Banks' dynamic interest rate risk hedging*

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November 16, 2025

Abstract

We use granular regulatory data on euro interest rate swap trades over the period 2021-2024 to analyse the dynamics of Italian banks' hedging of interest rate risk in their securities portfolio. We find that on average and over the full period, banks use swaps as hedging instruments: a third of the value losses on securities following a 100 basis points upward shift of the yield curve are offset by the associated gains on swap positions. The intensity in securities hedging through swaps increases by 6% after policy rates rise in mid-2022. Causality of such increase is assessed with an analysis based on monetary policy surprises. The increase in hedging intensity during the tightening period is more important for banks with initially lower capital and less stable funding.

Keywords: EMIR, interest rate risk, securities holdings, derivatives, banks.

JEL Codes: G11, G21, E43, E52.

*The authors thank Antoine Bouveret, Cecilia Caglio, Alessandro Conciarelli, Maciej Grodzicki, Luc Laeven, Teodora Paligorova, participants to the 2024 CEBRA Annual Meeting at Goethe University, the ECONDAT Conference 2024 at King's College, and the 2024 workshop EMIR data analytics for research, financial stability and supervision at Bank of Italy. The views in this paper are the authors' and do not necessarily reflect those of the Bank of Italy. Errors and omissions are the authors own responsibility.

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1 Introduction

A firm's interest rate risk can be defined as the reduction in its economic value of equity resulting from adverse movements of the yield curve. For banks, the maturity mismatch arising from their typical business model of borrowing short and lending long leads to net worth losses when rates rise, as the value of assets decreases more than that of liabilities. Banks can hedge their exposure to interest rate risk through derivative contracts that appreciate when rates rise. The convenience to engage in hedging of interest rate risk can depend on the expectations for the monetary policy path, which affects both the likelihood of rate increases and the cost of buying insurance against them. The failure in March 2023 of some US banks with significant valuation losses on their long-term securities holdings due to the Fed's monetary tightening has raised questions on whether banks effectively hedge their interest rate risk exposure along the monetary policy cycle.

Do banks use derivatives to hedge the interest rate risk of their securities portfolio? If so, does their hedging activity change with policy rates? And, which bank variables determine their hedging activity and its dependence on interest rates? Fundamental as these questions are, to the best of our knowledge they have not yet been answered by the literature primarily due to data challenges.

In this paper, we rely on regulatory bond-level data and recently collected transaction-level data on derivatives to explore in depth the dynamic patterns of Italian banks' interest rate risk hedging activities. Quantitatively assessing these practices requires contract-level data on banks' interest rate derivative exposures at a high frequency, which in the European Union became available to supervisory and financial stability authorities in 2014 following the implementation of the European Market Infrastructure Regulation (EMIR). The huge number of derivative transactions in which banks enter and the need to properly evaluate each derivative contract under different yield curves to estimate its interest rate risk exposure, makes the high-frequency quantification of banks' hedging activities over an extended time span computationally daunting. We build a measure of derivative portfolio interest rate risk exposure available at the bank level and weekly frequency. Its computation involves on average the evaluation of price changes following shifts in the yield curve of more than 145,000 contracts each week over the period January 2021 to April 2024, which covers the monetary policy tightening cycle initiated in the euro area in July 2022.[1]

[1]To the best of our knowledge, the only academic contribution quantifying European banks hedging activities using EMIR contract-level data is Hoffmann et al. (2019). The paper focuses on the cross-section of banks' hedging activities at a single end-year date. Alfaro et al. (2024) conduct a similar high-frequency quantification of interest rate risk exposure of UK pension fund and insurance sectors and its dependence on interest rates using UK EMIR data.

Securities account for around a quarter of total bank assets in Italy and they consist mostly of fixed-rate bonds. The value of these bonds declines when market interest rates rise. From an accounting perspective, securities can be recorded either at fair value (FV) or amortised cost (AC).[2] Our measure of interest rate risk exposure of a financial contract consists in the change in its present value, or ΔPV, resulting from an hypothetical 100 basis points (bps) parallel upward shift of the yield curve. The ΔPV of a fixed-rate debt security is negative, reflecting that its value decreases as interest rates increase. The interest rate risk exposure of a portfolio of securities is the sum of the ΔPV of its components.

We are interested on whether Italian banks use derivatives to hedge the interest rate risk of their securities portfolio. The euro-denominated interest rate derivative contracts most actively traded by Italian banks are interest rate swaps, overnight index swaps and forward rate agreements.[3] These contracts, which we generically refer to as "swaps", involve two parties that exchange cash flows based on different interest rates. One party pays a fixed interest rate and receives a floating rate on a notional amount during the maturity of the contract (long swap position), while the other receives the same fixed rate and pays the floating rate (short swap position). The long position benefits if interest rates rise, because the floating payments increase while the fixed payments remain unchanged. The opposite is true for the short position. Hence, the present value change associated with an upward shift of the yield curve, ΔPV, is positive (negative) for a long (short) swap position.

Banks can use long swap positions to hedge the interest risk exposure of their portfolio of securities (or that of other long-term assets). Instead, they can take short swap positions to benefit from an interest rate fall. Moreover, banks also provide financial services to their customers, which leads them to enter into long or short swap positions depending on client demands. Banks hence have long and short outstanding swap positions at any point in time, and their interest rate risk exposure in swaps results from the aggregation of the potentially offsetting ΔPVs of these contracts.

We find that on aggregate and over the period January 2021 to April 2024, the ΔPV of the Italian banks' swap portfolio is positive. This implies that swaps provide some hedge against the interest rate risk in the debt securities portfolio of the banking sector. Quantitatively, we find that a 100 bps upward shift of the yield curve increases on average over the entire period the value of the swap portfolio by 47 bps of risk-weighted assets (RWA), partially compensating losses of 143 bps of RWA on the debt securities portfolio

[2]Only value changes of securities recorded at FV affect regulatory capital.

[3]These contracts represent about three quarters of gross notional amounts in Italian banks' derivative portfolios.

upon the same yield curve shift. One third of the interest rate risk exposure in bonds is hence hedged through swaps. Interestingly, the value losses on FV debt securities amount on average to 51 bps of RWA, so that swaps eliminate almost all of the interest rate risk of these securities. Swaps hence neutralise the changes in regulatory capital that would be implied from marked-to-market valuation rules. Our finding that, on aggregate, Italian banks use swaps to reduce their exposure to interest rate increases is consistent with the results in Hoffmann et al. (2019) for the entire euro-area banking sector. However, it stands in contrast to those in McPhail et al. (2023) that US banks do not use swaps to hedge losses on their long-term assets induced by rate increases.

Although the direction in which Italian banks in aggregate trade swaps is consistent with hedging the interest rate risk in their securities portfolio, variation exists across institutions. In fact, should interest rates rise by 100 bps, swap positions reduce losses on debt securities by an average of 107 bps of RWA for three-quarters of the sample banks, while for the remaining banks, they increase losses by an average of 49 bps.

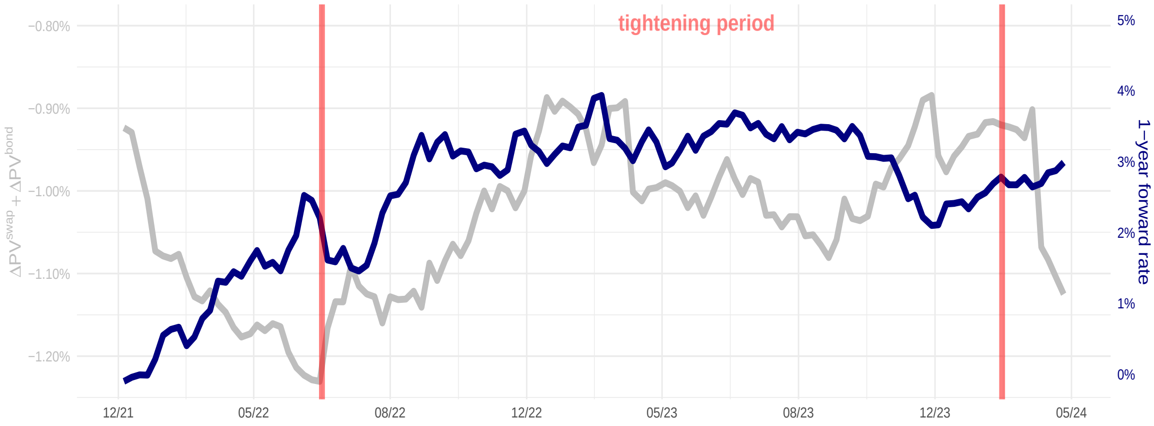
To further provide evidence that banks use swaps to hedge interest rate risk of securities as opposed to that of other long-term assets, we first focus on the comovement at the bank level and weekly frequency of the ΔPV of swaps and that of securities. We find a significantly negative relationship between the two, which suggests that when a bank purchases new securities and the interest rate risk exposure of securities portfolio increases, it tends to enter new long swap positions to increase the insurance provided by its swaps portfolio. Quantitatively, on average across banks and over the full period, around 20% of the value losses following a 100 bps upward shift of the yield curve on purchases of securities would be offset by the gains under the same shift of the curve on the new swaps the bank enters. We refer to such share as the *intensity in securities hedging*. Moreover, we fail to uncover an analogous significant relationship between the interest rate risk exposure of derivatives and that of other bank assets like loans and of bank liabilities like issued bonds or deposits.[4] All in all, our results suggest that Italian banks use swaps to hedge interest rate risk exposure of their securities portfolios more than that of other parts of their balance sheet.

We next turn to understanding the dependence of banks' hedging activity with swaps on the movements in interest rates. Figure 1 plots the evolution of interest rates in the period from January 2021 to April 2024 and the ΔPV of the portfolios of securities and swaps of the entire Italian banking sector. When interest rates start to increase, the net ΔPV of the overall portfolio of securities and swaps starts to increase, which means that

[4]It is worth noting that accurately establishing such relationships requires granular contract-level data, which we only have for derivatives and securities holdings. The reporting of banks' other balance-sheet items is done at quarterly frequency, in a far more aggregate form, and in much less detail.

Figure 1 – Banks' dynamic interest rate risk hedging

(a) Hedging and forward rate



Notes: The figure displays the evolution of 1-year forward interest rate (rhs, blue line) and the ΔPV of the portfolios of securities and swaps of the Italian banking sector (lhs, grey line). Quantities on the lhs are expressed relative to risk-weighted assets. Data are weekly from January 2021 to April 2024.

banks reduce their overall exposure to interest rate risk as rates start to rise. In other words, banks buy additional protection with respect to interest rate risk when such risk is already materialising.

We conduct a series of tests to better understand the stylised evidence provided in Figure 1. First, we focus on whether changes in interest rates affect our estimate of the intensity in securities hedging. Taking into account that the first increase in the ECB official interest rates in our sample happens in July 2022, we decompose our time span into a pre-tightening period from January 2021 to June 2022, and a tightening period from July 2022 to February 2024. We find that in response to tighter monetary policy, on average across banks, the intensity in securities hedging significantly increases by 6%, compared with prior to the tightening cycle. The results would be consistent with an increased awareness by banks on the possibility of important increases in interest rates after a decade in which they were at very low levels.

Furthermore, in order to establish a causal link between the intensity of securities hedging and policy rates, we consider a specification in which the ΔPV of the securities portfolio is interacted with monetary policy surprises obtained from Altavilla et al. (2019). We find that the interacted coefficient is again negative and significant. Quantitatively, following a monetary policy surprise of one standard deviation, the intensity in securities hedging increases by 7%. We obtain similar results when we interact the ΔPV of the securities portfolio with the 1-year forward rate, which captures the market assessment on the evolution of interest rates. The results thus provide causal evidence that banks react to increases in policy rates through more intense hedging of interest rate risk.

Next, we explore determinants of the intensity in securities hedging during the tightening period going from July 2022 to February 2024. We find that such intensity is larger for banks with a lower capital ratio. This result points to the fact that more thinly capitalised banks became more concerned about losses on their securities portfolio from interest rate increases as the tightening of monetary policy was unfolding. This led them to buy more insurance through swaps than banks with more capital and hence more capability to absorb potential losses. Furthermore, we find that the intensity in securities hedging when monetary policy was tightening is more pronounced for banks with pre-tightening higher levels of bond financing, which is short-term debt mostly with variable rates, and lower levels of deposits, which are predominantly retail and have little sensitivity to interest rates. This finding seems to suggest that the banks that had financed their activities with less stable sources of funding are those that more actively traded swaps to hedge securities during the tightening period.

Related literature Our results contribute to the literature on banks' use of derivatives to hedge interest rate risk, from which emerges important heterogeneity both within and across banking systems. Using a one-day snapshot of EMIR derivatives data at 2015 year-end, Hoffmann et al. (2019) show that the average European bank eliminates with swaps around a quarter of the interest rate risk on its balance-sheet. However, there is important cross-country variation: banks located in countries where fixed-rate mortgages predominate are more exposed to interest rate changes, and banks hedge more if the magnitude of interest rate risk from their on-balance-sheet positions is larger. We also use EMIR data to analyse at high-frequency the hedging patterns of interest rate risk of the securities portfolio in the Italian banking system. Our results confirm the use of derivatives in Italy to manage interest rate risk, and we further contribute by identifying an increase in the intensity of hedging as policy rates rise.

Contributions focusing on the US banking sector suggest a very different behaviour by banks in that jurisdiction. Using public balance-sheet data, Begenau et al. (2015) document that between 1995 and 2014 the largest US banks were trading derivatives to increase their interest rate risk exposures rather than to hedge it. Leveraging regulatory data on the individual swap positions of the largest US banks from 2017Q3 to 2019Q4, McPhail et al. (2023) conclude that swap positions are not economically significant in hedging the interest rate risk of bank assets, although variation exists across institutions.

In the wake of Silicon Valley Bank's failure in March 2023 following the Fed's monetary policy tightening that started in 2022, a body of papers focus on the analysis of hedging patterns in a rising-rate environment. The overall message confirms the limited role of hedging by US banks also in this period. Using quarterly security-level data, Fuster et al.

(2024) find that the use of "qualified" accounting hedges by large US banks remained limited in the 2022-23 rising-rate environment, although the interest rate risk in their securities portfolios increased. Unlike Fuster et al. (2024), our paper considers the full set of banks' interest rate swap derivatives, including those that are not designated as hedges for accounting purposes, yet able to reduce losses from asset depreciation when rates rise. Cross-bank heterogeneity is once again documented by Fuster et al. (2024), with higher hedging activity for banks that include unrealised gains and losses in regulatory capital, and to some extent for banks with larger share of US Treasuries in their portfolios. Focusing on year-end call report data for 2021 and 2022, Jiang et al. (2023) confirm previous findings that hedging activity is concentrated among the largest US banks, but these hedges leave the vast majority of interest rate risk unhedged. Interestingly, they also find that in 2022 banks more exposed to solvency runs (due to a higher share of uninsured deposit funding) reduced their hedges, which is suggestive of gambling for resurrection in the run-up to the March 2023 turmoil. Our paper contributes to this literature by providing the first high-frequency analysis of the dynamic dependence of interest rate risk hedging along the monetary policy cycle.

Somehow in contrast with the within-sector heterogeneity of the aforementioned studies, Khetan et al. (2023) show that UK banks are mostly homogeneous in the direction of traded swap notional: pay fixed and receive floating. Although the net notional positions of UK banks seem to imply insurance against interest rate rises, the authors also find that these swap positions strongly decline in value as rates increase, which contrasts with the idea of hedging and suggests an exacerbation of interest rate risk exposures. Although the work of Khetan et al. (2023) stands out as first large scale evidence provided with transaction-level data over an extended period of time, their focus is on the swap demand across sectors and its effect on prices rather than the risk that swap positions entail and the asset losses that banks want to hedge against.

The rest of the paper is organised as follows. Section 2 offers a primer on interest rate swaps and describes the EMIR and security holdings datasets. In Section 3 we show how to measure interest rate risk. Section 4 presents descriptive statistics on our data and the estimates of swap and bond portfolio exposures to interest rate risk. Section 5 reports the main empirical findings on banks' securities hedging with swaps. In Section 6 we discuss the relation between swaps and all balance-sheet exposures. Section 7 concludes.

2 Background and Data

Before describing in detail the regulatory datasets used for the analysis, we provide a short background on the main characteristics and use of the interest rate derivatives that we consider.

2.1 Primer on interest rate swaps

An interest rate swap is a financial derivative contract where two parties exchange cash flows based on different interest rates. The most common contract is the fixed-for-floating swap, where one party agrees to pay a fixed rate and to receive a floating rate on some notional amount for a fixed term, while the other party agrees to pay that floating rate and to receive that fixed rate on the same notional amount for the same term. A swap's interest rate payments are exchanged regularly throughout the life of the contract, e.g. twice a year. The fixed rate, which is called the swap rate, is determined at the time of the trade and is typically set such that the value of the swap at initiation is zero, or in other words, the payment of an upfront amount by one counterparty to the other is not required to enter into the swap. The floating rate is usually a compounded overnight rate or an interbank offered rate, whose future realisations determine the floating rate payments that will be exchanged for the fixed-rate payments.[5]

We henceforth adopt the following convention: the counterparty that pays fixed rate is the buyer of the swap ("long" position), while the counterparty that receives fixed rate is the seller of the swap ("short" position). The value of the long position increases if interest rates rise, because the floating payments that are received increase while the fixed payments that are paid remain unchanged. The opposite is true for the value of the short position.

Swap contracts can be used to manage interest rate risk or speculate on rate movements. The reason why both long and short positions exist is because financial markets involve different participants with varied and varying risk exposures and expectations on future rate paths. For instance, banks tend to have a positive duration gap (i.e. assets have longer duration than liabilities) so that an increase in interest rates reduces the value of their assets more than that of their liabilities. As a result, banks might demand long swap positions for hedging purposes. Instead, insurance companies and pension funds have negative duration gap and they might demand short swap positions to hedge against interest rate decreases. Furthermore, market participants may have heterogeneous expectations about future rate paths, which might lead them to take long (short) positions on interest rate swaps when they assign a higher likelihood to rate increases (decreases) than the market does. These expectations and how they compare with those

[5] Another common interest rate derivative contract is a forward rate agreement, which is essentially a single-period swap for forward settlement: counterparties exchange on a future date (settlement date) a single interest payment at a fixed rate for a payment at the then-prevailing value of a floating rate applicable to an investment starting on that date and lasting until the settlement date of the contract.

of the market may change over time, which could result in taking new positions that offset others previously taken. The co-existence of long and short positions at any point in time explains the position netting that is needed when assessing the interest rate swap exposure of each financial agent.

Although the value of a swap is typically zero at initiation, it will vary afterwards as interest rates change. In order to price a long fixed-for-floating swap (i.e. pay-fixed) one can think of such contract as a combination of a short position in a fixed-rate bond and a long position in a floating-rate bond. The value of the swap is hence

$$V^{swap} = B^{fl} - B^{fix} \ , \tag{2.1}$$

where B^{fix} and B^{fl} are the prices of the underlying fixed-rate and floating-rate bonds, respectively. We will show in Section 3 how these bond prices are computed.

2.2 Data sources

In this paper, we combine two regulatory and highly granular datasets. First, we use transaction-by-transaction EMIR data on derivatives to retrieve interest rate swap trades reported by Italian banks. Second, for each bank with swap positions, we use security-by-security holdings data to define their investments in fixed-rate bonds. We next provide detailed descriptions of these datasets.

2.2.1 Interest rate derivatives data

Following the introduction of European Market Infrastructure Regulation (EMIR) in 2014, transaction-by-transaction derivatives data are reported on a daily basis by entities resident in the EU and collected through trade repositories, which, in turn, make these data available to authorities.[6] The collected information includes details of each individual derivative transaction such as the identity of the counterparties, the type of derivative, the last updated value of the contract, its maturity and notional amount, the execution and clearing venues, and, if any, the collateral (margin) paid and received.

We work with EMIR data accessible to the Bank of Italy, which comprises transactions reported from December 29, 2020, by entities falling within the jurisdiction and financial stability mandate of the Bank of Italy.[7] We focus on a subsample restricted to the euro-

[6] See Regulation EU/2012/648.

[7] Bianchi et al. (2025) provides an exhaustive description of the full EMIR data and the portion of it that is accessible to the Bank of Italy and fully covers the Italian banks considered here. The paper also highlights data quality and practical issues faced when collecting and using EMIR data, and define

denominated interest rate derivatives of Italian banks consolidated at group level.[8] By consolidating swap portfolios at the group level, we include positions held by subsidiaries and exclude intragroup trades.[9]

Although EMIR data is recorded daily with about 30 million records available to us for each trading day, we choose, for tractability reasons, to conduct the analysis at weekly frequency by sampling swap trades outstanding on the Wednesday of each week from January 2021 to April 2024. We use "trade state" data, which contains all pending trades at the end of a given day.

Reporting under EMIR is dual-sided when both counterparties are EU residents. Therefore, for some trades, our dataset contains two reports. We identify these duplicate trades using the "trade id" field in EMIR together with the counterparty identifiers, and we sample only one report per trade to avoid double counting. Whenever two reports are available we follow a pecking order decision rule for which report to keep. In particular, we favour reports submitted by Italian banks over those of CCPs, clearing members, and other reporting entities.

We now describe in detail how we select the interest rate derivative contracts which constitute our topic of interest. We focus on single currency both spot- and forward-starting interest rate swaps (IRS) written on the euro interbank offered rate (EURIBOR) with maturity of 1, 3, 6, or 12 months, and the overnight index swaps (OIS) written on the euro overnight index average rate (EONIA) and the euro short-term rate (€STR).[10,11] A particular type of forward-starting IRS is constituted by forward rate agreements (FRA), which are single-period IRS for forward settlement. We use the term "swaps" when referring to all these contracts. EURIBOR swaps are the most traded and liquid contracts among the swaps we consider (Grassi et al., 2022). We do not consider cross-currency swaps, basis swaps, neither contracts with embedded options.

We identify the candidate swaps in EMIR as trades where: (i) the "asset class" field is equal to "IR" (for "interest rate"), (ii) the "contract type" field is equal to "SW" (for "swap") or "FR" (for "forward rate agreement"), (iii) either the "floating rate of leg 1" field or the "floating rate of leg 2" field is not blank, and whichever of these fields

the framework used here to move from raw to clean data suitable for the analyses.

[8]Consolidation is based on Banca d'Italia's regulatory group structure information in cases where the group parent is a bank that resides in Italy, whereas for all other groups it is based on information reported by the Global Legal Entity Identifier Foundation (GLEIF) established by the Financial Stability Board (FSB) in June 2014, to foster the widespread use of identifiers for legal persons.

[9]More specifically, for Italian banking groups we include the positions held by both local and foreign subsidiaries, while for foreign banking groups we only include the positions of the Italian subsidiaries.

[10]In a forward-starting swap, the exchange of payments does not begin until an agreed future date, T_1, after which they continue to the maturity date, T_2.

[11]EONIA was discontinued on 3 January 2022 but OIS contracts referenced to this rate continue to exist until their expiration. We treat these contracts as if they were OIS referencing to €STR.

is populated contains the term "euri", "str", "eona", or "eonia" (after lowercasing the text), (iv) either the "fixed-rate of leg 1" or the "fixed-rate of leg 2" field is not blank, and (v) only one of the "notional currency 1" and "notional currency 2" fields is not blank with value equal to "EUR", or they both contain this same value. Finally, we identify forward-starting IRS and OIS contracts as those swaps where the "effective date" field is after the "reference date" of the reporting.

In the sampled swaps, the buyer (long position) pays a fixed rate and receives a floating rate on some notional amount for a fixed term, while the seller (short position) pay the floating rate and receives the fixed rate on the same notional amount for the same term. We use the "counterparty side" field reported in EMIR, which is populated with either "B" for buy or "S" for sell, to distinguish between long and short positions.[12] We perform a number of data quality checks on the fixed rate, which is called the swap rate, and discard a few erroneous reports and trades whose last valuation is dated more than a week prior to the reporting date.[13]

After applying the aforementioned data-filtering criteria, we gather from EMIR the contractual features of every swap position of the 54 Italian banks active in the swap market in the 2021-2024 sample period.

2.2.2 Securities data

We next describe the data on bank securities portfolios available at the Bank of Italy. Starting from 2008, each bank or subsidiary located in Italy reports month-end ISIN-by-ISIN data on all the securities it holds.[14] The reporting provides the market value of all securities, regardless of their accounting treatment, i.e. the security is held at amortised cost or fair value. We focus on fixed-rate bonds issued in euros and consolidate the

[12]In Regulation EU/2013/148, the reporting rules of EMIR state, *"In the case of an interest rate derivative contract, the buy side will represent the payer of leg 1 and the sell side will be the payer of leg 2"*, where each leg can only be populated with either the fixed or the floating rate. More recently, Regulation EU/2017/105 has amended the reporting rules by stating, *"In the case of swaps related to interest rates or inflation indices, the counterparty paying the fixed-rate shall be identified as the buyer and the counterparty receiving the fixed-rate shall be identified as the seller"*. Taking into account this change of rules, we identify whether the reporting counterparty of a swap in our data is paying the fixed or floating rate by repricing the contract under both interpretations of the "counterparty side" field. We always choose the interpretation corresponding to the more recent regulation unless the repricing according to it, and not the other regulation, delivers a swap contract value with opposite sign from that of the value reported in EMIR (even after rescaling the former to have the same time series average as the latter). What we observe in practice is that, with very few exceptions corresponding to 5% of the sampled trades, entities submit their reports in accordance with the more recent regulation.

[13]We refer the reader to Bianchi and Ruzzi (2025) for a detailed description of the data manipulation and cleaning performed on the fixed-rate field in EMIR.

[14]The International Securities Identification Number (ISIN) is the internationally recognised code for the identification of financial instruments in the markets and in transactions. It is based on the ISO 6166 standard.

portfolios of securities at group level, excluding intragroup exposures.

In order to price securities under different market rate curves, we exploit the Securities Database that is managed by the Bank of Italy and contains details of each ISIN in banks' portfolios – including security type, maturity, coupon type and currency.

We focus on the period December 2020 to April 2024 and on the 54 banks that have swap exposures. Since our empirical analysis is conducted at weekly frequency starting from the first week of January 2021, we assume that the change in the securities portfolios observed between two consecutive end-month dates is equally split across weeks.

3 Measuring Interest Rate Risk: ΔPV

This section describes the methodology we follow to measure banks' interest rate risk exposure in their swap and fixed-rate bond portfolios.

Conceptually, our measure of interest rate risk exposure of a financial contract consists in the change in its present value, or ΔPV, resulting from an hypothetical movement in interest rates (shock). Owing to the asset class that is the focus of this study, the market shock that would trigger significant asset price fluctuations is a movement in the euro risk-free spot "yield curve" used to discount swap and bond expected future cash flows back to present day.[15] As a shock we apply an instantaneous 100 basis points (bps) parallel upward shift to the yield curve and assume that the shock passes through in full to the bonds' yield-to-maturity, implying that bond issuers' credit risk remains unchanged. To put the 100 bps shock into perspective, this value is more than three times larger than any single-day moves of 12-month EURIBOR rates in history, including the 29 bps change in June 2008 at the onset of the global financial crisis and the 15 bps change in July 2022 with the normalisation of the monetary policy by ECB. Although extremely unlikely within a day, a 100 bps move in rates may be observed over longer time horizons like the two-month periods in the second half of 2022 in our sample.

Once the euro riskless spot (i.e. zero-coupon) curve is estimated, we compute banks' interest rate risk exposure in swaps, ΔPV^{swap}, as the change in value of their swap portfolios after the rate shock. We do this by repricing each individual swap contract before and after the shift in the yield curve, and then taking the difference between the pre- and post-shock values, that is

[15] In Appendix A we provide detailed information on how to bootstrap the riskless spot curve that provides discount rates of swap and bond pricing. It should be noted that in the case of derivatives, including swaps, discount rates and risk-free rates are the same, whereas the discount rates of bonds have an extra component (spread) that reflects the credit risk of the issuer.

$$\Delta PV^{swap} = V^{swap}(\mathbf{z}+\delta) - V^{swap}(\mathbf{z}) \ , \tag{3.1}$$

where $V^{swap}(\mathbf{z})$ and $V^{swap}(\mathbf{z}+\delta)$ denote the swap values computed, respectively, before and after the shock δ to the riskless zero-coupon curve $\mathbf{z} = \begin{bmatrix} z^{(1)} & z^{(2)} & \cdots & z^{(n)} \end{bmatrix}'$, with $z^{(t)}$ being the spot interest rate for maturity t.

To calculate the value of a swap, which we know from eq (2.1) can be obtained as the difference between the prices of a fixed-rate bond, B^{fix}, and a floating-rate bond, B^{fl}, we implement the following pricing formulae. Let $z^{(t)}$ be the annualised spot interest rate observed today for maturity t (in months), and $f^{(t-1,t)}$ be the forward rate between times $t-1$ and t (in months) – i.e. the interest rate expected today on a zero-coupon investment starting at time $t-1$ and ending at t. Let us consider a spot-staring swap with maturity T and notional amount N. The fixed leg pays the annualised swap rate $s^{(T)}$ and makes q^{fix} payment(s) per year, for a total of I payments between today and T. Each payment amounts to $C^{fix} = s^{(T)}N/q^{fix}$. Let t_i and d_i be the time frames in months and in days, respectively, between today and the i-th fixed-rate payment date, with $i = 1, 2, ..., I$. The fixed-rate bond price gets computed as

$$B^{fix} = \sum_{i=1}^{I} \frac{C^{fix}}{(1 + z^{(t_i)} \frac{d_i}{365})} + \frac{N}{(1 + z^{(t_I)} \frac{d_I}{365})} \ . \tag{3.2}$$

The floating leg, which we assume is referencing the k-month EURIBOR, makes q^{fl} payment(s) per year, for a total of J payments between today and T. Let t_j and d_j be the time frames in months and in days, respectively, between today and the j-th floating-rate payment date, with $j = 1, 2, ..., J$. At each payment date j the floating rate bond pays the reference rate that prevailed on the market at the previous payment date, $j-1$. The expected value today of the future floating rate payments is $C_j^{fl} = f^{(t_{j-1},t_j)}N/q^{fl}$, with $f^{(t_{j-1},t_j)}$ denoting the k-month EURIBOR forward rate between times t_{j-1} and t_j. The floating-rate bond price gets computed as

$$B^{fl} = \sum_{j=1}^{J} \frac{C_j^{fl}}{(1 + z^{(t_j)} \frac{d_j}{365})} + \frac{N}{(1 + z^{(t_J)} \frac{d_J}{365})} \ . \tag{3.3}$$

Like in the case of swaps, we compute banks' interest rate risk exposure in bonds, ΔPV^{bond}, as the change in value of their bond portfolios after the rate shock. What is different from before, however, is that we do not reprice each individual bond position before and after the shift in the yield curve. Instead, we evaluate the impact of the yield curve shift on the euro-denominated fixed-rate bonds using a second-order approximation (delta-gamma) that relies on bond modified duration and convexity. Unlike the full revaluation approach adopted for swaps, we choose to keep the bond pricing framework as simple as possible. This is because the approximation error is small for this type of assets and the input data on bond modified duration and convexity needed for the estimation can be directly obtained from LSEG. Hence, ΔPV^{bond} gets computed at the individual bond level as

$$\Delta PV^{bond} = -V^{bond} \times MD \times \delta + \frac{1}{2} V^{bond} \times CX \times \delta^2 \ , \tag{3.4}$$

where V^{bond} denotes the observed bond market price before the shock δ to its yield-to-maturity, while MD and CX are, respectively, its modified duration and convexity, both valued before the interest rate shock.

4 Descriptive statistics

In this section we provide descriptive statistics on our data. We first characterise the 54 Italian banks in the sample across some financial metrics in Table 1. We then describe the aggregate evolution of banks' swap and securities portfolios in Section 4.1, while in Section 4.2 we present estimates of the exposures of such portfolios to interest rate risk.

Table 1 – Summary statistics

	Aggregate	Mean	St. Dev.	Median	p5	p95
Swap Notional	8319.8	148.6	768.4	0.2	0.0	134.3
Total Assets	3193.5	58.1	161.4	8.2	0.8	178.3
Loans	1654.0	30.1	79.8	3.2	0.2	93.9
Bonds	354.6	6.2	14.8	0.8	0.1	28.3
- of which AC	229.7	4.0	8.7	0.6	0.0	20.6
- of which FV	125.0	2.3	6.8	0.3	0.0	7.1
Deposits	1811.3	32.9	86.6	4.2	0.4	107.3
Issued Bonds	314.4	6.8	21.0	0.5	0.0	20.5
CET1	184.6	3.4	8.9	0.7	0.1	10.0
RWA	1203.5	21.9	58.7	2.8	0.3	63.2

Notes: This table provides summary statistics of selected financial metrics for the 54 Italian banks in the sample. Values are in € billions. Selected metrics are gross notional of interest rate swaps (i.e. the sum of pay-fixed and receive-fixed swap notionals), total assets, loans, market value of euro fixed-rate bond investments, also broken down into bonds carried at amortised cost (AC) and fair value (FV), deposits, issued bonds, Common Equity Tier 1 (CET1), and risk-weighted assets (RWA). Aggregate amounts are computed by first summing across banks on each date and then averaging across dates, whilst the remaining statistics are computed by pulling banks and dates together. Data are from January 2021 to April 2024.

The aggregate amounts reported in Table 1 show that, on average over the full period, the Italian banking system encompasses €8.3 trillion of notional amount in interest rate swap positions vis-a-vis €3.2 trillion of total assets. The latter consist for about 50%

of loans, while bond investments account for just over 10%. On the liability side of the balance sheet, deposits amount to €1.8 trillion, a figure that is five to six times larger than financing by bond issuance. Finally, the CET1 of the Italian sample banks adds up to 15.3% of their RWA.

4.1 Aggregate evolution of swap and securities portfolios

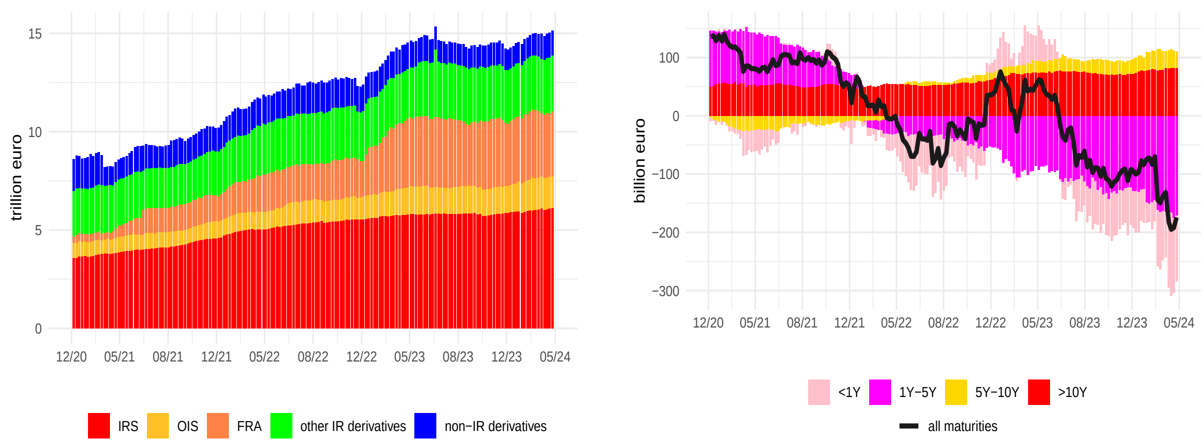
We begin by examining the derivatives portfolios of Italian banks. Our sample includes 373,508 unique swap contracts traded by 54 banks, for a total of 25,149,323 swap-week observations covering the sample period from January 2021 to April 2024.[16] As shown in Panel (a) of Figure 2, the swap positions our analysis focuses on, which consist of euro-denominated IRS, OIS and FRA, represent a sizeable share of derivative portfolios held by Italian banks. At the end of our study period, they account for about 76% and 84% of the gross notional amount (i.e. the sum of long and short notional amounts) of, respectively, all and interest-rate-only banks' derivative exposures. Against a background of monetary policy tightening, bank activity in these swaps has intensified, with the gross notional outstanding more than doubling since the start of 2021 to €11 trillion. This figure is made up of €6.2 trillion gross notional from IRS, €3.2 trillion from FRA, and €1.6 trillion from OIS. The documented rising trend in traded notional is consistent with evidence by Grassi et al. (2022) on the increased euro-area interest rate swap activity in 2022 as monetary policy expectations shifted.

The large gross notional amounts just described do not take into account that long and short positions offset each other, thus effectively reducing the interest rate risk exposure in swaps. This is crucial for banks, whose role as market makers and clearing members of central clearing counterparties (CCPs), often leads to the intermediation of trades by entering into a contract with a client and an identical contract of opposite direction with the CCP. Panel (b) of Figure 2 shows the evolution of net notional exposures both on aggregate and for four different maturity buckets of the swap portfolio. Before discussing the evidence in the panel, it is worth highlighting that the net notional swap exposures of a bank only identify whether the bank in the *short-term* is a net receiver of floating rates (positive net notional exposure) or a net payer of floating rates (negative net notional exposure). Such measure does not capture the interest rate exposure of swap positions, which depends also on other contract characteristics operating at longer horizons and that affect the value of swaps, such as their fixed rate and their maturity (Baker et al., 2021). For instance, FRA, which tend to have a maturity of 1 year, are much less exposed

[16]We have excluded 4 intermediaries for which we do observe swap positions in EMIR but we do not have available data on euro fixed-rate bonds or risk-weighted assets.

Figure 2 – Swaps traded by Italian banks

(a) Gross notional outstanding (b) Net notional positions by maturity



Notes: Based on weekly data for the 54 sample banks. Panel (a) displays the aggregate gross notional (sum of long and short notional) exposures of sampled banks in EURIBOR swaps (red), EONIA and €STR overnight index swaps (yellow), EURIBOR forward rate agreements (orange), other interest rate derivatives (green), and non-interest-rate derivatives (blue); values are in €trillion. Panel (b) displays the aggregate net notional (difference between long and short notional) exposures of sampled banks in swaps (IRS, OIS and FRA) when considered as a whole (solid black line) and when aggregated in four time-to-maturity buckets; values are in €billion with positive numbers denoting net long (pay-fixed) positions and negative numbers denoting net short (receive-fixed) positions.

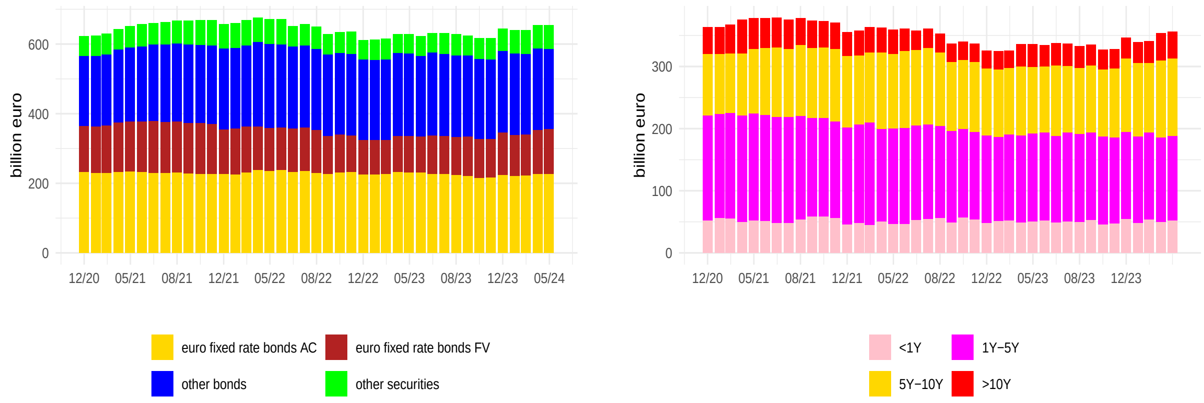
to interest rate risk than the longer-dated IRS and OIS.

Bearing this in mind, the solid black line in Panel (b) of Figure 2 shows that, as of April 2024, the €11 trillion gross notional amount of swaps in the Italian banking system falls to €170 billion after netting. The net notional is negative, implying that the notional of short (pay-floating) positions exceeds that of long (pay-fixed) ones. On aggregate and in terms of traded notional, banks were net payers of floating-rate payments also immediately before the first rate hike by the ECB in July 2022. Since then and until the first half of 2023, net short positions significantly decreased and turned into net long positions (i.e. the solid black line becomes less negative and turns positive).

Panel (b) also reports the net notional positions on swaps aggregated at four residual maturity buckets. The 1Y-5Y and >10Y maturities stand out with large net notional amounts in absolute terms: the former with a net short position of €178 billion at the end of the sample, and the latter with a net long position of €82 billion. Notice that the interest rate risk exposure of a 1Y-5Y maturity swap contract is, everything else equal, significantly lower than that of a >10Y maturity swap contract: it takes much more than one euro of notional on a short position in a short-maturity swap to generate a loss when interest rates increase that fully offsets the gain from one euro of notional on a long position in a long-maturity swap. This explains why, as we show in the next section, the aggregate swap portfolio of Italian banks always increases in value upon an upward shift in the yield curve (so it is a long swap portfolio from an interest rate risk exposure perspective) even though its aggregate net notional position in Figure 2 depicts it as net short on several occasions.

Figure 3 – Securities holdings of Italian banks

(a) Security type composition (b) Euro fixed-rate bonds by residual maturity



Notes: Based on monthly data for the 54 sample banks. Panel (a) displays the aggregate portfolio composition by security type. The category *other bonds* denotes foreign currency and floating-rate bonds, while *other securities* denote a residual class made of, e.g., equity and fund shares. Panel (b) shows the portfolio of euro fixed-rate bonds aggregated in four time-to-maturity buckets.

We next move to Italian banks' securities portfolios. We show in Panel (a) of Figure 3 the aggregate portfolio composition by security type, with all securities recorded at their fair value. From December 2020 to April 2024, the fair value of the aggregate securities portfolio of the sample banks is on average €643 billion, with a peak of €676 billion in March 2022. Euro-denominated fixed-rate bonds represent, on average, 55% of the securities holdings of the banks in the sample. Bonds carried at amortized cost (AC) represent 36% of the total portfolio, while bonds carried at fair value (FV) represent 19% of it. In Panel (b) we display the residual maturity of the euro-denominated fixed-rate bonds that we analyse, which comprise both AC and FV bonds. The 1Y-5Y and 5Y-10Y maturities stand out with large amounts, the former accounting for about 40% of the euro fixed-rate bond portfolio value at the end of the sample, and the latter for about 34% of such value.

4.2 The ΔPV of securities and swaps

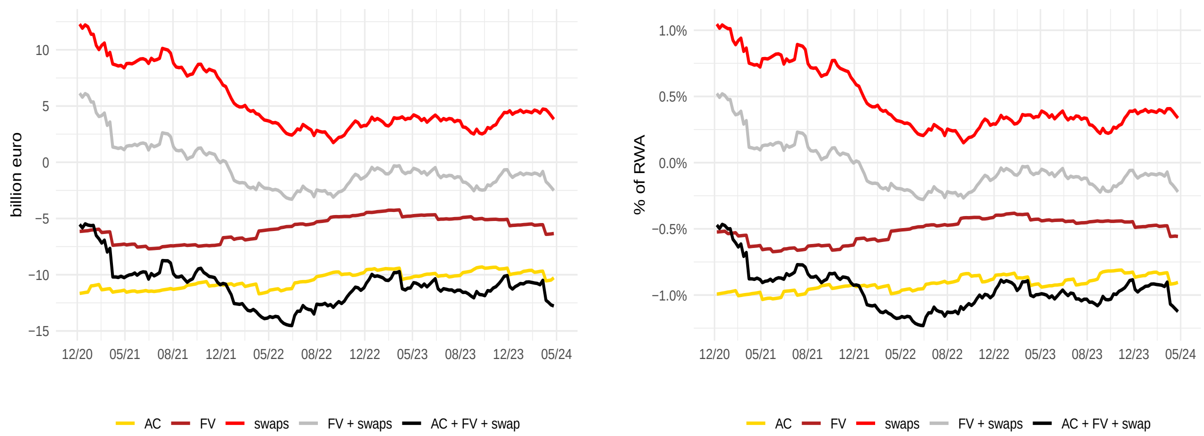
We next present the aggregate evolution of the exposure to interest rate risk of Italian banks' portfolio of securities and swaps. As discussed in Section 3, we measure interest rate risk exposure by the ΔPV of each of the portfolios, which is computed as the sum of the ΔPV of each of the contracts in the portfolio. We present our measures of ΔPV

both in € billion and as a fraction of the banks' overall risk-weighted assets (RWA). The latter allows to assess their magnitudes relative to the Common Equity Tier 1 (CET1) ratio, which on average is 15.3%.

Figure 4 plots the evolution of the aggregate ΔPV of the entire sample of banks at different levels of decomposition: the portfolio of fixed-rate bonds valued at amortised cost (AC, yellow line), the portfolio of fixed-rate bonds measured at fair value (FV, brown line), the portfolio of swaps (*swaps*, red line), the two latter portfolios (FV + *swaps*, black line), and all portfolios jointly considered (AC + FV + *swaps*, grey line).

Figure 4 – Aggregate ΔPV of bonds and swaps

(a) Absolute terms (b) Relative to RWA

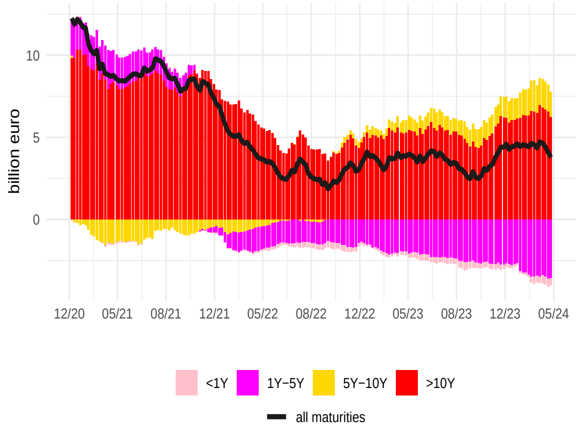


Notes: The figure shows the impact of a parallel upward shift of 100 bps in the yield curve (ΔPV) on the aggregate of the sample banks' portfolios of: *i)* fixed-rate bonds valued at amortised cost (yellow), *ii)* fixed-rate bonds measured at fair value (brown), *iii)* swaps (red), *iv)* the aggregation of FV bonds and swaps (black), and *v)* the aggregation of all bonds and swaps (grey). The impact is measured in € billion in Panel (a), and relative to bank risk-weighted assets in Panel (b). Data are weekly from January 2021 to April 2024.

We find that a parallel upward shift of 100 bps in the yield curve always leads to a profit on the swaps portfolio and, on the contrary and not surprisingly, a loss on the bond portfolio. In particular, it can be seen that the impact of the positive rate shock hovers around +€5 billion for swaps (or equivalently 47 bps of CET1 ratio), -€5 billion for FV bonds (51 bps of CET1 ratio), and -€11 billion for AC bonds (92 bps of CET1 ratio). As a consequence, the estimated total impact of the curve shift on the Italian banking system is negative, ranging from 50 to 150 bps of CET1 ratio.

The finding of a positive impact on the valuation of the swap portfolio is not trivial if one considers that the aggregate net notional in Figure 2 depicts on many occasions the Italian banking system as net short, and the value of a short swap position falls following a rise in rates. The result can however be explained in light of the positive relationship between contract maturity and ΔPV: Italian banks are net long on the longer-dated swaps (over 5 and most importantly 10 years), and when rates rise these positions appreciate in value by a larger extent than the depreciation on the shorter-dated swaps (between 1 and 5 years), on which banks have a short net notional position. This is shown graphically in Figure 5, from which one observes that the ΔPV of the banks' swap portfolio is almost completely determined by that of longer-dated contracts.

Figure 5 – ΔPV swap portfolio: maturity decomposition



Notes: Based on weekly data for the sample of 54 banks. The figure displays the impact of a parallel upward shift of 100 bps in the yield curve (ΔPV) on banks' aggregate portfolio of swaps considered as a whole (solid black line) and split across four time-to-maturity buckets; values are in € billion.

Another interesting finding from Figure 4 is that the aggregate gains on swaps, on average, fully offset the losses on FV bonds, which could suggest that banks use swaps to hedge the value of these assets against changes in interest rates. This is particularly important for banks in the EU as they are required to recognise unrealised losses on FV securities in regulatory capital, while banks in the US benefit from some exemptions (Fuster et al., 2024). The evidence thus implies that Italian banks' CET1 ratio would not be affected by variations in market values of their bonds and swaps portfolios associated with yield curve movements.

The evidence presented in the figures shows that swaps are of economic importance for Italian banks as an instrument to hedge interest rate risk in their fixed-rate bonds. This contrasts with some recent results reported for US banks by McPhail et al. (2023), who conclude that swap positions are on aggregate not economically meaningful in hedging the interest rate risk of the banks' assets. A possible factor in explaining the differences across the two jurisdictions could be the differential treatment for prudential purposes of valuation changes in FV securities we mentioned above.

Table 2 presents summary statistics of the ΔPV of bond and swap portfolios at the individual level for the sample of 54 Italian banks. All quantities are expressed relative to RWA. Panel A in the table presents statistics for the full sample of banks, Panel B for

Table 2 – Summary statistics: ΔPV relative to RWA

	Mean	St. Dev.	Median	p5	p95
Panel A – all banks					
AC	−158.1	335.6	−75.9	−406.6	−2.7
FV	−47.0	53.9	−23.8	−151.4	−1.8
swaps	101.2	354.0	18.9	−45.4	328.2
FV + swaps	54.2	362.9	−5.0	−186.3	312.8
AC + FV + swaps	−103.9	315.6	−76.6	−362.7	93.7
Panel B – large banks					
AC	−259.2	586.0	−88.7	−1017.1	−7.5
FV	−35.6	29.4	−21.0	−82.1	−5.0
swaps	90.3	135.3	73.8	−34.0	271.2
FV + swaps	54.7	142.3	37.1	−68.6	254.7
AC + FV + swaps	−204.5	457.3	−75.7	−841.8	16.2
Panel C – small banks					
AC	−134.2	210.5	−75.0	−396.6	−5.1
FV	−53.7	60.6	−31.7	−171.8	−1.7
swaps	120.0	412.2	11.2	−22.2	293.1
FV + swaps	66.3	423.8	−6.9	−184.1	269.0
AC + FV + swaps	−67.9	263.4	−76.6	−351.6	183.9

Notes: Based on weekly data for the sample of 54 Italian banks. The table provides summary statistics of banks' interest rate risk exposure, ΔPV, in swap and bond portfolios. Quantities are expressed in bps relative to bank risk-weighted assets. Statistics are computed by pulling banks and dates together. Panel A reports statistics for the full sample of Italian banks, while Panels B and C report statistics for, respectively, large (SI) and small (LSI) banks. AC and FV denote bonds valued at amortised cost and fair value, respectively.

the subsample of large banks, and Panel C for the subsample of small banks.[17] We first discuss results for the full sample in Table A. Not surprisingly, the ΔPV of the fixed-rate bonds is always negative (as bond prices move inversely to yields): the yield curve shift impact on AC bonds varies from -407 bps at the 5-th percentile to -3 bps at the 95-th percentile, while the impact on FV bonds varies from -151 to -3 bps. The ΔPV of the average bank is positive: following a 100 bps increase in rates, its swaps appreciate in value, boosting the CET1 ratio by 1 percentage point. We find important dispersion across banks: the rate shock impact on swaps varies from -45 bps at the 5-th percentile to +328 bps at the 95-th percentile. The distribution has a positive median (+19 bps), implying that the majority of Italian banks trade swaps in a way that their portfolio benefits from an increase in market interest rates, consistent with hedging their business risk of borrowing short and lending long. Interestingly, the average gains on the portfolio of swaps of the average bank exceed the losses on its FV bonds, implying an increase of 54 bps in CET 1 ratio for these two components, which immediately impact regulatory

[17]Large banks correspond to Italian *significant institutions* (SIs), while small banks denote *less significant institutions* (LSIs).

capital. Again, there is important heterogeneity across banks: the rate shock impact on the aggregate of swaps and FV bonds varies from -186 bps at the 5-th percentile to +312 bps at the 95-th percentile. Finally, when looking at the entire portfolio of bonds and swaps of the average bank, we find that swaps mitigate half of the losses on the bond portfolio following the shift in the yield curve, and the overall average impact is a 104 bps depletion of CET1 ratio. The impact ranges from losses of -363 bps at the 5-th percentile to gains of +94 bps at the 95-th percentile of the distribution.

Examining Panels B and C of Table 2 for large and small banks, respectively, two important observations can be made. First, variation exists across large banks and, to a greater extent, small banks, with some swap positions playing an offsetting role and some exacerbating bond market exposures to interest rate risk. The greater heterogeneity in the subsample of small banks stems from both a larger number of institutions in the set and more heterogeneity in their business model. Second, the use of derivatives by small banks seems more limited (the impact of the yield curve shift on swaps is +11 bps for the median small bank, as opposed to +74 bps for the median large bank) and concentrated in a few institutions (the distribution of the ΔPV of swaps has a marked positive skew, much more pronounced than for large banks).

5 Empirical Analysis

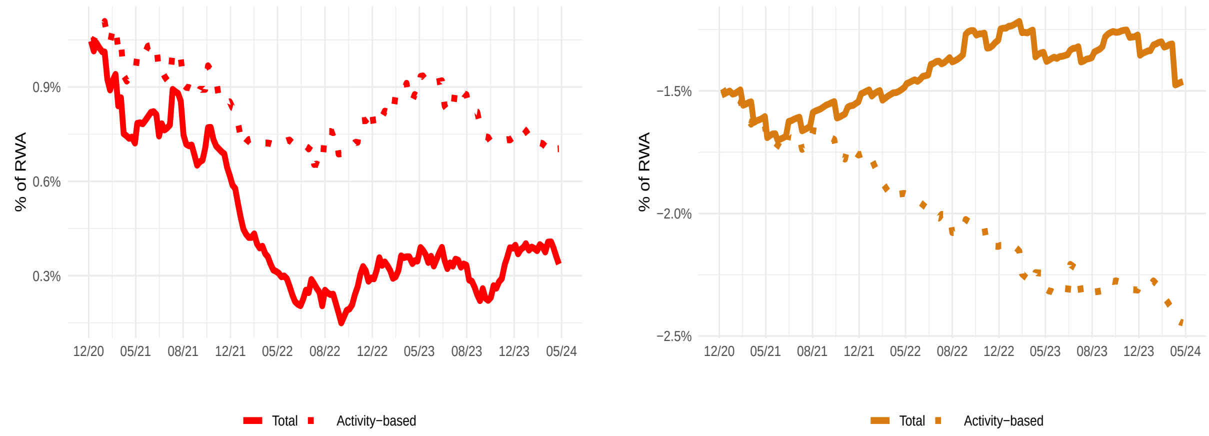
We now study how swap and bond trading interact with each other and whether this interaction is state-dependent. In order to provide statistical inference on such relationships we need to account for the fact that our ΔPV measures depend on the level of interest rates, hence they may vary also with no alteration to the swap and bond portfolio composition (trading activity). This is because swap and bond prices are convex functions of interest rates, which makes their ΔPVs lower when rates are higher.

Like in Alfaro et al. (2024), we cleanse the ΔPVs series of mechanical effects of rates due to convexity so that changes in the series only reflect trading activity, i.e. purchases or sales of bonds, opening of new swap contracts, and early termination of existing ones.[18] It is worth noting that stripping out the mechanical component is only possible thanks to the highly granular format of the data at our disposal, which allows to track individual bonds and swap contracts in bank portfolios over time. Figure 6 shows the total (i.e. including mechanical effects) swap and bond ΔPVs together with their cleansed series reflecting only trading activity.

[18]We refer the reader to Section 3.2 in Alfaro et al. (2024) for a detailed discussion and formulas of the decomposition of interest rate sensitivity into “mechanical” and “behavioural” components.

Figure 6 – Banks' exposure to interest rate risk

(a) Swap ΔPV (b) Bond ΔPV



Notes: The figure displays the total (solid line) and activity-based (dashed line) ΔPV (i.e. the impact of a 100 bps parallel upward shift in the yield curve) of the aggregate Italian banking system's portfolio of swaps in Panel (a) and of fixed-rate bonds in Panel (b). The activity-based series removes mechanical effects of interest rates on ΔPV due to the convexity of instruments. Quantities are expressed relative to risk-weighted assets. Data are weekly from January 2021 to April 2024.

We can see that Italian banks did not refrain from buying bonds in the 2022-23 rising rate environment. In fact, the activity-based ΔPV of banks' bond portfolios is on a downward trend (signalling more interest rate risk) since the end of 2021. At the same time we observe increased hedging activity by banks, which tilted their swap portfolios towards positions benefiting from a rate rise (the activity-based swap ΔPV is on an upward trend). These considerations could hardly be made based on the total ΔPV series, which show different trends due to mechanical effects. Therefore, our next analyses rely on the activity-based ΔPV series of swaps and bonds.

5.1 Swaps and bond hedging

In this section we check over the full sample period if banks effectively manage the interest rate risk of their debt securities portfolio, and if hedging differs for bonds classified among different accounting portfolios. In order to fully investigate the heterogeneity in swap exposure across banks (already partially documented in Section 4.2), we estimate weekly quantile panel regressions of the form

$$Q_\tau(\Delta PV_{i,t}^{swap} | PV_{i,t}^{bond}) \;=\; \alpha_i + \beta_1(\tau)\Delta PV_{i,t}^{bond} + \varepsilon_{i,t}\ , \tag{5.1}$$

where $\Delta PV_{i,t}^{swap}$ and $\Delta PV_{i,t}^{bond}$ are the activity-based ΔPV in week t for bank i's portfolio in, respectively, swaps and bonds. We consider the following bond portfolios: fixed-rate bonds carried at amortised cost (AC), those carried at fair value (FV), and the aggregation of the two (AC + FV). Swap and bond ΔPVs are expressed relative to bank risk-weighted assets and, to facilitate the interpretation of the coefficients, we transform the series using the inverse hyperbolic sine function. Therefore, the regression coefficients measure the percent change in swap ΔPV, even when its value is negative. We refer to the coefficient of interest β_1 as the *intensity in securities hedging* as it represents the share of interest rate risk stemming from the purchase of new bonds that gets reduced by new swaps the bank enters. $Q_\tau(\Delta PV_{i,t}^{swap}|\Delta PV_{i,t}^{bond})$ is the τ-th conditional quantile of $\Delta PV_{i,t}^{swap}$ given $\Delta PV_{i,t}^{bond}$. We consider quantiles $\tau = 0.25, 0.5, 0.75$, hence we estimate how changes in $\Delta PV_{i,t}^{bond}$ affect the lower quartile, median, and upper quartile of $\Delta PV_{i,t}^{swap}$. It is worth remembering that the lower (higher) quartile of $\Delta PV_{i,t}^{swap}$ denotes banks with less (more) swaps acting as hedge against interest rate rises. Finally, we include bank fixed effects in all model specifications. Estimates are reported in Table 3.

Table 3 – Bond hedging with swaps

	$\tau = 0.25$		$\tau = 0.5$		$\tau = 0.75$	
ΔPV^{AC+FV}	-0.210^{***}		-0.171^{***}		-0.155^{***}	
	(0.001)		(0.004)		(0.004)	
ΔPV^{AC}		-0.143^{***}		-0.264^{***}		-0.326^{***}
		(0.002)		(0.018)		(0.011)
ΔPV^{FV}		-0.229^{***}		-0.012^{***}		-0.004
		(0.015)		(0.003)		(0.004)
Num. obs.	7865	7865	7865	7865	7865	7865

Notes: This table provides the coefficient estimates for quantile panel regressions of activity-based interest rate risk exposure in swaps ΔPV^{swap} on the activity-based interest rate risk exposure in fixed-rate bonds carried at amortised cost ΔPV^{AC}, those carried at fair value ΔPV^{FV}, and the aggregation of the two ΔPV^{AC+FV}. Regressions are run for quantiles $\tau = 0.25, 0.5, 0.75$ and include bank fixed effects. Standard errors are reported in parentheses below the estimated coefficients. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels respectively. Data are weekly from January 2021 to April 2024.

We begin by reviewing the intensity in hedging a securities portfolio that groups AC and FV bonds together, that is the coefficients shown in the first row of Table 3. Across all quantiles considered, there exists a negative statistically significant relationship between the ΔPV of swaps and that of the whole bond portfolio, which is consistent with banks hedging the interest rate risk in their securities portfolios by entering swaps that gain from higher interest rates. Of particular importance, we find that the effect is not constant across the distribution of banks' interest rate risk exposure in swaps, but instead it decreases monotonically across the quantiles. This means that the banks entering more swaps to hedge their securities are the banks that are equipped with less hedges, and as such are placed in the lower quartile of the $\Delta PV_{i,t}^{swap}$ distribution. Quantitatively, the β_1 estimates indicate that the intensity in securities hedging over the full period ranges from 0.21 for the lower tail to 0.15 for the upper tail of the distribution. At the median quantile the intensity in securities hedging amounts to 0.17, in other words, just below 20% of the value losses following a 100 bps upward shift of the yield curve on purchases of securities would be offset by the gains under the same shift of the curve on the new swaps the bank enters.

Now looking at the estimates of when the ΔPVs of AC and FV bonds are used as separate regressors (second and third row of Table 3), we note that the hedging intensity varies with the bond classification used for accounting purposes. While it is true that the ΔPV of swaps is always negatively related to the ΔPV of both bond types, at the lower tail of the $\Delta PV_{i,t}^{swap}$ distribution the relationship is stronger with FV bonds, whereas at the higher tail only the relationship with AC bonds is significant from a statistical standpoint. At the median quantile, we find that over a quarter of each additional unit of interest rate risk in the AC bond portfolio gets hedged by taking opposite positions in the swap market. Although significant, the effect that exists for FV bonds is an order of magnitude smaller.

Taken together, the results of this section shows statistical evidence of hedging debt securities through swaps by Italian banks. This is true regardless of the accounting treatment used for securities. Nevertheless, we find substantial heterogeneity in the estimates, with banks less equipped with hedges being more active in hedging their securities, especially bonds carried at fair value. Motivated by these results, in the rest of the paper we focus on quantile regressions at the median and take a holistic view to study the link between swaps and the aggregate portfolio of debt securities, regardless of their accounting treatment.

5.2 Hedging activity and policy rates

In this section we assess how banks' interest rate risk management changes with policy rates and which bank variables mostly affected bond hedging with swaps during the recent monetary policy tightening.

The evidence displayed in Figure 6 shows that banks were active investors in the swap and bond markets during the period of monetary tightening. This raises the question of whether banks dynamically hedge their interest rate exposures based on macroeconomic conditions. In particular, we want to understand if higher interest rates, and thus the materialisation of risk, induce banks to buy more insurance against losses on their investments in debt securities. To answer this question and in attempt of establishing a causal claim, we use a regression framework that measures the relationship between the ΔPV of swaps and bonds – the so-called *intensity in securities hedging* – interacted with a number of rising-rate environment indicators. We test for the presence of time dependence in such relationship by estimating quantile panel regressions of the form

$$Q_{\tau=0.5}(\Delta PV_{i,t}^{swap}|PV_{i,t}^{bond}) \;=\; \alpha_i + \beta_1 \Delta PV_{i,t}^{bond} + \beta_2(\Delta PV_{i,t}^{bond} \times RRE_t) + \varepsilon_{i,t} \;, \quad (5.2)$$

where $\Delta PV_{i,t}^{swap}$ and $\Delta PV_{i,t}^{bond}$ are the activity-based ΔPV in week t for bank i's portfolio in, respectively, swaps and the aggregate of AC and FV bonds. As before, we express both swap and bond ΔPVs relative to bank risk-weighted assets and we transform the series using the inverse hyperbolic sine function. $Q_{\tau=0.5}(\Delta PV_{i,t}^{swap}|\Delta PV_{i,t}^{bond})$ is the conditional median of $\Delta PV_{i,t}^{swap}$ given $\Delta PV_{i,t}^{bond}$. RRE_t is a variable indicating a rising-rate environment. The variables chosen for this purpose are: D_T is a dummy variable equal to 1 from July 2022 (first rate hike by ECB) to February 2024 (peak of tightening cycle), 0 otherwise; Fwd is the euro-denominated 1-year forward rate in percentage; MP is the cumulative sum of monetary policy shocks in basis points identified by Altavilla et al. (2019). An increase in all these RRE_t variables is associated with a rate rise. Finally, we include bank fixed effects.

Table 4 – State-dependent hedging

	Model 1	Model 2	Model 3	Model 4
ΔPV^{bond}	-0.171^{***}	-0.176^{***}	-0.199^{***}	-0.136^{***}
	(0.004)	(0.005)	(0.011)	(0.001)
D_T		-0.019^{***}		
		(0.002)		
$D_T \times \Delta PV^{bond}$		-0.011^{***}		
		(0.001)		
Fwd			-0.013^{***}	
			(0.003)	
$Fwd \times \Delta PV^{bond}$			-0.007^{***}	
			(0.002)	
MP				-0.001^{***}
				(0.000)
$MP \times \Delta PV^{bond}$				-0.001^{***}
				(0.000)
Num. obs.	7865	7865	7865	6671

Notes: This table provides the coefficient estimates for quantile panel regressions of activity-based interest rate risk exposure in swaps ΔPV^{swap} on the activity-based interest rate risk exposure in fixed-rate bonds carried at both amortised cost and fair value ΔPV^{bond}, and on a set of identifiers for a rising-rate environment. D_T is a dummy variable equal to 1 from July 2022 to February 2024, 0 otherwise. Fwd is the euro-denominated 1-year forward rate in percentage. MP is the cumulative sum of monetary policy shocks in basis points identified by Altavilla et al. (2019). Regressions are run for the 0.5 quantile (median) and include bank fixed effects. Standard errors are reported in parentheses below the estimated coefficients. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels respectively. Data are weekly from January 2021 to April 2024.

Model 1 in Table 4 reports for convenience the estimate of regression equation (5.1), which was discussed in the previous section, while the remaining columns of the table report estimates of regression equation (5.2). We find that the β_2 coefficient estimates of

Models 2-4 are negative and statistically significant across all model specifications. This implies that the intensity in securities hedging becomes substantially stronger with higher interest rates. For instance, we estimate that in response to tighter monetary policy (July 2022 – February 2024) Italian banks raised bond hedging with swaps by 6%, compared with prior to the tightening cycle. Similarly, we find that a positive monetary policy shock of one standard deviation (11 bps) and an increase in market forward rates of one standard deviation (159 bps) are associated with increases in hedging of 8% and 5%, respectively. We interpret these results as compelling evidence that Italian banks dynamically hedge their interest rate exposures based on macroeconomic conditions and that the 2022-2023 monetary policy tightening led to a more active management of interest rate risk.

We now turn our attention to which banks engaged in more hedging during the tightening cycle. In particular, we test the link between banks' pre-tightening balance-sheet characteristics and their subsequent intensity in securities hedging. The bank characteristics are measured in the first quarter of 2022, just before first rate hike by ECB, and correspond to: CET1 ratio, book value of loans, issued bonds and deposits, all expressed relative to bank risk-weighted assets. We use the following quantile panel regression

$$Q_{\tau=0.5}(\Delta PV_{i,t}^{swap}|PV_{i,t}^{bond}) \;=\; \alpha_t + \beta_1 \Delta PV_{i,t}^{bond} + \beta_2(\Delta PV_{i,t}^{bond} \times X_{i,0}) + \varepsilon_{i,t} \;, \qquad (5.3)$$

where $\Delta PV_{i,t}^{swap}$ and $\Delta PV_{i,t}^{bond}$ are the activity-based ΔPVs for bank i's portfolio in, respectively, swaps and bonds in week t between July 2022 and February 2024, and X_0 is one of the balance-sheet characteristics of bank i as of the first quarter of 2022. As before, the ΔPV measures are expressed relative to bank risk-weighted assets and transformed by applying the inverse hyperbolic sine function. $Q_{\tau=0.5}(\Delta PV_{i,t}^{swap}|\Delta PV_{i,t}^{bond})$ is the conditional median of $\Delta PV_{i,t}^{swap}$ given $\Delta PV_{i,t}^{bond}$. We include time fixed effects. Estimates are reported in Table 5.

Models 1 to 4 feature a negative and statistically significant β_1 coefficient, confirming that swap trading for securities hedging purposes was a widespread and predominant phenomenon among Italian banks in the recent rising-rate environment. More interestingly, looking at the interaction with the CET1 ratio, we find a positive and statistically significant β_2 coefficient. Since the the CET1 ratio takes on only positive values while the ΔPV^{bond} is by construction always negative, this implies that the intensity in securities hedging during the tightening cycle is more pronounced for banks starting with lower capital buffers. Intuitively, these banks are more concerned with solvency issues as they are ill-equipped to deal with losses on their security investments, and as such engaged in more hedging during the tightening cycle.

Table 5 – Bond hedging with swaps during MP tightening

	Model 1	Model 2	Model 3	Model 4
ΔPV^{bond}	-2.316^{***}	-0.345^{***}	-0.685^{***}	-2.361^{***}
	(0.084)	(0.045)	(0.059)	(0.168)
Cet1 Ratio_0	0.170^{***}			
	(0.009)			
$\Delta PV^{bond} \times$ Cet1 Ratio_0	0.083^{***}			
	(0.005)			
Loans_0		-0.013^{**}		
		(0.001)		
$\Delta PV^{bond} \times \text{Loans}_0$		0.010^{***}		
		(0.000)		
Issued Bonds_0			-0.011	
			(0.010)	
$\Delta PV^{bond} \times$ Issued Bonds_0			-0.021^{***}	
			(0.007)	
Deposits_0				-0.217^{***}
				(0.080)
$\Delta PV^{bond} \times \text{Deposits}_0$				0.179^{***}
				(0.027)
Num. obs.	3721	3721	2676	3721

Notes: This table provides the coefficient estimates for quantile panel regressions of activity-based interest rate risk exposure in swaps ΔPV^{swap} observed during the tightening period (weeks from July 2022 to February 2024), on the simultaneous activity-based interest rate risk exposure in bonds ΔPV^{bond}, and on a set of pre-tightening balance-sheet characteristics measured as of June 2022. We consider the CET1 ratio, and the book values of loans, issued bonds, and deposits, all expressed in terms of RWA. Regressions are run for the 0.5 quantile (median) and include time fixed effects. Standard errors are reported in parentheses below the estimated coefficients. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

The interaction coefficients with the other balance-sheet characteristics reveal that the banks demanding additional hedging with the monetary tightening were those with less loans among assets, and with more bond financing and less deposits among liabilities. We explain the result for the loan portfolio based on the fact that less loans imply less not-marked-to-market assets, hence potentially higher exposure to interest rate risk stemming from bonds accounted for at fair value. Whereas we rationalise the findings on the liability side in terms of the specifics of the Italian banking system. First, the bonds issued by Italian banks are characterised by variable rates for over 50% of their amount outstanding and by a relatively short time to maturity of about 4 years. These are both features exposing banks to the refinancing risk of facing higher costs when rates rise. Second, Italian banks' deposits are predominantly retail deposits (over two thirds of the total) that are sticky and as such hardly sensitive to interest rates. These specifics of the Italian banking system lead us to conclude that banks with less stable funding (i.e. more bond financing and/or less deposits) are those that more actively traded swaps to hedge securities during the tightening period.

6 Derivatives and balance-sheet exposures

Having established that the ΔPV of swaps is significantly related to that of debt securities, we now explore the relationships that exist between the interest rate risk in banks' derivatives portfolios and in their balance sheet including, but not limited to, bond investments. It is worth noting that accurately establishing such relationships requires granular data, which to us is only available for derivatives and securities holdings.[19] For the purpose of this analysis, which is carried out at quarterly frequency because of data availability, we rely on a different dataset and use estimates of interest rate risk obtained with a different methodology from that described in Section 3.

The first change concerns the data used, not only for the observation frequency (from weekly to quarterly) but also for the source and composition. Data for both derivatives and balance-sheet items come from supervisory reports, from which we extract information on the repricing maturity of cash flows, broken down into 18 maturity buckets.[20] In the derivatives space, we consider all interest rate products (not only swaps) due to the aggregate form of bank reporting. As for balance-sheet exposures, we consider all assets and liabilities, regardless of any accounting and prudential rule. For fixed-rate instruments, repricing cash flows are distributed across the corresponding maturity bucket based on the residual cash flows. For variable-rate instruments, repricing cash flows correspond to the notional amount allocated to the bucket nearest to the repricing date.

The second change is about the measurement of interest rate risk, which we now estimate following the approach used by Hoffmann et al. (2019). This is an approximation that consists first in computing the present value of each future cash flow, and then in multiplying this value with the cash flow maturity and the 100 bps rate shock.[21] The estimation is performed for each maturity bucket of derivatives, of bond investments and loans on the asset side, and of deposits and issued bonds on the liability side. Due to the granularity and characteristics of the data, we are no longer able to cleanse the estimates of mechanical effects of rates and focus only on trading activity like we did in Section 5.

Once the exposures to interest rate risk are obtained, we regress the bank-level exposure of the derivatives portfolio on those of the different balance-sheet items. We explore the existence of state-dependent relationships by including also the monetary tightening

[19]The reporting of banks' balance-sheet exposures other than their securities holdings comes in a far more aggregate form and in much less detail.

[20]For a detailed description of the dataset we refer the reader to Circolare n. 115, *Istruzioni per la compilazione delle segnalazioni di vigilanza su base consolidata* and Circolare n.272, *Matrice dei conti of the Banca d'Italia*.

[21]The present value is estimated using income statement data, with cash flows discounted based on the observed historical income of sample banks. A limitation arises from the lack of granularity in the reports, which prevents the identification of distinct discount rates across banks and maturity buckets.

dummy D_T defined in Section 5.2. The results of these panel regressions are presented in Table 6.

One key finding that stands out is the negative and statistically significant relationship that exists between the derivatives and bond exposures to interest rate risk. This confirms, with a different set of data and at lower frequency, the role of derivatives for bond hedging previously documented in Section 5. On the other hand, we fail to uncover significant relationships between the exposure of derivatives and that of other balance-sheet items, with the only exception of deposits, whose interest rate risk is nevertheless rather small due to their short-term nature.

A second point that is worth making here is that the quarterly data do not provide compelling evidence for banks' use of derivatives to hedge bond securities more actively during the period of monetary policy tightening. Although its sign is negative as expected, the coefficient of interaction with D_T is not significant from a statistical standpoint.

Taken together, our results suggest that Italian banks use derivatives to hedge their bond portfolios more than the rest of their balance sheet, lending support to the assertion of Jiang et al. (2023) that securities and derivatives are the two main asset categories relevant in hedging transactions. Furthermore, we conclude that granular data available a high frequency is necessary to uncover time variation that exists in hedging relationships.

Table 6 – Derivatives vs balance-sheet exposures

	Model 1	Model 2	Model 3	Model 4	Model 5
Bonds	-0.219^{***}				-0.266^{***}
	(0.030)				(0.027)
$D_T\times$ Bonds	-0.001				0.006
	(0.014)				(0.016)
Loans		-0.016			0.014
		(0.011)			(0.024)
$D_T\times$ Loans		-0.008			-0.030^{*}
		(0.015)			(0.016)
Issued Bonds			0.036		-0.029
			(0.070)		(0.053)
$D_T\times$ Issued Bonds			-0.042		0.028
			(0.056)		(0.053)
Deposits				0.068^{**}	0.110^{***}
				(0.028)	(0.033)
$D_T\times$ Deposits				-0.027^{*}	-0.004
				(0.016)	(0.024)
D_T	0.056^{***}	0.009	0.029^{***}	0.041^{***}	0.025
	(0.018)	(0.026)	(0.009)	(0.013)	(0.025)
Num. obs.	647	647	647	647	647

Notes: This table provides estimates of regressing bank-level interest rate risk exposure of derivatives on the interest rate risk exposure of balance-sheet items on the asset side (Bonds and Loans) and the liability side (Issued Bonds and Deposits). All variables are expressed relative to bank risk-weighted assets. Regressions include bank fixed effects. The estimates are obtained through quantile panel regression at the 0.5 quantile. Standard errors are reported in parentheses below the estimated coefficients. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively. Data are quarterly from December 2020 to March 2024.

7 Conclusions

This paper provides novel evidence on how Italian banks manage interest rate risk in their securities portfolios through derivatives, using high-frequency, granular data from 2021 to 2024. We document that, on aggregate, banks employ interest rate swaps as effective hedging tools, with roughly one third of the value losses on securities from a 100 basis point upward shift in the yield curve being offset by gains on swap positions. Interestingly, swaps eliminate almost all of the interest rate risk of securities carried at fair value, thus mitigating regulatory capital volatility.

We further show that banks adjust their hedging strategies in response to changes in monetary policy. The intensity of hedging through swaps increases significantly following the start of the ECB's tightening cycle in mid-2022, with additional evidence from monetary policy surprises. These findings suggest that banks' hedging behaviour is forward-looking and responsive to shifts in the monetary policy stance.

Moreover, the heterogeneity in hedging intensity across banks is driven by structural balance sheet characteristics. Institutions with lower capital ratios and less stable funding profiles increase their use of derivatives more aggressively during periods of rising interest rates, indicating a stronger incentive to mitigate risk.

Our results underscore the role of derivative markets as an important channel for banks to manage interest rate risk dynamically. They also highlight the value of supervisory EMIR data in providing timely insights into risk management practices, which can be critical for financial stability monitoring in a changing monetary environment.

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Appendix

A Bootstrapping the yield curve

We review the procedure for bootstrapping the riskless spot (i.e. zero-coupon) curve that provides discount rates of swap and bond pricing and is the object of the shock in our sensitivity analysis.[22] Following the standard multi-curve method outlined by Hull and White (2015) and Smith (2013), among others, we bootstrap spot rates from €STR-referencing OIS rates, and from EURIBOR swap rates. To this end, we obtain from Refinitiv daily rate observations for €STR OIS with maturity up to 30 years, and for 6-month EURIBOR swaps with maturity up to 50 years. These are "par" (at-market) swap rates representing the fixed-rate paid on bonds valued at par (i.e. price of 100).[23] We linearly interpolate the swap rates to have data for maturities evenly spaced by 3-month intervals as we assume quarterly settlements of the swap contracts and, accordingly, four payments a year on the par bonds. OIS swaps of up to one-year's maturity have only a single payment at the contract end date, therefore, we use their rates as the spot rates of the corresponding maturity.

To infer the rest of the spot curve that is consistent with the sequence of OIS par swaps we rely on the following bootstrapping technique. Let $z^{(T)}$ be the annualised spot interest rate observed today for maturity T (in months), $s^{(T)}$ be the annualised par swap rate for maturity T, and $P^{(T)}$ be the T-maturity par bond's price, which is equal to its notional amount, $N = 100$. Under the assumption of quarterly settlement, each coupon payment of the par bond amounts to $C = s^{(T)}N/4$. Using the spot rates already available for all maturities before T, the next-in-line spot rate $z^{(T)}$ is the solution to the following bond pricing equation

$$P^{(T)} = \sum_{n \in D} \frac{C}{(1 + z^{(n)}\frac{n}{12})} + \frac{C + N}{(1 + z^{(T)}\frac{T}{12})} \ , \tag{A.1}$$

where $D = \{3, 6, ..., T - 3\}$. Equation (A.1) implies that the spot rate gets computed as

$$z^{(T)} = \frac{12}{T}\left[\frac{C + N}{P^{(T)} - \sum_{n \in D} \frac{C}{(1+z^{(n)}\frac{n}{12})}} - 1\right] . \tag{A.2}$$

We repeat the calculation sequentially until the longest maturity of the par swap rates,

[22] In the case of derivatives, including swaps, discount rates and risk-free rates are the same, whereas the discount rates of bonds have an extra component (spread) that reflects the credit risk of the issuer.

[23] The par swap rates are also the rates that make the market value of the swap contracts equal zero.

and then we linearly interpolate the spot rates to have data for maturities evenly spaced by 1-month intervals.[24] We use the above procedure to bootstrap one spot curve from OIS rates and one from EURIBOR swap rates. The former spot curve provides discount factors for maturities up to 30 years, which is the longest maturity observed in the €STR OIS market, and determines the forward rates affecting the cash flows of the OIS contracts sampled from EMIR.[25] The latter spot curve provides discount factors for maturities longer than 30 years and determines the forward rates affecting the cash flows of the FRA and IRS contracts sampled from EMIR. We compute EURIBOR and €STR forward rates, which represent the expected future rates on the floating leg of the swap contracts considered in our work, starting from the corresponding spot curve and assuming the absence of arbitrage. Letting $f^{(T_{i-1},T_i)}$ be the forward rate between times T_{i-1} and T_i (in months) – i.e. the interest rate expected today on a zero-coupon investment starting at time T_{i-1} and ending at T_i – the assumption of no-arbitrage implies that the following equality holds

$$f^{(T_{i-1},T_i)} = \frac{12}{T_i - T_{i-1}} \left(\frac{1 + z^{(T_i)} \frac{T_i}{12}}{1 + z^{(T_{i-1})} \frac{T_{i-1}}{12}} - 1 \right) . \tag{A.3}$$

[24]When discounting the future cash flows of the swap contracts sampled from EMIR, despite using an actual/365 convention, we will round to the nearest month the maturity of the relevant spot rates.

[25]EONIA was discontinued on 3 January 2022 and therefore we use €STR rates to value also the EONIA-referencing OIS contracts that continue to exist until their expiration.