Do Banks Hedge with Derivatives for Negative Interest Rate Policy? International Evidence

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Abstract

This study empirically investigates the effects of a negative interest rate policy (NIRP) on bank net worth and hedging using derivatives. We employ global panel data on 7,742 banks in 54 countries from 2001 to 2021, with a final sample of 13,298 bank-year observations available. Our findings indicate that a negative interest rate policy has a significant and positive effect on bank net worth while having a significant adverse effect on hedging. Implementing NIRP has no negative impact on the positive relationship between net worth and hedging, while the negative interest rates increase bank risk-taking to maintain the bank's net worth and profits. Simultaneously, when NIRP is implemented, banks are more likely to be cautious in selecting hedging strategies. Although hedging will help banks manage risk and reduce its impact, it will increase their operating costs. Furthermore, banks with a higher net worth are better at managing interest rate risk via financial derivatives. We also discover that larger banks have greater hedging and net worth levels. The evidence supports the theory that financial constraints impede bank financing and hedging. When negative interest rates would have encouraged banks to place their excess reserves in riskier investments, this would have favored increasing risk-taking. Banks much affected by negative interest rates are more willing to expand their lending, while choosing derivatives hedging strategy has a positive effect on loan growth. This makes lending less sensitive to interest-rate uncertainty.

Keywords: Negative Interest Rate Policy (NIRP); Hedging; Derivatives; Risk Management; Bank Net Worth

1. Introduction

A few previous papers attempt to explain the trend in bank hedging by financial derivatives instruments. Begenau et al. (2015) demonstrate how US bank derivatives positions increase their exposure to interest rates and conclude that these banks do not hedge the risk. Vuillemey (2019) show that net worth and hedging have a positive relationship, even though interest rate derivatives can ease their current financing constraints. Similarly, Rampini et al. (2020) indicate that net worth is a critical factor in determining risk management over time, both among banks and within banks: banks with a larger net worth hedge greater, whereas those with diminishing net worth, do so less. The hedging process's financial requirements significantly hamper risk management.

In order to address low inflation and stimulate economic development, six Europe central banks and the Bank of Japan have gradually implemented NIRP. According to Cœuré (2016), the introduction of negative interest rates enhanced credit availability by charging banks' excess reserves stored at the central bank. NIRP lead to result in a decline in financing expenses for both lenders and debtors, a concomitant increase in credit supply and demand, and, eventually, an improvement in economic development (Angrick & Nemoto, 2017; Bank et al., 2017; Blot & Hubert, 2016; Cœuré, 2016; Jobst & Lin, 2016). This negative interest rate policy move has prompted worries about its potential impact on bank revenue and jeopardy. Negative interest rates increase hedging expenses and affect profitability and net worth. Negative interest rates impact bank profits, but those effects take time to materialize. Instead of being a level business based on interest rates, the banking intermediation business depends on the gap between interest rates on deposits and loans. This interest rate spread influences the bank's lending decision. Thus, the short-term decline in deposit and credit interest rates should result in an acceptable profit for the bank. Additionally, they are hesitant to offer negative interest rates on savings accounts. Since interest rates fall below zero, a negative deposit interest rate forces savers to withdraw money from their accounts, even if they have cash on hand, due to the negative nominal return.

Our paper investigates two primary questions: (a) "Do banks hedge with derivatives for negative interest rate policy?" and (b) "Do banks hedge to improve their net worth when a negative interest rate policy is implemented?" We analyze the determinants influencing a bank's risk management decisions by means of off-balance sheet instruments (i.e., by using interest rate derivatives, exchange rate derivatives, equity derivatives, and commodity derivatives)[1]. Remarkably, most of the literature on hedging focuses on the relationship between hedging and equity value or the connection between profitability and negative interest rate policy. Studying the associations with hedging effectiveness, profitability or net value at a low level of interest rate is scarce in globally listed banks. For this reason, as a result, the purpose of this research is to investigate the connection between hedging, net worth, and a negative interest rate policy. We use a panel dataset of 7,742 banks operating in 54 countries that use financial derivatives from 2001 to 2021, with a final sample of 13,298 bank-year observations available. We employ a comprehensive approach for calculating hedges (via financial derivatives), negative interest rate policy, and banks' net worth, which includes the following: i) hedge includes net hedging, interest rate hedging, interest rate risk management, and derivatives hedging; ii) negative interest rate policy is a dummy variable (NIRP) that takes one if NIRP is adopted and zero otherwise; and iii) banks' net worth is calculated using an index based on size, book equity (market capitalization), net income, and dividends. Lastly, we include an interaction to see if the effect of the policy interest rate on banks varies depending on whether it is positive or negative. This variable may be used to compare the impact of positive and negative rate environments on banks.

Our models illustrate that negative interest rates impact banks' hedging and net worth more than positive interest rates. We find that net worth has a significant positive effect on hedging, while NIRP has a significant negative effect (Vuillemey (2019), Rampini, Viswanathan, et al. (2020), Begenau, Piazzesi, et al. (2015), and Bartram (2011), Turk (2016), Purnanandam (2007)). These outcomes remain suitable for three measurements of hedging (i.e., net hedging, interest rate hedging, and derivative hedging). This result indicates that the

[1] This paper's assessments of hedging theories are all focused only on derivatives that are employed for "hedging purposes."

bank's net worth is higher, hedging is more efficient, and banks use fewer derivative contracts for hedging purposes when interest rates are negative or go down. However, the previous finding does not consider the relationship between net worth and hedging in a negative interest rate environment. Thus, our study will test this association by using NIRP as a moderator. Interestingly, the implementation of NIRP has no negative impact on the strong relationship between net worth and hedging. Furthermore, we find a positive relationship between bank size and hedging, as well as interest rate level, interest rate volatility, capitalization, and lending, while earning assets has a negative effect. Based on these findings, hedging will help manage risk and reduce its impact while increasing the bank's costs. Although banks can be proactive in employing financial derivatives to hedge against interest rate increases (or decreases) or movements, they must exercise caution when selecting hedging strategies. Importantly, when NIRP is adopted, there is an increase in financial demand. In other words, banks further impacted by negative interest rates are more likely to take risks to maintain profits and net worth (Schelling and Towbin (2022) and Brewer et al. (2014)). However, due to the (low) negative interest rate environment, banks find it challenging to generate money via their traditional lending and funding techniques. We also discovered that larger banks have greater hedging and net worth levels.

We demonstrate that banks' net worth is positively related to interest rate risk management and derivative hedging, and this relationship is not changed in the NIRP period. Our findings support that risk management is more effective, and the bank's net worth is higher. Fascinatingly, the application of NIRP has no harmful impact on the strong relationship between net worth and risk management. For the control variable coefficients, we find that higher net worth is associated with larger and better-capitalized banks, and the same is true for ROE. We demonstrate a positive correlation between net worth and lending as deposits. Our outcomes determine a procyclical effect on net worth because real GDP growth and inflation coefficients have a significant positive influence. Long-term interest rates have the opposite effect on net worth as interest rate volatility. These results suggest that NIRP can contribute to additional monetary policy stimulus in an environment of solid GDP growth, falling interest rates, and proper inflation growth. Although banks benefit from

higher loan interest rates, they also face greater risk if they fluctuate rapidly. Furthermore, NIRP has no negative impact on a bank's net worth if policy interest rates remain mildly negative or non-negative for an extended period of time in order to avoid long-term negative effects on the financial sector. Our measures of banks' risk management enable us to accurately assess the effects of NIRP on banks' net worth and profitability, supplementing the literature findings. When negative interest rates would have encouraged banks to place their excess reserves in riskier investments, this would have favored increased risk-taking. Novelty, banks that are more affected by negative interest rates are more willing to lend, and choosing a derivatives hedging strategy has a positive effect on loan growth. It makes lending less sensitive to interest-rate uncertainty.

If the banks offer negative interest rates on deposits, they run the risk of losing savers to other banks. Bank profits will suffer if they refuse to pass on negative interest rates on client credits. As a result, a reduction in bank margins might result in a drop in equity capital, financial stability, and profitability Zimmermann (2019). In light of this, this paper seeks to investigate the impact of NIRP on hedging, bank net worth, and profitability in globally listed banks. This paper has three goals: whether banks hedge with derivatives for a negative interest rate policy; investigating how hedging has reacted to the effects of the negative interest rate policy period to improve net worth; determining whether negative interest rates have reduced banks' hedging efficiency in light of financial constraints and demands. This paper makes four contributions. First, unlike most studies on negative interest rates, which focus solely on individual countries or the European Union[2], our study includes 54 countries. Second, we consider how a negative interest rate policy impacts hedging and net worth. We use NIRP as a moderator variable for the relationship between net worth, interest rate levels, and hedging. Third, we investigate the effects of risk management (via derivatives held for hedging purposes) on bank net worth. We also use NIRP as a moderator variable for the relationship between risk management, interest rate levels, and net worth. Finally, we

[2] Switzerland (Basten & Mariathasan, 2018), Austria (Kerbl & Sigmund, 2017), Sweden and Denmark (Madaschi & Pablos Nuevo, 2017), and the European Union (Boungou, 2019).

investigate how net hedging has reacted to the effects of financial constraints and financial demands both before and after the NIRP application.

The study is organized as follows: Section 2 contains the literature review and the formulation of the study hypotheses. Section 3 provides descriptions of the observation sample, variables, empirical models, and methods. Section 4 of the report discusses the empirical findings. Finally, Section 5 presents the conclusion.

2. Literature review and hypotheses development

This section briefly reviews the literature on the relationship between bank net worth, negative interest rate policy, and hedging derivatives. In the opening section, we analyze the research on the connections between net worth, negative interest rate policy, and derivatives used for hedging. The following section concentrates on the association between net worth, bank profitability, risk management, and negative interest rate policy. In the final section, we discuss the connections between net hedging, loans, financial constraints, financial demand, and negative interest rate policy.

2.1 Hedging derivatives, net worth, and the negative interest rate policy

A few recent papers (Vuillemey, 2019; Rampini et al., 2020; Begenau et al., 2015; Di Tella & Kurlat, 2017) aim to explain correlations between interest rate hedging and a bank's net worth. Some of them are in favor of hedging and net worth having a positive relationship. For example, Vuillemey (2019) showed that banks with greater net worth engage in more hedging, while banks with declining net worth reduce hedging (i.e., interest rate risk hedging), consistent with empirical data from Rampini et al. (2020). Similarly, Rampini et al. (2020) observed that the financing demands related to hedging constitute a significant impediment to risk management. According to Begenau et al. (2015), US banks do not want to hedge because their derivatives positions increase their exposure to interest rates. The closest study is by Di Tella and Kurlat (2017), who discovered that banks are risk-averse and can best tolerate losses when interest rates rise because they anticipate higher spreads on deposits in the future.

According to Begenau et al. (2015), showed that the bank's net worth is declining at the level of interest rates, and a significant portion of hedging banks use derivatives to increase their exposure to rising interest rates. Similarly, Purnanandam (2007) indicated that the level of interest rates hurts derivatives-hedging decisions. Derivatives contracts are intended to reduce the risk associated with changing interest rates (i.e., interest rate swaps). Nevertheless, the low (negative) interest rate environment, for example, had an impact on fixed-to-float interest rate swaps. As said by Turk (2016), longer-term fixed-rate loans result in higher hedging costs against interest rate changes. Thus, when interest rates are negative, parties may incur significantly higher costs and have considerably less hedging flexibility. Besides that, Turk (2016) supplied evidence that the total cost of bank financing—combining short-term and long-term financing with interest risk hedging—has decreased since Sweden implemented negative interest rates. Therefore, despite the fall in lending rates after the implementation of the negative interest rate, bank funding cost compression has assisted in maintaining lending margins.

Currently, there has yet to be an agreement on the effects of NIRP on bank net worth and profitability. Some authors discovered that low (negative) interest rates reverse the effect on profitability. During the implementation of negative interest rates, bank profits fell, particularly for smaller banks (Dell'ariccia et al., 2017; Genay & Podjasek, 2014; Memmel, 2017). However, some other authors showed that a very low (negative) interest rate period has yet to reduce bank profits significantly. As studied by Altavilla et al. (2017), Basten & Mariathasan (2018), Jobst & Lin (2016), Kerbl & Sigmund (2017), López-Penabad, Iglesias-Casal, & Neto (2022), Madaschi & Pablos Nuevo (2017), and Scheiber et al. (2016). They discover that despite the implementation of negative rates and banks' resistance to enacting negative deposit rates, bank profitability has continued to rise. Different effects of negative rates on bank profitability can be explained by banks' capacity to diversify their sources of income.

Nevertheless, there is no assurance that the bank’s net worth and profit will endure over an extended period. Some authors stress that a variety of bank characteristics, such as bank size and business model, which have a significant impact on the relationship between low

(negative) interest rates and bank profitability, affect the impact of low (negative) interest rates on profitability. As with short-term interest rates, the implementation of NIRP reduces a bank's return on assets. Under a negative interest rate, banks find it challenging to generate non-interest income that makes up for lost interest income (López-Penabad, Iglesias-Casal, & Neto, 2022; Molyneux et al., 2020). According to Schelling and Towbin (2022), banks that are more impacted by NIRP are more willing to lend. This result also implies that banks are taking risks to maintain profits when interest rates are low. As per research by Brewer et al. (2014), using interest-rate derivatives positively affects loan growth and makes lending less sensitive to interest-rate uncertainty.

In summary, we expect a positive relationship between hedging and net worth. The banks will hedge less with derivatives under a negative interest rate policy to reduce financial risks. Additionally, they are more risk-taking, which reacts to the effects of the negative interest rate policy period to maintain net worth and profits. Although it is uncertain whether NIRP will significantly influence hedging costs, the following hypotheses have been developed in response to banks' difficulties in reducing the cost of hedging and securing their net worth in a negative interest rate environment.

Hypotheses 1: The bank's net worth is higher, and the hedging is greater.

Hypotheses 2: A negative interest rate policy leads to decreased hedging.

Hypotheses 3: A negative interest rate policy moderates the relationship between net worth and hedging. As a negative interest rate policy increases, the relationship between net worth and hedging will less positive.

2.1.2 Net worth, risk management, and negative interest rate policy

In recent years, several central banks have used negative interest rate policies to further endorse monetary policy in response to ongoing growth letdowns, low inflationary pressures, and declining real-balance interest rates. In particular, if policy rates are meager or NIRP is used for an extended period, NIRP may jeopardize financial sustainability. Two potential negative effects include excessive risk-taking and a decline in the profitability of banks and

other financial intermediaries. However, there has yet to be any conclusive proof to date that the NIRP has jeopardized financial stability (Arteta, Kose et al. (2016); Mohamed Rochdi, Keffala (2021).

We analyze the connections between net worth, risk management (via financial derivatives), and negative interest rate policy. There needs to be more research in the literature to analyze this relationship because negative interest rate policy is just implemented. Regarding the effects of negative rates on bank profitability, the findings of this literature are not all in agreement. Some studies show that negative interest rates harmfully affect profitability (Dell'ariccia et al., 2017; Genay & Podjasek, 2014; Memmel, 2017). The authors demonstrate that bank profits fell during the application of negative interest rates, particularly for smaller banks. Nevertheless, other studies show the conflicting outcomes (Basten & Mariathasan, 2018; Madaschi & Pablos Nuevo, 2017; Scheiber et al., 2016). Negative interest rates haven't significantly impacted net interest income or bank profitability yet. They learn that despite negative interest rates and banks' reluctance to implement negative deposit rates, bank profitability has kept rising.

Besides that, NIRP can contribute to additional monetary policy stimulus when the banks face an environment of weak growth, declining real interest rates, and low inflation expectations. In this condition, policy interest rates are only slightly negative or non-negative for an extended period to prevent long-term negative effects on the financial sector. In order to ensure their benefits while minimizing risks, these policies must be carefully controlled. As a result, a negative interest rate policy is one of a policymaker's tools. Recent empirical evidence suggests a correlation between short-term interest rates and low-interest rate environments, negatively impacting profitability (Claessens, Coleman et al. (2018); Borio, Gambacorta et al. 2017).

Some authors looked into the influence of derivatives activity on banks' profitability. They discovered a positive relationship between banks' profitability (i.e., ROA) and using derivatives (Li and Yu (2010); Shen and Hartarska (2013); Gitogo (2012); Ghosh (2017). Bartram (2011) found strong evidence that the use of financial derivatives reduces

both total and systematic risk. Using derivatives is associated with significantly higher value, abnormal returns, and larger profits during the economic downturn in 2001–2002, suggesting that firms are hedging downside risk. We examine whether NIRP has favored increased cost of risk management since its implementation. The connection between NIRP and interest rate risk management needs to be better documented. The current research indicates that a negative interest rate policy would have improved risk-taking by inspiring banks to invest their extra capital in riskier investments (Heider et al., 2019; Jobst & Lin, 2016). Our measures of banks' interest rate risk management allow us to precisely measure the effects of NIRP on banks' net worth and profitability, supplementing the literature's findings.

In conclusion, we anticipate a positive association between net worth and risk management (through derivatives held for hedging reasons), even in a negative interest rate situation. In evaluating this hypothesis, it may be critical to consider both the interest rate level and volatility. Although it is unclear if NIRP will significantly influence bank profitability and net worth, the following hypotheses are developed in response to banks' challenges in maintaining net worth and profit in a negative interest rate environment.

Hypothesis 4: More efficient risk management leads to increased bank net worth.

Hypothesis 5: A negative interest rate policy does not significantly reduce net worth.

Hypothesis 6: A negative interest rate policy moderates the relationship between net worth and risk management. As negative interest rate policy increases, the relationship between net worth and risk management will become less positive.

2.1.3 Net interest rate hedging, lending opportunities, and negative interest rate policy

Unlike non-financial firms, the essential characteristic of banks is that deposits are used to finance loans. When challenged with a deposit outflow (loans), the bank releases interbank debt or equity to close the funding gap. Financial frictions create incentives to accomplish interest rate jeopardy (Vuillemey, 2019). Because of collateral restrictions, the bank cannot increase counterparty debt, and releasing capital is expensive. As a result, risk can be controlled by using interest rate swaps or by holding onto unused debt capacity. According

to Vuillemey (2019), more distressed debt banks and large funding needs are more probably to hedge increases in interest rates. Furthermore, this model suggests that banks are more likely to hedge interest rate drops if lending possibilities fluctuate or persistently.

Since 2012, a few central banks have initiated NIRP to boost actual expenditure by increasing both the demand and supply of bank loans. Bank lending in NIRP-adopted countries fell after the policy was implemented, and bank capitalization and interest rate exposure make banks less eager to lend. For smaller banks with net interest margin-dependent business models, this harmful NIRP effect is more pronounced (Brunnermeier and Koby, 2016; Molyneux, Reghezza, et al., 2020). Vuillemey (2017) implied that higher loan growth volatility and persistence are related to greater negative net hedging, which suggests that banks with more unstable future lending have the potential to assume additional interest rate risk through derivatives. This negative interest rate policy instrument has elevated concerns about its potential effects on bank effectiveness and jeopardy. Negative interest rates might increase hedging costs and lower profitability and net worth. Negative interest rates impact bank profits, but those effects take time to materialize. Instead of being a transaction depending on the level of interest rates, banking intermediation is a spread business based on the difference between lending and deposit interest rates. This interest rate spread influences the bank's lending decision. Thus, the bank's profit should be acceptable with the decrease in deposit rates and credit interest rates in the short term. Banks are hesitant to implement negative interest rates on depositors' funds because a negative savings interest rate would cause depositors to withdraw money from their accounts because of the negative nominal yield, even though they had cash. However, Schelling (2022) discovered that banks negatively impacted by negative interest rates are more willing to lend. This result also implies that banks are taking risks to maintain profits when interest rates are low. Brewer (2014) investigated using interest-rate futures positively impacting loan growth and is less sensitive to lending interest-rate uncertainty.

Vuillemey (2019) and Rampini et al. (2020) say net hedging will be negative when the interest rate decreases. For this outcome, there are two primary explanations. First, the bank may be required to make sizable swap payments in the future when accepting a pay-fixed

position to increase its current debt capacity. The banks may need external funds, and it costs more for banks to use derivatives when future funding needs are uncertain. Thus, they accordingly tend to deploy fewer pay-fixed swaps. Following that, when interest rate shocks are more unpredictable or persistent, potential lenders are more likely to be motivated by negative interest rates. The optimal banker wants to invest more money with negative rates in future positions as the investment incentive grows. As a result, they tend to use fewer pay-floated swaps.

According to the theories, banks can hedge against changes in interest rates in the absence of speculative incentives. The value of net hedging is positive due to the utilization of pay-fixed positions (a hedge against rising interest rates). In pay-float scenarios, net hedging will have a negative value (a hedge against a declining interest rate). Thus, we research the bank's best hedging strategy. The following hypotheses are developed in response to banks' difficulties when presented with more unpredictable or persistent lending possibilities, particularly in a negative interest rate environment.

Hypothesis 7: Banks are more able to hedge interest rate decreased (i.e., net hedging has a negative value) when faced with more loan volatility and persistence.

Hypothesis 8: When NIRPs are adopted, banks used higher pay-floated swaps to hedge against falling interest rates (the value of net hedging will be negative)

Hypotheses 9: A negative interest rate policy moderates the relationship between net interest rate hedging and volatile or persistent lending opportunities. As a negative interest rate policy increases, the relationship between net hedging and volatile or persistent lending opportunities will less negative.

2.4 Net interest rate hedging, financial constraints, and negative interest rate policy

One popular risk management theory contends that financial constraints cause banks (or other financial organizations) to become increasingly risk-averse, encouraging them to hedge. However, financial constraints make risk management difficult (Froot et al., 1993). Based on this logic, when the banks are more constrained, they either hedge less or not.

Instead of allocating limited internal resources to risk management, they use their constrained net worth to make lends (Rampini & Viswanathan, 2010, 2013). Contrary to popular belief, financial constraints are only one of the things standing in the way of effective risk management, and they are also the reason why it is necessary. As a result, the fundamental premise of this theory is that banks with fewer financial constraints will hedge more, leading to a positive correlation between hedging measures and net worth (see Froot and Stein, 1998; Rampini & Viswanathan, 2019).

In order to correctly interpret the data below, it is essential to note that risk management is constrained, which is a sign of demand Vuillemey (2018). According to Froot (1993), hedging and net worth have a negative relationship. In contrast, Rampini (2010, 2019) shows that hedging is increasing in net worth measures. Similarly, Holmström (2000) contends that credit-constrained business owners may decide against purchasing full protection coverage against liquidity shocks, suggesting that poor risk management may be preferable. Mello (2000) makes the case that financial limitations might prevent hedging. The following hypotheses develope to test this conflict findings. The difference in forecast arises from our model taking into account the impact of a negative interest rate policy, as well as financial restrictions when hedging.

Hypothesis 10: *The bank, which has fewer financial constraints, tends to use derivatives to hedge more (i.e., its net hedging has a positive value).*

Hypothesis 11: *A negative interest rate policy moderates the relationship between financial constraints and hedging. As a negative interest rate policy increases, the relationship between financial constraints and net hedging will become less negative.*

2.4 Net interest rate hedging, book debt ratio, and negative interest rate policy

Graham and Rogers (2002) and Bartram (2011) show that the increase in debt capacity and leverage associated with hedging increases firm value. Bartram (2011) provides evidence that derivative users have significantly higher gross interest rate exposure, measured by higher leverage and lower quick ratios. Bartram, Brown, and Stulz (2011) find that leverage and liquidity are important determinants of both total and systematic risks. Allayannis and

Weston (2001) find that leverage is related to firm value. Vuillemey (2019) states that significant increases in leverage are linked to operational decisions to take pay-fixed swap positions. Hence, its net hedging ratio takes on a negative value when the bank increases leverage.

Hypothesis 12: *When a bank increases its book debt, it tends to use derivatives to hedge more (i.e., its net hedging has a positive value).*

Hypothesis 13: *A negative interest rate policy moderates the relationship between book debt and hedging. As a negative interest rate policy increases, the relationship between book debt and net hedging will become less positive.*

3. Data and Variable Definition

This section describes our data, empirical models, and research design. To begin, we demonstrate sampling and data collection. Following that, we provide empirical models containing the measurement of dependent and independent variables, bank and country control variables.

3.1 Sample and data collection

There are four primary sources of data in this study: a) balance sheet data from BankScope; b) annual report of banks from the bank's website[3]; b) market data from Thomson Reuters Eikon; c) country data from World Bank; d) interest rate from OECD[4] and central bank. Our sample period started from 2001 – 2021. The final balance sample contains 13,298 bank-year observations with financial derivatives greater than zero. We concentrate on holding companies (BHC) and individual banks. In case of a combination, the remaining bank is seen as existing both before and after the merger. All variables have detailed explanations in Appendix A.

[3] U.S. data from Call Reports (downloaded from FFIEC).
[4] OECD data (https://data.oecd.org/interest/short-term-interest-rates.htm).

We show the procedure for sample selection; see more information in Table 1. We first take into consideration all bank-year observations (788,798) for which annual accounting and financial information is available on BankScope and financial derivatives on annual reports, which include: financial derivatives with missing information (717,662); financial derivatives with a value equal to zero (52,167), no available data and unsuccessful match (2,671). We exclude missing information on financial derivatives because we only concentrate on derivatives-hedging activities in the bank sector. The initial sample is then updated using the following criteria: (a) excluding the lack of financial derivatives information (717,662); (b) financial derivatives with a value equal to zero (52,167); (c) bank-year observation of the unsuccessful match when they merged with Thomson Reuters Eikon, as well as missing information on control variables (1,621); (d) and observations of banks with no available data in all 20 years (1,050). As a result, we obtain a final sample of 13,298 bank-year observations over the period 2001–2021.

3.2 Empirical models

3.2.1 Dependent and independent variables

Gross interest rate hedging (Interest Rate Hedging): According to Vuillemey (2019), bank hedging is increasing in the level of interest rates. Banks may be required to completely hedge marketable risks, such as interest rate risk when there are financial constraints. However, many banks are not hedging interest rate risk in derivatives markets. To provide evidence of limited hedging by banks, we assess gross IR hedging for bank i and country j at time t is measured as

$$InterestRateHedging_{i,j,t} = \frac{Grossnotionalamount of IR derivative for hedging_{i,j,t}}{TotalAssets_{i,j,t}} (Eq.1)$$

where the denominator is total assets and the numerator includes all interest rate derivatives (swaps, futures, options, etc.). Notably, our measures include only derivatives used for hedging purposes, not trading. The annual reports (or U.S. Call Reports) data allows us to distinguish between derivatives contracts "held for trading" and "held for purposes other than

trading," that is, hedging; see Appendix A for details. As shown in Table 2, panels A and B, gross interest rate hedging is equal to zero at the 75th percentile, suggesting that many banks unarisen hedge interest rate derivatives. Additionally, the percentage of banks that hedge increases consistently with size. Similarly, Rampini et al. (2020) showed that non-hedging banks do not have lower interest rates than hedging banks. As a result, both hedging and non-hedging banks are exposed to interest rates.

Net interest rate hedging (NetHedgingRatio): According to Vuillemey (2019) and Rampini et al. (2020), many banks use derivatives to hedge interest rate decreases, i.e., they are net payers when interest rates rise and their equity value is low. To show this, we define net hedging ratio for bank i, and country j at time t is measured as

$$\left(NetHedgingRatio\right)_{i,j,t} = \frac{\left(PayFixedInterestSwap\right)_{i,j,t} - \left(PayFloatInterestSwap\right)_{i,j,t}}{TotalAssets_{i,j,t}} (Eq.2)$$

where we again include only derivatives held for hedging purposes, as shown in Appendix A. Net hedging can only be computed for a subset of banks (22,45% of bank year observations for which gross hedging is non-zero). A positive (respectively, negative) value of net hedging means that a bank is taking a net pay-fixed (respectively, pay-float) position; that is, it receives cash flows when interest rates increase (respectively, decrease). In panels C and D of Table 2, we show the distribution of net hedging if it is greater than zero, in line with the empirical result by Vuillemey (2019) and Rampini et al. (2020). The average net hedging in the panel dataset is negative, while the median is negative but close to zero. As a result, when interest rates rise, more than half of banks' derivative exposures turn into debts, reducing their equity value.

Risk management: The majority of earlier studies by (Deng et al., 2017; Petersen & Thiagarajan, 2000; Purnanandam, 2007) use derivatives as a stand-in for financial risk management. The derivative instruments reported by non-trading contracts are used for hedging. All derivatives are measured by the gross notional value of interest rate, foreign exchange, equity, and commodity derivatives used for financial risk management toolkits.

Interest rate derivatives comprise more than 85% of all derivatives and are banks' most frequently used risk management toolkits. This instrument was chosen because a bank with derivatives positions in other markets has all the necessary knowledge to use derivative instruments to manage interest rate risk. To summarize, our research measures financial risk management via two metrics: interest rate risk management and derivative hedging. We divide the gross notional value of interest rate derivatives held for interest rate risk management by total assets. The derivative hedging measurement is the total gross notional value of all derivatives held for non-trading purposes divided by total assets. Because banks face high-interest rate risks, their hedging actions directly influence their performance and manage risk through interest rate contracts and other derivatives.

$$InterestRateRiskManagement_{i,j,t} = \frac{InterestRateDerivatives_{i,j,t}}{TotalAssets_{i,j,t}} (Eq.3)$$

$$DerivativeHedging_{i,j,t} = \frac{InterestRate_{i,j,t} + ForeignExchange_{i,j,t} + Equity_{i,j,t} + Commodity_{i,j,t}}{TotalAssets_{i,j,t}} (Eq.4)$$

Net worth (NWIdex): The marginal value of net worth shows the number of financial constraints and influences risk management practices at banks. According to Vuillemey (2019) and Rampini et al. (2020), we use two different ways to measure the net worth index (NWIndex) for BHC and bank-level since market capitalization is not generally available at the bank level. For NWIndex at the bank level is constructed as the first principal component of four variables that are theoretically positively correlated with net worth: book equity over total assets; size (log total assets); net income (net income over total assets); and dividends (dividends over total assets). We get the loadings: book equity over assets (0.201), size (0.181), net income over assets (0.314), and dividends over assets (0.307)[5]. We define the NWIndex for bank i and country j at time t as

[5] These figures were calculated by Whited and Wu, (2006) and Rampini, Viswanathan, et al. (2020).

$$NWIndex^{bank}_{i,j,t} = 0.201 \times \frac{BookEquity_{i,j,t}}{TotalAssets_{i,j,t}} + 0.181 \times Size_{i,j,t} + 0.314 \times \frac{NetIncome_{i,j,t}}{TotalAssets_{i,j,t}} + 0.307 \times \frac{Dividends_{i,j,t}}{TotalAssets_{i,j,t}} \quad (Eq.5)$$

As a result, data loadings at the bank and BHC levels are somewhat comparable. These loadings are also comparable to those found in our baseline net worth index, which also uses market capitalization (see Appendix B2); the main difference is that the baseline index emphasizes size less and market capitalization more than the book equity index.

Negative interest rate policy (NIRP): In order to characterize the interest rate environment, we consider a dummy variable that indicates whether or not the central bank of the country in which the bank is based has implemented a NIRP. Panel A of Table 3 shows NIRP announcements and complementary policies. As a primary measure of negative interest rates, we use the annual average of the central bank rate that became negative. Firstly, a dummy variable (NIRP) captures the period of negative interest rate policy; this variable takes the value one starting from the year of implementation and continuing through the following year and the value 0 before this period. The vast majority of countries in our sample introduced negative rates in 2014, which is why NIRP takes the value of one from 2014[6]. Finally, we also include an interaction term to see if the effect of the policy interest rate on banks varies depending on whether it is positive or negative. This variable can be used to compare the effects of negative and positive interest rate environments on banks and to determine whether a threshold effect exists when the interest rate is less than zero (Boungou, 2019; López-Penabad, Iglesias-Casal, & Neto, 2022).

Bank profitability: We use two leading indicators to measure a bank's profitability: Net interest margin (NIM) is a substitute for bank margins that determine the profitability of bank loans while also increasing the current value of bank income. The net interest margin

[6] However, Denmark is the first country in the last decade to have introduced negative rates, so in 2012, NIRP was set at 1. For Sweden, NIRP has been equal to 1 since 2015. Finally, NIRP has been set to 1 for Japan, Hungary, and Bulgaria since 2016.

(NIM) is calculated by dividing net interest income by total assets (Adrian & Shin, 2010; Noman et al., 2015). A typical performance metric is a return on average assets (ROA), defined as the ratio of net income to total assets (Altman, 1977; Altavilla et al., 2017; Bikker & Vervliet, 2018).

Loans (Lending): According to the terms of the loan agreements, the lender will be paid a margin plus interest. Instead of being a level business based on the level of interest rates, banking intermediation is a spread business based on the difference between credit and deposit interest rates. Thus, the bank's decision to lend money is influenced by this interest rate spread. Banks that face more volatile (or persistent) shocks should have more volatile (or persistent) observed lending policies. As a result, for each bank i, we create a vector.

$$\Delta Loans_{i,j,t} = \log(Loans_{i,j,t}) - \log(Loans_{i,j,t-1}) (Eq.6)$$

where standard deviation and first-order autocorrelation of $\Delta Loan_{i,j,t}$ are then used to approximate the volatility σ_i and persistence ρ_i , respectively.

Financial constraints: We use four-lagged measures of financial restrictions to regress net hedging: size (log of total assets), net income over total assets, net interest income over total assets, book equity over total assets, and cash dividends over total assets (see section 3.3.4 for details).

Financial demands: We use book debt ratio (leverage) to measures of financial demands**:** Graham and Rogers (2002) and Bartram (2011) calculate that the increase in debt capacity and leverage associated with hedging increases The book debt ratio is the ratio of total debt divided by total assets. Derivative users have significantly higher gross interest rate exposure, as measured by higher leverage and lower quick ratios. Bartram, Brown, and Stulz (2011) find that size, leverage, and liquidity are important determinants of both total and systematic risks.

3.2.2 Control variables

Bank control variables: We use bank-level controls to monitor the relationship between dependent and independent variables. According to Li and Marinč (2014), the link between derivatives and risks is influenced by size and capitalization. Vuillemey (2019) and Rampini et al. (2020) show that bank size and capitalization are significant determinants of the hedging positions taken to increase firm value, the same as (Bartram et al., 2011; Rogers, 2002). The implementation of NIRP has a beneficial effect on economic activity by increasing loan supply and demand due to lower funding costs for both banks and borrowers (Cœuré, 2016). Banks with higher deposits use fewer financial derivatives (Li & Marinč, 2014; Purnanandam, 2007).

Interest rate policy: Short-term and long-term interest rate: we use the three-month interbank money market interest rate and ten-year Treasury interest rate (Bikker & Vervliet, 2018; Boungou, 2019; Delis & Kouretas, 2011; López-Penabad, Iglesias-Casal, & Neto, 2022). We prefer an interbank money market interest rate to the central bank's policy rate because the former reflects more appropriately the adoption of unconventional monetary policy measures. We first control for the level of interest rates (as measured by three-month money market rates during the year) as a proxy for the tightness of the money supply. In such a case, the cost of cash shortfall is larger, and hence the hedging approach may offer value (Bernanke & Gertler, 1995; Purnanandam, 2007). Following that, we consider the volatility of interest rates which is defined by the standard deviation of three-month money market rates for short-term loans during the year. Higher interest rate volatility causes an increase in the incentives for risk management via the methods of hedging (Bernanke & Gertler, 1995; Purnanandam, 2007).

Macroeconomic factors: We use GDP growth as the first macroeconomic indicator to control the relationship between dependent and independent variables. GDP is the nominal GDP for the given year and controls economic opportunity. Net worth and profitability are significantly influenced favorably by the business cycle, as indicated by real GDP growth (Albertazzi & Gambacorta, 2009; Bikker & Hu, 2002; Demirgüç Kunt & Huizinga, 1999). The second macroeconomic indicator is inflation. Most empirical evidence suggests that inflation positively impacts profits, but it can be challenging, if not impossible, to interpret

this coefficient. For instance, Demirgüç Kunt and Huizinga (1999) discovered a correlation between high inflation and higher income from bank float.

3.3 Research design

3.3.1 Interest rate hedging, net worth, and negative interest rate policy

This study employs the following research models to investigate hypotheses 1, 2, and 3. A multiple regression model examines how bank's net worth and negative interest rate policy performance influence the derivative hedging of globally listed banks.

$$\begin{aligned} Hedging_{i,j,t} = {} & \alpha_0 + \alpha_1 \times NWIndex_{i,j,t} + \alpha_2 \times NIRP_{j,t} \\ & + \alpha_3 \times NWIndex_{i,j,t} \times NIRP_{j,t} + \sum \left(ControlVariables \right)_{i,j,t} \\ & + \sum \left(BankFixedEffect \right)_{i,j,t} + \pi_{j,t} + \varepsilon_{i,t} (Eq.7) \end{aligned}$$

where (i) we report estimates using the three main measures of hedging: net hedging ratio, interest rate hedging, derivatives hedging; (ii) $NWIndex_{i,j,t}$ are measured using several variables as described above by equation (5); (iii) Negative interest rate policy is used for the two main measures: $NIRP_{j,t}$ takes the value of one if the country where the bank is based adopted an NIRP in year t and zero otherwise, and measures interest rate volatility by the standard deviation of the same interest rate series during the year, and measures interest rate level, which refers to the average interest rate (three-month Treasury) during the year; (v) bank control variables include bank size, capitalization, lending, deposit, and earning assets, GDP growth, inflation; (vi) bank fixed effects include bank fixed effects, country fixed effects, and year fixed effects. The estimation of all variables is shown in Appendix A. We scale each variable according to its standard deviation so that the coefficients can be understood as the result of a one standard deviation change in the explanatory variable. According to theory, banks with higher net worth can hedge more, and net hedging should be larger (in absolute value) as the exposure increases. We use the gross interest rate, the gross value of all financial derivatives, and the absolute value of net hedging to measure hedging (Deng et al., 2017; Li & Marinč, 2014; Purnanandam, 2007; Vuillemey, 2019).

3.3.2 Bank's net worth, profitability, risk management, and negative interest rate policy

This study employs the following research models to investigate hypotheses 4, 5, and 6. A multiple regression model examines how risk management and negative interest rate policy performance influence the net worth and profitability of globally listed banks.

$$NWIndex_{i,j,t} = \alpha_0 + \alpha_1 \times Riskmanagement_{i,j,t} + \alpha_2 \times NIRP_{j,t} + \alpha_3 \times Riskmanagement_{i,j,t} \times NIRP_{j,t} + \sum (ControlVariables)_{i,j,t} + \sum (BankFixedEffect)_{i,j,t} + \pi_{j,t} + \varepsilon_{i,t} (Eq.8)$$

$$ROA_{i,j,t} = \alpha_0 + \alpha_1 \times Riskmanagement_{i,j,t} + \alpha_2 \times NIRP_{j,t} + \alpha_3 \times Riskmanagement_{i,j,t} \times NIRP_{j,t} + \sum (ControlVariables)_{i,j,t} + \sum (BankFixedEffect)_{i,j,t} + \pi_{j,t} + \varepsilon_{i,t} (Eq.9)$$

$$NIM_{i,j,t} = \alpha_0 + \alpha_1 \times Riskmanagement_{i,j,t} + \alpha_2 \times NIRP_{j,t} + \alpha_3 \times Riskmanagement_{i,j,t} \times NIRP_{j,t} + \sum (ControlVariables)_{i,j,t} + \sum (BankFixedEffect)_{i,j,t} + \pi_{j,t} + \varepsilon_{i,t} (Eq.10)$$

where (i) $NWIndex_{i,j,t}$ are measured using several variables as described above by equation (3); (ii) ROA measures the bank's profitability; (iii) we report estimates using the two main measures of risk management: interest rate risk management and purpose hedging; (iv) Negative interest rate policy is used for the three main measures: $NIRP_{j,t}$ takes the value of one if the country where the bank is based adopted an NIRP in year t and zero otherwise, measures interest rate volatility by the standard deviation of the same interest rate series during the year, and measures interest rate level, which refers to the average interest rate (short-term and long-term interest rate) during the year; (v) control variables include bank size, capitalization, ROE, lending, deposit, GDP growth, inflation; and (vi) bank fixed effects include bank fixed effects, country fixed effects, and year-fixed effects. We scale each variable according to its standard deviation so that the coefficients can be understood as the

result of a one standard deviation change in the explanatory variable. The estimation of all variables is shown in Appendix A.

3.3.3 Net interest rate hedging, loans, and negative interest rate policy

We use the banks' net hedging ratio (specified in Equation 2) as the dependent variable to test hypotheses 7, 8, and 9. We employ the metrics of loan volatility and persistence developed as independent variables. A multiple regression model is used to investigate the impact of loan volatility, loan persistence, and the effectiveness of negative interest rate policy on the net hedging ratio of globally listed banks.

$$\begin{aligned} NetHedgingRatio_{i,j,t} = {} & \alpha_0 + \alpha_1 \times LoanGrowthVolatility(\sigma_i)_{i,j,t} + \alpha_2 \times LoanGrowthPersistence(\rho_i)_{i,j,t} \\ & + \alpha_3 \times NIRP_{j,t} + \alpha_4 \times LoanGrowthVolatility(\sigma_i)_{i,j,t} \times NIRP_{j,t} \\ & + \alpha_5 \times LoanGrowthPersistence(\rho_i)_{i,j,t} \times NIRP_{j,t} \\ & + \sum \left(ControlVariables \right)_{i,j,t} + \sum \left(BankFixedEffect \right)_{i,j,t} + \pi_{j,t} + \varepsilon_{i,t} \quad (Eq.11) \end{aligned}$$

where (i) net hedging ratio is defined in Equation (2); (ii) denoting $\Delta Loan_{i,j,t}=log(Loan_{i,j,t})-log(Loan_{i,j,t-1})$, we define σ_i and ρ_i for any bank i as the standard deviation and first-order autocorrelation of $\Delta Loan_{i,j,t}$, respectively; (iii) $NIRP_{j,t}$ takes the value of one if the country where the bank is based adopted an NIRP in year t and zero otherwise; (iv) control variables include bank size, financial constrains (i.e., log of net income, book equity, earning assets, net interest income), GDP growth, inflation; and (vi) bank fixed effects include bank fixed effects, country fixed effects, and year-fixed effects. The estimation of all variables is shown in Appendix A.

3.3.4 Net interest rate hedging, financial constraints, and negative interest rate policy

This study employs the following research models to investigate hypotheses 10, and 11. A multiple regression model examines the connection between net interest rate hedging, financial frictions, and negative interest rate policy by using data on globally listed banks.

$$NetHedgingRatio_{i,j,t} = \alpha_0 + \alpha_1 \times FinancialConstraints_{i,j,t} + \alpha_2 \times NIRP_{j,t} + \alpha_3 \times FinancialConstraints_{i,j,t} \times NIRP_{j,t} + \sum (ControlVariables)_{i,j,t} + \sum (BankFixedEffect)_{i,j,t} + \pi_{j,t} + \varepsilon_{i,t} (Eq.12)$$

where (i) net hedging at date t for bank i and country j is defined Equation (2); (ii) $NIRP_{j,t}$ takes the value of one if the country where the bank is based adopted an NIRP in year t and zero otherwise; (iii) we use four-lagged measures of financial constraints to regress net hedging: size (log of total assets), net income over total assets, net interest income over total assets, book equity over total assets, and cash dividends over total assets. We research the bank's best hedging strategy. We show how financial frictions encourage hedging against both increases and decreases in interest rates, particularly in negative interest rate environment.

3.3.5 Derivative hedging, financial demands and negative interest rate policy

The last model test hypotheses 12, and 13 also uses a multiple regression model to look at the relationship between net hedging, negative interest rate policy, and financial demands. The data used in this study comes from globally listed institutions.

$$NetHedgingRatio_{i,j,t} = \alpha_0 + \alpha_1 \times (\Delta BookDebtRatio)_{i,j,t-1} + \alpha_2 \times NIRP_{j,t} + \alpha_3 \times (\Delta BookDebtRatio)_{i,j,t-1} \times NIRP_{j,t} + \sum (ControlVariables)_{i,j,t} + \sum (BankFixedEffect)_{i,j,t} + \pi_{j,t} + \varepsilon_{i,t} (Eq.13)$$

where (i) net hedging at date t for bank i and country j is defined Equation (2); (ii) $NIRP_{j,t}$ takes the value of one if the country where the bank is based adopted an NIRP in year t and zero otherwise; (iii) Book debt ratio measures via standard deviation of book leverage $\Delta BookDebtRatio_{i,j,t} = \Delta[(1\text{-}BookEquity)/TotalAssets]$ between t and t + 1 is used to calculate leverage increases. Table 11 investigates whether banks adopted pay-fixed swap positions proactively during years of rising leverage in a negative interest rate environment. If net hedging increases in positive value while gross hedging likewise increases, a bank is deemed to have taken a pay-fixed position in year t.

4. Empirical findings and analysis

4.1 Evidence on the relationship between hedging, net worth, and negative interest rate policy

In this part, we show the estimation results of equation 7 and test hypotheses 1, 2, and 3, which allow us to examine the effects of bank net worth and NIRP implementation on hedging. The results are reported in Table 6.

The results of models [1] to [9] show that net worth has a significant positive effect on hedging, while NIRP has a significant negative effect. These outcomes remain suitable for three measurements of hedging (i.e., net hedging, interest rate hedging, and derivative hedging), corroborating our research hypotheses 1 and 2. According to models [1], [3], and [7], a one percentage point rise in the bank's net worth matches 0.09, 0.17, and 0.68 basis point rise in net hedging, interest rate hedging, and derivative hedging, respectively. Thus, the results support hypothesis 1, and this relationship is stronger before the NIRP period. These findings are in correspondence to the related literature of Vuillemey (2019), Rampini, Viswanathan, et al. (2020), Begenau, Piazzesi, et al. (2015), and Bartram (2011). Models [2], [5], and [8] show that NIRP and hedging have a significant negative relationship. Thus, these outcomes support hypothesis 2. The negative interest rate environment had an impact on fixed-to-float interest rate swaps. When interest rates are negative, parties may incur significantly higher costs and have considerably less hedging flexibility, which makes banks use fewer financial derivatives, consistent with Turk (2016) and Purnanandam (2007).

This result indicates that the bank’s net worth is higher, hedging is more efficient, and banks use fewer derivative contracts for hedging purposes when interest rates are negative or go down. However, the previous finding does not consider the relationship between net worth and hedging in a negative interest rate environment. Thus, our study tests this association by using NIRP as a moderator. According to hypothesis 3, a NIRP moderates the association between net worth and hedging since it will be less positive in a scenario of negative interest rates. Interestingly, the implementation of NIRP has no negative impact on the strong

relationship between net worth and hedging (see models [3], [6], and [9]). These results do not support Hypothesis 3, so we cannot reject it. In our following model, we will offer more evidence. We also imply that banks further affected by negative interest rates are more willing to take risks and grow loans to maintain profits and net worth (the coefficient of lending is positive). Simultaneously, they reduce using financial derivatives to decrease financial costs. This outcome is comparable to that of Schelling and Towbin (2022), Brewer et al. (2014), and Vuillemey (2017). Additionally, the banks with higher deposits use fewer derivatives, the same as Purnanandam (2007).

According to the regression coefficient, the level and volatility of the interest rate positively affect banks' hedging. This effect is more substantial in the previous NIRP period because the higher the interest rate, the greater the risk management (via the method of hedging), in line with Purnanandam (2007) and Li and Marinč (2014). We also find a positive effect of bank size and a convincing positive effect of capitalization and lending are found, similar to the findings of Vuillemey (2019) and Rampini et al. (2020). Because of this positive relationship, we have enough evidence to conclude that banks will be proactive in using financial derivatives to hedge against interest rate hikes (decreases) or fluctuations, particularly when there is a high level of financial demand (lending a positive effect to hedging). Furthermore, earning assets has a negative effect. Based on these findings, hedging will help manage risk and reduce its impact while increasing the bank's costs. The persistently low-interest interest rates lead to a reduction in earning assets. Therefore, parties may experience dramatically higher expenses and decreased hedging flexibility when interest rates are negative, corroborating our research hypothesis 2 (see Purnanandam (2007) and Turk (2016)). Banks find it difficult to make money from their regular lending and funding methods because of the (low) negative interest rate situation. In line with DemirgüçKunt and Huizinga (1999), Dietrich and Wanzenried (2011), and Jacob A. Bikker (2017), larger banks tend to have higher levels of hedging and net worth. Also, we find a beneficial effect of interest rate hedging and inflation, but GDP growth is slightly negative.

4.2 Evidence on the impact of risk management and NIRP on the bank net worth and profitability

In this section, we present the estimation results of equation 8 and test hypotheses 4, 5, and 6, which allow us to examine the effects of bank net worth and NIRP implementation on hedging. The results for the derivative hedging are shown in Table 7.

The analysis of models [10] to [15] leads us to conclude that banks' net worth is positively related to interest rate risk management and derivative hedging, corroborating our research hypotheses 4, 5, and 6. According to models [10] and [13], we can conclude that one percentage point rises in interest rate risk management and derivative hedging, and net worth increased by 1.502 basis points and 1.556 basis points, respectively. Thus, the consequences support hypothesis 4, and this relationship is not changed in the NIRP period. These findings are in correspondence to the related literature of Vuillemey (2019), Rampini, Viswanathan, et al. (2020), Begenau, Piazzesi, et al. (2015), and Bartram (2011). Besides that, we find a significant positive relationship between net worth and negative interest rate policy. Thus, these outcomes support hypothesis 5. These findings suggest that risk management is more effective, and the bank's net worth is higher. When interest rates are negative or go down, managers of banks must be careful in selecting hedging strategies.

However, the previous finding does not consider the relationship between net worth and risk management in a negative interest rate environment. Thus, our study also tests this association by using NIRP as a moderator. According to hypothesis 6, a NIRP moderates the association between net worth and risk management since it will be less positive in a scenario of negative interest rates. Interestingly, the application of NIRP has no harmful impact on the strong relationship between net worth and risk management (see models [11] and [14]). These results do not support Hypothesis 6, so we cannot reject it. For the coefficients of control variables, we find that net worth and the short-term interest rate have a significantly positive relationship. A one percentage point increase in the level of short-term interest rate is associated with a 0.345 basis point increase in the net worth. In line with Vuillemey (2019), Rampini, Viswanathan, et al. (2020), we also find that larger banks are associated with higher net worth as the coefficient of bank size is given by 0.0148, the relative size of lending increases by one percentage point, the bank net worth increases by 0.285 basis points. Healthier capitalized banks are associated with higher net worth, as does ROE. We similarly

find a pro-cyclical effect of the net worth as the coefficient of real GDP growth is slightly positive and the strong positive effect of inflation. While interest rate volatility has the opposite effect on net worth, so does the level of long-term interest rates. These results indicate that NIRP can help provide additional monetary policy stimulus in an environment of solid GDP growth, falling interest rates, and proper inflation growth. We also demonstrate a positive correlation between net worth and lending as deposits. Although banks can get more profitability when a loan's interest rate rises, they also face more risk if it quickly fluctuates. Besides, NIRP does not harm a bank's net worth if policy interest rates remain mildly negative or non-negative for an extended period to avoid long-term adverse effects on the financial sector. These findings are consistent with previous research (Claessens, Coleman, et al. (2018); Borio, Gambacorta, et al., 2017).

Our measures of banks' risk management enable us to accurately assess the effects of NIRP on banks' net worth and profitability, supplementing the literature findings. When negative interest rates would have encouraged banks to place their excess reserves in riskier investments, this would have favored increased risk-taking. According to Brewer et al. (2014) and Schelling and Towbin's (2022) research, banks that are more affected by negative interest rates are more willing to lend, and choosing a derivatives hedging strategy has a positive effect on loan growth. It makes lending less sensitive to interest-rate uncertainty. These findings were supported by Basten and Mariathasan (2018), Gitogo (2012), Jobst and Lin (2016), Kerbl and Sigmund (2017), Madaschi and Pablos Nuevo (2017), Scheiber et al. (2016), and Shen and Hartarska (2013). However, our results are opposite those of Dell'Ariccia et al. (2017), Genay & Podjasek (2014), and Memmel (2017).

4.3 Net interest rate hedging, loan opportunities, and negative interest rate policy

In this section, we present the estimation results of equation 11 and test hypotheses 7, 8, and 9, which allow us to examine the effects of volatile (or persistent) lending policies on net hedging in a negative interest rate scenario. Models [23] to [26] of Table 9 contain the empirical results of a GLS regression of the relationship between net hedging, NIRP, and lending opportunities. We confirm that banks deal with more unstable or persistent lending

opportunities with a negative net hedging ratio, in line with the model and Hypothesis 7 (see models [23] and [25]). Also, we show the same result with a negative interest rate policy. When NIRP is implemented, banks are more likely to use derivatives to hedge interest rate decreases (net interest rate hedging will get a negative value). Thus, the results support hypothesis 8. Next, we test Hypothesis 9 by using NIRP as a moderating variable to examine the relationship between net hedging and time-varying lending volatility (or persistence) measures. We discover a positive and significant correlation, as shown in models [24] and [26]. In the NIRP period, the relationship between net interest rate hedging and lending volatility (or persistence) is less negative, in line with the model and Hypothesis 9. Thus, banks with more distressed debt, leverage, and significant funding needs are more likely to hedge against interest rate rises. Furthermore, banks with more volatile or persistent lending opportunities are more likely to hedge interest rate reductions, similar to the prediction of Vuillemey (2019).

Moreover, the difference in interest rates between credit and deposits determines the bank's lending policy. As a result, when NIRP is implemented, banks will experience lower deposits and lending interest rates. As stated by Brunnermeier and Koby (2016) and Molyneux, Reghezza, et al. (2020), financial constraints, bank capitalization, and interest rate exposure seem to make banks less eager to lend, particularly for smaller banks and business models dependent on net interest margins. Additionally, our findings support that banks with a larger size, a higher net worth, or those more affected by NIRP are willing to take risks and grow to lend. Simultaneously, banks with more erratic future lending could also take on more interest rate risk via derivatives (Vuillemey, 2017). This finding provides more evidence for our previous result that the banks tend to use less interest rate hedging to reduce costs and improve profitability as net worth.

4.4 Net interest rate hedging, financial constraints, and negative interest rate policy

In this section, we present the estimation results of equation 12 and examine Hypotheses 10 and 11. We use four financial constraint measures (i.e., size, net income, dividends, and equity). As a result model [20] of Table 10, banks with fewer financial

restrictions can have a negative value of net hedging, as evidenced by their bigger size, higher dividends, and higher net income. This result supports hypothesis 10. Furthermore, the relationship between net hedging and NIRP is significantly negative. We discover that banks can engage in positive net hedging or take other measures to safeguard themselves against interest rate hikes under more severe financial restrictions. We test Hypothesis 11 by examining the link between net hedging and financial restrictions using NIRP as a moderating variable. As shown in models [21], [22], and [26], NIRP reduces the negative correlation between net hedging and net income, although cash dividend is insignificantly negative while book equity is not affected. According to the figures, banks can hedge interest rate rises and declines without speculative incentives. The valuation of net hedging had a positive value throughout the previous NIRP period due to the use of the hedge against interest rate increases(pay-fixed positions). During the NIRP period, net hedging will have a negative value in the hedge against interest rate decreases(pay-float positions).

4.5 Net interest rate hedging, book debt ratio, and negative interest rate policy

The final model adds additional evidence to the association between financial constraints, book debt ratio (leverage), and the hedging positions taken, as shown in models [24] and [25] of Table 11. There is a positive correlation between net hedging and book debt ratio, supporting Hypothesis 12. Our model suggests that operational choices to adopt pay-fixed swap positions are related to considerable increases in leverage. In other words, when considerable increases in financial demand, pay-fixed positions are taken to ease the present financial limitations. We test Hypothesis 13 by examining the association between net hedging and financial constraints using NIRP as a moderating variable. NIRP reduces the positive correlation between net hedging and book debt ratio, as expected. This result indicates that banks employ less interest rate hedging (net hedging has a negative value) while taking risks to expand loans in a negative interest rate environment. In contrast, increasing lending growth can make increasing the amount book debt ratio.

4. Empirical test

4.1 Dummy variable of banks operating in the United States of America and non-United States of America

Our sample is a highly representative sample of American banks. To confirm our findings, we run the primary samples using a dummy variable. Dummy USA takes the value of one if the country is the United States of America, and non-USA is zero).

The impact of bank net worth and negative interest rate policy on hedging are reported in Table 12, and the results remain similar to those in Table 6. This shows that net worth has a significant positive effect on hedging, while NIRP has a significant negative effect. Additionally, we also find a significant and negative relationship between net hedging, interest rate hedging, and dummy USA. This result indicates that U.S. banks use fewer derivative contracts for hedging purposes. Moreover, the level and volatility of interest rates positively affect banks' hedging. In other words, banks will be proactive in utilizing financial derivatives to hedge against interest rate hikes (decreases) or fluctuations, particularly when there is a high level of financial demand (lending a positive effect to hedging). Generally, the sensitivity test findings are not qualitatively different from the original analysis of the findings, demonstrating the validity of the basic results.

Similarly, the impact of risk management and the negative interest rate policy on net worth is reported in Table 13, and the results remain similar to those in Table 7. This shows that interest rate risk management and derivative hedging significantly positively affect the net worth, as does NIRP. Furthermore, we also find a significant and positive relationship between net worth and dummy USA. This result indicates that U.S. banks get higher revenue than others when NIRP is implemented. In other words, U.S. banks are less affected by NIRP[7]. Also, the level of interest rates positively affects banks' net worth, but its volatility has the opposite effect. In other words, banks can get more profitability when a loan's interest rate

[7] Despite never implementing negative interest rates, the Federal Reserve, the nation's central bank, had gone close to near-zero rates, most recently on March 15, 2020, when it lowered the benchmark rate to a range of 0%–0.25%. (From Board of Governors of the Federal Reserve System. "Federal Reserve issues FOMC statement.
https://www.federalreserve.gov/newsevents/pressreleases/monetary20200315a.htm

rises; however, they also face more risk if it quickly fluctuates. Generally, the sensitivity test findings are not qualitatively different from the original analysis of the findings, demonstrating the validity of the basic results.

4.2 Alternative hypothesis: profitability

In order to address low inflation and stimulate economic growth, six central banks in Europe[8], and the Bank of Japan have gradually implemented the negative interest rate policy (NIRP). Cœuré (2016) claims that the introduction of negative interest rates[9] was done in order to increase the availability of credit by taxing the excess reserves held by banks at the central bank. NIRP ought to result in a decline in financing costs for both lenders and borrowers, a consequent rise in the supply and demand for loans, and, ultimately, an improvement in economic growth (Angrick & Nemoto, 2017; Bank et al., 2017; Blot & Hubert, 2016; Cœuré, 2016; Jobst & Lin, 2016). This negative interest rate policy measure has raised concerns about its potential impact on bank profitability and risk. Negative interest rates could raise the cost of hedging, reduce banks' profitability, and reduce their net worth. Negative interest rates impact bank profits, but those effects take time to materialize. Banking intermediation is a spread business based on the difference between credit and deposit interest rates rather than a level business based on the level of interest rates. This interest rate spread influences the bank's lending decision. As a result, the bank's profit should be acceptable with the decrease in deposit rates and credit interest rates in the short term. Since banks are hesitant to apply negative interest rates to savers' deposits, there might be a threshold effect when interest rates drop below 0%. A negative deposit interest rate would cause savers to withdraw money from their accounts because of the negative nominal return, even though they had cash.

Bats et al. (2020) demonstrated how negative interest rates affect bank profitability via net interest margins. In practice, banks use interest rate swaps to recreate portfolios of fixed-rate assets that correspond to the estimated duration of their deposit liabilities (Kalkbrenner

[8]Denmark, Bulgaria, Euro Area, Sweden, Switzerland, Hungary
[9] Negative interest rate on the European Central Bank's savings deposits

& Willing, 2004; Jarrow and van Deventer, 1998). Deposits have a positive duration because they are a stable funding source for banks despite customers' ability to clear their sight deposit balances at any time. The deposit margin is the difference between the swap and deposit rates. While banks may provide loans with a longer average duration than their replicating portfolio, the remaining interest rate risk is typically hedged (Drechsler et al., 2018; Hoffmann et al., 2019). Furthermore, banks make money by lending: the lending margin is the difference between the lending rate and the rate on swap contracts with an equivalent average duration.

We briefly discuss an alternative interpretation of the relationship between profitability (via NIM and ROA) and risk management (interest rate derivatives and hedging). Tables 14 and 15 contain data on the essential outcomes of the robustness test.

For the results of this commonly used profitability measure (ROA), see Table 14 for details. These results suggest that interest rate risk management, derivatives hedging, and NIRP significantly benefit ROA. According to existing literature, there is a positive relationship between short-term interest rate levels and ROA. The return on assets increases by 0.884 basis points for every one percentage point increase in the short-term interest rate. This finding implies that the low-interest rate environment weakens bank performance (similarly, the interaction between short-term interest rate level and NIRP positively affects ROA). Also, for this profitability measure, a positive effect of bank size is found, as is the convincing positive effect of capitalization. Although the related literature does not fully support this effect (e.g., Athanasoglou et al., 2008; TrujilloPonce, 2013), it is similar to Dietrich and Wanzenried (2011) and Jacob A. Bikker (2017). Additionally, the coefficient of lending reveals that an extensive loan portfolio enhances bank profitability. Evidence of pro-cyclicality can be found in the positive effects of real GDP growth and inflation. Novelty, we discover a significant positive association between ROA and the dummy USA. The interactions indicate comparable outcomes with the basic models and control variables. In general, the sensitivity test results are not qualitatively different from the initial analysis of the data, indicating the core results' validity.

Table 15 shows that interest rate risk management and derivatives hedging benefit NIM significantly, but NIRP has the opposite effect. The relationship between NIM and short-term interest rate level is significantly positive, meaning a one percentage point increase in short-term interest rates corresponds to a 1.51 basis point increase in net interest margin. This finding is in correspondence to the related literature of Alessandri and Nelson (2015), Demirgüç-Kunt and Huizinga (1999), Genay and Podjasek (2014), and Jacob A. Bikker (2017). From these results, it can be concluded that the persistently decreased interest rate environment leads to a decline in the net interest margin, which is the bank's main source of profitability. This is in line with the presumption that as a consequence of the low-interest rate environment, banks struggle to generate profits from their traditional **lending** and funding practices. Innovation, we realize a significant negative association between NIM and the dummy USA. This result indicates that U.S. banks get higher NIM than others when NIRP is implemented. In other words, U.S. banks are less affected by NIRP. The interactions indicate comparable outcomes with the basic models and control variables. In general, the sensitivity test results are not qualitatively different from the initial analysis of the data, indicating the core results' validity.

5. Conlusions

We present evidence that higher-net-worth banks hedge more. There is a strong positive relationship between hedging interest rate risk and net worth among banks, and this relationship is stronger during the previous NIRP period. Interestingly, the positive association between net worth and hedging is not reduced when NIRP is implemented. Banks more affected by negative interest rates are more willing to take risks, and using interest-rate derivatives positively affects loan growth to maintain profits and net worth. Moreover, our model shows that more efficient risk management leads to increased bank net worth and profitability when NIRP is implemented.

The data also supports the notion that banks with more volatile or persistent lending opportunities are more likely to hedge interest rate reductions. When NIRP is implemented, banks are more likely to use derivatives to hedge interest rate decreases (net interest rate

hedging will get a negative value). Notably, banks tend to reduce risk by using interest rate hedging.

The risk management theory can explain this causal effect of net worth on hedging under the financial constraints of Rampini and Viswanathan (2010, 2013). We conclude that the financing needs associated with hedging are a substantial barrier to risk management for banks. Because those banks play a critical and quantitatively significant role in the macroeconomy, understanding the factors that drive their risk management is critical. According to our findings, financial constraints substantially impede financial firms' ability to control risk. Banks (or financial institutions), particularly those with little financial resources, are vulnerable to fluctuations in interest rates and other risks due to poor risk management. As negative interest rate policy becomes more popular in the future, it affects the distribution of risk exposures and may have severe consequences for monetary, financial, and macroeconomic shocks.

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Table 1

Procedure for collecting samples

Panel A: Procedure for choosing the final balanced samples

Procedure	Bank-year observation (N)
The initial number of observations found in BankScope for the period 2001–2021, for which we can extract the annual accounting and financial data.	788,798
Minus:	
Missing information on financial derivatives.	717,662
Observations from financial derivatives equal zero.	55,167
Bank-years of the unsuccessful match when they merged with Thomson Reuters Eikon, as well as missing information on control variables.	1,621
Observations of banks with no available data in all 20 years	1,050
Final balanced samples	**13,298**

Panel B: Descriptive statistics of samples

Year	Number of obsevations	Users of derivatives for hedging purposes		Users of derivatives for hedging purposes (Derivatives hedging >0)		Users of derivatives for hedging purposes by specialisation (Derivatives hedging >0)			
		Number	% of Total	Number	% of Total	Bank holding company	Commercial bank	Cooperative bank	Savings bank
2001	37,708	3,144	0.083	332	10.560	3	323	1	5
2002	37,714	4,083	0.108	424	10.385	7	404	1	12
2003	37,743	4,167	0.110	477	11.447	9	462	1	5
2004	37,770	4,049	0.107	480	11.855	9	460	1	10
2005	37,793	3,944	0.104	493	12.500	12	472	1	8
2006	37,598	3,853	0.102	557	14.456	13	532	3	9
2007	37,621	3,776	0.100	556	14.725	13	531	3	9
2008	37,654	3,683	0.098	606	16.454	13	578	4	11
2009	37,531	3,477	0.093	597	17.170	17	565	4	11
2010	37,551	3,379	0.090	653	19.325	22	616	4	11
2011	37,212	3,216	0.086	663	20.616	24	614	7	18
2012	37,294	3,252	0.087	714	21.956	22	645	9	38

Year	Number of obsevations	Users of derivatives for hedging purposes		Users of derivatives for hedging purposes (Derivatives hedging >0)		Users of derivatives for hedging purposes by specialisation (Derivatives hedging >0)			
		Number	% of Total	Number	% of Total	Bank holding company	Commercial bank	Cooperative bank	Savings bank
2013	37,347	3,167	0.085	745	23.524	23	667	10	45
2014	37,334	3,116	0.083	805	25.834	24	731	10	40
2015	37,352	3,004	0.080	847	28.196	23	767	12	45
2016	37,466	3,505	0.094	1,314	37.489	452	804	11	47
2017	37,494	3,449	0.092	1,318	38.214	452	809	10	47
2018	37,527	3,217	0.086	1,187	36.898	318	809	11	49
2019	37,556	2,979	0.079	1,084	36.388	197	828	10	49
2020	37,604	2,899	0.077	1,109	38.255	201	849	9	50
2021	37,929	1,777	0.047	1,008	56.725	206	747	8	47
Total Obs.	**788,798**	**71,136**	**0.090**	**15,969**	**0.224**	**2,060**	**13,213**	**130**	**566**

This table shows the procedure for sample collection. We first take into consideration all bank-year observations (788,798) for which annual accounting and financial information is available on BankScope, which include: financial derivatives with missing information (717,662); financial derivatives with a value equal to zero (52,167), no available data and unsuccessful match (2,671). We exclude missing information on financial derivatives because we only concentrate on derivatives-hedging activities in the bank sector. The initial sample is then updated using the following criteria: (a) excluding the lack of financial derivatives information (717,662); (b) financial derivatives with a value equal to zero (52,167); (c) bank-year observation of the unsuccessful match when they merged with Thomson Reuters Eikon, as well as missing information on control variables (1,621); (d) and observations of banks with no available data in all 20 years (1,050). As a result, we obtain a final sample of 13,298 bank-year observations over the period 2001–2021.

Table 2

Descriptive statistics on financial derivatives

Panel A: Include zeros: Yes

	All sample	Mean	Median	Perc.75	Perc.90	Perc.95	Perc.99
Interest Rate Risk Management	71,136	0.047	0.000	0.000	0.037	0.118	0.592
Interest Rate Hedging	71,136	0.047	0.000	0.000	0.037	0.118	0.592
Derivative Hedging	71,136	0.049	0.000	0.000	0.039	0.125	0.636
By size quintiles:							
1st quintile (small)	1,444	0.094	0.000	0.000	0.000	0.000	0.114
2nd quintile	12,470	0.024	0.000	0.000	0.000	0.000	0.078
3rd quintile	22,065	0.018	0.000	0.000	0.000	0.004	0.159
4th quintile	20,750	0.051	0.000	0.000	0.025	0.073	0.426
5th quintile (large)	14,407	0.114	0.009	0.073	0.230	0.437	1.477

Panel B: Include zeros: No

	All sample	Mean	Median	Perc.75	Perc.90	Perc.95	Perc.99
Interest Rate Risk Management	13,298	0.146	0.023	0.084	0.224	0.418	1.903
Interest Rate Hedging	13,298	0.146	0.023	0.084	0.224	0.418	1.903
Derivative Hedging	13,298	0.151	0.023	0.086	0.235	0.446	1.985
By size quintiles:							
1st quintile (small)	9	9.189	3.874	7.844	34.790	34.790	34.790
2nd quintile	158	1.006	0.066	0.452	1.985	9.415	15.135
3rd quintile	1,164	0.216	0.015	0.063	0.205	0.584	3.591
4th quintile	4,675	0.105	0.015	0.050	0.153	0.298	1.489
5th quintile (large)	7,292	0.140	0.035	0.111	0.272	0.467	1.578

Panel C: Net hedging ratio

	All sample	Perc.5	Perc.10	Mean	Median	Perc.75	Perc.90	Perc.95
Net Hedging /Total Assets	11,409	-0.045	-0.022	0.012	-0.001	0.000	0.014	0.062
By size quintiles:								
1st quintile (small)	2	-0.033	-0.033	-0.017	-0.017	0.000	0.000	0.000
2nd quintile	98	-0.054	-0.037	0.035	0.000	0.000	0.032	0.293
3rd quintile	997	-0.035	-0.017	-0.004	0.000	0.000	0.000	0.001
4th quintile	4,447	-0.025	-0.012	-0.003	-0.001	0.000	0.000	0.009
5th quintile (large)	5,865	-0.061	-0.032	0.025	-0.001	0.000	0.049	0.142

Panel D: Size distribution of hedging banks

	Perc.5	Perc.10	Perc.15	Mean	Median	Perc.75	Perc.90	Perc.95
Interest Rate Hedging>0	11.970	12.403	13.180	14.602	14.240	15.892	17.448	18.308
Net Hedging Ratio ≠0	12.030	12.430	13.120	14.532	14.070	15.614	17.420	18.394
All bank	9.311	9.586	10.466	12.242	11.894	13.593	15.364	16.589

Table 3

Descriptive statistics on Negative interest rate policy

Panel A: NIRP notifications and supplemental policies[10]

Country	Central bank	Policy rate	Date	Rate (%)
Denmark	Danmarks Nationalbank	1-week certificate deposit rate	July 2012	-0.20
Eurozone	European Central Bank	Overnight deposit facility rate	June 2014	-0.10
Switzerl and Swiss	National Bank	Overnight sight deposit rate	December 2014	-0.25
Sweden	Sveriges Riksbank	1-week repo rate	February 2015	-0.10
Bulgaria	Central Bank of Hungary	Overnight deposit rate	January 2016	-0.30
Japan	Bank of Japan	Current account deposit rate	January 2016	-0.10
Hungary	Magyar Nemzeti Bank	Overnight deposit rate	March 2016	-0.05

Panel B: Distribution of NIRP in our sample

	Bank-year observation
Previous NIRP	4,208
Period NIRP	9,090
Total	**13,298**

Panel C: Distribution of interest rate in our sample

	min	Perc.10	Perc.25	mean	Median	Perc.75	Perc.90	Perc.95	max
Short-term interest rate	-0.819	0.167	0.312	1.756	1.153	2.965	5.153	5.268	14.757
Long-term interest rate	-0.524	1.803	2.330	3.246	3.214	4.290	4.792	5.018	22.498

This table shows NIRP notifications and supplemental policies. From Panel A, the Danish National Bank started implementing a NIRP in 2012; the European Central Bank and National Bank in 2014; Sveriges Riksbank in 2015; the Central Bank of Hungary; the Bank of Japan; and the Magyar Nemzeti Bank in 2016. The great majority of countries in our survey instituted negative rates in 2014; hence, the NIRP uses 2014 as the year with a value of 1. Because Denmark is the first country to impose negative rates, NIRP is set at 1 in 2012. For Sweden, NIRP is set at one since 2015. Finally, NIRP has been set to 1 for Japan, Hungary, and Bulgaria since 2016. Additionally, Panel B displays the distribution of NIRP in our sample. The bank-year observations are 4,208 in the previous NIRP implemented, while the period NIRP is 9,090. In terms of Panel C, which shows the interest rate distribution in our sample, the means of short-term and long-term interest rates are 1.756 and 3.246, respectively.

[10] Sources: The central banks in question, Maria Celia Lopez-Penabad (2022)

Table 4

Descriptive statistics on variables

Variables	N	Mean	Std.Dev	Perc.25	Perc.50	Perc.75	Perc.95	Perc.99
Bank net worth and profitability								
Net Worth Index	13,298	2.216	0.285	2.000	2.160	2.410	2.766	2.898
ROA	13,298	0.009	0.015	0.006	0.009	0.013	0.020	0.047
NIM	13,294	0.048	0.176	0.031	0.036	0.044	0.064	0.137
Bank control variables								
ROE	13,298	0.111	3.132	0.057	0.089	0.123	0.198	0.315
Lending	13,298	0.204	0.235	0.176	0.286	0.346	0.408	0.441
Deposit	13,298	0.794	0.273	0.743	0.811	0.856	0.898	0.917
Bank size	13,298	14.602	1.922	13.180	14.240	15.892	18.308	19.249
Book Equity	13,298	0.118	0.127	0.087	0.101	0.119	0.174	0.745
Capitalization	13,298	0.882	0.127	0.881	0.899	0.913	0.939	0.970
Net Income	12,451	0.118	0.127	0.087	0.101	0.119	0.174	0.745
Book Equity	13,292	0.941	0.794	0.891	0.922	0.944	0.970	1.110
Earning Assets	13,298	0.046	0.173	0.031	0.036	0.044	0.062	0.091
Net Interest Income	13,291	0.046	0.173	0.031	0.036	0.044	0.062	0.091
Loan Growth Volatity	13,078	-0.001	0.083	-0.016	0.000	0.017	0.061	0.219
Loan Growth Persistence	12,898	0.042	0.080	0.013	0.024	0.040	0.118	0.527
Country characteristics								
GDPgrowth	13,298	1.878	2.197	1.667	2.281	2.783	5.671	5.671
Inflation	13,298	1.939	0.992	1.205	1.871	2.389	4.155	4.155

This table displays the descriptive statistics on variables used in this study for financial derivatives, bank net worth and profitability, negative interest rate policy, bank control factors, and country characteristics. Winsorization is performed on all continuous variables between 1% and 99%. Details of the variable establishment are given in Appendix A.

Table 5

Pearson correlations between derivative hedging, negative interest rate policy, bank net worth, and control variables

	Net Hedging Ratio	Interest Rate Hedging	Derivatives Hedging	IR Risk Management	Net Worth Index	ROA	NIM	Book Debt Ratio	NIRP
Net Hedging Ratio	1.000								
Interest Rate Hedging	0.0767***	1.000							
Derivatives Hedging	0.0737***	0.954***	1.000						
IR Risk Management	0.330***	1.0000	0.998***	1.000					
Net Worth Index	0.211***	0.613***	0.0259**	0.0186	1.000				
ROA	-0.0382***	-0.0271**	-0.0264**	-0.0271**	-0.0271**	1.000			
NIM	-0.0226*	0.0882***	0.0852***	0.0882***	0.0882***	0.0375***	1.000		
Book Debt Ratio	0.0040	0.203***	0.190***	0.203***	0.215***	-0.0017	0.225***	1.000	
NIRP	-0.104***	-0.0221*	-0.0048	-0.0059	0.139***	0.159***	-0.159***	0.0148	1.000
Interest Rate Volatility	-0.0123	0.0014	-0.0015	0.0014	0.0376***	-0.125***	0.144***	-0.0108	-0.781***
Short-term IR Level	0.0906***	0.0164	0.0024	0.0049	-0.0509***	0.0153	0.160***	0.0039	-0.474***
Long-term IR Level	0.0178	0.0004	-0.0033	0.0005	-0.0033	-0.0666***	0.186***	-0.0006	-0.717***
Bank size	0.212***	0.0576***	-0.0019	-0.0089	0.973***	-0.0132	-0.179***	0.0473***	0.126***
Earning Assets	0.203***	-0.0172	0.0208*	0.0131	0.985***	-0.0221*	-0.0950***	0.0766***	0.117***
Book Equity	0.0339***	0.719***	0.176***	0.174***	0.0273**	0.0398***	0.715***	0.221***	0.0341***
GDP growth	0.0374***	-0.0018	-0.0100	-0.0097	0.0119	0.132***	0.0042	-0.0008	0.0563***
Inflation	0.0194*	0.0037	0.0104	0.0132	-0.0540***	0.129***	0.0606***	-0.0101	-0.122***
Lending	0.236***	0.0332***	-0.0399***	-0.0356***	0.710***	-0.0043	0.113***	-0.0022	-0.0687***
Deposit	0.166***	0.0373***	-0.0097	-0.0159	0.967***	-0.0114	-0.0933***	0.0747***	0.146***
ROE	-0.0828***	-0.0016	-0.0012	-0.0017	0.0052	0.0589***	-0.0025	0.0006	0.0201*
Net Income	-0.123***	0.0573***	0.0591***	0.0573***	0.572***	0.0556***	0.0282**	0.0708***	0.135***
Capitalization	0.0046	-0.709***	-0.652***	-0.709***	-0.812***	0.0011	-0.895***	-0.221***	0.0087
Cash Dividend	-0.113***	0.0052	0.0058	0.0052	0.177***	0.0377***	0.0068	0.0331***	-0.0090
Net Interest Income	0.0380***	-0.0338***	-0.0365***	-0.0338***	-0.209***	0.141***	0.0467***	-0.0061	-0.345***
Loan growth volatity	-0.0627***	0.0150	0.0166	0.0150	0.0184	0.0158	-0.0146	-0.0055	-0.0398***
Loan growth persistence	-0.0012	-0.0170	-0.0178	-0.0170	-0.0059	-0.0070	-0.0018	-0.0072	-0.0112

	Interest Rate Volatility	Short-term IR Level	Long-term IR Level	Bank size	Earning Assets	BookEquity	GDPgrowth	Inflation	Lending
Interest Rate Volatility	1.000								
Short-term IR Level	-0.340***	1.000							
Long-term IR Level	-0.717***	0.535***	1.000						
Bank size	0.0332***	-0.0435***	-0.107***	1.000					
Earning Assets	0.0374***	-0.0496***	-0.0976***	0.969***	1.000				
Book Equity	0.0063	-0.0074	-0.0233*	-0.0291**	-0.141***	1.000			

GDP growth	-0.246***	0.139***	0.218***	0.0085	0.007	0.0189*	1.000		
Inflation	-0.0191*	0.425***	0.369***	-0.0540***	-0.0574***	0.014	0.579***	1.000	
Lending	-0.0251**	-0.0087	0.0918***	0.765***	0.712***	-0.0517***	0.005	-0.0785***	1.000
Deposit	0.0423***	-0.0740***	-0.130***	0.975***	0.966***	-0.0457***	0.004	-0.0594***	0.706***
ROE	-0.0185	0.0041	-0.0028	0.0051	0.005	-0.005	0.010	0.012	-0.004
Net Income	-0.112***	-0.0110	-0.0868***	0.916***	0.925***	0.0426***	0.0382***	0.0226*	-0.0573***
Capitalization	-0.0034	0.0012	-0.0017	0.0491***	-0.0472***	-1.000	-0.002	-0.003	0.0346***
Cash Dividend	0.0011	0.0678***	0.0402***	0.289***	0.277***	0.006	-0.009	0.0264**	0.158***
Net Interest Income	0.307***	0.381***	0.468***	-0.346***	-0.338***	-0.010	0.0404***	0.174***	0.286***
Loan growth volatity	0.0211*	-0.0135	0.0110	0.0491***	0.0428***	-0.008	0.020	-0.001	0.007
Loan growth persistence	-0.0830***	0.0467***	0.0788***	0.0033	0.017	-0.008	0.0630***	-0.0238*	0.135***

	Deposit	ROE	Net Income	Capitalization	Cash Dividend	Net Interest Income	Loan growth volatity	Loan growth persistence
Deposit	1.000							
ROE	0.004	1.000						
Net Income	0.931***	0.001	1.000					
Capitalization	-0.046***	-0.001	-0.0426***	1.000				
Cash Dividend	0.284***	-0.012	0.350***	-0.006	1.000			
Net Interest Income	-0.337***	-0.029**	-0.238***	0.010	0.0795***	1.000		
Loan growth volatity	0.0216*	-0.004	0.014	0.008	-0.0596***	-0.102***	1.000	
Loan growth persistence	0.013	-0.002	-0.001	0.008	0.002	0.0613***	-0.0243*	1.000

Table 6

Bank hedging, net worth and negative interest rate policy (Dependent variables: Net Hedging Ratio and Interest Rate Hedging)

Variables	Net Hedging Ratio			Interest Rate Hedging			Derivatives Hedging		
	[Model 1]	[Model 2]	[Model 3]	[Model 4]	[Model 5]	[Model 6]	[Model 7]	[Model 8]	[Model 9]
Constant	-0.0862***	-0.0903***	-0.0667***	-0.134***	-0.214***	-0.284***	-0.355***	-0.358***	-0.258***
	[-9.342]	[-9.776]	[-6.886]	[-6.464]	[-9.675]	[-13.637]	[-17.410]	[-17.371]	[-12.817]
Bank net worth									
Net Worth Index	0.0919***	0.192***	0.153***	0.169***	0.380***	0.618***	0.683***	0.701***	0.636***
	[3.576]	[7.677]	[6.056]	[2.742]	[5.834]	[9.879]	[11.233]	[11.445]	[10.658]
Interest rate policy									
Negative interest rate policy		-0.00812***	-0.0509***		-0.00485***	-0.0538***		-0.00234***	-0.101***
		[-44.095]	[-18.413]		[-7.154]	[-9.972]		[-3.161]	[-20.014]
Interest Rate Volatility	0.00299***	0.0120***	0.0111***	0.0153***	0.0148***	0.0203***	0.0287***	0.0269***	0.0268***
	[3.715]	[15.493]	[14.285]	[7.605]	[7.290]	[10.359]	[15.093]	[13.870]	[13.907]
Short-term IR level	0.00106***	0.00167***	0.00172***	0.000498**	0.000126	0.00243***	0.00146***	0.000962***	0.00137***
	[8.875]	[15.766]	[15.830]	[2.128]	[0.484]	[10.169]	[5.557]	[3.138]	[5.190]
Interactive Relationship									
Net Worth Index*NIRP			0.0205***			0.0246***			0.0468***
			[14.934]			[9.519]			[18.884]
Bank control variables									
Bank size	0.194***	0.0810***	0.108***	0.289***	0.276***	0.280***	0.293***	0.284***	0.298***
	[34.608]	[12.353]	[17.766]	[62.433]	[54.784]	[57.258]	[58.919]	[53.260]	[60.403]
Earning Assets	-0.00601	-0.0158***	-0.0145***	-0.0187**	-0.0487***	-0.0854***	-0.0912***	-0.0934***	-0.0870***
	[-1.600]	[-4.270]	[-3.928]	[-2.032]	[-5.017]	[-9.193]	[-10.136]	[-10.316]	[-9.840]
Capitalization	0.00989	0.0298***	0.0291***	-0.00404	0.0659***	0.158***	0.166***	0.172***	0.159***
	[1.179]	[3.592]	[3.537]	[-0.191]	[2.962]	[7.414]	[7.968]	[8.193]	[7.703]
Lending	2.122***	1.408***	0.1810	1.150***	1.007***	0.803***	1.151***	1.155***	1.268***

	[3.825]	[2.625]	[0.339]	[12.266]	[10.626]	[8.385]	[11.186]	[11.208]	[12.210]
Deposit	-0.0220***	-0.0165***	-0.0162***	-0.0247***	-0.0238***	-0.0246***	-0.0257***	-0.0251***	-0.0295***
	[-35.678]	[-30.089]	[-29.940]	[-25.071]	[-23.904]	[-25.471]	[-24.953]	[-24.276]	[-30.645]
Country characteristics									
GDP growth	0.0195**	0.114***	0.138***	0.0707***	0.0313	0.0453*	0.0457*	0.0383	0.120***
	[2.101]	[14.162]	[18.687]	[2.932]	[1.279]	[1.877]	[1.952]	[1.625]	[5.272]
Inflation	-0.0149	-0.164***	-0.261***	0.0837	0.0276	-0.167***	-0.350***	-0.328***	-0.481***
	[-0.604]	[-7.241]	[-11.717]	[1.507]	[0.483]	[-3.016]	[-7.504]	[-6.911]	[-10.936]
Bank Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11,181	11,181	11,181	13,140	13,140	13,140	13,145	13,145	13,145
Wald chi2	3,186***	5,567***	23,675***	9,454***	6,821***	11,279***	14,784***	12,609***	40,985***
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

This table depicts the relationship between bank hedging, net worth, and negative interest rate policy, as well as the joint impact of net worth and NIRP on hedging. We measure hedging via three metrics: net hedging ratio, interest rate hedging, and derivatives hedging. Net worth is defined in Equations (5) and (3b). $NIRP_{j,t}$ takes the value of one if the country where the bank is based implemented a NIRP in year t and zero otherwise. Control factors include Bank size (log of total assets), Earning assets (log of earning assets), Capitalization (log of book equity), Lending (log of loans), and Deposit (log of deposits). Country characteristics contain GDP growth and inflation. We estimate the GLS regression model for each hedging and net worth combination. Regression considers bank-fixed effects, country-fixed effects, and time-fixed effects, as well as pertinent metrics of derivative hedging, negative interest rate policy, and bank net worth. We take advantage of net hedging ratio's absolute worth. Variables are standardized and explained in Appendix A. Standard errors in parenthesis signify statistical significance at 10%, 5%, and 1%, respectively. The period spans from 2001 to 2021.

Table 7

Net worth, risk management, and negative interest rate policy (Dependent variable: Net Worth Index)

Variables	Dependent variable: Net Worth Index					
	[Model 10]	[Model 11]	[Model 12]	[Model 13]	[Model 14]	[Model 15]
Constant	4.855***	5.558***	4.895***	4.958***	5.207***	4.970***
	[45.737]	[56.694]	[37.554]	[47.508]	[53.796]	[38.348]
Risk Management						
IR Risk Management	1.502***	1.540***	1.398***			
	[22.697]	[25.161]	[20.358]			
Derivative Hedging				1.556***	0.603***	1.381***
				[26.513]	[5.110]	[21.738]
Interest rate policy						
Negative interest rate policy	0.647***	0.468***	0.554***	0.675***	0.484***	0.541***
	[16.584]	[14.607]	[8.490]	[17.784]	[12.631]	[8.361]
Short-term IR level	0.345***	0.368***	0.336***	0.342***	0.376***	0.333***
	[31.553]	[34.887]	[30.677]	[31.689]	[40.812]	[30.575]
Long-term IR level	-0.159***	-0.202***	-0.173***	-0.155***	-0.171***	-0.175***
	[-9.251]	[-12.157]	[-8.414]	[-9.088]	[-10.544]	[-8.569]
Interest Rate Volatility	-0.199***	-0.279***	-0.215***	-0.195***	-0.257***	-0.218***
	[-6.625]	[-11.533]	[-6.863]	[-6.606]	[-9.519]	[-7.032]
Interactive Relationship						
IR Risk Management*NIRP					0.926***	
					[6.144]	
Derivative Hedging*NIRP		0.227***				
		[6.714]				
Short-term IR level*NIRP			0.0363**			0.0482***
			[2.146]			[2.958]
Bank control variables						
Bank size	0.0148***	0.0148***	0.0148***	0.0148***	0.0148***	0.0148***
	[12581.347]	[5167.621]	[11802.694]	[13531.101]	[5810.419]	[13693.217]
Capitalization	0.0334***	0.0334***	0.0334***	0.0334***	0.0333***	0.0334***
	[1361.271]	[1325.521]	[1377.099]	[1375.222]	[1552.772]	[1393.981]
ROE	0.0800***	0.0815***	0.0800***	0.0790***	0.0771***	0.0794***
	[5.653]	[5.745]	[5.649]	[5.613]	[5.517]	[5.634]
Lending	0.285***	0.340***	0.292***	0.289***	0.343***	0.306***
	[4.881]	[5.913]	[4.994]	[4.978]	[6.299]	[5.256]

Variables	Dependent variable: Net Worth Index					
	[Model 10]	[Model 11]	[Model 12]	[Model 13]	[Model 14]	[Model 15]
Deposit	0.375***	0.265***	0.366***	0.375***	0.284***	0.369***
	[35.675]	[9.508]	[32.040]	[39.728]	[10.856]	[39.746]
Country characteristics						
GDP growth	0.0371***	0.0524***	0.0366***	0.0371***	0.0503***	0.0363***
	[6.161]	[9.336]	[6.071]	[6.112]	[8.337]	[5.980]
Inflation	0.195***	0.212***	0.204***	0.199***	0.186***	0.212***
	[13.075]	[16.181]	[13.266]	[13.356]	[13.696]	[13.815]
Bank Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,298	13,298	13,298	13,298	13,298	13,298
Wald chi2	1,149,810,000 ***	2,077,050,000 ***	1,047,680,000 ***	1,657,330,000 ***	2,347,350,000 ***	1,253,460,000 ***
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000

This table illustrates the association between net worth, risk management, and NIRP; the joint impact of risk management and NIRP on net worth; the joint impact of short-term and NIRP on net worth. Net worth is defined in Equations (3a) and (3b). We measure risk management via two metrics: interest rate risk management and derivative hedging. $NIRP_{j,t}$ takes the value of one if the country where the bank is based implemented a NIRP in year t and zero otherwise. Control factors include Bank size (log of total assets), ROE (net income divided by book equity), Capitalization (log of book equity), Lending (log of loans), and Deposit (log of deposits). Country characteristics contain GDP growth and inflation. We estimate the GLS regression model for each combination of net worth, profitability, risk management, and negative interest rate policy. Regression considers bank-fixed effects, country-fixed effects, and time-fixed effects, as well as relevant measures of net worth, risk management, and negative interest rate policy. Variables are standardized and explained in Appendix A. Standard errors in parenthesis signify statistical significance at 10%, 5%, and 1%, respectively. The period spans from 2001 to 2021.

Table 8

Net hedging, Loan growth, and negative interest rate policy

(Dependent variable: Net Hedging Ratio)

This table analyze the association between lending possibilities and bank's net hedging with NIRP as a moderating variable. Net hedging for bank i, country j at year t is defined in Equation (2). Denoting $\Delta Loan_{i,j,t}=log(Loan_{i,j,t})- log(Loan_{i,j,t-1})$, we define σ_i and ρ_i for any bank i as the standard deviation and first-order autocorrelation of $\Delta Loan_{i,j,t}$, respectively; $NIRP_{j,t}$ takes the value of one if the country where the bank is based adopted an NIRP in year t, and zero otherwise. All regressions considers bank-fixed effects, country-fixed effects, and time-fixed effects. Control factors include bank size (log of total assets) and financial constraints (log of net income, log of book equity, log of earning assets, log of net interest income). Variables are standardized and explained in Appendix A. Standard errors in parenthesis signify statistical significance at 10%, 5%, and 1%, respectively. The period spans from 2001 to 2021.

Variables	**Dependent Variable: Net Hedging Ratio**			
	[Model 16]	**[Model 17]**	**[Model 18]**	**[Model 19]**
Constant	0.146***	0.00173	0.265***	0.280***
	[10.145]	[0.114]	[19.231]	[20.010]
1Loans				
Loan Growth Volatility	-0.266***	-0.424***		
	[-8.062]	[-7.025]		
Loan Growth Persistence			-0.0638***	-0.157***
			[-6.762]	[-8.477]
Interest rate policy				
Negative interest rate policy	-0.00916***	-0.00576**	-0.0106***	-0.0128***
	[-6.290]	[-2.301]	[-8.802]	[-10.155]
Short-term IR level	0.000632***	0.000460***	0.000198***	0.000280***
	[9.641]	[6.320]	[2.690]	[3.732]
Long-term IR level	-0.000947***	-0.00000972	-0.00250***	-0.00257***
	[-8.210]	[-0.071]	[-22.273]	[-22.799]
Interest Rate Volatility	-0.00685	0.224*	0.772***	0.718***
	[-0.054]	[1.723]	[7.136]	[6.633]
Interactive Relationship				
Loan Growth Volatility*NIRP		0.411***		
		[6.108]		
Loan Growth Persistence*NIRP				0.124***

Variables	Dependent Variable: Net Hedging Ratio			
	[Model 16]	**[Model 17]**	**[Model 18]**	**[Model 19]**
				[5.882]
Bank control variables				
Bank size	0.00604	-0.0117**	-0.0219***	-0.0231***
	[1.207]	[-2.118]	[-7.734]	[-8.122]
ln.Net Income	-0.0164***	-0.0115***	-0.0116***	-0.0107***
	[-19.418]	[-9.217]	[-15.269]	[-13.844]
ln.Book Equity	0.0306***	0.0314***	0.0740***	0.0736***
	[9.772]	[8.855]	[26.487]	[26.331]
ln.Earning Assets	-0.0285***	-0.0164***	-0.0485***	-0.0485***
	[-8.015]	[-4.024]	[-19.269]	[-19.224]
ln.Net Interest Income	0.00222	-0.0388***	-0.00910***	-0.00867***
	[0.846]	[-16.441]	[-4.106]	[-3.918]
Country characteristics				
GDP growth	0.126***	0.0494	0.250***	0.246***
	[2.845]	[1.074]	[6.301]	[6.196]
Inflation	-0.0267	-0.0462	-0.885***	-0.816***
	[-0.280]	[-0.455]	[-10.312]	[-9.436]
Bank Fixed Effect	Yes	Yes	Yes	Yes
Country Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Observations	**10,729**	**10,729**	**10,983**	**10,983**
Wald chi2	**12470.5*** **	**1456.1*** **	**20998.3*** **	**21469.9*** **
Prob > chi2	**0.000**	**0.000**	**0.000**	**0.000**

Table 9

Net hedging, financial constraints and negative interest rate policy

Variables	Dependent Variable: Net Hedging Ratio			
	[Model 20]	[Model 21]	[Model 22]	[Model 23]
Constant	-0.217***	-0.192***	-0.217***	-0.196***
	[-54.084]	[-46.272]	[-53.284]	[-46.094]
Financial constraints				
ln.Net Income	-0.348***	-0.244***	-0.349***	-0.298***
	[-19.116]	[-15.959]	[-19.219]	[-17.345]
ln.Book Equity	0.447***	0.515***	0.304***	0.413***
	[5.966]	[6.509]	[2.762]	[5.394]
ln.Cash Dividend	-0.0442***	-0.0476***	-0.0446***	-0.0409***
	[-15.068]	[-23.537]	[-15.151]	[-11.156]
Interest rate policy				
Negative interest rate policy	-1.222***	-2.530***	-1.515***	-1.064***
	[-28.334]	[-20.622]	[-10.714]	[-21.430]
Short-term IR level	0.175***	0.171***	0.178***	0.159***
	[16.589]	[16.743]	[16.907]	[15.570]
Interest Rate Volatility	-0.736***	-1.057***	-0.740***	-0.594***
	[-27.962]	[-39.008]	[-28.298]	[-21.311]
Interactive Relationship				
ln.Net Income*NIRP		0.109***		
		[8.032]		
ln.Book Equity*NIRP			0.324**	
			[2.150]	
ln.Cash Dividend*NIRP				-0.00349
				[-0.696]
Bank control variables				
Bank size	-0.859***	-1.068***	-0.865***	-0.850***
	[-24.227]	[-34.684]	[-24.026]	[-20.933]
ln.Earning Assets	0.232***	0.227***	0.234***	0.216***
	[45.797]	[41.442]	[45.785]	[38.046]
ln.Net Interest Income	-1.563***	-1.658***	-1.578***	-1.395***
	[-25.330]	[-27.910]	[-25.576]	[-23.712]
Country characteristics				
GDP growth	-0.0357***	-0.0670***	-0.0361***	-0.0261***
	[-5.040]	[-9.246]	[-5.093]	[-3.256]
Inflation	-0.000875	0.168***	-0.00236	-0.0108
	[-0.041]	[7.881]	[-0.109]	[-0.486]
Bank Fixed Effect	Yes	Yes	Yes	Yes
Country Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes

Variables	Dependent Variable: Net Hedging Ratio			
	[Model 20]	[Model 21]	[Model 22]	[Model 23]
Observations	**11,670**	**11,670**	**11,670**	**11,670**
Wald chi2	**3,440*** **	**17,822*** **	**3,496*** **	**2,523*** **
Prob > chi2	**0.000**	**0.000**	**0.000**	**0.000**

This table analyzes the connection between net interest rate hedging, financial constraints, and NIRP using data on globally listed banks. Net hedging for bank i and country j at date t is defined in Equation (2). $NIRP_{j,t}$ takes the value of one if the country where the bank is based implemented an NIRP in year t and zero otherwise. We use four-lagged measures of financial constraints to regress net hedging: size (log of total assets), net income over total assets, net interest income over total assets, book equity over total assets, and cash dividends over total assets. All regressions include bank-fixed effects, country-fixed effects, and year-fixed effects. Control factors include bank size (log of total assets), log of earning assets, and log of net interest income. Variables are standardized and explained in Appendix A. Standard errors in parenthesis signify statistical significance at 10%, 5%, and 1%, respectively. The period spans from 2001 to 2021.

Table 10

Net hedging, financial demands, and negative interest rate policy

Variables	Dependent Variable: Net Hedging Ratio	
	[Model 24]	[Model 25]
Constant	-0.271***	-0.233***
	[-49.745]	[-40.671]
Finacial demands		
Book Debt Ratio	0.150***	0.0548***
	[75.284]	[7.855]
Interest rate policy		
Negative interest rate policy	-0.0149***	-0.0121***
	[-40.923]	[-31.723]
Short-term IR level	0.00125***	0.000899***
	[20.611]	[13.660]
Interest Rate Volatility	-0.00658***	-0.00643***
	[-30.764]	[-30.703]
Interactive Relationship		
Book Debt Ratio*NIRP		-0.0495***
		[-3.970]
Finacial Constraints		
Bank size	-0.00595***	-0.00384***
	[-15.279]	[-10.919]
ln.Net Income	-0.00312***	-0.00361***
	[-24.254]	[-28.075]
ln.Book Equity	0.0490***	0.0443***
	[16.749]	[15.638]
ln.Cash Dividend	-0.000257***	-0.000102***
	[-12.949]	[-4.323]
ln.Earning Assets	0.0216***	0.0187***
	[37.276]	[34.826]
ln.Net Interest Income	-0.0175***	-0.0113***
	[-35.303]	[-25.876]
Country characteristics		
GDPgrowth	-0.000514***	-0.000277***
	[-7.691]	[-3.526]
Inflation	0.000154	-0.000116
	[0.804]	[-0.621]
Bank Fixed Effect	Yes	Yes

Variables	Dependent Variable: Net Hedging Ratio	
	[Model 24]	[Model 25]
Country Fixed Effect	Yes	Yes
Year Fixed Effect	Yes	Yes
Observations	**11,409**	**11,409**
Wald chi2	**49,583*** **	**4,564*** **
Prob > chi2	**0.000**	**0.000**

This table analyzes the connection between net interest rate hedging, financial demands, and NIRP using data on globally listed banks. Net interest rate hedging for bank i and country j at date t is defined in Equation (2). $NIRP_{j,t}$ takes the value of one if the country where the bank is based implemented a NIRP in year t and zero otherwise. Book debt ratio measures via standard deviation of book leverage $\Delta BookDebtRatio_{i,j,t} = \Delta[(1\text{-}BookEquity)/TotalAssets]$ between t and t + 1 is used to calculate leverage increases. We examine whether banks accepted pay-fixed swap positions proactively during years of rising leverage in a (low) negative interest rate environment. If net hedging rises in positive value while gross hedging likewise rises, a bank is deemed to have taken a pay-fixed position in year t. All regressions include bank-fixed effects, country-fixed effects, and year-fixed effects. Control factors include bank size (log of total assets), log of net income, log of book equity, log of earning assets, and log of net interest income. Variables are standardized and explained in Appendix A. Standard errors in parenthesis signify statistical significance at 10%, 5%, and 1%, respectively. The period spans from 2001 to 2021.

Table 11
The impact of bank net worth and negative interest rate policy on hedging
(Dummy variable: USA and non-USA)
(Robustness test)

Variables	Net Hedging Ratio			Interest Rate Hedging			Derivative Hedging		
	[Model 26]	[Model 27]	[Model 28]	[Model 29]	[Model 30]	[Model 31]	[Model 32]	[Model 33]	[Model 34]
Constant	-0.0064	-0.0841***	-0.0482***	-0.128***	-0.178***	-0.275***	-0.314***	-0.340***	-0.288***
	[-0.907]	[-10.288]	[-5.501]	[-6.166]	[-8.158]	[-13.576]	[-15.353]	[-16.448]	[-14.815]
Bank net worth									
Net Worth Index	0.101***	0.108***	0.0891***	0.238***	0.372***	0.656***	0.710***	0.783***	0.773***
	[4.947]	[4.776]	[3.812]	[3.880]	[5.808]	[10.809]	[12.545]	[13.676]	[14.186]
Interest rate policy									
Negative interest rate policy		-0.00845***	-0.0178***		-0.00485***	-0.0506***		-0.00517***	-0.0945***
		[-41.263]	[-6.011]		[-7.363]	[-9.329]		[-7.101]	[-18.848]
Interest Rate Volatility	-0.000102	0.00817***	0.00659***	0.0151***	0.0145***	0.0205***	0.0147***	0.0128***	0.0196***
	[-0.159]	[11.568]	[9.276]	[7.487]	[7.123]	[10.461]	[7.025]	[6.040]	[9.800]
Short-term IR level	0.00176***	0.000762***	0.000492***	0.000537**	-0.0000521	0.00245***	0.000593**	-0.000316	0.000591**
	[17.188]	[5.956]	[3.892]	[2.275]	[-0.204]	[10.233]	[2.235]	[-1.059]	[2.103]
Interactive Relationship									
Net Worth Index*NIRP			0.00480***			0.0231***			0.0431***
			[3.299]			[8.947]			[17.638]
Dummy USA	-0.0193***	-0.0143***	-0.0156***	-0.0229***	-0.0233***	-0.0196***	-0.00898***	-0.00751**	-0.00540*
	[-9.759]	[-7.262]	[-7.940]	[-14.924]	[-15.972]	[-14.272]	[-3.041]	[-2.541]	[-1.827]
Bank control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Variables	Net Hedging Ratio			Interest Rate Hedging			Derivative Hedging		
	[Model 26]	[Model 27]	[Model 28]	[Model 29]	[Model 30]	[Model 31]	[Model 32]	[Model 33]	[Model 34]
Observations	**11,181**	**11,181**	**11,181**	**13,140**	**13,140**	**13,140**	**13,145**	**13,145**	**13,145**
Wald chi2	**77,197*** **	**8,103*** **	**9,240*** **	**10,974*** **	**9,743*** **	**13,723*** **	**74,889*** **	**57,855*** **	**253,798*** **
Prob > chi2	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

This table depicts the relationship between bank hedging, net worth, and negative interest rate policy, as well as the joint impact of net worth and NIRP on hedging. We measure hedging via three metrics: net hedging ratio, interest rate hedging, and derivative hedging. Net worth is defined in Equations (3a) and (3b). NIRP takes the value of one if the country where the bank is based implemented a NIRP in year t and zero otherwise. Control factors include Bank size (log of total assets), Earning assets (log of earning assets), Capitalization (log of book equity), Lending (log of loans), and Deposit (log of deposits). Country characteristics contain GDP growth and inflation. Dummy USA takes the value of one if the country is the United States of America, and non-USA is zero. We estimate the GLS regression model for each hedging and net worth combination. Regression considers bank-fixed effects, country-fixed effects, and time-fixed effects, as well as pertinent metrics of derivative hedging, negative interest rate policy, and bank net worth. We take advantage of net hedging ratio's absolute worth. Variables are standardized and explained in Appendix A. Standard errors in parenthesis signify statistical significance at 10%, 5%, and 1%, respectively. The period spans from 2001 to 2021.

Table 12
The impact of risk management and negative interest rate policy on net worth
(Dummy variable: USA and non-USA)
(Robustness test)

Variables	Dependent variable: Net Worth Index					
	[Model 35]	[Model 36]	[Model 37]	[Model 38]	[Model 39]	[Model 40]
Constant	3.645***	3.863***	3.379***	3.623***	3.091***	3.380***
	[32.155]	[37.236]	[23.911]	[31.069]	[21.854]	[23.847]
Risk Management						
IR Risk Management	1.459***	0.959***	1.303***			
	[26.675]	[12.051]	[19.968]			
Derivative Hedging				1.413***	0.268*	1.193***
				[26.270]	[1.947]	[17.542]
Interest rate policy						
Negative interest rate policy	0.530***	0.423***	0.318***	0.529***	0.211***	0.329***
	[12.516]	[14.183]	[5.127]	[12.256]	[4.745]	[5.324]
Short-term IR level	0.363***	0.388***	0.353***	0.369***	0.368***	0.354***
	[35.507]	[32.118]	[32.451]	[35.075]	[28.817]	[32.055]
Interest Rate Volatility	-0.403***	-0.310***	-0.445***	-0.390***	-0.361***	-0.431***
	[-13.107]	[-11.624]	[-14.420]	[-12.607]	[-11.384]	[-14.103]
Interactive Relationship						
IR Risk Management*NIRP		0.378***				
		[10.286]				
Derivative Hedging*NIRP					1.086***	
					[6.470]	
Short-term IR level*NIRP			0.0482***			0.0478***
			[2.909]			[2.865]
Dummy USA	1.036***	0.997***	1.075***	1.070***	1.073***	1.088***
	[22.696]	[21.128]	[23.071]	[23.165]	[21.631]	[22.940]
Bank control variables	Yes	Yes	Yes	Yes	Yes	Yes

Country characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**
Wald chi2	1,003,260,000 ***	1,651,600,000 ***	995,520,634 ***	945,424,493 ***	596,244,744 ***	887,691,484 ***
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000

This table illustrates the association between net worth, risk management, and NIRP; the joint impact of risk management and NIRP on net worth; the joint impact of short-term and NIRP on net worth. Net worth is defined in Equations (3a) and (3b). We measure risk management via two metrics: interest rate risk management and derivative hedging. $NIRP_{j,t}$ takes the value of one if the country where the bank is based implemented a NIRP in year t and zero otherwise. Control factors include Bank size (log of total assets), ROE (net income divided by book equity), Capitalization (log of book equity), Lending (log of loans), and Deposit (log of deposits). Country characteristics contain GDP growth and inflation. Dummy USA takes the value of one if the country is the United States of America, and non-USA is zero. We estimate the GLS regression model for each combination of net worth, profitability, risk management, and negative interest rate policy. Regression considers bank-fixed effects, country-fixed effects, and time-fixed effects, as well as relevant measures of net worth, risk management, and negative interest rate policy. Variables are standardized and explained in Appendix A. Standard errors in parenthesis signify statistical significance at 10%, 5%, and 1%, respectively. The period spans from 2001 to 2021.

Table 13
Bank profitability, risk management, and negative interest rate policy
(Dependent variable: ROA)
(Robustness Test)

Variables	Dependent variable: ROA						Dependent variable: ROA					
	[Model 41]	[Model 42]	[Model 43]	[Model 44]	[Model 45]	[Model 46]	[Model 47]	[Model 48]	[Model 49]	[Model 50]	[Model 51]	[Model 52]
Constant	0.494***	0.390***	0.690***	0.463***	0.489***	0.540***	-0.0655**	-0.0393	0.127***	0.0303	-0.298***	0.104***
	[20.909]	[17.069]	[24.921]	[19.588]	[19.361]	[17.621]	[-2.570]	[-1.615]	[4.477]	[0.823]	[-9.185]	[2.833]
Risk Management												
IR Risk Management	0.0451***	0.0361***	0.0435***				0.0424***	0.0223**	0.0444***			
	[4.985]	[3.674]	[4.771]				[5.057]	[2.263]	[5.259]			
Derivative Hedging				0.500***	0.157***	0.427***				0.351***	0.206***	0.528***
				[35.199]	[3.437]	[20.634]				[17.459]	[4.303]	[40.973]
Interest rate policy												
Negative interest rate policy	0.344***	0.375***	0.184***	0.370***	0.355***	0.282***	0.328***	0.302***	0.0916***	0.308***	0.360***	0.324***
	[53.044]	[52.615]	[12.861]	[55.027]	[37.978]	[27.474]	[33.134]	[29.766]	[5.986]	[31.443]	[52.145]	[27.118]
Short-term IR level	0.0884***	0.0772***	0.0779***	0.0723***	0.0632***	0.0461***	0.108***	0.0909***	0.0823***	0.0658***	0.0634***	0.0806***
	[56.307]	[34.486]	[30.823]	[40.085]	[21.984]	[16.736]	[48.131]	[35.896]	[36.469]	[54.441]	[26.559]	[32.930]
Interactive Relationship												
IR Risk Management*NIRP		0.0331***						0.0415***				
		[4.454]						[5.459]				
Derivative Hedging*NIRP					0.165***						0.304***	
					[2.768]						[5.074]	
Short-term IR level*NIRP			0.0617***			0.0398***			0.0679***			0.00218
			[15.065]			[12.650]			[15.595]			[0.601]
Dummy USA							0.512***	0.519***	0.548***	0.435***	0.471***	0.476***
							[38.367]	[38.530]	[39.309]	[24.812]	[26.192]	[27.106]
Bank control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Variables	Dependent variable: ROA											
	[Model 41]	[Model 42]	[Model 43]	[Model 44]	[Model 45]	[Model 46]	[Model 47]	[Model 48]	[Model 49]	[Model 50]	[Model 51]	[Model 52]
Country characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**
Wald chi2	20,705 ***	14,984 ***	11,805 ***	70,113 ***	16,076 ***	12,611 ***	18,665 ***	11,482 ***	10,464 ***	56,330 ***	44,885 ***	1,082,998 ***
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

This table provides evidence of the combined effects of risk management and NIRP on bank profitability; the joint impact of risk management and NIRP on profitability; the joint impact of short-term and NIRP on profitability. We employ return on average assets (ROA) as a measure of profitability, and ROA is defined as the ratio between net incomes to total assets. We measure risk management through two metrics: interest rate risk management and derivative hedging. $NIRP_{j,t}$ takes the value of one if the country where the bank is based implemented a NIRP in year t and zero otherwise. Control factors include Bank size (log of total assets), ROE (net income divided by book equity), Capitalization (log of book equity), Lending (log of loans), and Deposit (log of deposits). Country characteristics contain GDP growth and inflation. Dummy USA takes the value of one if the country is the United States of America, and non-USA is zero. We estimate the GLS regression model for each combination of net worth, profitability, risk management, and negative interest rate policy. Regression considers bank-fixed effects, country-fixed effects, and time-fixed effects, as well as relevant measures of net worth, risk management, and negative interest rate policy. Variables are standardized and explained in Appendix A. Standard errors in parenthesis signify statistical significance at 10%, 5%, and 1%, respectively. The period spans from 2001 to 2021.

Table 14
Bank profitability, risk management, and negative interest rate policy
(Dependent variable: NIM)
(Robustness Test)

Variables	Dependent variable: NIM											
	[Model 53]	[Model 54]	[Model 55]	[Model 56]	[Model 57]	[Model 58]	[Model 59]	[Model 60]	[Model 61]	[Model 62]	[Model 63]	[Model 64]
Constant	8.353***	9.083***	6.989***	6.839***	10.70***	11.15***	9.107***	8.020***	9.503***	6.951***	6.711***	8.807***
	[99.932]	[91.330]	[48.570]	[81.082]	[102.277]	[71.450]	[63.769]	[47.850]	[56.346]	[70.957]	[74.811]	[58.754]
Risk Management												
IR Risk Management	1.442***	1.909***	2.127***				2.576***	1.897***	2.308***			
	[11.977]	[14.348]	[18.995]				[24.971]	[14.743]	[20.386]			
Derivative Hedging				1.755***	1.120***	2.662***				1.504***	0.229***	1.809***
				[25.561]	[13.605]	[31.094]				[21.180]	[6.433]	[15.969]
Interest rate policy												
Negative interest rate policy	-0.161***	-0.540***	-0.127**	-0.252***	-0.135***	-0.134**	-0.0908***	-0.595***	-0.469***	-0.280***	-0.230***	-0.480***
	[-4.069]	[-14.484]	[-2.232]	[-9.378]	[-5.009]	[-2.565]	[-2.603]	[-13.591]	[-7.622]	[-10.349]	[-10.017]	[-9.852]
Short-term IR level	0.324***	0.372***	0.0988***	0.263***	0.219***	0.366***	0.245***	0.285***	0.226***	0.262***	0.237***	0.146***
	[44.651]	[48.790]	[12.535]	[51.890]	[54.395]	[51.420]	[33.344]	[32.880]	[22.924]	[56.351]	[65.183]	[16.621]
Interactive Relationship												
IR Risk Management*NIRP		1.177***						0.516***				
		[20.700]						[5.919]				
Derivative Hedging*NIRP					1.423***						2.423***	
					[11.610]						[26.164]	
Short-term IR level*NIRP			0.0610***			0.0580***			0.186***			0.313***
			[4.013]			[3.976]			[12.068]			[23.992]
Dummy USA							-0.0337	-0.493***	-0.406***	-0.177***	-0.497***	-0.508***
							[-0.382]	[-3.871]	[-4.462]	[-3.852]	[-10.788]	[-5.979]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Variables	Dependent variable: NIM											
	[Model 53]	[Model 54]	[Model 55]	[Model 56]	[Model 57]	[Model 58]	[Model 59]	[Model 60]	[Model 61]	[Model 62]	[Model 63]	[Model 64]
Bank Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**	**13,298**
Wald chi2	35,724 ***	222,355 ***	225,747 ***	108,832 ***	369,271 ***	681,618 ***	1,190,761 ***	67,436 ***	37,329 ***	163,034 ***	11,232,141 ***	156,203 ***
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix A

Variable Definitions

Abbreviation	Variable	Description	Data source	Reference
Panel A: Derivative measures				
Derivatives Hedging	All derivative contracts held for hedging purposes	The proportion of the total gross notional value of all derivative contracts held for hedging purposes (including interest rate, foreign currency, equity and commodity) divided by total assets; for the period 2001 to 2021; winsorized annually at the 99th percentiles.	Anual reports or Call reports	Purnanandam (2007) Li and Marinč (2014) Vuillemey (2017) Deng et al. (2017) Rampini et al. (2020)
Interest Rate Hedging	Interest rate derivatives held for hedging purposes	The proportion of the total gross notional value of interest rate derivatives held for hedging is divided by total assets; for the period 2001 to 2021; winsorized annually at the 99th percentiles.	Anual reports or Call reports	Vuillemey (2017) Deng et al. (2017) Rampini et al. (2020)
Net Hedging Ratio	Net interest rate hedging	The proportion of the total notional value of fixed-rate swaps use for hedging minus the notional value of floating-rate swaps used for hedging is divided by total assets; for the period 2001 to 2021; winsorized annually at the 99th percentiles.	Anual reports or Call reports	Vuillemey (2017) Rampini et al. (2020)
IR Risk Management	Interest rate derivatives held for risk management purposes	The proportion of the total gross notional value of interest rate derivative contracts held for risk management purposes or hedging purposes divided by total assets; for the period 2001 to 2021; winsorized annually at the 99th percentiles.	Anual reports or Call reports	Purnanandam (2007) Li and Marinč (2014)
Interest Rate Trading	Interest rate derivatives held for trading purposes	The proportion of the total gross notional value of interest rate derivatives held for trading is divided by total assets; for the period 2001 to 2021; winsorized annually at the 99th percentiles.	Anual reports or Call reports	Purnanandam (2007) Li and Marinč (2014) Vuillemey (2017) Rampini et al. (2020)
Derivative Trading	All derivative contracts held for hedging trading purposes	The proportion of the total gross notional value of all derivative contracts held for trading purposes (including interest rate, foreign currency, equity and commodity) divided by total assets; for the period 2001 to 2021; winsorized annually at the 99th percentiles.	Anual reports or Call reports	Purnanandam (2007) Li and Marinč (2014)
	Total financial derivatives	Interest rate derivatives + Exchange rate derivatives + Equity derivatives + Commodity derivatives	Anual reports or Call reports	Purnanandam (2007) Li and Marinč (2014)
	Financial derivatives for trading	Interest rate derivatives for trading + Exchange rate derivatives for trading + Equity derivatives for trading + Commodity derivatives for trading	Anual reports or Call reports	Purnanandam (2007) Li and Marinč (2014)
	Financial derivatives for hedging	Interest rate derivatives for hedging + Exchange rate derivatives for hedging + Equity derivatives for hedging + Commodity derivatives for hedging	Anual reports or Call reports	Purnanandam (2007) Li and Marinč (2014)

Abbreviation	Variable	Description	Data source	Reference
	Interest rate derivative contracts	Interest rate derivatives for hedging + Interest rate derivatives for trading (including future, forward, swaps, and options)	Anual reports or Call reports	Purnanandam (2007) Li and Marinč (2014)
Panel B: Net worth and profitability				
Net Worth Index	Net worth	$NWIndex^{bank}_{i,j,t} = 0.201 \times \frac{BookEquity_{i,j,t}}{TotalAssets_{i,j,t}} + 0.181 \times Size_{i,j,t} + 0.314 \times \frac{NetIncome_{i,j,t}}{TotalAssets_{i,j,t}} + 0.307 \times \frac{Dividends_{i,j,t}}{TotalAssets_{i,j,t}}$ $NWIndex^{BHC}_{i,j,t} = 0.307 \times \frac{MarkCap_{i,j,t}}{TotalAssets_{i,j,t}} + 0.149 \times Size_{i,j,t} + 0.272 \times \frac{NetIncome_{i,j,t}}{TotalAssets_{i,j,t}} + 0.272 \times \frac{Dividends_{i,j,t}}{TotalAssets_{i,j,t}}$	BankScope; Thomson Reuters Eikon	Vuillemey (2017)
ROA	Return on asset	The proportion of net income divided by total assets	BankScope	López-Penabad, Iglesias-Casal and Silva Neto (2022); Vuillemey (2017); Keffala (2021); Tran et al. (2021)
NIM	Net interest income	The proportion of net interest income divided by total assets	BankScope	López-Penabad, Iglesias-Casal and Silva Neto (2022); Vuillemey (2017); Keffala (2021); Tran et al. (2021)
Panel C: Interest rate measures				
Short-term IR level	Short-term interest rate level	The average interest rate (three-month Treasury) during the year, measured as a percentage	OECD data	Purnanandam (2007);López-Penabad, Iglesias-Casal and Neto (2022)
Long-term IR level	Long-term interest rate level	The average interest rate (ten year Treasury) during the year, measured as a percentage	OECD data	Purnanandam (2007);López-Penabad, Iglesias-Casal and Neto (2022)

Abbreviation	Variable	Description	Data source	Reference
Interest Rate Volitility	Interest rate volitility	The standard deviation of the same interest rate series during the year	OECD data	Purnanandam (2007); López-Penabad, Iglesias-Casal and Silva Neto (2022)
NIRP	Negative interest rate policy (Dummy variable)	Takes the value of one if an NIRP implemented, and zero otherwise	Central bank OECD data	Molyneux et al. (2020) López-Penabad, Iglesias-Casal and Silva Neto (2022)
Panel D: Bank variables measures				
Bank size	Bank size	Bank size is calculated as a natural logarithm of total assets.	BankScope	Vuillemey (2017)
Market capitalization	MarkCap/TotalAssets	The ratio of market capitalization is normalized by total assets	Thomson Reuters Eikon	Vuillemey (2017)
Net Income	NetIncome/TotalAssets	The proportion of net income is normalized by total assets	BankScope	López-Penabad, Iglesias-Casal and Silva Neto (2022); Vuillemey (2017)
Cash Dividends	Dividends/TotalAssets	The proportion of cash dividends is normalized by total assets	BankScope	Vuillemey (2017)
BookEquity	Total equity capital	The proportion of total equity capital divided by total assets	BankScope	López-Penabad, Iglesias-Casal and Silva Neto (2022); Vuillemey (2017)
ROE	Return on equity	The proportion of net income divided by book value of equity	BankScope	López-Penabad, Iglesias-Casal and Silva Neto (2022); Vuillemey (2017); Keffala (2021)
TotalAsset	Total assets	Total assets	BankScope	López-Penabad, Iglesias-Casal and Silva Neto (2022); Vuillemey (2017)
Book debt ratio	Leverage	The proportion of total debt divided by total assets	BankScope	Purnanandam (2007)
Panel E: Country variables measure				
GDPgrowth	Real GDP growth	Yearly growth rate of the real GDP	World Bank	López-Penabad, Iglesias-Casal and Silva Neto (2022)
Inflation	Inflation	Yearly growth rate of the consumer price index	World Bank	López-Penabad, Iglesias-Casal and Silva Neto (2022)

Appendix B:

B.1 Measuring hedging at bank and BHC level

We construct gross and net hedging variables as defined in Equations (1) and (2). Importantly, our measures include only derivatives used for hedging purposes, not trading, as the annual report's data allow us to distinguish between derivatives contracts "held for trading" and "held for purposes other than trading," that is, hedging.

Gross hedging includes all types of interest rate derivatives (swaps, options, forwards, etc.). In contrast, net hedging may be calculated only for a select group of banks that use only swaps and no other derivatives. Banks do report the notional value of interest rate derivatives held for hedging and any fixed-rate swaps they use for hedging. The floating-rate swaps, however, are not reported. The previous two figures (by computing the notional value of interest rate derivatives minus the notional amount of swaps held for hedging on which they pay a fixed rate) are only for the subset of banks that only use swaps and can be used to calculate the notional amount of swaps held for hedging on which they pay a floating rate. When only banks that use swaps are considered, 14.175 bank observations with net hedging greater than zero are obtained.

Using bank-level data, we can create an alternative measure of net interest rate hedging for the subset of banks that only use swaps and no other interest rate derivatives. Net hedging for these banks can be calculated using two pieces of information: first, the notional amount of interest rate derivatives held for hedging, and second, the notional amount of swaps held for hedging on which they pay a fixed rate. Despite not being reported, the subset of banks that only use swaps can be inferred from these two numbers regarding the notional amount of swaps held for hedging on which they pay a floating rate. Thus, we define the net hedging ratio for bank i, country j at time t is measured as equation [2]. This ratio can be calculated for 20.54% of bank-year observations for banks that use derivatives. The median size of banks for which net hedging can be calculated is 12.86 (in log assets), which is greater than the 75th percentile of bank size distribution.

Because of the differences in reporting requirements between BHCs and banks, an equal measure must be created at a different level than the BHC level. Our measurement approach for BHC data is related to that of Begenau, Piazzesi, and Schneider (2015) and Rampini et al. (2020). We consider a BHCs that has a net hedging position with market value $MV_{j,t}$ as of date t, as recorded in our data. Assume that the market value changes by $\Delta MV_{j,t+1} = MV_{j,t+1} - MV_{j,t}$ from date t to date $t+1$, while

the applicable benchmark interest rate changes by $\Delta r_{j,t+1} = r_{j,t+1} - r_t$. The net hedging of BHCs is calculated as follows

$$\left(NetHedgingRatio\right)_{i,j,t} = \left(\frac{\Delta MV_{i,j,t+1} / TotalAssets_{i,j,t}}{\Delta r_{j,t+1}} \right) \qquad \text{Eq.14}$$

Net interest rate hedging has a positive (negative) value for a bank that takes a net pay-fixed (pay-float) position or hedges against rising (falling) interest rates. Table 2 depicts the size quintile distribution of net hedging. In the panel dataset, the average net hedging is negative, while the median is negative but close to zero. To confirm that derivatives reported for hedging are used for risk management, we indicate those above the 75th percentile vs. below the 25th percentile. The shift in distributions is evident and consistent with hedging: banks with a higher negative net hedging value, i.e., more net floating rate liabilities, tend to have a net pay-fixed interest rate position.

B.2 Adapting net worth index for bank and BHC level data

Net worth: The marginal value of net worth shows the number of financial constraints and influences risk management practices at banks. According to Whited and Wu, (2006) and Rampini, Viswanathan, et al. (2020), we use two different ways to measure the net worth index (NWIndex) for BHC and bank-level since market capitalization is not available at the bank level.

For NWIndex at the bank level is constructed as the first principal component of four variables that are theoretically positively correlated with net worth: book equity over total assets; size (log total assets); net income (net income over total assets); and dividends (dividends over total assets). We get the loadings: book equity over assets (0.201), size (0.181), net income over assets (0.314), and dividends over assets (0.307)[11]. We define the NWIndex for bank i and country j at time t as Equation [5].

For NWIndex at the BHC level, the net worth index's other three components (size, net income over total assets, and dividends over total assets) remain unchanged. In contrast, book equity (BookEquity) over total assets is replaced with market capitalization (MarkCap) over total assets. We obtain the loadings: market capitalization by assets (0.307), size (0.149), net income over assets and dividends over assets (0.272)[12]. Using the same method as at the bank level, we define the NWIndex for bank i and country j at time t as

[11] These figures were calculated by Whited and Wu, (2006) and Rampini, Viswanathan, et al. (2020)
[12] These figures were calculated by Whited and Wu, (2006) and Rampini, Viswanathan, et al. (2020)

$$NWIndex_{i,j,t}^{BHC} = 0.307 \times \frac{MarkCap_{i,j,t}}{TotalAssets_{i,j,t}} + 0.149 \times Size_{i,j,t}$$
$$+0.272 \times \frac{NetIncome_{i,j,t}}{TotalAssets_{i,j,t}} + 0.272 \times \frac{Dividends_{i,j,t}}{TotalAssets_{i,j,t}} \quad (Eq.3b)$$

Eq.15

Appendix C: Figues

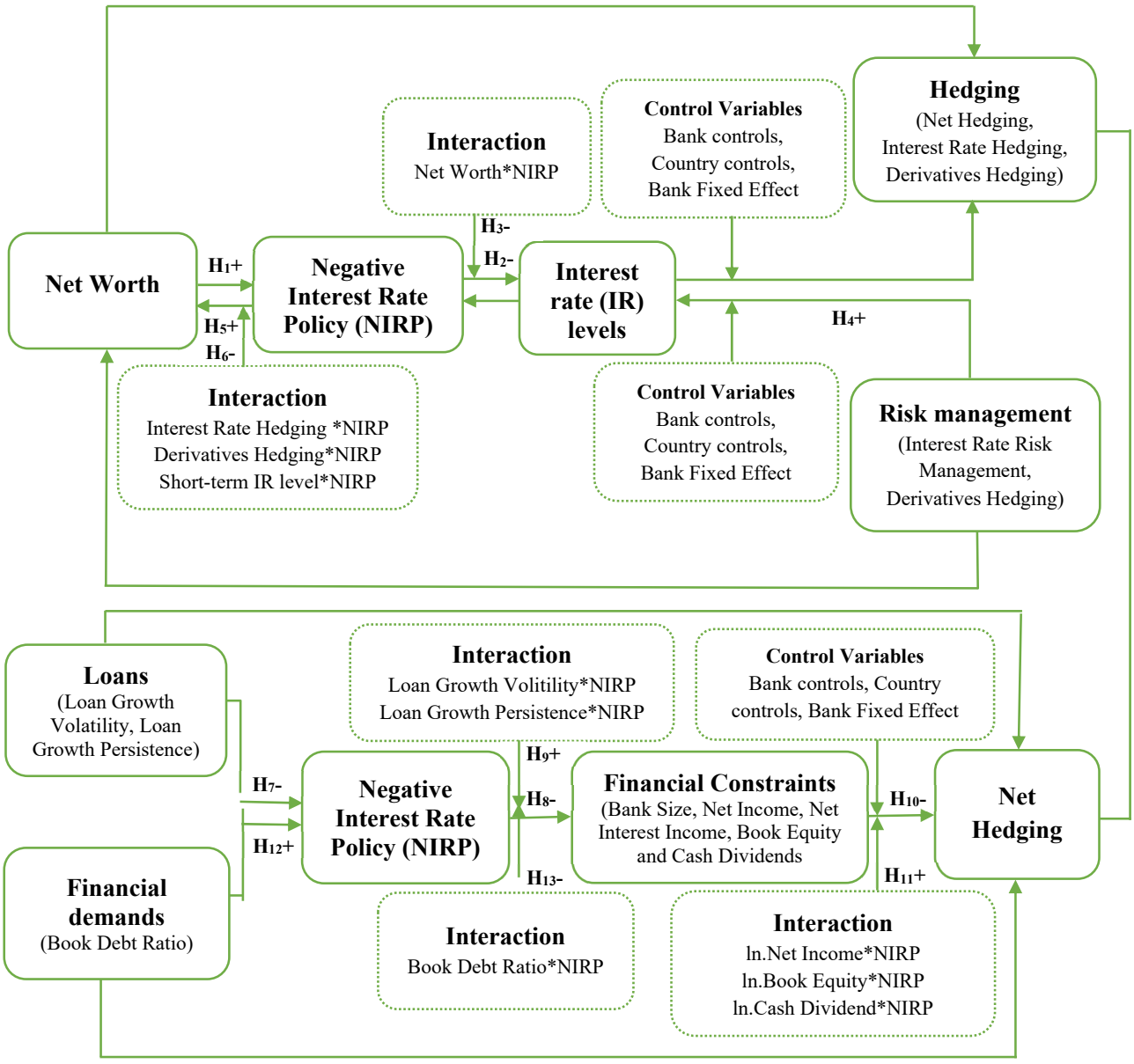

Figure 1. Conceptual Framework

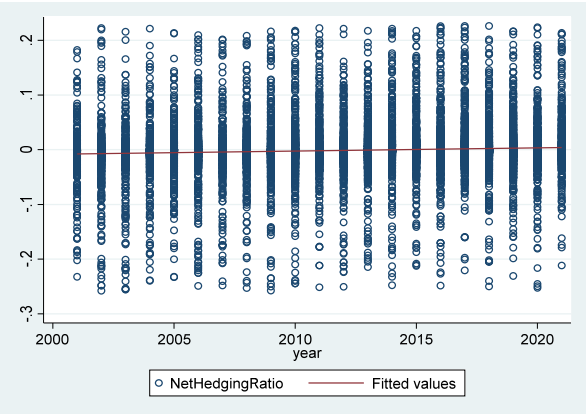

Figure 2a. Net hedging of banks

Notes. This figure describes the distribution of net hedging for banks. The net hedging ratio is defined in Equation (2). We use a circle plot to depict the distribution of net hedging each year. The red line indicates that a positive (respectively, negative) value of net hedging suggests a net pay-fixed (respectively, pay-float) position. The sampling period runs from 2001 through 2021. The data is included in Appendix A.

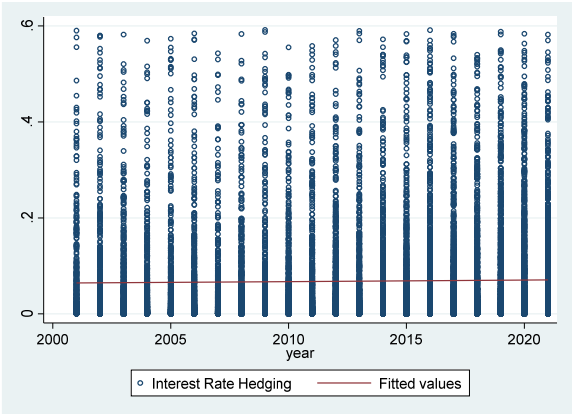

Figure 2b. Interest rate hedging of banks

Notes. This figure describes the distribution of interest rate hedging for banks. The interest rate hedging is defined in Equation (1). We use a circle plot to depict the distribution of interest rate hedging each year. The red line indicates an increased (or decreased) value of interest rate hedging. The sampling period runs from 2001 through 2021. The data is included in Appendix A.

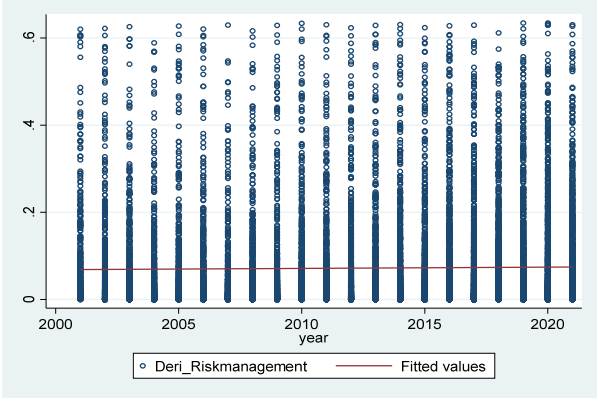

Figure 2c. Derivatives hedging of banks

Notes. This figure describes the distribution of all derivatives held for hedging purposes. The derivatives hedging is defined in Equation (4). We use a circle plot to depict the distribution of derivatives hedging each year. The red line indicates an increased (or decreased) value of derivatives hedging. The sampling period runs from 2001 through 2021. The data is included in Appendix A.

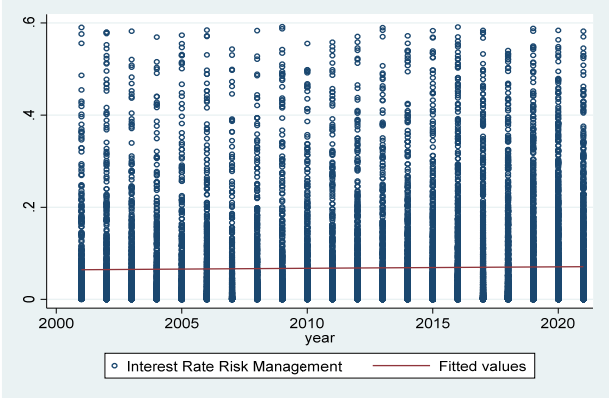

Figure 2d. Interest rate risk management of banks

Notes. This figure describes the distribution of interest rate derivatives held for risk management. The interest rate derivatives risk management is defined in Equation (3). We use a circle plot to depict the distribution of interest rate derivatives each year. The red line indicates an increased (or decreased) value of interest rate derivatives. The sampling period runs from 2001 through 2021. The data is included in Appendix A.

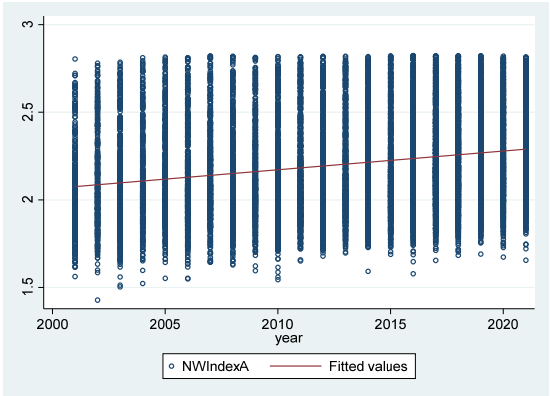

Figure 3. Net worth of banks
Notes. This figure describes the distribution of net worth for banks. The derivatives hedging is defined in Equation (5). We use a circle plot to depict the distribution of net worth each year. The red line indicates an increased (or decreased) value of net worth. The sampling period runs from 2001 through 2021. The data is included in Appendix A.

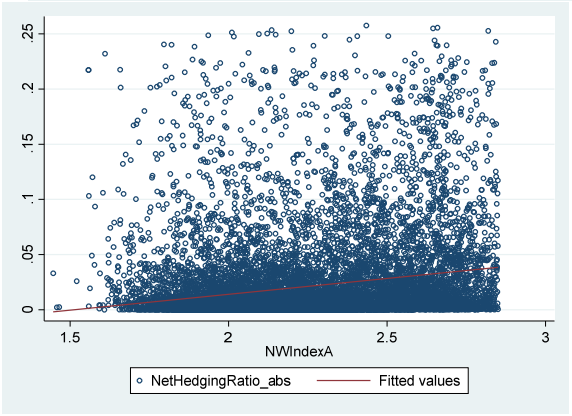

Figure 4a. Net hedging and net worth of banks
Notes. This figure describes the distribution of the relationship between net hedging and the net worth of banks. We use a circle plot to depict the distribution of the relationship, and the red line indicates a positive (or negative) association.

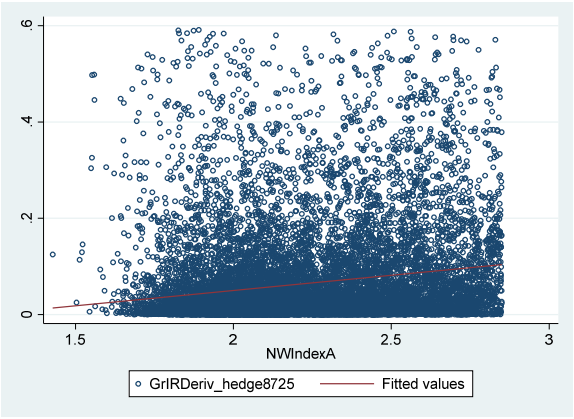

Figure 4b. Interest rate hedging and net worth of banks
Notes. This figure describes the distribution of the relationship between interest rate hedging and the net worth of banks. We use a circle plot to depict the distribution of the relationship, and the red line indicates a positive (or negative) association.

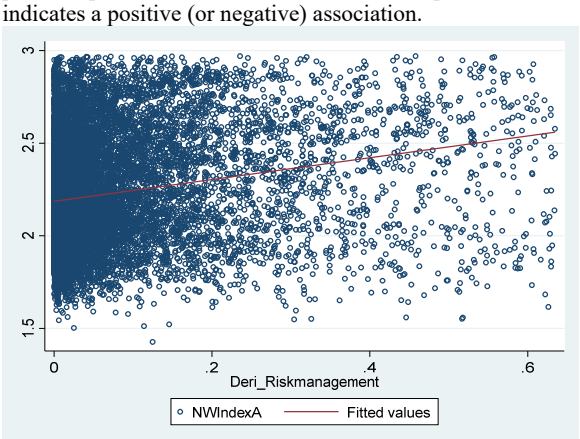

Figure 5a. Net worth and derivatives hedging and of banks
Notes. This figure describes the distribution of the relationship between the net worth and derivatives hedging of banks. We use a circle plot to depict the distribution of the relationship, and the red line indicates a positive (or negative) association.

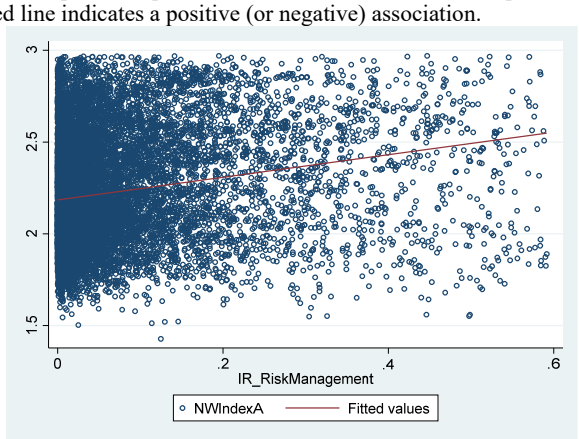

Figure 5b. Net worth and interest rate risk management of banks
Notes. This figure describes the relationship distribution between the net worth and interest rate derivatives held for risk management. We use a circle plot to depict the distribution of the relationship, and the red line indicates a positive (or negative) association.

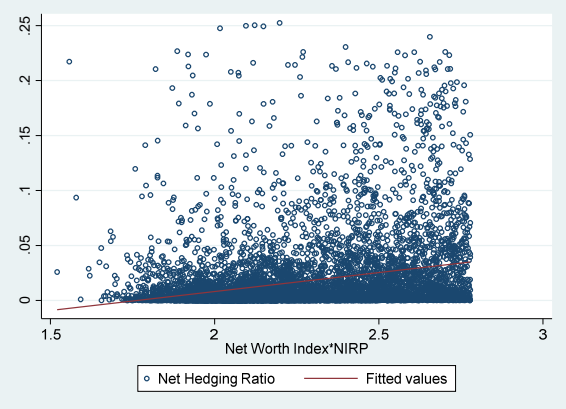

Figure 6a. Net hedging and the joint impact of net worth and negative interest rate policy

Notes. This figure describes the relationship distribution between the net hedging and the joint impact of net worth and NIRP. We use a circle plot to depict the distribution of the relationship, and the red line indicates a positive (or negative) association.

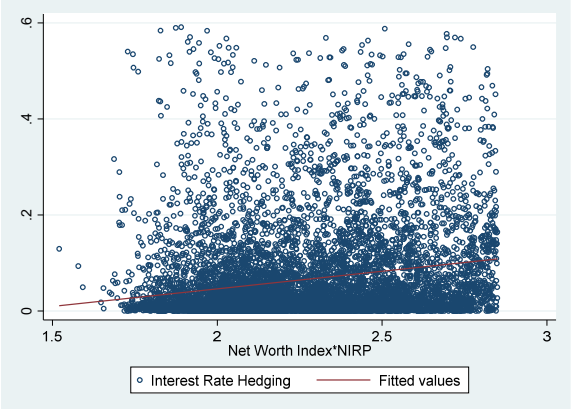

Figure 6b. Interest rate hedging and the joint impact of net worth and negative interest rate policy

Notes. This figure describes the relationship distribution between the interest rate hedging and the joint impact of net worth and NIRP. We use a circle plot to depict the distribution of the relationship, and the red line indicates a positive (or negative) association.

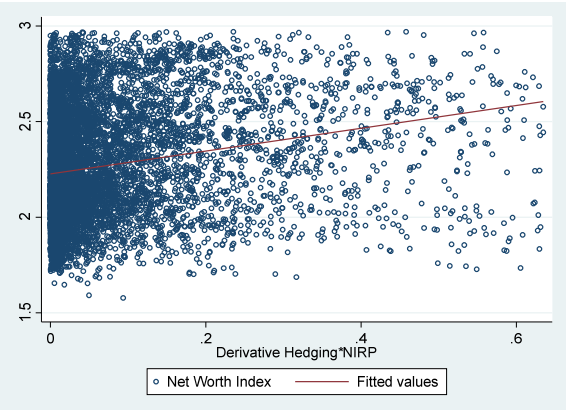

Figure 7a. Net worth and the joint impact of derivatives hedging and negative interest rate policy

Notes. This figure describes the relationship distribution between net worth and the joint impact of derivatives hedging and NIRP. We use a circle plot to depict the distribution of the relationship, and the red line indicates a positive (or negative) association.

Figure 7b. Net worth and the joint impact of interest rate hedging and negative interest rate policy

Notes. This figure describes the relationship distribution between net worth and the joint impact of interest rate hedging and NIRP. We use a circle plot to depict the distribution of the relationship, and the red line indicates a positive (or negative) association.