** (0.08)	-0.454*** (0.08)	-0.306*** (0.05)
R ²	0.57	0.34	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.552*** (0.07)	0.027 (0.05)	-0.579*** (0.04)
R ²	0.53	0.11	0.52

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 3645 banks located in 59 countries over the period 2011-2018, consisting of 19996 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Our results show that banks responded to the NIRP implementation by lowering their gross interest income (-0.760pp). Indeed, gross interest income is pulled down by interest income on loans and other interest income which fell by 0.454pp and 0.306pp, respectively. The NIRP implementation has most certainly reduced the cost of credit (as suggested by the theoretical literature) but they have also favored the reduction of other interest income. The results about gross interest expenses show that banks located in countries that have adopted NIRP reduced their gross interest expense by 0.552pp. This reduction in gross interest expenses is entirely explained by other interest expenses (-0.579pp), not customer deposit expenses. It is noteworthy that NIRP did not have a significant effect on interest expenses on customer deposits as it suggests that banks have been reluctant to pass through the negative interest

rates to retail deposits. This is confirmed by the R^2 of this regression (only 0.11) relative to the other variables considered in Table 4.2 (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 reduced interest expenses on non-customer deposit liabilities. Our results contrast with Lopez et al. (2020) who find a decrease in gross interest expenses (-0.037pp), but a positive effect of NIRP on interest expenses on customer deposits (0.115pp) and on other interest expenses (although not significant for the latter) (see page 9 of their study).⁵⁵ Our results 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.

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 4.3 shows the estimated parameters of Equation (1) with these dependent variables.

⁵⁵ See Table 2 on page 9 of their paper. Gross interest expenses being the sum of customer deposit expenses and other interest expenses, this result is hard to rationalize.

Table 4.3. Breakdown of non-interest flows

	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.037 (0.07)	-0.046 (0.05)	-0.019 (0.04)
R ²	0.03	0.03	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.132*** (0.05)	-0.084*** (0.02)	-0.048 (0.04)
R ²	0.04	0.08	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 3645 banks located in 59 countries over the period 2011-2018, consisting of 19996 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 have not been 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 retail deposits. These studies show that banks with a funding structure more oriented towards retail 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 4, 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 saw their non-interest expenses decrease by 0.132pp 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 0.084pp. The reduction in such expenses appears to be the channel through which banks responded to the NIRP implementation in order to sustain 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.⁵⁶

In order to respond to the decrease in net interest income, banks have reduced 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 the banking sector is common to all countries not just those who experienced negative interest rates. Our results suggest that NIRP may have spurred more restructuring and accelerated 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 the decrease in interest rates. Nevertheless, Arce et al. (2018) and Heider et al. (2019) suggest that banks exposed to NIRP have not increased 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 4.2) suggests that the credit demand effect has not been at work, at least not enough to offset the effect of the decreasing of loan interest rates.

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 were 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 the 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

⁵⁶ Figures updated on 08-06-2020. Source: Structural Indicators for the EU Banking Sector, section EU structural financial indicators, Table 1.

deposits, and the ratio of personnel expenses to overhead costs. Table 4.E in the Appendix shows the effect of the NIRP implementation when controlling for these bank specialization measures. The main findings presented in Tables 4.1 to 4.3 hold.

In addition, Tables 4.F to 4.K in the Appendix shows the estimates of the effect of NIRP using alternative control groups or samples. In Tables 4.F (respectively 4.G), the baseline control group excludes low-income countries (respectively low- and lower-middle-income countries) based the World Bank classification. In Tables 4.H and 4.I, the thresholds defining the control group are relaxed and the control groups include 589 and 787 banks respectively. In Tables 4.J and 4.K, we present the descriptive statistics and estimates for a treated group subsample focusing on the Euro area. The main findings presented in Tables 4.1 to 4.3 continue to hold.

3.3. 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 the bank exposure variable, the treated dummy and the NIRP dummy.⁵⁷ The identification now stems from the cross-sectional variation in bank exposure to NIRP when this policy is introduced in the treated countries.

⁵⁷ 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 4.4. Using bank exposure to NIRP for identification

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
Securities*DiD	-0.159*	-0.585***	0.426***
	(0.10)	(0.05)	(0.10)
R ²	0.04	0.26	0.03
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
Securities*DiD	-0.830***	-0.866***	0.036
	(0.08)	(0.07)	(0.07)
R ²	0.60	0.39	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
Securities*DiD	-0.218***	0.029	-0.247***
	(0.07)	(0.03)	(0.07)
R ²	0.53	0.12	0.51
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
Securities*DiD	-0.085	-0.214	0.213*
	(0.21)	(0.21)	(0.13)
R ²	0.03	0.03	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
Securities*DiD	-0.510**	-0.147***	-0.363*
	(0.22)	(0.05)	(0.22)
R ²	0.04	0.06	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 3611 banks located in 59 countries over the period 2011-2018, consisting of 19826 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 4.4 shows the estimates of the specification with the liquidity measure (Table 4.L 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 – are associated with a larger reduction in their net income due to a larger decrease in net interest income despite a larger increase in net non-interest income. The channels through which banks respond to NIRP are confirmed: interest income on loans decrease sharply but customer deposit expenses remains unaffected. At the opposite, non-interest expenses are reduced to sustain profitability.

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 4.M in the Appendix and confirms the main results of this paper.

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 4.N in the Appendix confirms the earlier findings.

3.4. The dynamic responses of banks to NIRP

While there is a consensus that NIRP *per se* does not hamper bank profitability (see Table 4.1 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 “low-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 4.5 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 the banks' responses to it build up in time. For instance, the negative effect on gross interest income went monotonically from -0.186 in 2014 to -1.459 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 increased in the years just after 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 so far, this is consistent with the decision of Commerzbank to apply negative interest rates on corporate deposit accounts.⁵⁸ The

⁵⁸ 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>.

response of the interest paid on non-customer deposit liabilities has been strong and immediate, and continued to increase across years.

On the side of non-interest flows, while fees decreased during the first two years after the NIRP implementation, it appears that they started increasing at the very end of the sample in 2018. Banks might therefore be starting to charge higher fees to their customer to preserve their profits. The dynamic of non-interest expenses is worth noting: other non-interest expenses such as information technology, marketing and administrative costs decreased the first two years only, whereas personnel expenses started to decrease slowly but the trend continued over the five years.

Table 4.5. The dynamic bank responses to NIRP

	Net Inc.		Net Int. Inc.		Net Non-Int. Inc.	
DiD 2014	0.095	(0.08)	0.046	(0.04)	0.050	(0.07)
DiD 2015	-0.042	(0.07)	-0.089*	(0.04)	0.047	(0.07)
DiD 2016	-0.069	(0.07)	-0.172***	(0.06)	0.103	(0.10)
DiD 2017	-0.120*	(0.07)	-0.222***	(0.07)	0.101	(0.06)
DiD 2018	-0.139*	(0.07)	-0.370***	(0.07)	0.231***	(0.06)
Interest flows						
	Gross Int. Inc.		Int. Inc. on Loans		Oth. Int. Inc.	
DiD 2014	-0.186***	(0.07)	-0.110	(0.07)	-0.076	(0.05)
DiD 2015	-0.451***	(0.08)	-0.288***	(0.08)	-0.163***	(0.05)
DiD 2016	-0.557***	(0.11)	-0.336***	(0.11)	-0.221***	(0.06)
DiD 2017	-0.801***	(0.12)	-0.498***	(0.11)	-0.303***	(0.05)
DiD 2018	-1.459***	(0.12)	-0.989***	(0.12)	-0.470***	(0.06)
	Gross Int. Exp.		Cust. Dep. Exp.		Oth. Int. Exp.	
DiD 2014	-0.228***	(0.05)	0.038	(0.03)	-0.265***	(0.03)
DiD 2015	-0.365***	(0.07)	0.077*	(0.05)	-0.443***	(0.04)
DiD 2016	-0.383***	(0.08)	0.161**	(0.07)	-0.544***	(0.05)
DiD 2017	-0.557***	(0.09)	0.111	(0.76)	-0.668***	(0.05)
DiD 2018	-1.073***	(0.11)	-0.209**	(0.09)	-0.864***	(0.06)
Non-interest flows						
	Gross Non-Int. Inc.		Fees		Oth. Non-Int. Inc.	
DiD 2014	-0.153***	(0.05)	-0.122***	(0.05)	-0.029	(0.04)
DiD 2015	-0.114	(0.09)	-0.078*	(0.04)	-0.095	(0.07)
DiD 2016	-0.059	(0.10)	-0.073	(0.08)	-0.017	(0.05)
DiD 2017	-0.132	(0.11)	-0.014	(0.08)	-0.152**	(0.06)
DiD 2018	-0.021	(0.06)	0.065*	(0.04)	-0.083	(0.05)
	Gross Non-Int. Exp.		Perso. Exp.		Oth. Non-Int. Exp.	
DiD 2014	-0.203**	(0.08)	-0.068**	(0.03)	-0.135**	(0.06)
DiD 2015	-0.160***	(0.05)	-0.073***	(0.02)	-0.087**	(0.04)
DiD 2016	-0.162**	(0.07)	-0.107***	(0.04)	-0.055	(0.04)
DiD 2017	-0.233***	(0.08)	-0.222***	(0.037)	-0.081	(0.06)
DiD 2018	-0.252***	(0.06)	-0.165***	(0.03)	-0.087	(0.06)

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 3645 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.

These results confirm our previous results on how the banks responded 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 continue longer.

4. 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.⁵⁹

⁵⁹ 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).

Table 4.6. Deposits

	Net Income		Net Interest Income		Net Non-Int. Income	
	Low	High	Low	High	Low	High
DiD	-0.293 (0.22)	-0.061 (0.07)	-0.225*** (0.05)	-0.442*** (0.02)	-0.069 (0.22)	0.381*** (0.07)
R ²	0.04	0.05	0.06	0.38	0.04	0.08
Interest flows						
	Gross Int. Inc.		Int. Inc. on Loans		Oth. Int. Inc.	
	Low	High	Low	High	Low	High
DiD	-0.905*** (0.07)	-1.073*** (0.04)	-0.683*** (0.06)	-0.675*** (0.03)	-0.222*** (0.06)	-0.398*** (0.04)
R ²	0.37	0.77	0.25	0.52	0.12	0.46
	Gross Int. Exp.		Cust. Dep. Exp.		Oth. Int. Exp.	
	Low	High	Low	High	Low	High
DiD	-0.663*** (0.06)	-0.639*** (0.03)	-0.117*** (0.02)	0.000 (0.01)	-0.546*** (0.05)	-0.639*** (0.03)
R ²	0.36	0.75	0.20	0.22	0.30	0.72
Non-Interest flows						
	Gross Non-Int. Inc.		Fees		Oth. Non-Int. Inc.	
	Low	High	Low	High	Low	High
DiD	0.197 (0.04)	0.143* (0.08)	0.029 (0.28)	0.103* (0.06)	0.203 (0.01)	0.032 (0.03)
R ²	0.04	0.03	0.04	0.02	0.02	0.02
	Gross Non-Int. Exp.		Perso. Exp.		Oth. Non-Int. Exp.	
	Low	High	Low	High	Low	High
DiD	0.266 (0.26)	-0.238** (0.10)	-0.003 (0.07)	-0.153*** (0.04)	0.269 (0.25)	-0.086 (0.06)
R ²	0.06	0.05	0.05	0.26	0.03	0.01
Obs.	5838	13174	5838	13174	5838	13174
Nb. banks	1241	2158	1241	2158	1241	2158

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 (72%). Low refers to banks with a ratio of deposits to total assets less than 72%. 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.

4.1. Deposits

We analyze the effects of NIRP on banks' financial statements according to the share of deposits held by banks. We divide the overall sample in two subsamples, above and below the median of the ratio of deposits to total assets (72%). 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 4.6 shows the subsample estimates. We find that the reduction in the net interest income is stronger for high deposit banks (-0.442pp) compared to banks with a low share of deposits (-0.225pp). This pattern is consistent with the result that banks highly dependent on deposits are reluctant to apply negative interest rates on retail deposits because they may fear losing their core funding base: the effect on customer deposit expenses is negative for low-deposit banks and null for high-deposit banks. However, fees in banks with a high share of deposits increased after the NIRP implementation. In addition, we find that high-deposit banks reduced much more their non-interest expenses than low-deposit banks. This is especially true for personnel expenses such as salaries and employee benefits. Thus, banks with higher deposits are associated with higher non-interest income after the NIRP implementation. Our results suggest that high deposit banks were the most impacted by NIRP, which in turn led to stronger responses than low deposit banks. Indeed, high deposit banks were able to reduce the negative effects of NIRP on their overall profitability by diversifying their sources of revenue.

Other works 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.

4.2. 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 (6.36). 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.

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 4.7 indicates a somehow more mixed picture. We find that net income of small and large banks responds differently to the NIRP implementation. Large banks experience a larger decrease of net interest income, but also a larger increase of net non-interest income. We also find that the reduction in the interest income on loans is greater for large banks (-0.812pp vs. -0.583pp). At the opposite, small banks have lost more than large banks from other interest income (-0.425pp vs. -0.173pp). Moreover, we find that large banks have been more inclined, in response to negative interest rates, to reduce personnel expenses to maintain their profits. This is consistent with the larger positive effect on net non-interest income for larger banks. These results suggest that large banks have more capacity to cushion the effects of the NIRP implementation.

Table 4.7. Bank size

	Net Income		Net Interest Income		Net Non-Int. Income	
	Small	Large	Small	Large	Small	Large
DiD	-0.187	-0.172***	-0.332***	-0.383***	0.145	0.211***
	(0.20)	(0.04)	(0.03)	(0.03)	(0.20)	(0.04)
R ²	0.03	0.07	0.13	0.27	0.03	0.07
Interest flows						
	Gross Int. Inc.		Int. Inc. on Loans		Oth. Int. Inc.	
	Small	Large	Small	Large	Small	Large
DiD	-1.008***	-0.985***	-0.583***	-0.812***	-0.425***	-0.173***
	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)
R ²	0.62	0.59	0.32	0.47	0.45	0.17
	Gross Int. Exp.		Cust. Dep. Exp.		Oth. Int. Exp.	
	Small	Large	Small	Large	Small	Large
DiD	-0.665***	-0.614***	-0.032**	-0.063***	-0.634***	-0.551***
	(0.03)	(0.05)	(0.02)	(0.02)	(0.03)	(0.04)
R ²	0.65	0.52	0.26	0.20	0.63	0.47
Non-Interest flows						
	Gross Non-Int. Inc.		Fees		Oth. Non-Int. Inc.	
	Small	Large	Small	Large	Small	Large
DiD	0.318	0.134	0.109	0.082	0.332	0.051
	(0.37)	(0.09)	(0.24)	(0.07)	(0.22)	(0.05)
R ²	0.04	0.03	0.05	0.01	0.02	0.05
	Gross Non-Int. Exp.		Perso. Exp.		Oth. Non-Int. Exp.	
	Small	Large	Small	Large	Small	Large
DiD	0.173	-0.076	-0.021	-0.081***	0.194	0.005
	(0.29)	(0.07)	(0.07)	(0.02)	(0.26)	(0.05)
R ²	0.08	0.03	0.07	0.23	0.04	0.01
Obs.	10187	8825	10187	8825	10187	8825
Nb. banks	1821	1578	1821	1578	1821	1578

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 (6.36). Small refers to banks with a natural logarithm of assets less than 6.36. 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.

4.3. 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 (10%) and conversely the bank is considered as highly-leveraged if its equity to assets ratio is below 10%.

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 Demirguc-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 4.8 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 (-0.206pp) compared to banks with low leverage (the effect is not significant). Contrary to high-leverage banks, low-leverage banks have been able to pass on the reduction in interest rates to customer deposits (-0.056pp). 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. However, it is again interesting to note that high-leverage banks are able to increase more their net non-interest income following the NIRP implementation. This driven by a larger decrease in personnel expenses and other non-interest expenses.

Table 4.8. Leverage

	Net Income		Net Interest Income		Net Non-Int. Income	
	Low	High	Low	High	Low	High
DiD	-0.172 (0.16)	-0.206*** (0.03)	-0.340*** (0.03)	-0.433*** (0.02)	0.167 (0.16)	0.227*** (0.03)
R ²	0.03	0.09	0.11	0.35	0.02	0.16
Interest flows						
	Gross Int. Inc.		Int. Inc. on Loans		Oth. Int. Inc.	
	Low	High	Low	High	Low	High
DiD	-0.989*** (0.40)	-1.074*** (0.06)	-0.619*** (0.04)	-0.707*** (0.03)	-0.371*** (0.03)	-0.367*** (0.06)
R ²	0.59	0.61	0.31	0.50	0.35	0.24
	Gross Int. Exp.		Cust. Dep. Exp.		Oth. Int. Exp.	
	Low	High	Low	High	Low	High
DiD	-0.635*** (0.03)	-0.655*** (0.05)	-0.056*** (0.01)	-0.021 (0.02)	-0.578*** (0.02)	-0.634*** (0.05)
R ²	0.63	0.53	0.24	0.19	0.58	0.51
Non-Interest flows						
	Gross Non-Int. Inc.		Fees		Oth. Non-Int. Inc.	
	Low	High	Low	High	Low	High
DiD	0.365 (0.28)	0.012 (0.03)	0.157 (0.20)	0.029 (0.02)	0.284* (0.15)	-0.036 (0.02)
R ²	0.04	0.09	0.03	0.07	0.02	0.06
	Gross Non-Int. Exp.		Perso. Exp.		Oth. Non-Int. Exp.	
	Low	High	Low	High	Low	High
DiD	0.197 (0.22)	-0.215*** (0.03)	-0.017 (0.05)	-0.134*** (0.01)	0.215 (0.19)	-0.081*** (0.02)
R ²	0.05	0.19	0.08	0.29	0.02	0.08
Obs.	10073	8939	10073	8939	10073	8939
Nb. banks	1741	1658	1741	1658	1741	1658

Note: DiD is the Difference-in-Differences parameter, estimated from Equation (1). High correspond to banks with a equity to assets ratio greater than or equal to the median (10%). Low refers to banks with a equity to assets ratio less than 10%. 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, we find that large banks with higher deposits and higher leverage ratios are associated with higher non-interest income after the NIRP implementation. This is mainly driven by a reduction in personnel expenses and other non-interest expenses (that include overhead costs). Banks, whatever their characteristics, have not responded through fees to cushion the compression of their net interest margin as they try to limit the increase in customer deposit expenses. This suggests that large banks with higher deposits and higher leverage ratios would better resist to negative interest rates because of more room for costs reduction. At the opposite, small banks that were potentially more efficient in their cost structure, but were relying relatively

more on interest income than on non-interest income, are more severely hit by the NIRP implementation.

5. 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).⁶⁰ Table 4.O 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 4.P 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 monetary policies since these different policies were 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 4.Q 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,

⁶⁰ Our results are similar when using logit model.

during this year, banks were 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 coefficients associated with our difference-in-differences estimator are similar to the previous results and leave our conclusions unchanged. These results are reported in Table 4.R in the Appendix. Overall, these sets of results provide support for our main findings about the channels of banks' responses to negative interest rates.

6. Conclusion

This paper uses a large database of disaggregated profit and loss account data from 3645 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 retail deposits because of its downward rigidity due to the reluctance of banks to charge a negative interest rate on customer deposits. Banks responded 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 banks adjust their response as negative interest rates persist over time. Banks have started 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.

Appendix

Table 4.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 4.B. Pre-NIRP descriptive statistics

Treated group					
Variable	Obs.	Mean	Std. Dev.	Min	Max
Size	7645	6.16	1.88	-0.95	14.59
Capitalization	7645	0.10	0.06	0	0.99
Liquidity	7645	0.18	0.16	0	0.99
Funding	7645	0.67	0.19	0	0.97
Control group 1 - Baseline					
Variable	Obs.	Mean	Std. Dev.	Min	Max
Size	349	10.66	1.74	8.50	19.33
Capitalization	349	0.09	0.03	0.03	0.29
Liquidity	349	0.16	0.10	0.04	0.93
Funding	349	0.63	0.17	0.01	0.90
Control group 2					
Variable	Obs.	Mean	Std. Dev.	Min	Max
Size	883	8.93	1.98	6.22	19.33
Capitalization	883	0.11	0.05	0.01	0.44
Liquidity	883	0.18	0.14	0.04	0.94
Funding	883	0.63	0.20	0	0.91
Control group 3					
Variable	Obs.	Mean	Std. Dev.	Min	Max
Size	1146	8.16	2.26	4.75	19.33
Capitalization	1146	0.12	0.07	0.01	0.77
Liquidity	1146	0.19	0.14	0.04	0.95
Funding	1146	0.61	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 4.C. Correlation matrix

	Size	Cap.	Liquidity	Funding	HHI	GDP	Inflation
Size	1						
Cap.	-0.22	1					
Liquidity	-0.11	0.15	1				
Funding	-0.34	-0.27	0.03	1			
HHI	0.10	0.10	0.01	0.00	1		
GDP	0.12	-0.01	0.06	0.16	0.06	1	
Inflation	0.04	0.01	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 4.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 Inc.	Oth. Non-Int. Inc.	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.107** (0.05)	-0.202*** (0.04)	0.095** (0.05)	-0.760*** (0.08)	-0.454*** (0.08)	-0.306*** (0.05)	-0.552*** (0.07)	0.027 (0.05)	-0.579*** (0.04)	-0.037 (0.07)	-0.046 (0.05)	-0.019 (0.04)	-0.132*** (0.05)	-0.084*** (0.02)	-0.048 (0.04)
Size	0.121 (0.19)	-0.189*** (0.05)	0.310 (0.20)	-0.337*** (0.10)	-0.230*** (0.06)	-0.107 (0.09)	-0.138* (0.085)	-0.017 (0.02)	-0.121 (0.08)	-0.992** (0.43)	-0.536** (0.05)	-0.653* (0.34)	-1.302*** (0.37)	-0.526*** (0.10)	-0.776*** (0.29)
Cap.	4.373 (4.49)	3.359*** (0.82)	1.014 (4.55)	1.429 (0.93)	0.198 (0.64)	1.232* (0.69)	-1.748** (0.70)	0.318** (0.14)	-2.067*** (0.70)	6.245 (5.84)	7.921 (5.08)	-1.962 (0.04)	5.232 (4.31)	3.602* (1.96)	1.630 (2.96)
Liquidity	-0.180 (0.50)	-0.442*** (0.14)	0.262 (0.52)	-0.376* (0.21)	-0.274* (0.15)	-0.102 (0.18)	0.006 (0.18)	-0.080* (0.05)	0.089 (1.75)	-0.202 (0.63)	-0.273 (0.58)	-0.144 (0.28)	-0.464 (0.52)	-0.284 (0.24)	-0.179 (0.39)
Deposits	-0.164 (0.55)	0.488*** (0.18)	-0.652 (0.54)	0.118 (0.27)	0.152 (0.16)	-0.035 (0.27)	-0.443* (0.25)	0.168*** (0.06)	-0.611** (0.26)	-0.647 (0.65)	-0.232 (0.69)	-0.437 (0.30)	0.005 (0.46)	0.127 (0.23)	-0.122 (0.29)
HHI	-1.842*** (0.58)	1.088*** (0.32)	-2.930*** (0.55)	2.150*** (0.48)	1.409*** (0.45)	0.075 (0.05)	0.680* (0.38)	-2.836*** (0.34)	3.516*** (0.35)	-1.547* (0.94)	0.058 (0.74)	-0.363 (1.14)	1.383 (0.86)	0.859*** (0.28)	0.524 (0.71)
GDP	-0.004 (0.00)	-0.014*** (0.00)	0.010** (0.00)	-0.027*** (0.01)	0.013** (0.01)	-0.041*** (0.05)	-0.012* (0.01)	-0.011* (0.01)	-0.001 (0.00)	0.025*** (0.01)	0.015** (0.01)	0.008* (0.00)	0.015* (0.01)	0.000 (0.00)	0.014* (0.01)
Inflation	0.000 (0.00)	0.003 (0.00)	-0.004 (0.00)	0.010* (0.06)	0.004*** (0.00)	0.006 (0.06)	0.006* (0.00)	0.000 (0.00)	0.006*** (0.00)	-0.005 (0.01)	-0.001 (0.00)	-0.002 (0.00)	0.000 (0.00)	0.000 (0.00)	-0.001 (0.00)
R ²	0.03	0.15	0.02	0.57	0.34	0.26	0.53	0.11	0.52	0.03	0.03	0.01	0.04	0.08	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 3645 banks located in 59 countries over the period 2011-2018, consisting of 19996 observations. The within R² is reported. ***, **, * and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 4.E. Including additional controls about bank specialization

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.072 (0.05)	-0.201*** (0.04)	0.130** (0.05)
R ²	0.03	0.15	0.07
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.755*** (0.08)	-0.458*** (0.08)	-0.297*** (0.04)
R ²	0.57	0.35	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.546*** (0.07)	0.028 (0.05)	-0.574*** (0.04)
R ²	0.54	0.11	0.52
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.027 (0.06)	-0.029 (0.05)	-0.032 (0.04)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.157*** (0.05)	-0.069*** (0.02)	-0.088** (0.04)
R ²	0.05	0.13	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 3620 banks located in 59 countries over the period 2011-2018, consisting of 19907 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 4.F. Restricting the control group to high and middle-income countries

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.103*	-0.198***	0.095*
	(0.05)	(0.04)	(0.05)
R ²	0.03	0.15	0.02
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.750***	-0.450***	-0.300***
	(0.09)	(0.08)	(0.04)
R ²	0.57	0.34	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.546***	0.026	-0.572***
	(0.07)	(0.05)	(0.04)
R ²	0.54	0.11	0.52
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.036	-0.047	-0.022
	(0.07)	(0.05)	(0.04)
R ²	0.03	0.03	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.131***	-0.083***	-0.048
	(0.05)	(0.02)	(0.04)
R ²	0.04	0.08	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 3643 banks located in 57 countries over the period 2011-2018, consisting of 19988 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 4.G. Restricting the control group to high and upper-middle-income countries

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.050 (0.05)	-0.159*** (0.04)	0.109** (0.05)
R ²	0.03	0.15	0.02
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.655*** (0.08)	-0.410*** (0.09)	-0.245*** (0.04)
R ²	0.58	0.35	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.491*** (0.07)	0.076 (0.05)	-0.565*** (0.04)
R ²	0.54	0.13	0.52
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.029 (0.07)	-0.060 (0.05)	-0.013 (0.04)
R ²	0.03	0.03	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.137*** (0.05)	-0.091*** (0.02)	-0.047 (0.04)
R ²	0.04	0.08	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 3599 banks located in 50 countries over the period 2011-2018, consisting of 19890 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 4.H. Using the alternative control group 2

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.125** (0.05)	-0.194*** (0.04)	0.069 (0.05)
R ²	0.03	0.13	0.02
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.824*** (0.07)	-0.466*** (0.07)	-0.358*** (0.05)
R ²	0.48	0.26	0.20
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.615*** (0.05)	-0.067 (0.05)	-0.548*** (0.04)
R ²	0.45	0.05	0.48
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.114* (0.07)	-0.061 (0.05)	-0.070 (0.04)
R ²	0.03	0.03	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.182** (0.07)	-0.062** (0.02)	-0.121* (0.07)
R ²	0.04	0.08	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 3988 banks located in 80 countries over the period 2011-2018, consisting of 21470 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 4.I. Using the alternative control group 3

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.133*** (0.05)	-0.176*** (0.04)	0.043 (0.05)
R ²	0.03	0.13	0.02
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	0.48	0.26	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	0.42	0.05	0.43
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.070 (0.08)	-0.035 (0.04)	-0.047 (0.06)
R ²	0.03	0.02	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.114 (0.08)	-0.039* (0.02)	-0.075 (0.07)
R ²	0.05	0.08	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 4186 banks located in 83 countries over the period 2011-2018, consisting of 22134 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 4.J. Pre-NIRP descriptive statistics for a euro area subsample test

Treated group					
Variable	Obs.	Mean	Std. Dev.	Min	Max
Size	7162	6.22	1.86	-0.95	14.59
Capitalizati	7162	0.09	0.06	0	0.99
Liquidity	7162	0.18	0.15	0	0.99
Funding	7162	0.67	0.20	0	0.97
Control group					
Variable	Obs.	Mean	Std. Dev.	Min	Max
Size	346	10.67	1.75	8.50	19.33
Capitalizati	346	0.09	0.03	0.03	0.29
Liquidity	346	0.16	0.10	0.04	0.93
Funding	346	0.63	0.17	0.01	0.90

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 4.K. The effect of NIRP for a euro area subsample

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.118** (0.06)	-0.204*** (0.04)	0.086* (0.05)
R ²	0.03	0.14	0.02
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.734*** (0.08)	-0.421*** (0.08)	-0.313*** (0.04)
R ²	0.58	0.34	0.27
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.526*** (0.07)	0.073 (0.05)	-0.599*** (0.04)
R ²	0.54	0.08	0.55
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.037 (0.07)	-0.051 (0.05)	-0.018 (0.04)
R ²	0.03	0.03	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.124** (0.05)	-0.084*** (0.02)	-0.039 (0.04)
R ²	0.04	0.08	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 3390 banks located in 50 countries over the period 2011-2018, consisting of 18876 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 4.L. Using a funding measure for the bank exposure to NIRP

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
Deposits*DiD	-0.250*** (0.08)	-0.158** (0.07)	-0.092 (0.08)
R ²	0.03	0.15	0.02
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
Deposits*DiD	-0.494*** (0.10)	-0.169** (0.07)	-0.325*** (0.09)
R ²	0.56	0.34	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
Deposits*DiD	-0.311*** (0.09)	0.087** (0.04)	-0.398*** (0.08)
R ²	0.53	0.12	0.51
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
Deposits*DiD	-0.215 (0.16)	-0.07 (0.15)	-0.150** (0.06)
R ²	0.03	0.03	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
Deposits*DiD	-0.123 (0.14)	-0.068 (0.06)	-0.055 (0.13)
R ²	0.04	0.08	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 3645 banks located in 59 countries over the period 2011-2018, consisting of 19996 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 4.M. Using a discrete measure of liquidity for the exposure to NIRP

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
DSecurities*DiD	-0.027	-0.119***	0.092***
	(0.02)	(0.01)	(0.02)
R ²	0.03	0.15	0.02
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DSecurities*DiD	-0.209***	-0.260***	0.051***
	(0.02)	(0.02)	(0.02)
R ²	0.56	0.35	0.25
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DSecurities*DiD	-0.079***	0.014*	-0.092***
	(0.02)	(0.01)	(0.02)
R ²	0.52	0.11	0.50
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DSecurities*DiD	0.021	0.003	0.040
	(0.04)	(0.03)	(0.03)
R ²	0.03	0.03	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DSecurities*DiD	-0.072**	-0.020*	-0.053*
	(0.03)	(0.01)	(0.03)
R ²	0.04	0.08	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 3645 banks located in 59 countries over the period 2011-2018, consisting of 19996 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 4.N. Using exposure to NIRP only on the treated group

	Net Income	Net Int. Inc.	Net Non-Int. Inc.
Securities*NIRP	-0.069 (0.10)	-0.407*** (0.05)	0.338*** (0.11)
R ²	0.04	0.27	0.03
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
Securities*NIRP	-0.298*** (0.08)	-0.837*** (0.06)	0.539*** (0.08)
R ²	0.64	0.45	0.29
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
Securities*NIRP	0.134* (0.07)	-0.033* (0.02)	0.166** (0.07)
R ²	0.57	0.20	0.54
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
Securities*NIRP	-0.203 (0.22)	-0.289 (0.22)	0.202 (0.14)
R ²	0.04	0.03	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
Securities*NIRP	-0.542** (0.22)	-0.090* (0.05)	-0.452** (0.22)
R ²	0.04	0.07	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 3365 banks located in 59 countries over the period 2011-2018, consisting of 18842 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 4.O. Propensity Score Matching

	Net Inc.	Net Int. Inc.	Net Non-Int. Inc.
DiD (PSM)	-0.140*** (0.03)	-0.403*** (0.02)	0.263*** (0.02)
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD (PSM)	-1.248*** (0.09)	-0.775*** (0.05)	-0.473*** (0.01)
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD (PSM)	-0.830*** (0.02)	-0.239*** (0.01)	-0.591*** (0.05)
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD (PSM)	0.136** (0.06)	0.057 (0.06)	0.112*** (0.02)
	Gross Non-Int. Exp	Perso. Exp.	Oth. Non-Int. Exp.
DiD (PSM)	-0.126 (0.11)	-0.100*** (0.03)	-0.027 (0.05)

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 3645 banks located in 59 countries over the period 2011-2018, consisting of 19996 observations. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels respectively.

Table 4.P. Nominal interest rate

	Net Inc.	Net Int. Inc.	Net Non-Int. Inc.
Nom. int. rate	0.110***	0.097***	0.014
	(0.02)	(0.02)	(0.01)
R ²	0.03	0.15	0.02
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
Nom. int. rate	0.470***	0.171***	0.300***
	(0.03)	(0.02)	(0.03)
R ²	0.62	0.35	0.31
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
Nom. int. rate	0.370***	0.158***	0.211***
	(0.02)	(0.02)	(0.02)
R ²	0.60	0.22	0.54
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
Nom. int. rate	-0.081***	-0.070***	0.015
	(0.02)	(0.01)	(0.01)
R ²	0.03	0.03	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
Nom. int. rate	-0.094***	-0.009	-0.085***
	(0.01)	(0.00)	(0.01)
R ²	0.04	0.08	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 3632 banks located in 59 countries over the period 2011-2018, consisting of 19963 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 4.Q. Controlling for other unconventional monetary policies

	Net Inc.	Net Int. Inc.	Net Non-Int. Inc.
DiD	-0.108**	-0.177***	0.069
	(0.05)	(0.04)	(0.05)
R ²	0.03	0.15	0.02
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.705***	-0.450***	-0.255***
	(0.08)	(0.08)	(0.05)
R ²	0.57	0.34	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.519***	0.022	-0.541***
	(0.07)	(0.05)	(0.04)
R ²	0.54	0.11	0.52
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.068	-0.054	0.026
	(0.02)	(0.05)	(0.04)
R ²	0.03	0.03	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.138***	-0.081***	-0.056
	(0.05)	(0.02)	(0.04)
R ²	0.04	0.08	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 3640 banks located in 59 countries over the period 2011-2018, consisting of 19975 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Table 4.R. Treatment year

	Net Inc.	Net Int. Inc.	Net Non-Int. Inc.
DiD	0.005 (0.03)	-0.051 (0.04)	-0.027 (0.04)
R ²	0.01	0.14	0.02
Interest flows			
	Gross Int. Inc.	Int. Inc. on Loans	Oth. Int. Inc.
DiD	-0.184** (0.09)	-0.345*** (0.06)	0.160** (0.08)
R ²	0.56	0.34	0.26
	Gross Int. Exp.	Cust. Dep. Exp.	Oth. Int. Exp.
DiD	-0.131* (0.07)	0.038 (0.04)	-0.169*** (0.06)
R ²	0.52	0.11	0.51
Non-Interest flows			
	Gross Non-Int. Inc.	Fees	Oth. Non-Int. Inc.
DiD	-0.139** (0.06)	-0.072* (0.04)	-0.069** (0.03)
R ²	0.03	0.03	0.01
	Gross Non-Int. Exp.	Perso. Exp.	Oth. Non-Int. Exp.
DiD	-0.112*** (0.04)	-0.049** (0.02)	-0.063** (0.03)
R ²	0.04	0.08	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 3654 banks located in 59 countries over the period 2011-2018, consisting of 19996 observations. The within R² is reported. ***, ** and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

List of Acronyms

DID Difference-in-Differences Method

ECB European Central Bank

EMU Economic and Monetary Union

ETA Equity to Total Assets

EU European Union

FE Fixed Effects

GDP Gross Domestic Product

GFC Global Financial Crisis

GMM Generalized Method of Moments

HHI Herfindahl-Hirschman Index

IMF International Monetary Fund

M0 Monetary Base

M1 Money Supply M1

M2 Money Supply M2

M3 Money Supply M3

NIM Net Interest Margins

NIRP Negative Interest Rate Policy

NPLs Non-Performing Loans

OECD Organization for Economic Co-operation and Development

OLS Ordinary Least Squares

PSM Propensity Score Matching Method

PSPP Public Sector Bonds Purchase Programmes

R² R-Squared

ROA Return on Assets

RWA Risk Weighted Assets

SNB Swiss National Bank

UMPs Unconventional Monetary Policies

VIF Variance Inflation Factor

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Essais sur l'intermédiation bancaire et l'environnement de taux d'intérêt négatifs

Résumé : Cette thèse a pour but d'enrichir le débat sur les effets du passage des taux d'intérêt directeurs en territoire négatif. Nous analysons la manière dont l'implémentation des taux d'intérêt directeurs négatifs (TIDN) impacte les banques. La littérature sur ce sujet étant limitée (mais en pleine expansion), cette thèse vise à contribuer à celle-ci de deux manières : (i) Dans une première partie, nous identifions les effets de TIDN sur les marges nettes d'intérêt des banques et sur l'offre de crédit ; (ii) la deuxième partie analyse les différents canaux de réponses des banques (y compris les incitations à la prise de risque) à l'introduction des taux d'intérêt négatifs. Le premier chapitre montre que les TIDN ont réduit les marges nettes d'intérêt (MNI) des banques. Il y est également observé que la compression des MNI provient de la réticence des banques à réduire, voire à appliquer, un taux d'intérêt négatif sur les dépôts des épargnants. Les résultats du deuxième chapitre soulignent que les banques affectées par des TIDN ont ajusté leur comportement de prêts en augmentant le volume de crédit et en priorisant les prêts avec des durées plus longues. De plus, le troisième chapitre évalue l'influence de la réduction des marges nettes d'intérêt, liée aux TIDN, sur la prise de risque des banques. Nos résultats indiquent que malgré la réduction de MNI, les banques n'ont pas été incitées à prendre plus de risques. Enfin, le quatrième chapitre, suggère que la diminution des revenus d'intérêt due aux taux d'intérêt négatifs n'a été atténuée que partiellement par une augmentation des revenus non liés aux taux d'intérêt. Nos résultats soulignent également que les réponses des banques ne sont pas instantanées et qu'elles les ajustent à mesure que les taux d'intérêt négatifs persistent dans le temps.

Mots clés : Politique de taux d'intérêt négatifs, Marges des banques, Prise de risque des banques, Bilan des banques

Essays on banking intermediation and negative interest rate environment

Abstract: The purpose of this thesis is to enrich the debate on the effects of the shift of policy interest rates into negative territory. We analyze how the implementation of negative interest rate policy (NIRP) impacts banks. As the literature on this topic is limited (but burgeoning), this thesis aims to contribute to it in two ways: (i) In the first part, we identify the effects of NIRP on banks' net interest margins and credit supply; (ii) the second part analyzes the different channels of banks' responses (including risk-taking incentives) to the introduction of negative interest rates. The first chapter shows that NIRP have reduced banks' net interest margins (NIM). It is also observed that the compression of NIM stems from the reluctance of banks to reduce or even charge a negative interest rate on savers' deposits. The results of the second chapter highlight that banks affected by NIRP adjusted their lending behavior by increasing the volume of credit and prioritizing loans with longer maturities. In addition, the third chapter assesses the influence of the NIRP-related reduction in net interest margins on banks' risk taking. Our results indicate that despite the reduction in NIM, banks did not have an incentive to take more risk. Finally, the fourth section, suggests that the decrease in interest income due to negative interest rates was only partially mitigated by an increase in non-interest income. Our results also highlight that banks' responses are not instantaneous and that they adjust them as negative interest rates persist over time.

Keywords: Negative interest rate policy, Bank margins, Bank risk-taking, Bank balance sheet

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