Interest Rate Risk and Monetary Policy Normalisation in the Euro Area

Abstract

A low interest rate environment is susceptible to sudden increases in policy rates and heightened interest rate risk (IRR). By using a sample of 81 euro area banks during the period 2014Q4-2018Q1 and a confidential supervisory measure of IRR, this paper identifies which bank-specific characteristics can amplify or weaken the impact of a 200 basis points positive shock in interest rates. We find that banks reliant on core deposits, that hold more floating-interest rate loans and that diversify their lending, either by sector or geography, are less exposed to a positive change in interest rates. Interestingly, we discover that banks that did not exploit the exceptional financing provided by the European Central Bank (ECB) reveal greater IRR exposure. These findings advance the debate on the impact of a possible return to a normalised monetary policy on the euro area banking sector.

Keywords: Interest Rate Risk; Low Interest Rate Environment; Balance-sheet Determinants; Unconventional Monetary Policies.

JEL classification: E43; E44; E52; G21; F44

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"Nonetheless, the Committee considers Interest rate risk in the banking book (IRRBB) to be material, particularly at a time when interest rates may normalise from historically low levels"

(Basel Committee on Banking Supervision, 2016)

1. Introduction

Central banks in advanced economies responded to the deep recession that followed the Global Financial Crisis (GFC) by sharply reducing key policy interest rates through a combination of conventional and unconventional monetary policies (UMPs). As a consequence, interest rates have been exceptionally low for more than a decade. Protracted periods of low interest rates have been found to substantially impact bank net interest margins – as deposit rates are usually downwards stickier compared to loan rates (Borio et al., 2017; Borio and Gambacorta, 2017; Claessens et al., 2018; Brei et al., 2020). This compression creates incentives for banks to "search for yield" as they move away from low-yield short-term liquid assets to high-yield long-term illiquid assets (Rajan, 2006; Borio and Zhu, 2012; Dell'Ariccia and Marquez, 2013; Matthys et al., 2020), potentially increasing their IRR exposure because they are willing to accept lower premiums for bearing duration risk (Stein, 2013).

Although the positive long-term effects for banks associated with higher interest rates are widely recognised in the literature (Samuelson, 1945; Flannery, 1981; Hancock, 1985), the corresponding impact in the short-term is not clear (English et al., 2018). Higher short-term interest rates can adversely affect banks' financial conditions, by impacting their balance sheet and profit and loss statement. A spike in interest rates can asymmetrically alter the value of bank assets and liabilities (due to their different maturities), thereby lowering banks' net worth and capital strength. At the same time, increasing interest rates might affect the repricing of both assets and liabilities as the income associated with long-term assets commonly responds to market prices more slowly than the expenses paid on the liabilities, thereby compressing interest margins and bank profits. Moreover, the overall effect on banks' net worth is also influenced by macroeconomic conditions, given that changes in interest rates are not random, but rather dictated by monetary authorities and based on inflation targets and macroeconomic prospects.[1]

In this regard, bank-specific characteristics and monetary policy measures play a crucial role in potentially mitigating or amplifying the effect on banks of interest rate movements. For instance, banks that fund a substantial portion of their assets with sticky and zero interest-rate liabilities, such as retail deposits that act as a sort of buffer, should be less vulnerable to positive interest rate changes (Drechsler et al., 2021). On the contrary, banks that mostly hold fixed-interest rate loans might be more exposed to IRR in the event of a monetary policy tightening (Hoffmann et al., 2018). Banks that predominantly issue floating-rate loans, funded by core deposits, can benefit from higher interest rates thanks to the improved conditions for newly originated loans and the repricing of those outstanding, with deposit rates remaining sticky-upward.[2] Banks that actively manage their IRR exposure by using derivatives should potentially be able to offset any adverse impact arising from interest rate fluctuations. In addition, country- and specific monetary policy-settings, such as the degree of banking sector competition and the extent of extraordinary liquidity provision by the central bank, can also play an important role. UMPs targeted to ease banking sector liquidity constraints (for instance, the ECB's targeted longer-term refinancing operations - TLTROs) may contribute to a reduction in banks' IRR exposure by providing cheaper-than-the-market funding.

This paper aims to empirically identify the specific characteristics of banks that are "shocked" by a return to a "normal" interest rate environment. Our research question is topical and policy-relevant as in the upcoming years the process of monetary policy normalisation will likely raise

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[1] Interest rate risk is, jointly with currency, commodity and equity risk, one of the sources of market risk that could impact banks' income, solvency, and in turn its net worth.

[2] In this context, it is worthwhile mentioning that regulatory curbs on banks' risk may induce banks to understate their exposures by altering the behavioural assumptions used to model the interest rate risk profile of deposits. For instance, the ECB found that banks were often employing behavioural deposit models only on the basis of a period of decreasing rates, thus adding model risk to the estimated IRR measures (refer to ECB press release of 9 October 2017 on IRR stress tests). Reinforced by this evidence and supervisory experience, in 2018 the European Banking Authority (EBA) published revised guidelines "on the reporting of non-trading book interest rate risk". Numerous recommendations are made to supervisors in order to ensure that the discussed type of model risk are contained, although their effectiveness will inevitably depend on the level of supervisory scrutiny. Nevertheless, the introduction of a second interest rate risk measure in our analysis not based on banks' own reporting (and thus a potentially biased modelling of deposit stickiness) mitigates this concern.

concerns about IRR in the banking book (IRRBB – ESRB, 2016). In this regard, banks have reacted to persistent low interest rates by moving away from low-yield short-term liquid assets to high-yield long term illiquid assets, reinforcing IRR concerns (ECB, 2017). Figure 1 represents confidential supervisory data obtained from 81 euro area banks of the impact on bank's net interest income (NII), weighted on bank gross income, following a 200 basis point increase in interest rates during 2014Q1-2018Q4. The distribution of ΔNII for the selected sample of banks is highly heterogeneous. In the event of a positive change in the level of interest rates, some banks are better off (in terms of change in the NII), while others are negatively impacted. Hence, understanding which features characterise the typology of banks more prone to experience losses from a possible interest rate spike is of primary interest for policymakers. This topic assumes even greater relevance in a context of protracted and exceptionally low interest rates.

This paper contributes to the existing literature in several ways. First, we employ a unique earning-based measure of IRRBB, collected from confidential ECB quarterly supervisory reports. Unlike most of the prior literature (refer to Section 2 for a review of the relevant literature), which adopts proxies for bank IRR, either derived from accounting-based information or indirectly from the sensitivity of bank stocks' prices to changes in interest rates, our measure relies on a granular breakdown of bank balance sheet and income statement items and is believed to offer a more accurate representation of the actual IRR position. Moreover, our measure has the advantage of incorporating the effect of hedging, thus capturing banks' net IRR exposure. Second, and connected to the previous point, our empirical investigation benefits from the inclusion of novel IRR explanatory factors compared to the existing academic contributions. More specifically, the high granularity of the dataset enables us to consider: (i) banks' core deposits; (ii) banks' floating/fixed-rate loans; (iii) the degree of lending concentration, both at a sectoral and geographical level; and (iv) bank-level amounts of ECB's TLTRO-liquidity. To the best of our knowledge, framed in an exceptional monetary policy environment, we are the first to explore the relevance of both bank- and monetary-specific factors in terms of banks' IRR exposure, following an upsurge in interest rates. Finally, the increase in IRR experienced by U.S. banks following the process of normalisation of monetary stance (Bednar and Elamin, 2014), which started in late 2014 with the conclusion of the large-scale asset purchase programme, lends further support to our investigation.[3] In this perspective, it is crucial to identify and monitor those euro area banks that are likely to be more affected in the event of a return to a normalised monetary policy.

[Insert Figure 1 Here]

In order to explore the impact of a 200 bps increase in interest rates on bank IRR, we use a sample of euro area banks, directly supervised by the ECB in its role as Single Supervisor during the period 2014Q4-2018Q1, and employ a panel fixed-effects approach. To preview our main findings, there are indications that banks more reliant on core deposits, that hold more floating-interest rate loans and have their lending diversified, either by sector or geography, are less exposed to a positive change in interest rates. Interestingly, we discover that banks that did not exploit the extraordinary liquidity provided by the ECB reveal greater IRR exposure when monetary policy tightens. Our results are robust to a variety of tests, such as (i) the use of quantile regression (QR) with fixed effects to account for the specific bank IRR distribution; (ii) alternative construction of our measures of loan concentration; (ii) the exclusion of the category of Global Systemically Important Banks (G-SIBs) from our sample; and (iv) the use of an alternative dependent variable.

The remainder of the paper is organized as follows. Section 2 reviews the prior academic literature on bank IRR. Section 3 introduces the data and methodology. Section 4 presents and discusses the main empirical results. Section 5 provides some robustness checks and Section 6 concludes the paper.

2. Literature Review

Since the seminal work of Samuelson (1945), who found that "the banking system as a whole is immeasurably helped rather than hindered by an increase in interest rate" (p.25), there has been an active academic debate about how interest rate risk (IRR) impacts bank performance and soundness. Early US studies show that bank IRR is typically minimised through asset and

[3] Started in late 2014, the process of normalisation of the monetary policy stance by the Federal Reserve has ended in order to tackle the effects of the COVID-19 crisis.

liability management and has only a modest influence on bank accounting performance (Flannery, 1981; Hancock, 1985) although it can have a substantial influence on bank stock prices (Flannery and James, 1984). The onset of the US Savings and Loans (S&L) crisis in the mid-1980s, triggered by a hike in market interest rates due to a tightening of monetary policy, also drew attention to the adverse impact of IRR shocks (Brewer, 1989; Brewer et al. 1996). What has emerged from the early empirical IRR literature are four strands of work that focus on: (i) banks' stock sensitivity to unpredicted interest rate changes; (ii) IRR management; (iii) the sensitivity of banks' net interest margins to interest rates movements; and the effects of low interest rates on banks' performance and soundness.

The sensitivity of banks' stock returns to IRR represents a key area within the academic literature. In a major contribution, Flannery and James (1984) explore the effect of interest rate changes on common stock prices for U.S. banks during 1976-1981. The authors show that bank stock returns are negatively related to increases in the level of interest rates. Moreover, they provide empirical evidence that larger maturity mismatches between assets and liabilities in banks' portfolios are associated with greater stock price sensitivity to interest rates. Fraser et al. (2002) focus on the U.S. banking sector during 1991-1996 and note a significant and inverse relationship between bank stock returns and changes in interest rates. They show that banks' exposure to IRR is inversely associated with the equity to capital ratio, the ratio of demand deposits to total deposits and the proportion of loans granted by banks. IRR also displays a positive relationship with bank non-interest income, thus reflecting a possible reduction in securities-related activity (underwriting, advising and M&A services). Foos et al. (2017) investigate the sensitivity of 36-euro area banks' stock prices to IRR over the period 2005-2014. Their findings suggest that overall banks benefit from increases in interest rates. Moreover, banks with larger balance sheets, greater capital, higher customer loans (to total assets) and lower deposits (to total liabilities and equity) are more vulnerable to interest rate movements. Finally, English et al. (2018) estimate the reaction of bank stock prices to the Federal Open Market Committee (FOMC) announcements over the period 1997-2007 and link these reactions to bank-specific characteristics. Bank stock prices significantly decline following unexpected upward changes in the level or slope of the yield curve. Furthermore, the associated reaction is more pronounced for banks that are primarily funded with core deposits and more limited for banks with a large maturity mismatch.

A second strand of literature focuses on IRR management (building on the early work of Fraser, 1980) and the use of off-balance sheet derivatives for hedging and/or speculation purposes. On the one hand, Gorton and Rosen (1995), Schrand (1997) and Zhao and Moser (2009) find that banks that rely on interest rate derivatives mostly hedge against off-balance sheet exposure to IRR. On the other hand, Esty et al. (1994), Gunther and Siems (1995) and Hirtle (1997) provide empirical evidence that banks employ interest rate derivatives to enhance IRR exposure (and the associated source of bank revenue). Purnanandam (2007) explores the relation between bank-specific characteristics and derivative-based hedging activities against IRR, over the period 1993-2003, for 8,000 U.S. banks. The author documents that large banks, able to exploit economies of scale, hedge their IRR exposure by using financial derivatives. Banks that face a high degree of financial distress tend to manage their IRR either by reducing the maturity gap between assets and liabilities or by engaging in derivatives activity. Finally, high growth banks and banks with less liquid assets use more derivatives for IRR hedging purposes. Au Young et al. (2009), using a sample of Asia-Pacific banks, explore the relationship between the usage of interest rate derivatives and exposure to IRR. Their findings suggest that the degree of derivative activities is positively related to long-term interest rate exposures and negatively associated with such exposure over the short-term. Esposito et al. (2015), in analysing the IRR management of Italian banking groups over the period 2008-2012, document an overall limited exposure to IRR. The authors find that banks strategically manage on-balance sheet IRR and off-balance sheet exposure so as to offset each other. Moreover, most of the Italian banks are prone to boost gains arising from an increase in interest rates at the expense of an increased funding gap. Finally, Entrop et al., (2017) investigate the determinants of IRR for US listed banks and find that while on average IRR is low, there is big variation among banks. Leverage and bank assets size are found to be related to IRR exposures and that during the global financial crisis liquidity and maturity mismatches became determinants of high IRR exposure.

There is also a body of literature examining the relationship between interest rates and bank net interest margins. As noted earlier, Flannery (1981) investigates whether short-term fluctuations in interest rates adversely impact the profits of U.S. commercial banks between 1959 and 1978. The main findings suggest that banks are effectively hedged thanks to a strategic composition of assets and liabilities based on their maturities. Demirgüç-Kunt and Huizinga (1999) investigate the determinants of bank margins using a sample of 80 countries between 1988 and 1995. They find that a variety of bank- and country- specific features (including macroeconomic conditions, tax rates, deposit insurance and institutional features) all can have an influence on margins and profitability. Margins and profits tend to be lower in less concentrated banking systems and foreign banks are found to have higher profits and margins in developing countries whereas the opposite holds true for industrialised countries. Margins are higher in countries with higher inflation – which points to higher margins in countries with higher market interest rates. English (2002) examines the impact of changes in interest rates on net interest margins for a sample of commercial banks in ten industrialised countries. The author finds a positive association between the level of interest rates and bank margins. Alessandri and Nelson (2015) arrive at a similar conclusion for UK banks during the period 1992-2009. More recently, Borio et al. (2017) use a sample of 109 international banks over the period 1995-2012 and document a positive relationship between the level of short-term interest rates and bank profitability. Altavilla et al. (2018), for a sample of European banks during the period 2000-2016, find that a decrease in short-term interest rates is not linked to reduced bank profitability even when the monetary policy easing is prolonged over time.

A fourth strand of literature focuses on the potential effects of protracted periods of exceptionally low interest rates on banks' activity and soundness (Borio et al., 2017; Claessens et al., 2018; Brei et al., 2020). The main underlying argument is that prolonged low interest rates compress bank interest margins, thereby eroding bank profitability and the capability to organically generate capital (with detrimental repercussions in terms of bank soundness and overall financial stability). Therefore, banks might have incentives to "search for yield" (or "search for risk") and move away from low-yield short-term liquid assets to high-yield long-term illiquid assets, possibly financed by cheap(er) central bank funding, such as TLTROs (in the euro area). For certain banks, this condition might have widened the existing mismatch between assets and liabilities thereby increasing their exposure to IRR. A further rebalancing of asset portfolios may imply a shift from lending to trading activity, with the latter able to generate fee-based income and higher returns (Rajan, 2006). In addition, in a low interest rate environment, retail customers are expected to be more inclined towards securities/investment-related services (Albertazzi and Gambacorta, 2010). Brei et al. (2020) investigate the effect of persistently low interest rates on bank intermediation activity. For a sample of 113 large international banks, the authors document a shift of banks' activities from interest-based to fee-related and trading activities (higher-yielding businesses). Chaudron (2018) explores the IRR position of Dutch banks during the period 2008-2015. The author documents a limited overall exposure to IRR and suggests that banks did not strategically exploit the favourable (low) interest-rate environment by widening their IRR positions. The degree of IRR for Dutch banks is inversely associated with on-balance sheet leverage and presents a U-shaped relation with solvency for banks that do not employ derivatives. Moreover, banks that received government assistance during the GFC reveal higher IRR. Hoffmann et al. (2018), using alternative IRR measures, find a limited but highly heterogeneous exposure to IRR for a cross-section of 104-euro area banks in 2015. In countries where fixed-rate mortgages are predominant, banks are more exposed to sudden increases in interest rates. Moreover, large and less capitalised banks are more likely to benefit from interest rate reductions.

Our study can be positioned within the growing body of literature that analyses the effect of IRR on bank performance. More specifically, we are interested in analysing the effect of a sudden increase in interest rates, framed in the perspective of a return to a more normal monetary policy stance, on banks' exposure to IRR. Despite the comprehensive literature on the effects of interest rates on bank financial conditions and soundness, there exists a gap on the impact of a normalisation pattern of monetary policy on banks' exposure to IRR. In this regard, the identification of the specific features which characterise those banks potentially more vulnerable to upward changes in key policy interest rates is of crucial interest and yet to be explored.

3. Methodology and Data

3.1 Methodology

This section presents the econometric approach we follow in order to capture the influence of time-varying bank-specific variables on euro area banks' IRR exposure following a 200 bps increase in interest rates. The baseline model is specified as follows:

$$E_t(\Delta Y_{ijt+1}) = \beta X_{ijt} + \gamma B_{ijt} + \delta C_{jt} + \theta_t + \eta_i + \varepsilon_{it} \quad (1)$$

where Y_{ijt} is our measure of IRR. More specifically, and in-line with the international standards (BCBS, 2016), this represents the reported NII of bank i in country j at time t expected to change in one-year time in response to an increase of 200 bps in interest rates (ΔY_{ijt+1}). The decision to only consider a positive interest rate shock has been motivated by our main research question, which points to assess banks' potential reaction to monetary policy normalisation after a prolonged period of exceptionally low interest rates. Given that the dependent variable measures an interest rate shock-related projection of NII, potential endogeneity issues related to the simultaneity of the data are mitigated. Higher values of Y correspond to positive gains in the event of an upward movement in interest rates and, therefore, to lower IRR exposure. Moreover, for improved comparability across institutions, the dependent variable has been weighted on bank gross income. X_{ijt} is a vector of bank- and monetary-specific characteristics that can mitigate or amplify the effect of a positive interest rate shock on banks' IRR. Specifically, we include: the ratio of fixed-rate loans to total loans (FIXED); the ratio of total demand and transaction deposits to total assets (CADEP); the Herfindahl-Hirschman Index (HHI) measure of loans concentration by productive sector (HHISECTOR) and by geographic area (HHIGEO); the ratio of TLTRO-liquidity to total assets (TLTRO). B_{ijt} includes bank control variables, such as the ratio of equity to total assets (E/TA); the ratio of fee and commission income to total assets (FEE); the ratio of non-performing loans to gross loans (NPL); the ratio of high-quality liquid assets to total assets (HQLA). C_{jt} includes the growth of nominal GDP (GDP) and inflation (INFLATION) as country-specific variables. In order to avoid potential multicollinearity issues, we conduct a correlation analysis through the variance inflation factor (VIF) technique. More specifically, a mean VIF of 1.62 suggests that our covariates are not highly correlated, also evident from the correlation matrix reported in Table A1 in the Appendix. θ_t is a vector of time effects to control for potential time-variant common shocks on IRR and to limit potential omitted variable bias. η_i is a vector of time-invariant bank fixed-effects that we use to control for unobservable bank characteristics with a potential impact on bank IRR exposure. Lastly, robust standard errors (ε_{it}) are employed and clustered at the bank-level.

For robustness purposes, we complement our analysis by using quantile regression (QR) with fixed-effects to account for the specific shape of the IRR distribution, which is centred on median and average values close to zero. Furthermore, this method enables us to evaluate the impact of changes in the distribution of the covariates (X) on quantiles of the distribution of the main variable of interest (Y). Therefore, within our empirical setting, we are able to assess how changes in the selected variables of interest influence changes in the IRR distribution. The impact of various explanatory factors (in terms of direction, magnitude and significance) can vary depending on the quantiles of the dependent variable (IRR), thus reflecting heterogeneous responses of IRR to bank- and monetary-specific characteristics. Building on the standard QR approach (Koenker and Bassett, 1978) we employ the estimator developed by Machado and Silva (2019), which has the advantage of allowing for the inclusion of fixed-effects (in our settings, bank fixed-effects) in order to control for unobserved heterogeneity across entities.

3.2 Data

Unlike most of the related studies on bank IRR, but similar to Memmel (2011), Esposito et al. (2015) and Chaudron (2018), our paper employs confidential quarterly data on IRRBB and individual balance sheet data gathered from ECB supervisory and monetary policy statistical sources (namely, COREP/FINREP reports, Monetary Financial Institutions, MFIs, Interest Rate Statistics, iMIR).[4] The high-granularity of the dataset permits us to explore a unique perspective of the IRR topic in the European banking context. Macroeconomic variables are collected from the ECB Statistical Data Warehouse. Our sample includes 81 banks from 16

[4] Common Reporting (COREP) is the standardised reporting framework issued by the EBA and used by banks and investment firms to report key information to the supervisory authorities under the Capital Requirements Directive (CRD). The framework covers credit risk, market risk, operational risk, own funds and capital adequacy ratios.

euro area countries, over the period 2014Q4-2018Q1. Compared to Hoffmann et al. (2018), which to some extent can be considered the closest work to our paper, we were able to employ a longer time series, thereby investigating more than a single cross-section. The selected banks are those subject to direct supervision from the ECB (namely, Significant Institutions, SIs) in its role as euro area Single Supervisor since late 2014. The sample size is driven by data availability, especially with respect to the most granular variables employed in our empirical analysis (for example, the FIXED variable). Our panel is relatively unbalanced, as suggested by a 0.63 Ahrens and Pincus gamma-index. Moreover, we are able to account for novel explanatory factors, such as FIXED and TLTRO, never employed in prior literature on bank IRR. Table 1 provides details on the composition of the sample, in terms of selected countries, number of bank-observations per each country and associated percentage/cumulative distributions.

[Insert Table 1 Here]

Table 2 reports the definitions of the variables employed in the empirical analysis, as well as the expected signs on the coefficients, while Table 3 presents the related summary statistics. Panel A of Table 3 displays the summary statistics for our dependent variable, namely ΔNII. A potential drawback of this measure is the reliance on banks' internal assumptions. In order to test the validity of our main and for robustness purposes, we employ an alternative measure of IRR (namely, ΔNIM), which is not based on banks' own estimates (refer to Section 5). As previously discussed, our measure of IRR reflects the expected change, over one-year time, in banks' NII in response to an increase of 200 basis points (bps) in interest rates (in-line with the requirements established by the BCBS for the management of the IRRBB within Pillar 2) weighted by bank gross income. More specifically, this measure of the income gap is defined as the difference between assets and liabilities with a duration of less than one year.[5] The income gap is negative when short-term liabilities re-price before long-term assets. This type

[5] More specifically, the assets covered by banks in the IRR assessment include debt securities, loans and advances, derivatives and other assets. On the liability side, the items included consist of debt securities issued, non-maturity deposits of credit institutions, financial and non-financial corporates, households, deposits with fixed maturities and derivatives. The sectoral distinction of the non-maturity deposit item is crucial to model depositors' behavioural assumptions surrounding future deposit dynamics.

of measure has the advantage of incorporating the effect of the hedging activity, hence capturing banks' net IRR exposure. IRR is on average close to zero, however, some banks report losses up to 4.50% of their gross income in case of a 200 bps increase in interest rates (Table 3).[6]

[Insert Table 2 Here]

Variables of interest. Panel B of Table 3 presents the summary statistics on the main variables of interest. FIXED measures the portion of fixed-rate loans with an initial fixation period over 5 years (up to 10 years) and over 10 years to total assets. A number of related contributions (Reichert and Shyu, 2003; Au Young et al., 2009 and Ballester et al., 2009, among others) employ the ratio of gross loans to total assets as an indicator of on-balance sheet IRR. The underlying reason is that, on average, the maturity of bank loans is greater than that of other assets and liabilities, likely leaving banks exposed to IRR. However, the contractual nature of the existing loans and, in particular, their degree of interest rate indexation is also of primary importance. Banks that mostly hold fixed-rate loans are potentially more affected by increasing interest rates, which is the case we explore in our paper. This is because outstanding (fixed-rate) loans are not subject to repricing, while interest expenses on liabilities rise, with detrimental impacts in terms of banks' IRR. Our highly granular dataset, which distinguishes between the amount of fixed/floating rate loans at the individual bank-level, enables us to arrive at a more accurate estimation of banks' IRR exposure. Moreover, while we recognize that this measure does not represent the full share of fixed/floating rate loans in a bank's balance sheet, we can benefit from a greater level of detail and accuracy compared to approaches based on the simple distinction between countries where loans predominantly have floating or fixed interest rates (Albertazzi and Gambacorta, 2009; Hoffmann et al., 2018; Molyneux et al., 2019).

Ballester et al. (2009) and Chaudron (2018) consider the ratio of total deposits to total liabilities in order to assess whether banks that rely more on deposits are less exposed to IRR. However, we recognize the limitations of this indicator as a measure of bank funding structure, due to the

[6] Worthwhile to mention is that the present study focuses on one dimension of bank IRR (income gap) other than the duration gap.

inclusion of deposits characterised by different sensitivities to interest rate fluctuations. In-line with Entrop et al. (2017) and English et al. (2018), we, therefore, employ the ratio of total demand and transaction deposits to total deposits (CADEP). Banks funded with core deposits are expected to reveal lower IRR exposure due to the reduced sensitivity of these types of deposits to interest rate movements and their predominant use for savings, rather than investment purposes. Hence, we expect an inverse relationship between CADEP and our IRR measure.

Additionally, we construct two comprehensive Herfindahl-Hirschman Index (HHI) measures of lending concentration to test whether banks with a more diversified loan portfolio, either by sector or geography, exhibit lower or higher IRR. The first indicator (HHISECTOR) is computed on the basis of 18 different productive sectors, detailed in Table 2, while the second measure (HHIGEO) accounts for the overall amount of loans issued towards each country outside the euro area (namely, those countries subject to a different monetary policy stance). The predicted signs of the two indicators depend on the composition of the loan portfolio, in terms of maturities and repricing characteristics, as well as the rationale driving the lending concentration (or lack of diversification). In the case of determining factors such as specialisation or market power, the effect of loan concentration on IRR may be beneficial (reduced IRR exposure). Otherwise, if the lending concentration is driven by managerial inadequacy and/or lack of expertise, then the resulting effect on banks' IRR could be detrimental (increased IRR exposure). Moreover, banks with a diversified loan portfolio, on a geographical basis, may also be exposed to foreign interest rate fluctuations, resulting in an overall higher IRR exposure (Madura and Zarruk, 1995). In the related literature (Acharya et al., 2006; Goetz et al., 2016; Yildirim and Efthyvoulou, 2018; among others), the debate on loan concentration versus diversification is still ongoing. Opposing views lend support to both strategies and associated implications for banks. For instance, based on Acharya et al. (2006), greater loan portfolio diversification across industries and sectors does not necessarily imply greater safety for banks. Results vary for high- versus low-risk banks and are consistent with the theory suggesting a deterioration in the effectiveness of bank monitoring. Berger et al. (2017) document a positive relationship between internationalization and bank risk. On the other hand, Goetz et al. (2016) find that geographic expansion reduces banks' risk by lowering their exposure to idiosyncratic local risks. Yildirim and Efthyvoulou (2018), by differentiating between banks from developing and emerging countries, as well as global versus regional diversification, find that the diversification effects depend, among others, on a bank's home country. In our setting, we aim to shed some light on the mixed evidence about the relationship between concentration/diversification of the loan portfolio and bank risk, in general, and interest rate risk, in particular.

We employ the ratio of TLTRO-liquidity to total assets to capture the standardised amount of liquidity injections that euro area banks received from the ECB starting from 2014. Specifically, we consider banks' exposures to the first and second TLTRO operations, respectively introduced in 2014 and 2016. Due to the relative novelty of this (unconventional) monetary tool implemented to support bank credit supply by reducing funding costs, the literature on TLTROs is growing but still mainly focused on the impact of TLTROs on banks' lending policies (Altavilla et al. 2020; Altavilla et al. 2021; Andreeva and García-Posada Gómez, 2021; Laine, 2021; Rostagno et al. 2021). The impact of TLTRO is relatively complex and potentially ambiguous. The price and maturity components of TLTRO are likely to reduce IRR. While in principle the variable rate may add IRR, the funding cost profiles of banks that resorted to TLTRO liquidity were mostly higher than the rate offered by the ECB. Moreover, the ECB floating rate linked to conditionality on the amount of extended loans implies that banks have some form of control over the associated costs. Lastly, in banks' projection of IRR up to 1 year, the length of the funding (if banks met their lending targets, for example over 4 years) helps mitigate IRR thanks to the knowledge, with a relatively limited margin of deviation, of the cost of TLTRO in that year. TLTROs have been extended in a low-for-long interest rate environment, therefore ensuring a degree of certainty about the lower cost of this liquidity compared to non-TLTRO funds. In such a context, through forward guidance, banks expect the ECB rates to be negative for longer, meaning that TLTROs remained a convenient source of funds for an extended period of time. In our investigation, we therefore argue that, to the extent to which this extraordinary source of liquidity is available to euro area banks, the positive effects in terms of reduced and diversified funding costs (and increased lending volumes) may entail lower IRR exposure.

Bank control variables. Similarly to other studies on the determinants of IRR (Fraser et al., 2002; Reichert and Shyu, 2003; Au Young et al., 2009; Hoffmann et al., 2018, among others), we also include a set of relevant bank control variables. In particular, we use (i) the equity capital ratio (E/TA) computed as the ratio of equity to total assets; (ii) the ratio of non-performing loans to total gross loans (NPL); (iii) the ratio of fee and commission income to total assets (FEE), as a proxy for the bank business model; and (iv) the ratio of high-quality liquid assets (HQLA) to total assets, as required by the Basel standards for the computation of the liquidity coverage ratio (LCR) and the net stable funding ratio (NSFR). Panel C of Table 3 reports the summary statistics for the selected bank control variables.

Country control variables. Prior literature (Ballester et al., 2009; Esposito et al., 2015; Hoffmann et al., 2018) does not generally consider macroeconomic variables in order to explore the determinants of banks' IRR exposure. Time dummies are typically included to limit potential endogeneity arising from variables affected by common macroeconomic factors. In our analysis, we employ two country-level variables (namely, GDP growth and inflation) with the aim of further controlling for heterogeneity at the macroeconomic level across euro area countries. Panel D of Table 3 reports the summary statistics on the selected country-level variables.

[Insert Table 3 Here]

4. Empirical results

This section discusses the empirical results for the panel data regression analysis based on Equation (1). Table 4 reports the findings for the different model specifications where we progressively add bank controls, as well as country controls and time fixed-effects. Bank-fixed effects are always included and robust standard errors are clustered at the bank-level.

As anticipated, we find that banks that mostly hold fixed-rate loans (FIXED) are more exposed to increases in interest rates in the case of a monetary policy tightening. The related coefficient is always negative and statistically significant at the 10% level in all the econometric specifications. An increase by one standard deviation in the amount of loans with an initial fixation period over 5 years (up to 10 years) and over 10 years corresponds to a decrease in ΔNII of nearly 16%. The present value loss arising from an increase in interest rates is more pronounced for fixed-rate contracts compared to variable-rate contracts. Moreover, in the case of upward movements in interest rates, the outstanding fixed-rate loans would not be subject to any repricing, while higher expenses on the liabilities would adversely impact banks' exposure to IRR. Our results suggest that the portion of core deposits relative to total assets (CADEP) assumes a role in explaining the variation of euro area banks' IRR exposure. The coefficient on the CADEP variable is positive and always statistically significant at the 5% level. An increase by one standard deviation in the amount of transactions and demand deposits to total deposits implies an increase in ΔNII of about 15%. Hence, we envisage that banks whose deposit base is mostly consisting of core deposits reveal lower IRR in the event of a 200 bps positive change in the level of interest rates. The greater stickiness of banks' core deposits and the limited pass-through of deposit rates (with banks able to exert market power also thanks to their deposit franchise - Drechsler et al., 2021) entail lower funding costs and IRR exposure (Fraser et al., 2002; Entrop et al., 2017). In this respect, core deposits act as a buffer in mitigating the effects of a sudden rise in interest rates. This evidence is in-line with the evidence in Black et al. (2007), according to which traditional banks tend to maintain a "buffer stock" of core deposits in order to ease the effects of a monetary shock.

The coefficients on the two measures of lending concentration (HHISECTOR and HHIGEO) are both negative and statistically significant at the 1% level, in most of the specifications. This evidence suggests that banks' loan portfolios with a greater degree of concentration (namely, higher values of HHIs), either by sector or geographically, tend to be more exposed to IRR in the event of monetary policy tightening. An increase by one standard deviation in the lending concentration indicators implies a decrease in ΔNII of about 36% for HHISECTOR and 22% for HHIGEO. A high concentration in bank lending (and thus a limited degree of diversification) might be the outcome of specific managerial reasons, such as the lack of incentives and/or expertise. Furthermore, locational limitations (based on cultural, political and economic differences), as well as regulatory impediments, might also drive the level of lending concentration (Entrop et al., 2017). Based on our results, euro area banks more prone to diversity their loan portfolios, on a sectoral and/or geographical basis, are better able to offset the negative impact of rising interest rates. This evidence, therefore, highlights the positive effects of a more diversified lending strategy in terms of lower exposure to idiosyncratic shocks. Moreover, banks with greater international reach and potential to increase lending abroad (namely, achieving greater geographic diversification in the loan portfolios) can offset the detrimental effect of low interest rates on bank profitability by diversifying their lending towards countries not characterised by low interest rates (Molyneux et al., 2019). This evidence appears to be in-line with prior findings in the literature on diversification versus focus, such as for instance Goetz et al. (2016), according to which geographic expansion has the potential to reduce risk by lowering banks' exposure to idiosyncratic local risk.

Among specific monetary and macroeconomic characteristics, we document a strong and positive relationship between the TLTRO variable and ΔNII (statistically significant at the 1% level in all specifications). In the event of a positive shock in interest rates, an increase by one standard deviation in the amount of TLTRO-liquidity (to total assets) corresponds to an increase in ΔNII of about 25%. Our findings suggest that banks that secure funding from the ECB under the TLTRO schemes are less exposed to IRR. TLTROs provide lower-than-market-priced liquidity to banks, with this liquidity being linked to specific lending targets. Banks that meet lending targets, towards non-financial companies and households (excluding mortgages), benefit from lower interest rates on TLTRO borrowings. The borrowing rate under the schemes in place prior to the COVID pandemic could be as low as the interest rate on the official ECB deposit facility rate prevailing at the time of the auctions. Therefore, fostering new lending can impact participating banks' funding costs, in turn supporting net interest margins in a low interest rate environment. However, TLTROs, especially when protracted over time, might prevent or slow down banks' balance sheet adjustments. Hence, the positive contingent effects might be offset by increased risks in the medium-term, thereby threatening financial stability. In this respect, it is thus crucial to ensure effective functioning of banks in the perspective of a return to more normal monetary conditions and that policymakers understand these potential risks.

[Insert Table 4 Here]

5. Robustness checks

As a first robustness check, and in order to account for the specific IRR distribution, we employ QR with fixed-effects, as developed by Machado and Silva (2019). This approach enables us to estimate the relationships existing between our dependent variable (ΔNII) and the selected covariates, at each quantile of the dependent variable. More specifically, in our econometric setup, we estimate the slope coefficients for the 10^{th}, 25^{th}, 50^{th}, 75^{th} and 90^{th} quartile of the ΔNII distribution. Given that the ΔNII distribution is leptokurtic and mostly centred around both mean and median close to zero (Figure 1), we can assume that banks falling in the left (10^{th} and 25^{th} quantiles) and right (75^{th} and 90^{th} quantiles) tail would, respectively, gain/suffer from an increase in interest rates.

Table 5 reports the empirical results for the QR with fixed-effects, inclusive of our selected bank-specific and monetary controls. The coefficients on the FIXED and CADEP variables, which respectively capture the fraction of loans that are issued at fixed-rate and the amount of core deposits to total assets, reveal a direction and magnitude in-line with the main findings, as discussed in Section 4. More specifically, FIXED is in an inverse relationship with ΔNII and the decreasingly negative coefficients lose statistical significance from the 50^{th} quartile onwards. Also in the case of the CADEP variable, the magnitude of the associated coefficients (mostly positive in sign) progressively decreases by moving towards the right-side tail of the ΔNII distribution. As for FIXED, from the 50^{th} quartile onwards the coefficients on CADEP lose statistical significance. This evidence suggests that banks in the 10^{th} quartile of the ΔNII distribution are those that would benefit the most in terms of ΔNII from changes in the amount of floating rates and/or core deposits. This effect diminishes for banks in the 25^{th} and 50^{th} quartiles of the distribution and becomes insignificant for the 75^{th} and 90^{th} quartiles. Opposite results are revealed for the HHISECTOR and HHIGEO variables, for which the related coefficients are negative and increase in magnitude across the entire ΔNII distribution. Although the benefits associated with a more diversified loan portfolio are evident for all quartiles of the distribution, banks in the 75^{th} and 90^{th} quartiles are those gaining more from greater diversification (both by sector and geography). Finally, we provide evidence of a positive, but at declining rates, relationship between TLTRO and our variable of interest, throughout the entire distribution of bank ΔNII. The associated coefficients are positive and statistically significant at the 1% level in each quartile. The progressively decreasing magnitude of the coefficients suggests that banks that participate more to the TLTRO scheme exhibit greater benefits in terms of ΔNII in the event of a monetary policy tightening. This additional step of our empirical analysis, based on QR with fixed-effects, confirms and extends the main findings discussed in Section 4.

Bernanke and Gertler (1995) show a different sensitivity of commercial and residential loans to monetary policy shocks. Moreover, according to Fraser et al. (2002) banks tend to grant commercial loans on a floating-rate basis, while residential loans are mainly issued at fixed-rate. Therefore as a second robustness check and in order to remove the possibility that our main findings are driven by differences in the interest rate indexation and sensitivity to monetary policy shocks across sectors, we re-construct our HHISECTOR variable by excluding the category of residential loans in the "real estate activity" sector. The related results, reported in Panel A of Table 6, retain the same direction and a comparable magnitude to those presented in Table 4. Statistically significant coefficients at the 1% level, for each specification, validate our main findings.

As a third robustness test, we re-construct our variable HHIGEO in order to control for low versus high-interest rates environments across the countries selected for the computation of the original variable. We argue that banks whose lending activity is more focused towards countries where the market and monetary conditions allow them to exploit higher margins (namely, countries with prevailing higher interest rates) might display higher ΔNII. For this purpose, we follow the approach as in Claessens et al. (2018) and classify as "low-interest rate countries" those countries with the average 3-month implied sovereign yields lower or equal to 1.25% and as "high-interest rate countries" all the others. Accordingly, our new HHIGEO variable reflects whether the loan portfolio of the considered banks is concentrated towards low-interest rate countries or whether it is diversified across high-interest rate countries. As evident in Panel B of Table 6, the related coefficients are negative and highly statistically significant, confirming therefore the findings of our main analysis. Banks whose lending strategy is more diversified towards countries characterised by higher interest rates reveal a lower exposure to IRR.

As a fourth robustness test, we remove the Global Systemically Important Banks (G-SIBs) from our sample. Lucas et al. (2019), in analysing the business models for a sample of European banks during 2008-2015, argue that G-SIBs significantly engage in cross-border lending activities. Specifically, between 40-50% of G-SIBs' loans are cross-border. Thus, by removing G-SIBs from our sample, we aim to control for the possibility that our results of lending concentration (HHISECTOR and HHIGEO) are driven by a specific category of banks, characterised by a very peculiar business model compared to the other banks in the sample. The findings presented in Table 7 are consistent with those of our main model specification, thus adding further robustness to our main results.

Finally, in a further robustness check, in order to avoid potential biases arising from the use of banks' own estimates, we consider an additional measure of IRR (ΔNIM), which does not rely on banks' internal assumptions. We follow Hoffmann et al. (2018), and construct ΔNIM as follows:

$\Delta NIM_{it} = GAP_{t+1} \text{x } \Delta \text{r}$

where:

$$GAP_{t+1} = CF^{a}_{t+1} - CF^{l}_{t+1}$$

with CF^{a}_{t+1} and CF^{l}_{t+1} indicating the re-pricing cash-flows from assets and liabilities in t+1, respectively, and Δr representing the assumed change in the interest rates (i.e. positive 200 bps, in our case). GAP_{t+1} is computed by considering the net notional amount difference between the assets and liabilities that reprice within a one-year time. ΔNIM is a measure of income sensitivity, which indicates by how much a bank's income would change, in the short-run, following an interest rate shock. For consistency reasons, ΔNIM is also normalised by bank gross income and for our sample, it ranges between -6.2% and 4.1% (Table 3). The results reported in Table 8 present coefficients in line with those for the baseline regression, both in terms of signs and magnitude, thus further corroborating our main empirical analysis.

6. Conclusions

This paper aims to analyse euro area banks' exposure to IRR. More specifically, we assess what type of banks exhibit greater vulnerability in the event of a monetary policy tightening. Using a confidential dataset and a unique earning-based measure of IRRBB for a sample of 81 euro area banks, we show that different balance sheet compositions influence the exposure to IRR in case of a positive shock in key policy interest rates. Banks whose funding structure relies more on core deposits, that tend to grant a greater portion of floating-interest rate loans and have their lending activity diversified, either by sector or geography, are less prone to be affected by increasing interest rates. Moreover, banks that borrow liquidity from the ECB under the TLTRO schemes reveal a lower exposure to IRR in the event of a 200 bps increase in interest rates. The use of banks' internal estimates, as our main variable of interest, might represent a limitation of our empirical analysis. The reliance on banks' assumptions could bias the computation of IRR and therefore our results. However, as discussed in the paper, we believe that the benefits arising from the granularity and accuracy of the dataset, compared to alternative approaches based on IRR proxies, offset the potential problems associated with the use of banks' internal estimates. Moreover, in recognizing the implications arising from our research strategy, we perform several robustness checks including the use of an alternative IRR measure (ΔNIM), which validates our main findings, while enriching the paper.

In light of a possible revision of the euro area monetary stance, our results provide relevant insights into the role of different bank-specific characteristics in terms of IRR exposure. Our main findings, robust to a series of additional checks, suggest a heterogenous response across banks to a sudden upsurge in interest rates. The different strategies and levers exploited by banks to face a prolonged period of exceptionally low interest rates have influenced their capability to tackle a process of monetary policy normalisation. The identification and monitoring of banks potentially more exposed to increasing interest rates is important for both policymakers and supervisors in order to avoid unintended adverse consequences, also associated with the unavoidable conclusion of UMPs, such as the ECB's TLTRO schemes. To the best of our knowledge, this paper is the first attempt to identify which banks are more prepared for monetary policy normalisation in the euro area.

References

Acharya, V.V., Hasan, I., Saunders, A. 2006. Should banks be diversified? Evidence from individual bank loan portfolios. *Journal of Business*, 79, 1355-1412.

Albertazzi, U., Gambacorta, L. 2009. Bank profitability and the business cycle. *Journal of Financial Stability*, 5, 393-409.

Altavilla, C., Barbiero, F., Bouchina, M., Burlon, L. 2020. The great lockdown: Pandemic response policies and bank lending conditions. *ECB Occasional Paper Series*, No. 2465/September 2020.

Altavilla, C., Lemke, W., Linzert, T., Tapkins, J., von Landesberger, J. 2021. Assessing the efficacy, efficiency and potential side effects of the ECB's monetary policy instruments since 2014. *ECB Occasional Paper Series, ECB Strategy Review*, No. 278/September 2021.

Alessandri, P., Nelson, B. 2015. Simple banking profitability and the yield curve. *Journal of Money, Credit and Banking,* 47, 143-75.

Altavilla, C., Boucinha M., Peydró, J.L. 2018. Monetary policy and bank profitability in a low interest rate environment. *Economic Policy*, 33, 531-586.

Andreeva. C.D., Garcia-Posada, M. 2021. The impact of the ECB's targeted long-term refinancing operations on banks' lending policies: The role of competition. *Journal of Banking and Finance,* 122, 105922.

Au Young, H.H., Faff, R., Chalmers, K. 2009. Derivative activities and Asia-Pacific banks' interest rate and exchange rate exposures. *Journal of International Financial Markets, Institutions and Money*, 19, 16-32.

Ballester, L., Ferrer, R., González, C. 2009. Determinants of interest rate exposure of Spanish commercial banks. *Instituto Valenciano de Investigaciones Economicas*, WP-EC 2009-07.

Basel Committee on Banking Supervision (BCBS), 2016. Interest rate risk in the banking book. Bank for International Settlements: Basel.

Bednar, W., Elamin, M. 2014. Rising interest rate risk at US banks. *Economic Commentary*, Federal Reserve Bank of Cleveland, issue June, 12.

Berger, A.N., El Ghoul, S., Guedhami, O., Roman, R.A. 2017. Internationalization and bank risk. *Management Science*, 63, 2049-2395.

Bernanke, B.S., Gertler, M. 1995. Inside the black box: The credit channel of monetary policy transmission. *Journal of Economic Perspective*, 9, 27-48.

Black, L., Hancock, D., Passmore.S W. 2007. Bank core deposits and the mitigation of monetary policy. *Federal Reserve System (FEDS) Working Paper* 65. Federal Reserve System: Washington DC.

Borio, C., Gambacorta, L. 2017. Monetary policy and bank lending in a low interest rate environment: Diminishing effectiveness? *Journal of Macroeconomics*, 54, 217-231.

Borio, C., Gambacorta, L., Hofmann, B. 2017. The influence of monetary policy on bank profitability. *International Finance*, 20, 48-63.

Borio, C., Zhu, H. 2012. Capital regulation, risk-taking and monetary policy: A missing link in the transmission mechanism? *Journal of Financial Stability*, 8, 236-251.

Brei M., Borio, C., Gambacorta, L. 2020. Bank intermediation activity in a low-interest-rate environment. *Economic Notes,* 49*,* doi.org/10.1111/ecno.12164

Brewer, E., Jackson, W.E., Mondschean, T. 1996. Risk, regulation, and S&L diversification into nontraditional assets. *Journal of Banking and Finance*, 4, 723-744.

Chaudron, R.F.D.D. 2018. Bank's interest rate risk and profitability in a prolonged environment of low interest rates. *Journal of Banking and Finance*, 89, 94-104.

Claessens, S., Coleman, N., Donnelly, M. 2018. Low-for-long interest rates and banks' interest margin and profitability: Cross-country evidence. *Journal of Financial Intermediation*, 35, 1-16.

Dell'Ariccia, G., Marquez, R. 2013. Interest rates and bank risk-taking channel. *Annual Review of Financial Economics*, 5, 123-141.

Demirgüç-Kunt, A., Huizinga, H. 1999. Determinants of commercial bank interest margins and profitability: Some international evidence. *World Bank Economic Review*, 379-408, World Bank: Washington DC

Drechsler, I., Savov, A., Schnabl, P. 2021. Banking on deposits: Maturity transformation without interest rate risk. *Journal of Finance*, 76, 1091-1143.

Driscoll, J.C., Judson, R. 2013. Sticky deposit rates. *Finance and Economics Discussion Series 2013/80, Board of Governors of the Federal Reserve System*.

ECB, 2017. Euro Area financial institutions, Financial Stability Review, November 2017, European Central Bank: Frankfurt.

English, W.B. 2002. Interest rate risk and bank net interest margin. *Bank for International Settlements Quarterly Review* (December), BIS: Basel.

English, W.B., Van Den Heuvel, S.J., Zakrajsek, E. 2018. Interest rate risk and bank equity valuations. *Journal of Monetary Economics*, 98, 80-97.

Entrop, O., Von la Hausse, L., Wilkens, M. 2017. Looking beyond banks' average interest rate risk: Determinants of high exposures. *Quarterly Review of Economics and Finance*, 63, 204-218.

Esposito, L., Nobili, A., Ropele, T. 2015. The management of interest rate risk during the crisis: Evidence from Italian banks. *Journal of Banking and Finance*, 59, 486-504.

ESRB, 2016. Macroprudential policy issues arising from low interest rates and structural changes in the EU financial system. November 2016. European Systemic Risk Board: Frankfurt.

Esty, B.C., Tufano, P., Headley, J., 1994. Banc One Corporation: Asset and liability management. *Harvard Business School Case*, 294-079.

Flannery, M.J. 1981. Market interest rate and commercial bank profitability: An empirical investigation. *Journal of Finance*, 36, 1085-1101.

Flannery, M.J., James, M.C. 1984. The effect of interest rate changes on common stock returns of financial institutions. *Journal of Finance*, 39, 1141-1153.

Foos, D., Lütkebohmert, E., Markovych, M., Pliszka, K. 2017. Euro area banks' interest rate risk exposure to level, slope and curvature swings in the yield curve. *Deutsche Bundesbank Discussion Paper*, No 24/2017, Deutsche Bundesbank: Frankfurt.

Fraser, D.R., Madura, J., Weigand, R.A. 2002. Sources of bank interest rate risk. *The Financial Review*, 37, 351-368.

Goetz, M.R., Laeven, L., Levine, R. 2016. Does the geographic expansion of banks reduce risk? *Journal of Financial Economics*, 120, 346-362.

Gorton, G., Rosen, R. 1995. Banks and derivatives. *NBER Macroeconomic Annual*, 10, 299-339, National Bureau of Economic Research: Cambridge, MA.

Gunther, J., Siems, T.F. 1995. Who's capitalising on derivatives? *Federal Reserve Bank of Dallas Financial Industry Studies*, July: 1-8.

Hancock, D. 1985. Bank profitability, interest rates, and monetary policy. *Journal of Money, Credit and Banking*, 17, 189-202.

Hirtle, B.J. 1997. Derivatives, portfolio composition, and bank holding company interest rate risk exposure. *Journal of Financial Services Research*, 12, 243-266.

Hoffmann, P., Langfield, S., Pierobon, F., Vuillemey, G. 2018. Who bears interest rate risk? *Review of Financial Studies*, 32, 2921-2954.

Koenker, R., Bassett, G. 1978. Regression quantiles. *Econometrica*, 46, 33-50.

Laine, O.M. 2021. The effect of targeted monetary policy on bank lending. *Journal of Banking and Financial Economics*, 1, 25-43.

Lucas, A., Schaumburg, J., Schwaab, B. 2019. Bank business models at zero interest rates. *Journal of Business & Economic Statistics*, 37, 542-555.

Machado, J.A.F., Santos Silva, J.M.C. 2019. Quantiles via moments. *Journal of Econometrics*, 213, 145-173.

Madura, M. Zarruk, E. 1995. Bank exposure to interest rate risk: A global perspective. *Journal of Financial Research*, 18, 1-13.

Matthys, T., Meuleman, E., Vander Vennet, R. 2020. Unconventional monetary policy and bank risk taking. *Journal of International Money and Finance*, 109, 102233.

Memmel, C. 2011. Banks' exposure to interest rate risk, their earnings from term transformation, and the dynamics of the term structure. *Journal of Banking and Finance*, 35, 282-289.

Molyneux, P., Reghezza, A., Xie, R. 2019. Bank margins and profits in a world of negative rates. *Journal of Banking and Finance*, 107, 105613.

Purnanandam, A. 2007. Interest rate derivatives at commercial banks: An empirical investigation. *Journal of Monetary Economics*, 54, 1769-1808.

Rajan, R.G. 2006. Has finance made the world riskier? *European Financial Management*, 12, 499-533.

Reichert, A., Shyu, Y. 2003. Derivative activities and the risk of international banks: A market index and VaR approach. *International Review of Financial Analysis*, 12, 489-511.

Rostagno, M., Altavilla, C., Carboni, G., Lemke, W., Motto, R., Saint Guilhem, A., Yiangou, J. 2021. *Monetary Policy in Times of Crisis A Tale of Two Decades of the European Central Bank*, Oxford University Press.

Samuelson, P.A. 1945. The effect of interest rate increases on the banking system. *American Economic Review*, 35, 16-27.

Schrand, C.M. 1997. The association between stock-price interest rate sensitivity and disclosure about derivative instruments. *Accounting Review*, 72, 87-109.

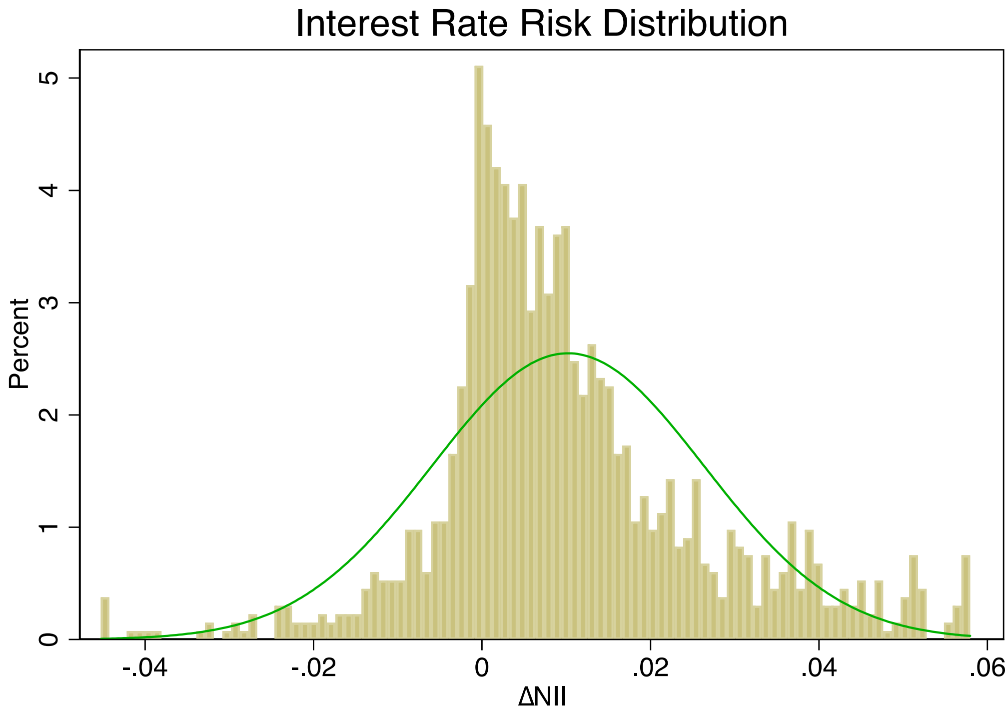
Sørensen, K.C., Werner, T. 2006. Bank interest rate pass-through in the euro area: A cross-country comparison. *European Central Bank (ECB) Working Paper Series* 580. ECB: Frankfurt.

Stein, J. 2013. Overheating in credit markets: Origins, measurement, and policy responses. Restoring household financial stability after the Great Recession: Why household balance sheets matter. *Federal Reserve Bank of St. Louis symposium*.

Yildirim, C., Efthyvoulou, G. 2018. Bank value and geographic diversification: Regional vs global. *Journal of Financial Stability*, 36, 225-245.

Zhao, F., Moser, J. 2009. Use of derivatives and bank holding companies interest rate risk. *Banking and Finance Review*, 1, 51-62.

Figure 1. Bank interest rate risk (IRR) distribution for the selected euro area banks (2014Q4-2018Q1)



Description: This figure illustrates the distribution of our measure of IRR, namely ΔNII weighted on bank gross income, following a 200 bps increase in interest rates, for 81 euro area banks during the period 2014Q1-2018Q4. In the right (left) tail of the exposure distribution, there are those banks that gain (suffer) from an increase in interest rates.

Table 1. Sample composition: Countries, number of banks, related percentages and macroeconomic descriptive statistics

Country	**N. of Banks**	**%**
Austria	2	2.46
Belgium	5	6.17
Cyprus	4	4.93
Germany	16	19.75
Spain	12	14.81
Finland	2	2.46
France	6	7.40
Greece	4	4.93
Ireland	4	4.93
Italy	9	11.11
Lithuania	2	2.46
Latvia	3	3.70
Malta	2	2.46
Netherlands	4	4.93
Portugal	3	3.70
Slovenia	3	3.70
Total	81	100

Description: This table reports the euro area countries included in the sample, the number of banks and the related percentage (proportion of the total number of banks).

Table 2. Definition of variables and expected signs

Variable	Label	Definition	Exp. sign
		Dependent variables	
Interest rate risk	ΔNII	The reported bank net interest income (NII) expected to change over a one-year time in response to an increase of 200 bps in interest rates. This measure is weighted on bank gross income.	
Interest rate risk	ΔNIM	The projected change in net interest margin (NIM) over one-year time in response to an increase of 200 bps in interest rates. This measure is weighted on bank gross income.	
		Variables of interest	
Fixed-rate loans	FIXED	The ratio of loans with fixation period over 5 years (up to 10 years) and over 10 years to total assets.	+
Funding structure	CADEP	The ratio of demand and transaction deposits to total assets.	-
Lending concentration (by productive sector)	HHISECTOR	The Herfindahl-Hirschman Index (HHI) measure of lending concentration based on the following 18 productive sectors (as per the ECB's classification): agricultural; mining and quarrying; manufacturing; electricity, gas, steam and air conditioning; water supply; construction; wholesale and retail trade; transport and storage; accommodation and food service activities; information and communication; real estate activity; professional, scientific and technical activity; administrative and support service activities; public administration defence and compulsory social security; education; human health; services and social work activities; others.	+/-
Lending concentration (by geographic area)	HHIGEO	The Herfindahl-Hirschman Index (HHI) measure of lending concentration computed using the amount of outstanding loans issued towards 172 countries outside the euro area.	+/-
TLTRO	TLTRO	The ratio of TLTROI and TLTROII-liquidity to total assets.	-
		Bank control variables	
Capitalisation	E/TA	The ratio of equity to total assets.	
Non-performing loan ratio	NPL	The ratio of non-performing loans to gross loans.	
Business model	FEE	The ratio of fee and commission income to total assets.	
Liquidity	HQLA	The ratio of high-quality liquid assets to total assets.	
		Country control variables	
GDP growth	GDP	The quarterly growth rate of nominal GDP.	
Inflation	INFLATION	The quarterly Consumer Price Index (CPI).	

Description: This table provides a definition of the selected variables employed in the empirical analysis. The associated expected signs for the coefficients on the main variables of interest are also reported.

Table 3. Summary statistics

Variables	Obs.	Mean	Std.Dev.	Min	Max
Panel A. Dependent variables					
ΔNII	1598	0.015	0.019	-0.045	0.057
ΔNIM	1593	-0.001	0.020	-0.062	0.041
Panel B. Variables of interest					
FIXED	1214	0.099	0.130	0.000	0.404
CADEP	1595	0.308	0.205	0.147	0.871
HHISECTOR	1656	0.229	0.189	0.078	1.000
HHIGEO	1656	0.505	0.394	0.000	1.000
TLTRO	1595	0.010	0.030	0.000	0.364
Panel C. Bank control variables					
E/TA	1595	0.080	0.039	0.016	0.250
NPL	1552	0.095	0.118	0.004	0.550
FEE	1576	0.005	0.005	0.001	0.063
HQLA	1522	0.155	0.108	0.009	0.729
Panel D. Country control variables					
GDP (%)	1656	0.606	1.436	-5.800	10.180
INFLATION (%)	1656	0.526	1.221	-5.401	4.400

Description: Organised in four panels, this table presents the summary statistics for the variables employed in the empirical analysis. Panel A reports the summary statistics for the dependent variables, Panel B for the variables of interest, Panel C for the bank control variables and Panel D for the country control variables.

Note: ΔNII is the reported bank NII that is expected to change in one-year time in response to an increase of 200 bps in interest rates (weighted on bank gross income). ΔNIM is the projected change in the NIM over a one-year time in response to an increase of 200 bps in interest rates (weighted on bank gross income). FIXED is the ratio of loans with a fixation period over 5 years (up to 10 years) and over 10 years to total assets. CADEP is the ratio of total demand and transaction deposits to total assets. HHISECTOR is the Herfindahl-Hirschman Index (HHI) of lending concentration by productive sector. HHIGEO is the Herfindahl-Hirschman Index (HHI) of lending concentration by geographical area. TLTRO is the ratio of TLTRO-liquidity to total assets. E/TA is the ratio of equity to total assets. NPL is the ratio of non-performing loans to gross loans. FEE is the ratio of fee and commission income to total assets. HQLA is the ratio of high-quality liquid assets to total assets. GDP is the quarterly growth rate of nominal GDP. INFLATION is the quarterly Consumer Price Index (CPI) in percentage.

Table 4. Main panel data regression

	(1) ΔNII	(2) ΔNII	(3) ΔNII
FIXED	-0.0270*	-0.0265*	-0.0278*
	(0.0144)	(0.0138)	(0.0146)
CADEP	0.0252**	0.0210**	0.0273**
	(0.0109)	(0.0103)	(0.0117)
HHISECTOR	-0.0325***	-0.0288***	-0.0319***
	(0.0094)	(0.0091)	(0.0109)
HHIGEO	-0.0051*	-0.0070***	-0.0082***
	(0.0028)	(0.0025)	(0.0028)
TLTRO		0.1081***	0.1303***
		(0.0363)	(0.0400)
Observations	990	990	990
R-squared	0.2656	0.2775	0.3118
Number of Banks	81	81	81
Bank Controls	Yes	Yes	Yes
Country Controls	No	Yes	Yes
Bank-FE	Yes	Yes	Yes
Time-effects	No	No	Yes
Cluster	Bank	Bank	Bank

Description: IRR is the reported bank NII that is expected to change in a one-year time in response to an increase of 200 bps in interest rates. This measure is weighted on bank gross income. FIXED is the ratio of loans with a fixation period over 5 years (up to 10 years) and over 10 years to total assets. CADEP is the ratio of total demand and transaction deposits to total assets. HHISECTOR is the Herfindahl-Hirschman Index (HHI) of lending concentration by productive sector. HHIGEO is the Herfindahl-Hirschman Index (HHI) of lending concentration by geographical area. TLTRO is the ratio of TLTRO-liquidity to total assets. Bank controls are: E/TA (the ratio of equity to total assets), NPL (the ratio of non-performing loans to gross loans), FEE (the ratio of fee and commission income to total assets), HQLA (the ratio of high-quality liquid assets to total assets). Country controls are: GDP (the quarterly growth rate of nominal GDP) and INFLATION (the quarterly CPI in percentage). Robust standard errors, in parentheses, are clustered at the bank-level.
Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Table 5. Quantile regression (QR) with fixed-effects

	(1) ΔNII **(10th)**	(2) ΔNII **(25th)**	(3) ΔNII **(50th)**	(4) ΔNII **(75th)**	(5) ΔNII **(90th)**
FIXED	-0.0321*	-0.0296**	-0.0256**	-0.0198	-0.0146
	(0.0175)	(0.0139)	(0.0116)	(0.0182)	(0.0280)
CADEP	0.0361**	0.0297***	0.0192**	0.0039	-0.0095
	(0.0132)	(0.0105)	(0.0088)	(0.0138)	(0.0213)
HHISECTOR	-0.0226*	-0.0271**	-0.0343***	-0.0448***	-0.0542**
	(0.0129)	(0.0118)	(0.0099)	(0.0155)	(0.0240)
HHIGEO	-0.0080**	-0.0089***	-0.0103***	-0.0124***	-0.0142**
	(0.0040)	(0.0031)	(0.0026)	(0.0041)	(0.0064)
TLTRO	0.2351***	0.1973***	0.1547***	0.1255***	0.1077***
	(0.0641)	(0.0416)	(0.0266)	(0.0317)	(0.0399)
Observations	990	990	990	990	990
Number of Banks	81	81	81	81	81
Bank Controls	Yes	Yes	Yes	Yes	Yes
Country Controls	Yes	Yes	Yes	Yes	Yes
Bank-FE	Yes	Yes	Yes	Yes	Yes

Description: This table reports the results for the quantile regressions. IRR is the reported bank NII that is expected to change over a one-year time in response to an increase of 200 bps in interest rates. This measure is weighted on bank gross income. FIXED is the ratio of loans with a fixation period over 5 years (up to 10 years) and over 10 years to total assets. CADEP is the ratio of total demand and transaction deposits to total assets. HHISECTOR is the Herfindahl-Hirschman Index (HHI) of lending concentration by productive sector. HHIGEO is the Herfindahl-Hirschman Index (HHI) of lending concentration by geographical area. TLTRO is the ratio of TLTRO-liquidity to total assets. Bank controls are: E/TA (the ratio of equity to total assets), NPL (the ratio of non-performing loans to gross loans), FEE (the ratio of fee and commission income to total assets), HQLA (the ratio of high-quality liquid assets to total assets). Country controls are: GDP (the quarterly growth rate of nominal GDP) and INFLATION (the quarterly CPI in percentage). Robust standard errors, in parentheses, are clustered at the bank-level.
Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Table 6. IRR and lending concentration measures

	(1) ΔNII	(2) ΔNII	(3) ΔNII
Panel A. ΔNII and HII by productive sector (excluding loans in "real estate activity" sector)			
HHISECTOR	-0.0513***	-0.0427***	-0.0611***
	(0.0145)	(0.0129)	(0.0191)
Obs.	990	990	990
R-squared	0.2866	0.3001	0.3396
N. of banks	81	81	81
Bank controls	Yes	Yes	Yes
Country controls	No	Yes	Yes
Bank-FE	Yes	Yes	Yes
Time-effects	No	No	Yes
Cluster	Bank	Bank	Bank
Panel B. ΔNII and HHI by geographical area (low vs high-interest rate countries)			
HIIGEO	-0.0217***	-0.0202***	-0.0212***
	(0.0074)	(0.0074)	(0.0078)
Obs.	990	990	990
R-squared	0.2730	0.2924	0.3237
N. of banks	81	81	81
Bank controls	Yes	Yes	Yes
Country controls	No	Yes	Yes
Bank-FE	Yes	Yes	Yes
Time-effects	No	No	Yes
Cluster	Bank	Bank	Bank

Description: Panel A presents the empirical results for the panel data regression that considers the HHISECTOR variable as the main explanatory variable, excluding the "real estate activity" sector from its computation. Panel B reports the empirical results for the panel data regression that considers HHIGEO as the main explanatory variable and differentiates between "low" and "high" interest rates countries. IRR is the reported bank NII that is expected to change over a one-year time in response to an increase of 200 bps in interest rates. This measure is weighted on bank gross income. Robust standard errors, in parentheses, are clustered at the bank-level.
Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Table 7. Results for the sample without G-SIBs

	(1) ΔNII	(2) ΔNII	(3) ΔNII
FIXED	-0.0296*	-0.0292*	-0.0296*
	(0.0153)	(0.0147)	(0.0154)
CADEP	0.0294**	0.0249**	0.0308**
	(0.0127)	(0.0120)	(0.0135)
HHISECTOR	-0.0311***	-0.0276***	-0.0312***
	(0.0095)	(0.0091)	(0.0110)
HHIGEO	-0.0053***	-0.0072***	-0.0083***
	(0.0028)	(0.0026)	(0.0029)
TLTRO		0.1082***	0.1274***
		(0.0365)	(0.0405)
Observations	878	878	878
R-squared	0.2752	0.2870	0.3232
Number of Banks	73	73	73
Bank Controls	Yes	Yes	Yes
Country Controls	No	Yes	Yes
Bank-FE	Yes	Yes	Yes
Time-effects	No	No	Yes
Cluster	Bank	Bank	Bank

Description: IRR is the reported bank NII that is expected to change in a one-year time in response to an increase of 200 bps in interest rates. This measure is weighted on bank gross income. FIXED is the ratio of loans with a fixation period over 5 years (up to 10 years) and over 10 years to total assets. CADEP is the ratio of total demand and transaction deposits to total assets. HHISECTOR is the Herfindahl-Hirschman Index (HHI) of lending concentration by productive sector. HHIGEO is the Herfindahl-Hirschman Index (HHI) of lending concentration by geographical area. TLTRO is the ratio of TLTRO-liquidity to total assets. Bank controls are: E/TA (the ratio of equity to total assets), NPL (the ratio of non-performing loans to gross loans), FEE (the ratio of fee and commission income to total assets), HQLA (the ratio of high-quality liquid assets to total assets). Country controls are: GDP (the quarterly growth rate of nominal GDP) and INFLATION (the quarterly CPI in percentage). Robust standard errors, in parentheses, are clustered at the bank-level.
Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Table 8. Results for model specification with the alternative dependent variable

	(1) ΔNIM	(2) ΔNIM	(3) ΔNIM
FIXED	-0.0300***	-0.0231***	-0.0223***
	(0.0086)	(0.0058)	(0.0058)
CADEP	0.0019**	0.0090**	0.0087**
	(0.0087)	(0.0035)	(0.0037)
HHISECTOR	-0.0095***	-0.0045***	-0.0046***
	(0.0033)	(0.0021)	(0.0022)
HHIGEO	-0.0000	-0.0010	-0.0011
	(0.0012)	(0.0007)	(0.0008)
TLTRO		0.0281*	0.0268*
		(0.0163)	(0.0166)
Observations	990	990	990
R-squared	0.4248	0.4358	0.3118
Number of Banks	81	81	81
Bank Controls	Yes	Yes	Yes
Country Controls	No	Yes	Yes
Bank-FE	Yes	Yes	Yes
Time-effects	No	No	Yes
Cluster	Bank	Bank	Bank

Description: IRR is the projected change in net interest margin (NIM) over a one-year time in response to an increase of 200 bps in interest rates. This measure is weighted on bank gross income. FIXED is the ratio of loans with a fixation period over 5 years (up to 10 years) and over 10 years to total assets. CADEP is the ratio of total demand and transaction deposits to total assets. HHISECTOR is the Herfindahl-Hirschman Index (HHI) of lending concentration by productive sector. HHIGEO is the Herfindahl-Hirschman Index (HHI) of lending concentration by geographical area. TLTRO is the ratio of TLTRO-liquidity to total assets. Bank controls are: E/TA (the ratio of equity to total assets), NPL (the ratio of non-performing loans to gross loans), FEE (the ratio of fee and commission income to total assets), HQLA (the ratio of high-quality liquid assets to total assets). Country controls are: GDP (the quarterly growth rate of nominal GDP) and INFLATION (the quarterly CPI in percentage). Robust standard errors, in parentheses, are clustered at the bank-level.
Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Appendix

Table A1. Correlation matrix for the variables employed in the empirical analysis

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) FIXED	1.000										
(2) CADEP	-0.310*	1.000									
(3) E/TA	-0.301*	0.353*	1.000								
(4) FEE	-0.197*	0.433*	0.168*	1.000							
(5) NPL	-0.318*	0.093*	0.212*	-0.022	1.000						
(6) HQLA	-0.130*	0.350*	0.098*	0.339*	-0.171*	1.000					
(7) HHISECTOR	0.012	-0.256*	-0.214*	0.039	-0.206*	0.237*	1.000				
(8) HHIGEO	-0.011	0.071*	0.070*	0.073*	-0.048	0.160*	0.385*	1.000			
(9) TLTRO	-0.153*	0.053	-0.031	0.035	0.178*	-0.169*	-0.130*	-0.148*	1.000		
(10) GDP growth	0.003	0.073*	0.057	-0.010	-0.052	0.025	0.005	-0.001	-0.045	1.000	
(11) Inflation	0.148*	0.055	-0.083*	0.084*	-0.493*	0.222*	0.062	0.022	-0.058	0.071*	1.000

Description: This table reports the correlation matrix for the variables employed in the empirical analysis. FIXED is the ratio of loans with a fixation period over 5 year (up to 10 years) and over 10 years to total assets. CADEP is the ratio of total demand and transaction deposits to total deposits. E/TA is the ratio of equity to total assets. FEE is the ratio of fee and commission income to total assets. NPL is the ratio of non-performing loans to gross loans. HQLA is the ratio of high-quality liquid assets to total assets. HHISECTOR is the Herfindahl-Hirschman Index (HHI) of lending concentration by productive sector. HHIGEO is the Herfindahl-Hirschman Index (HHI) of lending concentration by geographical area. TLTRO is the ratio of TLTRO-liquidity to total assets. GDP is the quarterly growth rate of nominal GDP. INFLATION is the quarterly Consumer Price Index (CPI) in percentage.
Note: * significant at the 1% level.