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Euro area banks' interest rate risk exposure to level, slope and curvature swings in the yield curve

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Abstract

We investigate the interest rate risk exposures of euro area banks during times of crises and very low interest rates. First, we assess sensitivities of banks' stock prices to changes in the level, slope and curvature of the yield curve using the Bayesian DCC M-GARCH model. Our findings reveal that stock price sensitivities change over time and that, on average, banks benefit from increases in the level, slope and curvature of the yield curve. Second, we observe that banks with higher capital ratios, more customer lending and less deposit financing are particularly sensitive to interest rate movements.

KEYWORDS

bank stock returns, Bayesian DCC M-GARCH model, interest rate risk, maturity transformation, term structure of interest rates

JEL CLASSIFICATION

C11, C51, C55

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1 | INTRODUCTION

Changes in interest rates represent one of the most important risks financial institutions are exposed to. On the one hand, the net present value of future cash flows of maturity-transforming banks might decrease when interest rates rise, due to the higher maturity of assets compared to liabilities. On the other hand, the net interest income might improve when rates increase as the proportion of an interest rate change which is passed through on the current interest revenue earned with banks' assets is usually higher than the pass-through on interest expenses paid for banks' liabilities (see ECB, 2009). Hence, there is a rationale for both a positive and negative exposure to shifts in interest rates for maturity-transforming banks and also the empirical literature remains inconclusive in this regard.

This paper contributes to the subject of banks' interest rate risk exposure in two major aspects. First, we investigate the sensitivity of individual banks' share prices to level, slope and curvature changes in the yield curve. Though the risks arising from different shifts in the yield curve might not immediately materialize in the bank's profit, the underlying hazards are apparent in banks' equity valuations on the stock market. This indirect link makes a stock market reaction to changes in the yield curve indicative of vulnerabilities in individual financial institutions as well as of the financial stability of the whole banking sector. Second, we analyze which bank-specific characteristics can explain banks' stock price sensitivities to interest rate movements in the cross-section as well as over time. In this way, we determine publicly available indicators that can serve as 'warning signs' regarding interest rate risk sensitivity, which banks exhibit, with important implications for regulatory and monitoring practices.

Concerning the first part of our contribution, we investigate the interest rate sensitivity of major euro area banks with respect to movements of (quasi) risk-free euro area interest rates. Specifically, we refer to listed European banks which fall under the ECB's single supervisory mechanism (SSM) in the euro area.¹ This sample covers the most relevant banks in the euro area and captures more than 80% of the total assets of all euro area banks. To evaluate whether banks with their unique business model are differently exposed to interest rate risk than nonfinancial firms, we run the analysis also on European nonfinancial corporates. This sample allows us to make conclusions for the euro area as a whole. Our data ranges from 2005 to 2014 and covers the global financial crisis and the subsequent European sovereign debt crisis.

Our methodology for measuring an entity's stock price sensitivity to interest rate risk consists of two main building blocks. First, we use principal components of changes in the yield curve, which capture the shape of the euro area yield curve, to approximate the interest rate risk factors that banks are facing. Such a method allows us to quantify banks' exposure to different shifts in the yield curve separately, including curvature swings in the yield curve—an element that has barely been covered in the empirical literature (an exception is Czaja et al., 2009). Second, an entity's interest rate risk exposure is assessed based on the Bayesian dynamic conditional correlation multivariate GARCH model (Bayesian DCC M-GARCH, see

¹These banks have to meet at least one of the following criteria (see ECB, 2014a): (i) the total value of its assets exceeds 30 billion EUR or—unless the total value of its assets is below 5 billion EUR—exceeds 20% of national GDP; (ii) it is one of the three most significant credit institutions established in a member state; (iii) it is a recipient of direct assistance from the European Stability Mechanism; (iv) the total value of its assets exceeds 5 billion EUR and the ratio of its cross-border assets/liabilities in more than one other participating member state to its total assets/liabilities is above 20%. A complete list of the SSM banks is provided in ECB (2014b). We refrain from adding further small listed banks (outside the SSM) to our sample because their equity is less likely to exhibit liquid trading.

Fioruci et al., 2014). This model allows us to establish a link between interest rate risk factors and their impact on stock prices. More specifically, we can directly infer each entity's exposure from conditional variance–covariance matrices between its stock returns and interest rate risk factors at any point in time. The method is robust to multicollinearity that might lead to imprecise estimates and allows us to incorporate interdependent interest rate risk components into a conventional regression. Moreover, the Bayesian DCC M-GARCH model, as pointed out by Virbickaite et al. (2015), is much better at explaining asymmetries in volatilities and heavy-tailed asset return distributions that cannot be captured by parametric models, and is, thus, well suited for our analysis, as crises are included in the covered time period. In particular, in times of crises, asset returns (i.e., stock returns) exhibit fat tails, volatility clusters and time-varying correlations.

We find that all banks in our sample exhibit a positive exposure to an increasing level of interest rates such that stock prices tend to increase when the interest rate level rises. For example, a parallel upward shift of 25 basis points in the yield curve increases the stock prices, on average, by 3.65%, pointing out the significant economic impact of level changes. Moreover, stock prices of almost all banks tend to increase when yield curves become steeper, that is, when the slope increases and most banks are significantly affected by curvature swings. We find that the largest daily fall in the curvature factor was associated with a decrease in share prices of 1.93% for an average bank. This underlines the importance of taking changes in the curvature of the yield curve into account when assessing banks' interest rate risk exposure. Further, our results show that banks' sensitivities to interest rate risk factors vary considerably over time. This is in line with the recent study conducted by von la Hausse et al. (2016) on the system of US bank holding companies. While banks' stock prices have been barely sensitive to slope changes and negatively related to curvature changes in the period from 2005 to 2009, a positive sensitivity to both risk factors can be observed in the years 2010–2014.

Concerning our second contribution, we analyze which bank-specific indicators make a bank particularly vulnerable to interest rate risk factors. Therefore, we build on the first part of our paper and measure banks' risk exposures through the reaction of each individual bank's equity price to level, slope and curvature shifts in the yield curve. We then run a panel regression to investigate how banks' sensitivities to interest rate risk factors vary depending on individual banks' characteristics (e.g., balance sheet composition and reliance on interest income). We include country-level fixed effects (FE) to account for country-specific conditions that might influence banks' balance sheet and income structure. Further, we use time FE on a yearly level to account for any systematic changes in interest rate risk exposure that affect the whole sample of banks. Running regressions for sensitivities w.r.t. level, slope and curvature factors separately allows us to identify sources that make banks prone to specific movements of the yield curve.

Our results indicate that banks with a higher ratio of net customer loans to total assets, a lower amount of deposit financing and a higher amount of subordinated debt are more sensitive to level swings. Moreover, less profitable banks as measured by their return on assets and banks with lower Core Tier capital ratios are more exposed to the level of interest rates. As level shifts explain most of the variability in yields, the aforementioned characteristics are primary indicators for banks' exposure to interest rate risk. We further identify secondary factors which make a bank particularly vulnerable to nonparallel shifts in the yield curve such as slope and curvature swings. Interestingly, we find that banks with larger derivative liabilities are positively exposed to curvature changes in the yield curve while this indicator is insignificant for explaining exposure to level shifts.

The remainder of the paper is organized as follows. Section 2 contains an overview of the related literature. In Section 3, we describe the methodology based on the Bayesian DCC M-GARCH model used to capture each SSM bank's stock price reaction to movements in level, slope and curvature of the yield curve. Moreover, we present the data and discuss the results on banks' interest rate sensitivity. Section 4 looks for bank-level characteristics which can best explain the estimated sensitivities from the previous section, while Section 5 concludes. The Appendix contains a set of further robustness checks, and a separate Internet Appendix is available as Supporting Information on the Journal's website.²

2 | LITERATURE

The research in the first part of our paper adds to the literature which adopts an "economic value" perspective on investigating banks' exposure to interest rate risk. The basic idea behind this is that interest rate risk embedded in banks' trading and banking books translates into the corresponding changes in their equity prices on the stock market. We undertake this study direction for several reasons. First, as noted by Van den Heuvel (2014), unlike the accounting-based perspective, which relies on lagged data to measure interest rate risk exposure, an approach that is based on banks' equity valuations is more forward-looking. It takes into account the effect of interest rate changes on the present value of all future cash flows and thus captures the long-term impact of interest rate movements on banks' overall positions. Second, the above-mentioned method enables us to trace banks' interest rate risk exposure over shorter time horizons (i.e., daily, weekly, monthly), which is not possible when using the usually annually published accounting-based business figures. Third, this approach tests implicitly how the stock market processes information about changes in the level and shape of the yield curve.

Most papers in this direction start either with a two-factor model suggested by Stone (1974), who uses a CAPM core enhanced with an interest rate risk component or with various extensions of the Fama-French three-factor model,³ which incorporate additional regressors to capture the impact of changes in interest rates on banks' equity valuations (see, e.g., Mirza & Alexandre, 2010; Saunders & Yourougou, 1990; Schuermann & Stiroh, 2006). The existing literature in this line of research, however, provides rather mixed evidence. The majority of authors report that there is a negative association between changes in interest rates and banks' equity prices, meaning that, on average, banks lose in equity value when interest rates go up (see Benink & Wolff, 2000; Czaja et al., 2009; English et al., 2018; Esposito et al., 2015; Fraser et al., 2002; von la Hausse et al., 2016). Others, in contrast, claim that the relationship is negligible and that interest rate risk has an inconclusive impact on banks' stocks (see Schuermann & Stiroh, 2006). In contrast, Ballester et al. (2009) find a positive relation between stock prices and interest rates for Spanish banks in the period 1994–2006. This is an indication that the European market might react differently on interest rate changes, because continental Europe consists mostly of bank-based financial systems. Instead of the originate-to-distribute model, which is more widespread in Anglo-Saxon countries, many banks in the SSM area keep their credit exposures on the balance sheet, which exposes them differently to interest rate

²The Supporting Information: Internet Appendix contains details of the Bayesian DCC M-GARCH approach and a description of the variables used.

³Fama and French extend the basic CAPM model (Lintner, 1965; Sharpe, 1964) by taking into account size effects, measured via market capitalization, as well as companies' book-to-market ratios (see Fama & French, 1992).

risks. Global differences in interest rate exposures have also been documented in the literature for a long time (Madura & Zarruk, 1995). Interestingly, however, the discrepancies in the directional impact of rate changes remain even when the authors analyze the same market (see Benink & Wolff, 2000 vs. Schuermann & Stiroh, 2006, who study the US banks' interest rate risk exposure). Begenau et al. (2015) provide another approach to model time variations in banks' interest rate risk exposure and employ it in US banks for the period 1990 and 2014. The authors conclude that US banks have a positive exposure to interest rate risk and find evidence that interest rate risk exposures increased strongly after the financial crisis of 2007–09. We confirm both findings for euro area banks.

Conceptually, our approach is closely related to Elyasiani et al. (2020), who identify interest rate risk factors with level and slope parameters in the yield curve model of Nelson and Siegel (1987) and then estimate banks' time-varying interest rate risk sensitivity by applying the DCC M-GARCH framework. However, our paper deviates in various aspects. First, we employ principal components of the yield curve instead of the Nelson–Siegel parameters.⁴ While the latter are usually strongly correlated, principal components are by definition independent from each other and hence allow an unbiased interpretation as level, slope and curvature factors. This enables us to measure banks' sensitivity to different shifts in the yield curve separately. Second, we do not limit banks' interest rate risk exposure to level and slope swings in the term structure of interest rates but incorporate curvature movements as well. This is motivated by the fact that the first three principal components of the yield curve are able to explain, on average, more than 90% of total interest rate variation (compare Litterman & Scheinkman, 1991 or Gerhart & Lütkebohmert, 2020 for an analysis of yield curves covering the same time period as our study). A further advantage is that a broad variety of (simple or complex) interest rate scenarios like, for example, the six new interest rate shock scenarios introduced in the new Basel standards for interest rate risk in the banking book (see BCBS, 2016, pp. 44–47) can be assessed within our analysis by combining level, slope and curvature shifts. Our third deviation is that the Bayesian extension of the DCC M-GARCH model, developed by Fioruci et al. (2014), enables us to relax the restrictive assumption regarding the normality in the time series of stock returns and determines the distribution by the Bayesian inference procedure. Finally, rather than pooling the banks into a single portfolio and calculating an average exposure of the sample, we concentrate on each individual bank, which enables us to study the variation in interest rate risk exposure across SSM banks.

The second step in our analysis relates to the literature which tries to explain banks' interest rate risk sensitivity via some bank-level characteristics. Such research usually concentrates on the maturity composition of banks' interest rate risk-sensitive assets and liabilities. In this context, among the most discussed 'vulnerability' sources, which are documented in earlier studies, are a larger maturity gap, or income gap (see Akella & Greenbaum, 1992; Flannery & James, 1984; Gomez et al., 2021; Kwan, 1991), and a positive duration gap (Czaja et al., 2010; Fraser et al., 2002). In particular, Gomez et al. (2021) demonstrate that an income gap, calculated as the nominal difference between banks' interest rate risk-sensitive assets and liabilities that mature within one year, is a major factor explaining a cross-sectional variation in

⁴The Nelson–Siegel model sets parameters to observed yields by using numerical optimization algorithms. However, the estimated parameters are strongly correlated with each other and thus cannot be interpreted separately. Moreover, parameter limits are usually set to avoid big jumps and economically implausible results in the optimization process. Specifically, we estimated the Svensson parameters and it turned out that the correlation coefficient between level and slope was -0.7689 .

banks' interest rate risk sensitivity. Czaja et al. (2010) and Fraser et al. (2002) explain the differences in banks' sensitivity to interest rate risk based on the positive duration gap inherent in the balance sheet. In this context, when interest rates change, banks with a non-zero duration gap experience a variation in the market value of their equity. These conclusions are in line with the maturity mismatch and nominal contracting hypotheses, which motivate the above-mentioned line of research. Purnanandam (2007) examines hedging activities for interest rate risk of about 8000 US banks for the period 1980–2003. It turns out that banks hedge their interest rate risk depending on their probability of financial distress. Further, banks' risk management behaviour depends upon the usage of derivatives. Specifically, banks which do not use derivatives implement conservative asset-liability management policies in tighter monetary policy regimes. These findings indicate clearly that the sensitivity to interest rate risk is linked to the composition of banks' balance sheets and to other measures. This encourages us to investigate the link between interest rate risk and bank-level characteristics for SSM banks in this paper.

The maturity and duration gap hypotheses provide a solid intuition behind the vulnerability to interest rate risk across banks. In testing these hypotheses, the limited availability of a broader sample of detailed data on banks' asset/liability structures and maturities of the underlying claims,⁵ has meant that several studies have tried to explain banks' interest rate risk exposure through publicly available statistics (e.g., banks' capital structure, reliance on interest income, size, hedging activities, overall liquidity in the balance sheet or some other indicators published in banks' financial and regulatory disclosure). In this paper, we will also not analyze detailed maturity data and, therefore, proceed in a similar way to these studies.

For instance, Ballester et al. (2009), who analyze Spanish banks, find that there is a positive relation between banks' size, derivative activities, granted loans and interest rate risk Spanish banks undergo. Drakos (2001), who concentrates on Greek banks, claims that working capital, equity capital and total debt ratio can explain heterogeneity in interest rate risk exposure across banks. Reichert and Shyu (2003) explore large international dealer banks in the United States, Europe and Japan, and attribute the variation in banks' interest rate risk exposure to variation in capital and liquidity ratios as well as in loan loss provisions. The paper suggests, however, that the impact of these indicators on banks' interest rate risk sensitivity is not the same across the regions. Fraser et al. (2002) reach similar conclusions for the US market. The authors state that equity capital ratios, demand deposits and loans normalized to total assets have explanatory power in determining banks' interest rate risk exposure. Furthermore, institutions generating a smaller part of their profit from the interest income are more exposed to interest rate risk, which might be due to their greater reliance on securities-related activities, such as underwriting or acquisitions. This is because securities-related services are usually contracted in times of higher interest rates and reduced economic growth. More recent research by von la Hausse et al. (2016), covering the US market, indicates that exposure of the banking system to interest rate factors changes over time, and can be linked to the banking system's leverage, measured as the ratio of banks' total assets to book value of equity. Au Yong et al. (2009), in turn, distinguish between time horizons related to interest rate risk exposure. The authors conclude that, in the long run, derivative usage makes banks more sensitive to interest rate shocks, while, in the short term, this association is less pronounced. The studies on the German

⁵Deriving maturities for assets and liabilities is very challenging and requires subjective assumptions, as several instruments do not have a contractual maturity or are equipped with embedded optionalities. Examples include nonmaturing deposits, prepayable fixed-rate loans and derivatives.

market reach similar conclusions (see Czaja & Scholz, 2006; Entrop et al., 2009). We take the conclusions gathered in the above-mentioned studies as a starting point to investigate which bank-level characteristics make a particular SSM bank sensitive to level, slope and curvature swings in the term structure.

3 | MEASURING SSM BANKS' INTEREST RATE RISK EXPOSURE

In this section, we estimate the sensitivity of SSM banks' stock prices to various shifts in the yield curve. The methodology described in Section 3.1 is based on the Bayesian DCC M-GARCH approach to estimate the sensitivity of banks' stock returns with respect to various changes in the yield curve. In particular, we analyze the level, slope and curvature shifts of the term structure characterized by the first three principal components of the variance–covariance matrix of changes in the yield curve. Our data set is presented in Section 3.2, results are summarized in Section 3.3 and robustness checks are presented in Section 3.4.

3.1 | Methodology

3.1.1 | Interest rate risk factors

To capture various movements of the term structure of interest rates, we first retrieve interest rates from the ECB's estimates for the Svensson parameters (see Svensson, 1994). Within the Svensson model, the term structure of interest rates is fitted to an exponential-polynomial family of functions described by six parameters. It is flexible enough to describe reasonable term structure shapes and the model is used, along with several other central banks (see BIS, 2005), by the Deutsche Bundesbank and the European Central Bank (see ECB, 2015). The ECB publishes estimates of the Svensson parameters on a daily basis. From these, we can extract time series of interest rates for different maturities. Then, we calculate the variance–covariance matrix of interest rate changes for various maturities. Finally, we calculate the eigenvectors (factor loadings) of the variance–covariance matrix as well as the principal components, that is, the projections of the daily interest rate changes onto the eigenvectors.

The principal components allow us to capture banks' exposure to interest rate risk for a broad spectrum of movements of the yield curve without fitting a specific model. Most papers exploring banks' interest rate risk exposure via the stock market reaction use changes in risk-free interest rates related to certain maturities to proxy for interest rate risk. For example, among recent papers, Ferrer et al. (2016) use yields on 10-year European government bonds to investigate banks' long-term interest rate risk exposure. Beirne et al. (2009) adopt daily changes in 90-day Treasury bill rates and in 10-year government bond yields to approximate interest rate risk. Schuermann and Stiroh (2006) proxy alterations in the term structure using changes in 3-month Treasury rates and the term spread as measured by the difference between 10-year and 3-month Treasury rates. While these approaches are reasonable approximations, they do not capture interest rate fluctuations for all relevant interest rate movements. Thus, such an approach may be too rough, as banks, on the one hand, try to reduce volatility in their net

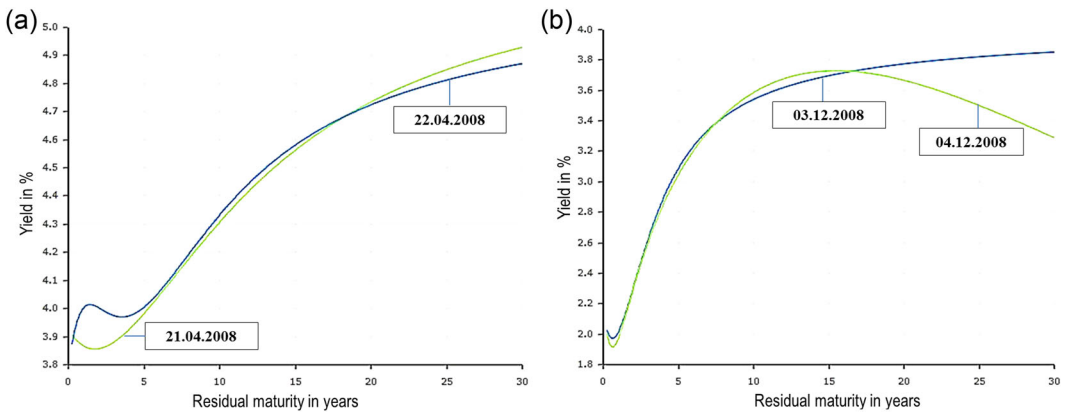


FIGURE 1 Swings in the euro area yield curve (a) Curvature swing on 22 April 2008; (b) Curvature swing on 4 December 2008. The figures depict the euro area yield curves based on the AAA-rated euro area government bonds estimated on 21 and 22 April (left-hand side) as well as on 3 and 4 December 2008 (right-hand side). The left-hand figure demonstrates a curvature swing in the yield curve that happened in 1 day at maturities up to 5 and over 20 years. The right-hand figure presents changes in the curvature over the long end of the euro area yield curve (at maturities over 17 years), whereas the short-term yields remained unchanged. *Source:* ECB; details of the estimation procedure may be found in ECB (2015).

interest income to generate stable earnings for a 1-year period⁶ and, on the other hand, hold assets and liabilities mostly to maturities well below 10 years.

Further, our methodology enables us to estimate banks' interest rate risk exposure not only to linear changes in the term structure, that is, level or slope surprises, but also to curvature swings in the yield curve. In the empirical literature, this component is usually not analyzed. Curvature swings in the yield curve, that is, when short and long-run yields go in one direction while midterm yields move in another direction, might expose banks to material losses if interest rate risk is not fully hedged. In contrast to the level and slope shifts in the yield curve, movements in curvature are hard to capture analytically when using a standard approach, that is, calculating differences in term spreads between the observed yields on some securities. This would require a number of subjective judgements regarding which maturities to use to locate the humps in the interest rate term structure (see Phoa, 2000). Moreover, at some points in time, there might be several humps at different maturities, even though the slope and level may remain the same (see Figure 1); this is clear evidence for incorporating curvature swings in the model.

The approximation of interest rate risk factors through changes in principal components, which describe the shape of the yield curve, addresses this problem and allows us to capture 'curvature' risk (along with slope and level changes in the term structure) over the entire maturity spectrum; Figure 1 and our results in Section 3.3 reveal the significance of this additional interest rate risk factor. It is important to emphasize, however, that such changes in the shape of the interest rate structure never affect just a single principal component. They are always reflected by the interaction of the level, slope and curvature factors.

⁶The new BCBS standards on interest rate risk in the banking book require banks to measure the net interest income over 1 year (BCBS, 2016, p. 15).

3.1.2 | Bayesian DCC M-GARCH model for stock price sensitivities

To capture SSM banks' interest rate risk exposure to swings in the euro area yield curve, we use the Bayesian DCC M-GARCH model. This methodology considers fat tails, volatility clusters and lowers the statistical requirements for the considered time series. Further, as pointed out by Virbickaite et al. (2015), a Bayesian DCC M-GARCH model is much better at explaining asymmetries in volatilities and heavy-tailed asset return distributions. In particular, as times of crises are covered in our analysis, asset returns (i.e., stock returns) exhibit fat tails, volatility clusters and time-varying correlations. Moreover, it allows us to directly estimate banks' time-varying interest rate risk exposure based on the corresponding conditional variance–covariance matrices between banks' equity returns and interest rate risk factors. The sensitivity of banks' stock returns to a particular interest rate risk factor is then expressed as a factor-related beta coefficient (interest rate beta). Additionally, we run an ordinary least squares (OLS) regression to verify the results obtained from the Bayesian DCC M-GARCH model.

For each individual bank in the sample, we assess the Bayesian DCC M-GARCH time-varying interest rate beta coefficient based on the following formula:

$$\beta_{\text{IR},t}^{(i)} = \text{Cov}(r_{it}, \text{IR}_t) / \text{Var}(\text{IR}_t), \quad (1)$$

where $\text{Cov}(r_{it}, \text{IR}_t)$ denotes the conditional covariance between bank i 's stock return r_{it} in $(t - 1, t]$ and interest rate risk factor IR_t during $(t - 1, t]$ while $\text{Var}(\text{IR}_t)$ is the conditional variance of interest rate risk factor IR_t . The interest rate risk factors, in turn, are identified using the first three principal components capturing the yield curve shape, that is, level (pc_{1t}), slope (pc_{2t}) and curvature (pc_{3t}). Hence, $\beta_{\text{IR},t}^{(i)}$ represents the interest rate risk exposure of bank i in the period $(t - 1, t]$ (i.e., one trading day) to the interest rate risk factor IR during the same time period.⁷

Banks' interest rate risk exposure to swings in the level (pc_1), slope (pc_2) and curvature (pc_3) of the yield curve is assessed at each point in time (each bank is considered separately in this step). Conditional variances of risk factors and conditional covariances between banks' stock returns and interest rate risk factors are modelled based on the Bayesian DCC M-GARCH model, which we describe in more detail in the Supporting Information: Internet Appendix.

To derive the sensitivity of each bank's stock returns to changes in the yield curve, we run the Bayesian DCC M-GARCH model separately for each SSM bank. To ensure stable results, we run 100,000 iterations each time when the parameters in the variance–covariance matrices are calibrated. Based on these matrices we then assess interest rate beta coefficients $\beta_{\text{IR},t}^{(i)}$ for exposures to level, slope and curvature changes in the yield curve using Equation (1).

3.2 | Data

We analyze the interest rate risk exposure of the SSM banks and thus cover the most relevant banks in the euro area. Specifically, we apply the analysis to all listed banks therein which have

⁷For instance, while assessing bank i 's interest rate risk exposure to level swings in the yield curve, the following expression is calculated: $\beta_{pc_{1t}}^{(i)} = \text{Cov}(r_{it}, pc_{1t}) / \text{Var}(pc_{1t})$, where pc_{1t} captures changes in the yield curve level in the period $(t - 1, t]$.

a sufficiently good data quality.⁸ In doing so, we can include 36 banks (see ECB, 2014b) and cover around 40% of the total assets in the euro area. Among these banks, 12 are headquartered in Italy, 4 banks are based in Germany, 5 are domiciled in Spain and the remaining 15 banks are located in one of the other euro area countries. We abstain from including further banks to broaden our sample because of the following reasons. First, we evaluate all results at bank level and, thus, additional smaller banks would not contribute to econometric robustness. Second, while our sample is well representative of large, internationally active European banks that are active in interest rate risk-bearing businesses, this is not the case for smaller, specialised, locally active European banks. As only very few of the latter are listed, the interest rate sensitivity of these banks would have to be researched using another method that is not based on share price information.

To capture the evolution of SSM banks' interest rate risk exposure to swings in the euro area yield curve, we collect a time series of daily stock prices of 36 SSM banks, a time series of the EURO STOXX 50 excluding financials (SX5GNFT) index to control for the overall market conditions, as well as a time series of Svensson parameters capturing the shape of the euro area yield curve, which is estimated on a daily basis by the ECB. The analysis overlaps the time period 1/2005–12/2014, which was rich in events: In the summer of 2008, the term structure became almost flat; then, after the Lehman failure, the term structure steepened dramatically. Moreover, this period is characterized by declining interest rates, which (for short maturities) remained close to zero in the last years. These events allow a meaningful estimation of level, slope and curvature parameters—expanding the observation period to more recent years would have put a lot of weight on a period with almost no fluctuations in the yield curve so that our results would unlikely be representative for different interest rate environments. Moreover, interest rates turned negative (even for very long maturities) after 2014. In June 2014, the ECB was the first larger central bank to set the effective marginal policy rate to a negative value. It has been shown by Borio et al. (2017) and Jobst and Lin (2016) that the unusually low and flat yield curves, which were observable after 2014, as well as substantial interest rate cuts, reduce bank profitability.⁹ In such an environment, Molyneux et al. (2021), Heider et al. (2019) and Bottero et al. (2019) show that banks tend to adapt their business model to maintain profitability. Hence, to avoid dilution of our results by the effects of the negative interest rate period which was also characterized by various unconventional monetary policy measures, we restrict our data set to the period 2005–2014.

Stock prices for banks are obtained from Thomson Reuters Datastream. Banks' closing stock prices are adjusted for splits and dividend payments.¹⁰ Based on these prices we calculate time series of each bank's log-returns, $r_t = \ln(P_t/P_{t-1})$, where P_{t-1} and P_t denote bank i 's closing stock prices during two subsequent trading days. Overall market conditions are approximated by log-returns on the EURO STOXX 50 excluding financials index, a blue-chip index capturing the stock market performance of the largest and most liquid

⁸In total, there are 46 listed banks among the SSM banks as of December 2014. However, four banks are excluded from the analysis because the available time series of returns is too short (less than 3 years), and six more banks are excluded because of the illiquidity of its stocks, which results in a long series of zero log-returns. The list of included banks is available in Table 2.

⁹Compare Alessandri and Nelson (2015), Altavilla et al. (2019) and Claessens et al. (2018) for further studies on the link between nonstandard monetary policy or interest rates and bank profitability.

¹⁰Prices of the stocks, which are listed on more than one stock exchange within a country, are taken from the primary exchange of that country; this is not necessarily the 'home' exchange of the stock. Source: Datastream.

nonfinancial corporates in the euro area. The data on the EURO STOXX 50 excluding financials index is taken from the STOXX website.

Moreover, as a robustness check, we test whether nonfinancial corporates are exposed to interest rate changes in the same way as banks. We take closing stock prices which are adjusted for splits and dividend payments for the individual nonfinancial corporates from the EURO STOXX 600, filtering out companies from outside the euro area and companies with the industry classification 'Financials'. This leaves us with 174 corporates. Another robustness check relies on data on a weekly basis and we also include the average expected default frequency (EDF) from Moody's CreditEdge for a representative group consisting of more than 5000 Western European companies accounting for credit risk.

Euro area yield curve shape parameters (i.e., Svensson parameters), which are used for calculating the variance–covariance matrix of interest rates for various maturities, are obtained from the ECB website. The ECB's Directorate General Statistics releases the euro area yield curves, including the shape parameters, every trading day. The ECB estimates zero-coupon yield curves based on the Svensson model. A selected bond basket is used to calculate the euro area yield curves consisting of AAA-rated euro area central government zero-coupon bonds of different maturities.¹¹ This is equivalent to Flannery and James (1984) or Schuermann and Stroh (2006) who use US Treasury and US government-guaranteed debt obligations for approximating risk-free interest rates for the US market or to Ballester et al. (2009) who use Spanish government bond yields for approximating risk-free rates for Spanish banks in a similar context. In addition, we use euro area swap rates for constructing the yield curve as a robustness check. Alternatively, we could have used country-specific or even bank-specific yield curves. However, even if AAA-rated bond yields might not reflect the financing costs for each bank in each country, our set-up is most closely related to the literature by focusing on banks' exposure to (quasi) risk-free interest rates. Furthermore, bank-specific or country-specific interest rates cannot be retrieved in each case in sufficiently high quality.

We collect daily time series of Svensson model parameters capturing the shape of the euro area yield curve over the period 1/2005–12/2014 and retrieve the corresponding interest rates for maturities 0.25, 0.5, 1, 2, 3, 4, 5, 10 and 15 years using the Svensson model. Next, we calculate the variance–covariance matrix for the time series of interest rate changes for the nine above-mentioned maturities. Then, we calculate the first three principal components representing level (pc_1), slope (pc_2), and curvature (pc_3) of the yield curve.

The first principal component explains 76.3%, the second 11.6% and the third 8.2% of the total variation in the yield curve. Accordingly, we explain 96.09% of the total variation by the first three principal components—this is a very parsimonious way of capturing the main properties of yield curve changes and additional principal components would barely increase the explained variation. The relatively high proportions of the second and the third principal component suggest that the interest rate movements in the considered period differ from interest rate fluctuations in normal times indicating that simple measures like the difference between a long-term and a short-term rate would not be sufficient for capturing the observed rate movements.

According to Litterman and Scheinkman (1991, pp. 57–58) and also confirmed in Figure 2, principal components of the yield curve allow for an economical interpretation. The first

¹¹The fact that ECB uses only AAA-rated bonds to fit the yield curve also allows us to disentangle the effects of changes in risk-free rates from the effects of changes in the risk spreads that would enter the analysis if we had used government bonds of lower ratings. Further details of euro area yield curve estimation are provided in ECB (2015).

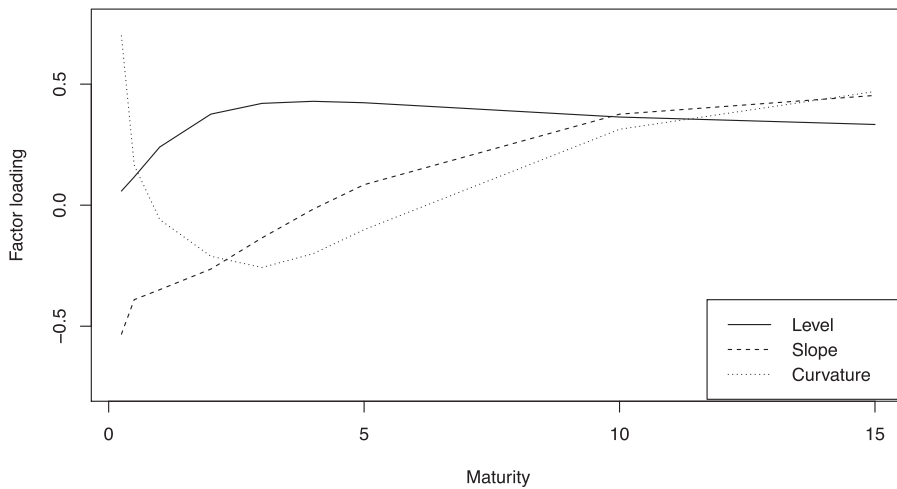


FIGURE 2 Factor loadings of principal components. This figure depicts factor loadings for each maturity of the risk-free interest rates for the level (first eigenvector), slope (second eigenvector) and curvature (third eigenvector).

principal component is a weighted sum of interest rate changes across all maturities. It can be interpreted as the extent to which the yield curve changes in its level. More precisely, as the weighting coefficients are positive for all maturities, an increase in the first principal component can be understood as an upward shift in the level of the yield curve. The second principal component weights interest rate changes for short maturities with a negative sign and interest rate changes for medium as well as for long maturities with a positive sign and, thus, models the slope of the yield curve. An increase in the second principal component can, therefore, be interpreted as an increase in the slope of the yield curve. The third principal component associates positive signs with short-term and long-term interest rate changes and associates negative signs with medium-term interest rate changes. Therefore, it represents a measure of the curvature.

We obtain the daily values of the principal components referring to level, slope and curvature by taking the coefficients as shown in Figure 2 for each maturity and multiply them by the time series of interest rate changes of the same maturity (0.25, 0.5, 1, 2, 3, 4, 5, 10 and 15 years), that is, the projection of interest rate changes onto the first, second, and third eigenvector. Accordingly, we receive a daily value for each of the three interest rate risk factors; the course of changes in the market risk factor and in the principal components are shown in Figure 3. The mean values (standard deviations) for the risk factors are 0.0001 (0.0062) for the market factor, -0.0030 (0.0954) for the level factor, 0.0005 (0.0372) for the slope factor and -0.0007 (0.0312) for the curvature factor.

A pairwise correlation matrix between these components is provided in Table 1. As the principal components are by definition orthogonal to each other, we have no issues with strong correlation or multicollinearity between the considered variables. Periods during which a big variation in the yield curve is observed support the inclusion of three principal components. Two examples of such events are presented in Figure 1, where a substantial change in the yield curve shape happened overnight triggering a change in the third principal component pc_3 . In Figure 1a,b, for instance, curvature swings in the yield curve,

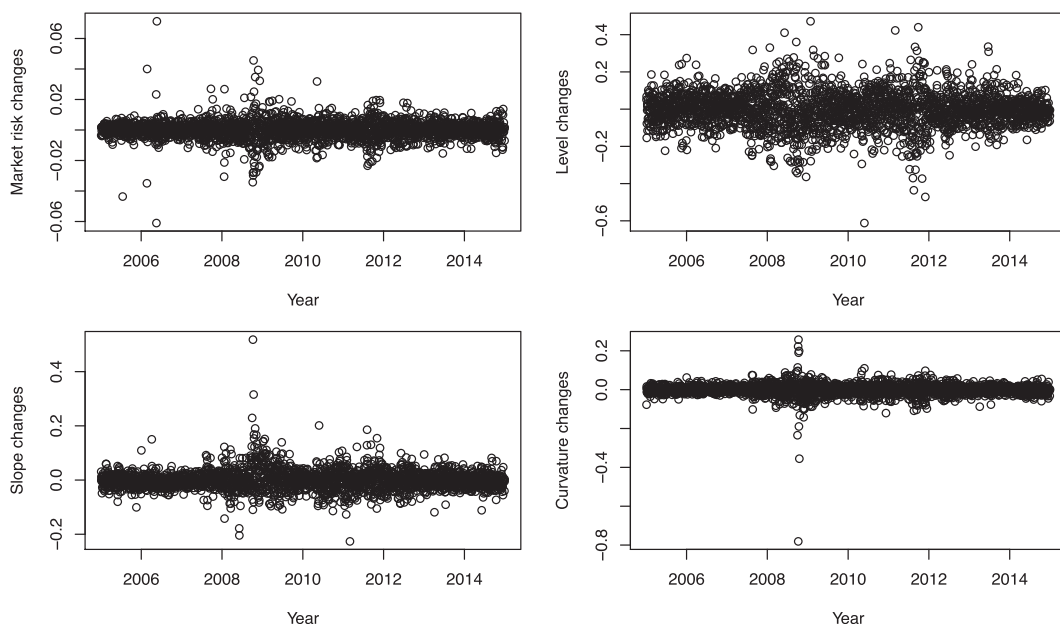


FIGURE 3 Changes in the market risk and in the interest rate risk factors. The upper left figure shows the changes to the market risk factor. The upper right figure visualizes the level changes, the lower left figure shows the slope changes and the lower right figure depicts the curvature changes of the yield curve.

TABLE 1 Pairwise correlation matrix between interest rate risk factors

This table reports a pairwise correlation matrix between the market risk factor and the principal components capturing the shape of the euro area yield curve. The variable r_m stands for the market risk as approximated by the EURO STOXX 50 (excluding financials). The variable pc_1 corresponds to level changes in the yield curve reflected in the first principal component; pc_2 represents changes in the yield curve slope captured by the second principal component; pc_3 captures changes in the yield curve curvature corresponding to the third principal component.

	Market risk (r_m)	Level (pc_1)	Slope (pc_2)	Curvature (pc_3)
Market risk (r_m)	1.000			
Level (pc_1)	0.2948	1.000		
Slope (pc_2)	0.0608	0.000	1.000	
Curvature (pc_3)	-0.0284	0.000	0.000	1.000

which happened at the peak of the global financial crisis (e.g., from 21 to 22 April 2008 and from 3 to 4 December 2008), were accompanied by big jumps in pc_3 (see Figure 3 for curvature changes in 2008).

All the time series used in the analysis are checked for stationarity and normality. We use Augmented Dickey–Fuller, Phillips–Perron unit root tests as well as the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) stationarity test to check whether time series are stationary. In each case, we find that time series are stationary (log-returns on banks' stocks and EURO

STOXX 50 excluding financials index as well as principal components¹²). Furthermore, while the Bayesian methodological approach comes with certain advantages over the conventional regression-based methods, we also conduct normality checks on the data to ensure that the additional complexity is warranted. We use Kolmogorov–Smirnov, Shapiro–Wilk and Jarque–Bera normality tests to check whether the return series, as well as interest rate risk factors, follow a normal distribution. The normality assumption is rejected in all cases. While there is a stylized fact that return distributions might exhibit fat tails as well as leptokurtosis, it is not that obvious for the interest rate risk factors. Thus, we also double-check the normality of the EURO STOXX 50 excluding financials index as well as level, slope and curvature interest rate risk factors on QQ plots, which reconfirm the outcome of the previous tests (see Figure A1). Thus, we argue that the results of normality tests justify the additional complexity that stems from the incorporation of the Bayesian inference procedure into the DCC M-GARCH framework. If we had observed a normal distribution, this complication could have been avoided.

Each SSM bank is analyzed separately at this stage; thus, in total we consider 36 separate input matrices to analyze each bank's sensitivity to swings in the euro area yield curve. The only difference between these matrices is that the first column, which corresponds to individual bank stock returns, varies. Similarly, we have 39 input matrices for the calculation of corporates' exposures to interest rate risk. Specifically, a corporate's stock price is employed in the first column of the input matrix.

In the OLS model which serves as a robustness check (see Section 3.1.2), we conduct a separate regression for each bank and for each year. As we cover the period 2005–2014 (10 years) for each of the 36 banks, this sums up to 360 regressions. Similarly to the Bayesian DCC M-GARCH model, we include the market risk factor and the three interest rate factors as explanatory variables. It should be noted that the OLS regressions deliver for each year a constant sensitivity, whereas the Bayesian DCC M-GARCH model equips us with daily (time-varying) sensitivities.

3.3 | Results

We estimate each entity's market risk and interest rate risk exposure to swings in the level, slope and curvature of the euro area yield curve for each trading day during 1/2005–12/2014. The exposure to a particular risk factor is calculated in the Bayesian DCC M-GARCH framework as the arithmetic means over the daily exposures to the corresponding factor observed over each year.

Interest rate risk exposure is measured via the interest rate beta coefficient in Equation (1) describing the percentage change in an entity's stock return associated with a change in the corresponding interest rate risk factor, that is, the principal component of changes in the euro area yield curve. A bank-specific overview of the estimated exposures is summarized in Table 2 (full period) and Table A1 (subperiods). The table for the full period shows that out of 36 banks, all exhibit a significantly positive coefficient to level changes, which indicates that their stock prices tend to increase if interest rate levels rise. Thirty-five banks have a positive coefficient for

¹²More specifically, the product of eigenvectors of the variance–covariance matrix of interest rate changes and historical changes in interest rates for various maturities.

TABLE 2 Banks' interest rate risk exposure to level, slope and curvature swings in the yield curve (full period)

This table reports Single supervisory mechanism (SSM) banks' average daily exposure to changes in the respective risk factors during 1/2005–12/2014. 'Market' corresponds to banks' exposure to market risk (known as 'market beta'), 'Level', 'Slope' and 'Curvature' denote banks' exposure to swings in the level, slope and curvature of the euro area yield curve (see Section 3.1.1 for details). As the sensitivities do not follow the normal distribution, we employ the Wilcoxon signed-rank test to assess whether the sensitivities are asymmetrically distributed around zero. All the exposures are given as a percentage change in a bank's stock price associated with a 1 percentage point change in the corresponding interest rate risk factor. The column 'Share price impact of a 25 bps upward shift' denotes the percentage change of the share prices after a 25-basis points parallel upward shift of the yield curve. *** indicates statistical significance at the 1% level.

SSM bank	Country	Market	Level (pc_1)	Slope (pc_2)	Curvature (pc_3)	Share price impact of a 25 bps upward shift (%)
Erste Group Bank AG	AT	1.4482***	0.0638***	0.0394***	-0.0020***	3.60
Dexia SA	BE	0.6294***	0.0785***	0.0110**	0.0067	5.34
KBC Group NV	BE	1.0548***	0.0681***	0.0302***	0.0337***	4.80
Hellenic Bank	CY	0.3148***	0.0347***	-0.0196***	0.0108*	3.00
Aareal Bank AG	DE	1.5679***	0.0560***	0.0106***	-0.0027	3.61
Commerzbank AG	DE	1.5948***	0.0687***	0.0336***	0.0433***	4.98
Deutsche Bank AG	DE	1.6206***	0.0591***	0.0241***	0.0075	3.76
IKB Deutsche Industriebank AG	DE	0.7389***	0.0372***	0.0220***	0.0260***	2.67
Bankinter SA	ES	1.2277***	0.0558***	0.0485***	0.0404***	3.74
BBVA SA	ES	1.5946***	0.0605***	0.0419***	0.0131	3.64
Banco de Sabadell SA	ES	0.9722***	0.0374***	0.0345***	0.0141***	2.20
Banco Popular Español SA	ES	1.1518***	0.0505***	0.0404***	0.0085	2.88
Banco Santander SA	ES	1.9087***	0.0634***	0.0381***	0.0144***	3.93
BNP Paribas SA	FR	0.9409***	0.0661***	0.0461***	0.0240***	4.16
Crédit Agricole SA	FR	1.5017***	0.0708***	0.0352***	0.0139	4.49

(Continues)

TABLE 2 (Continued)

SSM bank	Country	Market	Level (pc_1)	Slope (pc_2)	Curvature (pc_3)	Share price impact of a 25 bps upward shift (%)
Société Générale SA	FR	1.2077***	0.0703***	0.0399***	0.0074	4.23
Alpha Bank AE	GR	0.9052***	0.0718***	0.0808***	0.0922***	5.28
Eurobank Ergásias SA	GR	0.7427***	0.0831***	0.0621***	0.1014***	6.61
National Bank of Greece SA	GR	0.4717***	0.0322***	0.0321***	0.0214***	2.04
Piraeus Bank SA	GR	1.0715***	0.0701***	0.0614***	0.0788***	5.26
Allied Irish Banks. Plc	IE	0.9274***	0.0650***	0.0220***	0.0099	4.27
Bank of Ireland	IE	1.3481***	0.0668***	0.0123***	-0.0263***	3.84
Banca Carige SpA	IT	0.9594***	0.0425***	0.0183***	-0.0025***	2.53
Banca Monte dei Paschi di Siena SpA	IT	1.3843***	0.0588***	0.0700***	0.0135	2.98
Banca Popolare dell'Emilia Romagna SC	IT	1.4150***	0.0377***	0.0566***	0.0476	2.48
Banca Popolare di Milano Scarl	IT	1.7740***	0.0548***	0.0371***	-0.0065***	2.93
Banca Popolare di Sondrio SCpA	IT	0.9868***	0.0306***	0.0469***	0.0417***	2.06
Banco Popolare Società Cooperativa	IT	1.4601***	0.0612***	0.0797***	0.0081	2.85
Credito Emiliano SpA	IT	1.2837***	0.0510***	0.0194***	0.0075***	3.30
Credito Valtellinese Società Cooperativa	IT	0.7276***	0.0364***	0.0551***	0.0256***	1.97
Intesa Sanpaolo SpA	IT	1.6105***	0.0656***	0.0620***	0.0434***	4.22
Mediobanca SpA	IT	1.3215***	0.0532***	0.0389***	0.0223	3.38
UniCredit SpA	IT	1.2544***	0.0746***	0.0667***	0.0411***	4.70
Unione di Banche Italiane SCpA	IT	1.4050***	0.0523***	0.0567***	0.0283***	3.09
Banco BPI SA	PT	0.9625***	0.0477***	0.0386***	0.0331***	3.22
Banco Comercial Português SA	PT	1.4039***	0.0428***	0.0249***	0.0492***	3.48
Mean		1.191	0.0566	0.0394	0.0247	3.65

slope changes (i.e., a steepening yield curve) and 31 banks show a positive coefficient for curvature changes.

We want to assess the statistical significance of our estimates. In doing so, we test the sensitivities for normality by the Kolmogorov–Smirnov, Shapiro–Wilk and Jarque–Bera test. As all tests reject normality for each factor and for each bank, we cannot conduct a *t* test for testing the significance and use, thus, the nonparametric Wilcoxon signed-rank test. This test indicates significance if the majority of the data points (i.e., sensitivities) is above (or below) zero. We only indicated those observations as significant if the majority of observations had the same sign as the mean. It turns out that the market risk, as well as the interest rate risk factors for level and slope, are significant for all banks. Moreover, 24 out of 36 banks are significantly affected by curvature swings.

The economic impact of the interest rate risk factors proves to be highly significant. On average, a bank has sensitivities of 0.0566 (level), 0.0394 (slope) and 0.0247 (curvature) (see Table 2). To illustrate the economic impact of a relatively small change in interest rates, we calculate how, according to our estimate, markets would react to a 25-basis point parallel upward shift of the yield curve. On average, this leads to an increase in the stock prices of an average bank by 3.65%. Values for individual banks are displayed in Table 2. We also evaluate the economic impact of individual changes in the market factor and the principal components on banks' share prices. Looking at the 2% and 98% quantiles of daily changes in these variables, which represent extreme but still realistic changes in the interest rate structure, we find that these changes correspond to a share price impact of around 1.5% (market factor), 1.2% (level factor), 0.3% (slope factor) and 0.13% (curvature factor) for the average bank. These numbers show that the economic impact of changes in the three term structure parameters is very important for the average analyzed bank. The effects of a level shift in the interest rate structure on the share price are almost as great as the effects of comparable fluctuations in the market factor. The effects caused by slope and curvature fluctuations are smaller, but still economically significant.

Therefore, a substantial part of the total risk can be attributed to the systematic risk factors and only a small fraction needs to be explained by idiosyncratic risk. However, some entities were more severely affected by the crises than others and decoupled from general market movements. This becomes apparent in our data set, as the market risk factor fails in capturing the market risk for some Cyprian and Greek banks.

Box plots showing the interest rate risk exposure across all SSM banks covering the period 1/2005–12/2014 are presented in Figure 4, illustrating that banks' interest rate risk exposure changes considerably over time. SSM banks are positively exposed to level increases in the term structure. Furthermore, on average, banks' stock prices react positively after the global financial crisis to slope increases as well as to increases in the curvature; the latter combines decreases in midterm rates and increases in short-term and long-term rates. Interestingly, we observe a substantial negative sensitivity in the year 2008. This year was dominated by the global financial crisis coming along with a lot of noise and sharp movements of the yield curve. It is possible that our interest rate factors capture side effects from the global financial crisis which are unrelated to interest rate risk in the year 2008.

The positive relation between stock price increases and rising interest rates is in line with evidence for Spanish banks provided by Ballester et al. (2009). Furthermore, our results on SSM banks' average daily interest rate risk exposure over the period 1/2005–12/2014, provided in Tables 2 and A1, suggest that banks domiciled in the European core countries (i.e., Germany,

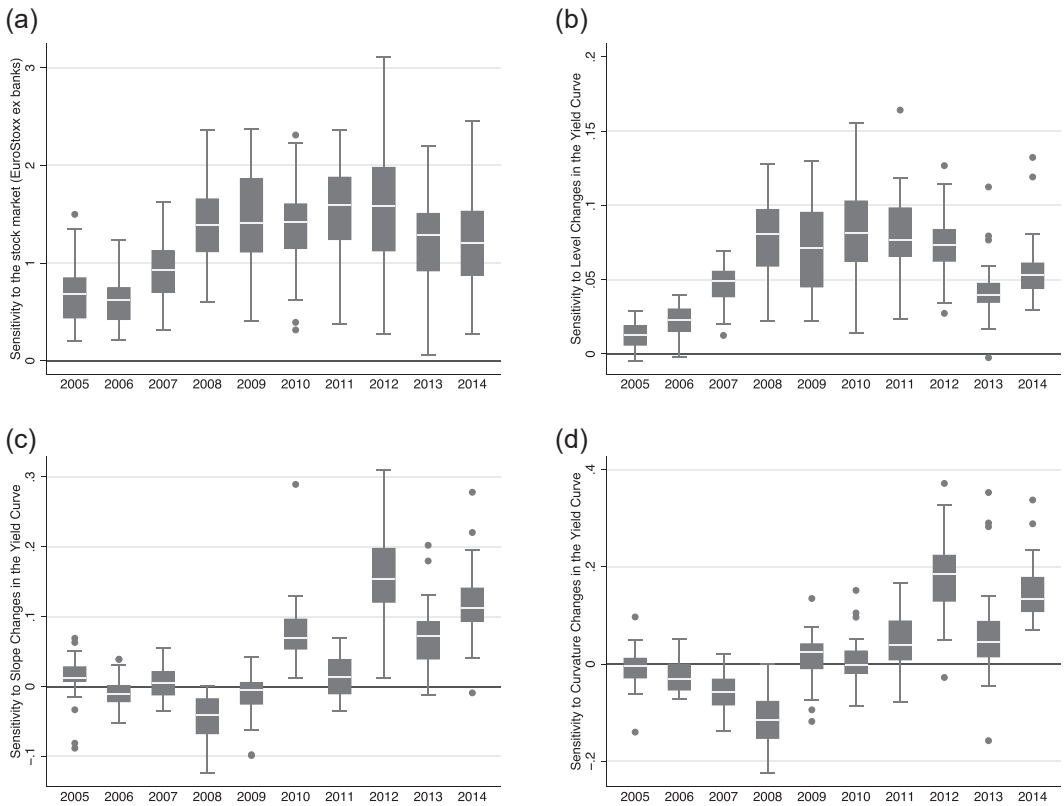


FIGURE 4 Single supervisory mechanism (SSM) banks' exposure to the market risk factor as well as to level, slope and curvature swings in the euro area yield curve—yearly data (a) Sensitivity to the market risk factor (r_m); (b) Sensitivity to level swings (pc_1); (c) Sensitivity to slope swings (pc_2); (d) Sensitivity to curvature swings (pc_3). These figures present the variation in the market risk exposure and in the interest rate risk exposure to swings in the euro area yield curve observed among the SSM banks. (a) shows a positive relation between banks' stock prices and the market risk factor. (b) shows that banks' stock prices are positively associated with the first principal component which goes along with interest rate increases. Accordingly, interest rate increases lead to hikes in stock prices. (c) reveals that banks have been barely sensitive to slope changes in the years 2005–2009. However, a positive sensitivity can be observed for the years 2010–2014. The sensitivity to curvature is depicted in (d). It turns out that the sensitivity is slightly negative in the years 2005–2009 but becomes positive for 2010–2014. The dots visualize outliers.

France, Austria) are more sensitive to European market conditions than banks in the countries located closer to or at the periphery.

As depicted in Figure 4 and shown in Table A1, after the financial crisis of 2007–2009, the interest rate risk exposure of the SSM banks has been increasing. This observation is in line with the evidence presented by Begenau et al. (2015), who, by using a different estimation procedure, document that big banks increased their interest rate risk exposure after the financial crisis. Of particular interest is that the exposure to slope and curvature swings in the yield curve has dramatically increased between 2010 and 2014. As these exposures were almost negligible in 2005–2007, this might be an explanation for why previous studies have partly neglected the slope and always disregarded the sensitivity to curvature movements. Interestingly, the increased sensitivity occurred almost in parallel with the onset of very low

interest rates in the euro area starting end-2011. However, reaching negative interest rates in mid-2014 seems to play only a minor role and does not change the sensitivity beyond formerly experienced amplitudes. Further, it is noteworthy that almost all banks exhibit the same sign during the examined period, that is, the results hold true for (almost) all banks and are not driven by a few outliers (see Figure 4a,d).

We apply two additional tests to investigate whether the interest rate sensitivity of banks stems from their specific business model which involves maturity transformation. We employ the Bayesian DCC M-GARCH model on nonfinancial corporates (see Section 3.1) and find that their sensitivity to market risk, as well as fluctuations in the level, slope and curvature of the yield curve, generally follows a similar pattern. However, the sensitivity with regard to level swings (entire period) and slope swings (from 2010 onwards) is on average almost twice as high for banks than for nonfinancial corporates. From this, we conclude that the latter is only to a limited extent sensitive regarding fluctuations in the yield curve and that the maturity transformation function of banks seems to be one reason for their interest rate sensitivity.

Finally, Figure A3 further shows the time variations in sensitivities to the market and the interest rate risk factors of the five biggest banks included in our sample. It turns out that the sensitivities vary in time but remain mostly positive. Specifically, the market risk factor and the level interest rate risk factor remain almost completely in positive territory. The sensitivities to slope and curvature changes are jumping around zero in the years until mid-2011 but remain mostly positive afterwards. In addition, there seem to be idiosyncratic differences between the banks. Given that result, we present in Section 4, an analysis of banks' accounting data and regulatory disclosure to understand what bank-level characteristics can explain the above-mentioned heterogeneity.

3.4 | Robustness checks

Our results are confirmed in several robustness checks.¹³ First, we estimate the Bayesian DCC M-GARCH model using weekly data (see Section 3.1), which smoothes some spikes in the data set but reduces the number of observations. This robustness check confirms our results entirely. All individual banks have a positive exposure to level and the vast majority of banks has a positive exposure to slope and curvature.

Second, as discussed in Section 3.2, we use swap rates for approximating risk-free euro area interest rates as a robustness check. As expected, the results are in line with the ones for government bond yields, that is, we have clearly positive exposures to level, slope and curvature swings. Almost all the assessed conditional correlations of banks' stock price returns with interest rate risk factors, and, hence, the SSM banks' interest rate risk exposures, are statistically significant.

Third, we conduct a further robustness check by including credit risk as measured by EDFs from Moody's CreditEdge as a control variable. As expected, stock prices of all banks are negatively related to the EDFs. The inclusion of the EDFs affects the sensitivity of stock prices to the market risk factor [i.e., EURO STOXX 50 (excl. financials)] in terms of magnitude but leaves the sensitivities to the interest rate risk factors nearly unchanged. Furthermore, it is noteworthy that the principal components of the changes in the euro area yield curve are only

¹³These results are available upon request.

weakly correlated to the market risk factor (see Table 1) and to the credit risk proxy in the robustness check.¹⁴ This suggests that our results are robust and we are capturing interest rate risk and not another systematic risk factor.

Fourth, the positive exposure is confirmed with the OLS regression (see Figure A2). However, it is noteworthy that although the direction and the general variation over time are similar for the results based on both the Bayesian DCC M-GARCH model and the OLS regression, the latter exhibits a lower variation across banks over time. That said, it seems that the OLS model smooths out some dynamic patterns, justifying the use of the more complex Bayesian DCC M-GARCH. As an R^2 is available as a measure for the estimation accuracy in the OLS regressions, we can now also give more precise statements about the explanatory power of the risk factors. The average R^2 for all sample banks is 0.217, but the model's explanatory power differs significantly between the sample banks. While banks severely affected by the crisis exhibit a model fit below average (probably due to a higher importance of idiosyncratic risk factors), the share prices of the largest banks can be explained exceptionally well. Not least, as the explanatory power of the Bayesian DCC-M-GARCH model should be even higher as it reflects dynamic patterns better than the OLS model, these numbers illustrate that a substantial portion of the variation in banks' stock prices can be explained by risk factors.

4 | EXPLAINING SSM BANKS' INTEREST RATE RISK EXPOSURE

In the previous Section 3, we assessed banks' overall interest rate risk exposures based on market data. However, the sources which make a particular bank more vulnerable to interest rate risk remained unclear. In this section, we investigate these channels using accounting data, such as banks' balance sheet structure or their off-balance sheet items. In this step of the analysis, we connect the SSM banks' interest rate risk sensitivities for level, slope and curvature swings with individual bank-level characteristics that could explain the variation in banks' sensitivities in the cross-section and over time. As level shifts account for more than 75% of interest rate risk variability (see Section 3.2), they are clearly the most relevant risk factor to be examined. Besides analyzing the sources of banks' interest rate risk exposure that could potentially serve as 'red flags' for regulators and other stakeholders, this step also constitutes a validation procedure of the results obtained in the initial stage.

4.1 | Expectations of how bank characteristics shape interest rate risk

In this section, we discuss the relation between bank characteristics and banks' interest rate risk exposure which we expect based on findings in the literature. To investigate which particular positions on both the asset and the liability side might expose a bank to interest rate risk, we reconstruct a representative balance sheet from the available data on banks' financial

¹⁴We have correlations of -0.18 , 0.08 and -0.02 between credit risk (as measured by EDFs from Moody's Credit Edge) and the first, second and third principal components of changes in the yield curve.

positions (see Table A2). The details of each position are provided in the Supporting Information: Internet Appendix.

Among the available data, we preselect the positions which are either rate-sensitive due to the instruments they contain, or which have been reported to be potential indicators of interest rate risk exposure in earlier studies. These positions include financial assets on the asset side, deposits, other debt and derivatives on the liability side (with respective subcategories), as well as the Core Tier capital ratio and the gap between customer-related assets and liabilities. All balance sheet positions are normalized by total assets or, respectively, by the sum of total liabilities (and equity) to make them comparable across the sample. Further, we consider the return on average assets (ROAA)¹⁵ and other income-based variables (the net interest income relative to operating revenue) and the net fee income relative to risk-weighted assets, as well as the relation of loan loss reserves to gross customer loans. The logarithm of banks' total assets accounts for size effects in their interest rate risk exposure.

We expect banks with positions which hint towards a high maturity gap (e.g., securities, customer loans) to be more interest rate risk-sensitive. From a net present value perspective, stock prices of positive maturity-transforming banks would decline if interest rates increase. This is because stock prices can be interpreted as the future cash flow stream from assets and liabilities, which would—after an interest rate increase—lose in value. However, from a net interest income perspective, the proportion of an interest rate increase which is passed through on assets is usually higher than on liabilities. Thus, the prospect of higher income from a new business could improve and cash flows (and, in turn, stock prices) could increase after an interest rate increase. Depending on which perspective—net present value or net interest income—dominates, an interest rate increase could affect stock prices in either direction. Table 3 summarizes the expected directional impact of the bank characteristics on banks' interest rate risk and provides also an overview of factors which prove to have a significant impact in our analysis.

As regards the variables on the asset side, we expect a positive relation between *financial assets* and, in particular, *securities* on banks' balance sheets and their interest rate risk exposure. Compared to nonfinancial assets (e.g., real-estate investments) their value depends more directly on the level and shape of the term structure, which makes them more exposed to interest rate risk from a present value perspective. Instead, banks whose balance sheet consists of a high degree of *customer loans* granted (which usually do not reprice on a high frequency) should be more exposed to interest rate risk from an earnings perspective. The latter effect would be in line with prior evidence by Fraser et al. (2002), Au Yong et al. (2009) and Ballester et al. (2009).

As regards banks' liability side, banks' leverage as measured by the *Core Tier capital ratio* is expected to be negatively related with their interest rate risk exposure, because equity on the balance sheet should serve as a cushion to adverse developments such as sudden interest rate changes and make a bank safer. This expectation is in line with empirical evidence by Fraser et al. (2002), Saporoschenko (2002), Au Yong et al. (2009) and von la Hausse et al. (2016).

We expect a negative relation between *deposits* and banks' interest rate risk exposure, which has also been identified in the literature (Ballester et al., 2009; Fraser et al., 2002; English et al., 2018; Saporoschenko, 2002). The interest paid on both *demand deposits* and *term deposits*,

¹⁵The inclusion of ROAA in the analysis is motivated by the findings of Hao et al. (2011), who find that firms' profitability affects their stock price sensitivity to market-wide information (market betas). In this context, banks' overall profitability might also have an impact on their sensitivity to swings in the term structure.

TABLE 3 Bank characteristics which determine banks' interest rate risk exposure

This table reports the lists of bank characteristics which determine banks' interest rate risk exposure. The symbols +, – and +/- indicate a positive, negative and inconclusive/ambiguous relation of the bank characteristics on interest rate risk. The symbol ~ stands for inconclusive empirical results. ^aEmpirical results that are only significant during the first half of the period (subperiod: 2005–2009) and ^bempirical results that are only significant during the second half of the period (subperiod: 2010–2014). The symbol ~ stands for inconclusive empirical results.

Bank characteristic	Expected relation	Empirical results w.r.t.		
		Level	Slope	Curvature
Total financial assets to total assets	+	~	~	+ ^a
Securities to total assets	+	~	~	~
Net customer loans to total assets	+	+	~	+
Core Tier capital ratio	–	+	–	+
Deposits to total liabilities (and equity)	–	–	~	–
Term deposits to deposits	–	~	– ^a	+ ^a /– ^b
Total debt to total liabilities (and equity)	–	–	~	–
Subordinated debt to total liab. (and equity)	+/-	– ^a	~	–
Senior debt to total liabilities (and equity)	–	–	+ ^a	–
Derivative liabilities to total liab. (and equity)	+/-	+ ^b	~	+
Net interest income to operating revenue	–	–	–	+
Net fee income to risk-weighted assets (RWA)	–	~	– ^b	–
Return on average assets	+/-	–	~	~
Net customer loans minus deposits to total assets	+	+	~	+
Loan loss reserves to gross customer loans	–	–	~	+ ^b /– ^a
Size	+/-	~	+ ^b	+ ^a /– ^b

which we consider as a specific variable, depends to a much lesser degree on changes in the yield curve than the interest paid, for example, on the money market.

Instead, the association between *total debt* (other than deposits) and banks' interest rate risk is more difficult to grasp. Generally, medium and long-term debt financing should reduce banks' exposure to yield curve changes because, assuming that these instruments have fixed coupons, future interest payable does not depend on the future term structure. This is particularly true for *senior debt* and less so for *subordinated debt*. Hence, we expect a negative association of senior debt and banks' sensitivity to term structure changes while subordinated debt, due to its junior status, has a downside risk that resembles equity, which makes the bank vulnerable, particularly if interest rate increases come along with reduced economic growth which can increase a bank's default risk (see Fraser et al., 2002).

Derivative liabilities, instead, may be positively or negatively related to banks' interest rate risk exposure, depending on their use for hedging or speculation. Unfortunately, this information cannot be retrieved from accounting data. English et al. (2018) provide

comprehensive evidence regarding their impact on banks' sensitivity to interest rate changes, but we leave it as an empirical question to identify a positive or negative relation.

Net interest income to operating revenue measures banks' reliance on interest income and, thus, approximates their income structure at different points in time. Fraser et al. (2002) argue that institutions generating a smaller part of their profit from the interest income are more exposed to interest rate risk, which might be due to their greater reliance on securities-related activities, such as underwriting or acquisitions, which are usually contracted in times of higher interest rates and reduced economic growth. *Changes in net fee income, normalized by risk-weighted assets*, indicate banks' involvement in 'noninterest' business lines, such as credit card servicing, nondeposit product sales, trust and mortgage banking (see FDIC, 2018). In line with Fraser et al. (2002), we expect it to be negatively related to banks' interest rate risk exposure.

The expected relation of the ROAA and banks' sensitivity to interest rate risk are unclear because, on the one hand, high margins may be a sign of higher risk-taking (e.g., by maturity transformation), but on the other hand, they may also be considered as a cushion against events that adversely affect banks' income (e.g., changes in the term structure).

Further, we consider *loans minus deposits* as a liquidity indicator that measures the gap between customer-related assets and liabilities.¹⁶ As this imbalance between banks' assets and liabilities may not only imply liquidity risk but also interest rate risk, we expect a positive relation of this variable to banks' sensitivities.

The *loan loss reserves to gross customer loans* ratio reflects the overall credit quality of banks' credit portfolios (see Bolt et al., 2012). If credit risk and interest rate risk are negatively related, we should expect a negative sign for this variable.

Finally, *size*, defined as the logarithm of banks' total assets, accounts for the differences in banks' policies, lending and borrowing practices as well as other circumstances, which are linked to this indicator. For example, large banks are more prone to the moral hazard problem and might, thus, accept larger interest rate risk. Ballester et al. (2009) and Saporoschenko (2002) have empirically detected this positive relation, and we also expect to identify it in our study. However, Kashyap and Stein (2000) come to another empirical result. They find that small banks and banks with less securities on their balance sheets are more vulnerable to monetary policy because they are less liquid. This hampers absorbing losses due to changes in interest rates or macroeconomic conditions.

Unfortunately, we do not have an exact measure of the banks' maturity composition of assets and liabilities, which is a very important determinant of interest rate sensitivity. However, a number of the indicators presented above gives some indication of possible maturity gaps. For example, *securities* and *net customer loans* typically have a longer term than other assets, which increases the maturity gap. In fact, banks that have a high proportion of these positions relative to total assets are more sensitive to interest rate fluctuations. The opposite applies to the positions *total debt* and *senior debt* relative to total liabilities (and equity). Banks with high values tend to close maturity gaps and are, therefore, less sensitive to interest rate fluctuations.

The data on SSM banks' balance sheets, income statements, asset quality and regulatory capital reporting is obtained from SNL Financial, and it covers the 36 large banks in our sample over the time period of 2005–2014. To ensure consistency in the measurement across the

¹⁶In the empirical literature, banks' liquidity is also measured as the ratio of loans to deposits. However, as net customer loans minus deposits are normalized to total assets and, thus, comparable across banks, the initial specification does not make a difference in the analysis.

sample, we use only the observations reported based on IFRS accounting standards.¹⁷ As comprehensive quarterly (or more frequent) reporting is not available for some SSM banks in the sample, the data is collected on an annual basis, but as some bank-level data is missing for some years, the resulting panel is unbalanced. The outlined variables are then matched to SSM banks' interest rate risk exposures to level, slope and curvature swings in the euro area yield curve, estimated in the first step of our analysis (see Section 3). Each bank's interest rate risk exposure to swings in the yield curve in a given year is calculated as the average of daily exposures to a particular interest rate risk factor observed during that year.¹⁸

4.2 | Methodology

In line with Ballester et al. (2009), we use a country-level FE panel data framework. This approach allows us to eliminate a potential bias related to the time-invariant country-specific conditions, which might have, among many others, an impact on banks' behaviour, their balance sheet composition and income structure. Furthermore, we include time FE on a yearly level, which captures any systematic changes in interest rate risk exposure that might happen throughout the entire sample over time. As a robustness check, we estimate regression models without these time FE as well.

The basic linear model used in the analysis is

$$\beta_{IR,t}^{(i)} = X_{i,t}^T b + Y^T \theta + Z_{i,t}^T \gamma + \epsilon_{i,t}, \quad (2)$$

where $\beta_{IR,t}^{(i)}$ corresponds to bank i 's sensitivity to a particular interest rate risk factor (i.e., to level, slope or curvature swings in the euro area yield curve) at time t ;¹⁹ $X_{i,t}$ refers to the matrix of bank-specific characteristics. As the accounting data for year t is released only at the end of the year, it is possible that during year t investors condition their expectations regarding SSM banks' interest rate risk exposure on the previous year's financial and regulatory reporting. Thus, we use averages of the independent variables over the beginning and the end of the respective year, that is, $\bar{X}_{i,t} = 0.5 \times (x_{i,t} + x_{i,t-1})$. This is consistent with the view that investors use to some extent information that accumulates over the current year but is only reflected in accounting figures at the end of the year. To some extent, however, investors also refer to information that is already contained in the accounting figures for the previous year. The averaging takes both sources of information into account. As a robustness check, however, we also estimate the regression models based on end-year balance sheet values. Y is the matrix of time- and country-FE; $\epsilon_{i,t}$ are independently, identically distributed error terms. We run separate regressions for SSM banks' sensitivities to level $\beta_{pc1,t}^{(i)}$, slope $\beta_{pc2,t}^{(i)}$, and curvature swings $\beta_{pc3,t}^{(i)}$ in the euro area yield curve by replacing $\beta_{IR,t}^{(i)}$ in Equation (2) with the respective sensitivity. Depending on which interest rate sensitivity is used as the dependent variable, we also include the other interest rate sensitivities and the sensitivity to the market factor—in each

¹⁷For instance, IKB Deutsche Industriebank AG is excluded from the analysis during 2013 and 2014, because it switched to German GAAP.

¹⁸As an alternative, we calculated the median which proved to be in the vast majority of cases almost identical to the mean.

¹⁹Even in the presence of measurement error in the dependent variable, the zero conditional mean assumption is not violated and the subsequent estimates are unbiased.

case as year-specific averages—in the regression. The three interest rate factors are uncorrelated with each other, but not with the market risk factor (Table 1), which might possibly result in sensitivities being interrelated. $Z_{i,t}$ refers to this matrix of bank-specific sensitivities.

Please note that the model we are currently using is mainly identified through heterogeneity in the cross-section of banks and only partly through the time series because we want to analyze which characteristics make banks more sensitive to interest rate changes, instead of investigating how their sensitivities change if bank characteristics fluctuate over time. Therefore, we do not include bank-level FE in our regression models. There is the risk that without bank-level FE, unobserved bank-specific characteristics could lead to biased coefficient estimates if they are correlated with the explanatory variables. But the use of bank-level FE would require that there is sufficient variation in the independent variables over time, but banks' balance sheet ratios are very static. In unreported robustness checks, however, we confirm most of our key results in models with bank-level FE. This helps us to allay concerns that, due to the correlation with unobserved factors, the coefficients of the country-level FE regressions are broadly biased.

As pointed out in Section 3.3, particularly some Cyprian and Greek banks were strongly affected by the crisis and decoupled from the general market movements. Accordingly, for these banks, a material part of the risk needs to be explained by idiosyncratic risk. Thus, to ensure the robustness of our results, we excluded six more banks during crisis years from the analysis. However, the results in Table 3 were similar in magnitude and significance.

It should be noted that we calculate banks' sensitivities to level, slope and curvature by taking the daily average over a year. As these sensitivities are exposed to estimation risk, we tested their significance with the Wilcoxon signed-rank test (see Section 3.3) and carried out the regressions in Section 4.3 based on median values of the sensitivities as a robustness check. Moreover, a variety of model specifications allows us to ensure the robustness of our results across several dimensions. First, we consider two different regression settings, in which we control for different bank-specific characteristics as explained in Section 4.3. Second, we estimate both models for the full period (2005–2014) as well as for the pre- and postcrisis subperiods (2005–2009 and 2010–2014).

4.3 | Detailed results

4.3.1 | Exposure to level swings

Table 4 presents regression results that explain how bank-specific factors shape SSM banks' interest rate risk exposure to level swings in the yield curve.

As mentioned in Section 4.2, the results are presented for two different regression settings, which differ in terms of the explanatory variables included [(1a–1c) vs. (2a–2c)]. Further, we consider the full period as well as the pre- and the postcrisis subperiods (2005–2009 and 2010–2014) because the sensitivity was considerably larger from 2010 to 2014. As the dependent variable (banks' sensitivity to level changes in the yield curve, $\beta_{pc,t}^{(i)}$) has almost exclusively positive values (see Figure 4b and Tables 2 and A1), a positive coefficient for the explanatory variables implies that the positive sensitivity to level changes in the yield curve is even more

TABLE 4 Explaining single supervisory mechanism banks' sensitivity to level changes

This table reports regression results. The dependent variable corresponds to banks' interest rate risk exposure to level changes in the euro area yield curve. RWA refers to risk-weighted assets. Core Tier capital ratio is defined as a ratio of a bank's core equity capital to risk-weighted assets. Banks' size is calculated as a logarithm of total assets. The details of the items included in other positions are provided in the Supporting Information: Internet Appendix. All the data is collected on an annual basis from the SNL Financial database. Time period: 2005 to 2014. In each case, the regression is run while controlling for time- and country-fixed effects. Standard errors are clustered at bank level; *t* statistics are shown in brackets. *, ** and *** indicate significance at the 10%, 5% and 1% levels.

Regressors	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
	Full period	2005–2009	2010–2014	Full period	2005–2009	2010–2014
Total financial assets to total assets	0.035 (0.55)	0.128 (1.45)	0.019 (0.27)			
Securities to total assets				0.056 (1.43)	0.010 (0.10)	−0.005 (−0.08)
Net customer loans to total assets				0.079* (1.80)	−0.025 (−0.26)	0.030 (0.58)
Core Tier capital ratio	0.136** (2.10)	0.215 (1.28)	0.185*** (2.81)	0.087 (1.30)	−0.014 (−0.07)	0.102 (1.34)
Deposits to total liabilities (and equity)				−0.079** (−2.50)	−0.002 (−0.05)	−0.102** (−2.14)
Term deposits to deposits				0.014 (0.70)	0.002 (0.06)	0.002 (0.11)
Total debt to total liabilities (and equity)	−0.069*** (−2.83)	−0.002 (−0.08)	−0.058* (−1.82)			
Subordinated debt to total liabilities (and equity)				0.193 (1.36)	−0.401** (−2.10)	0.248 (1.27)
Senior debt to total liabilities (and equity)				−0.070** (−2.14)	0.048 (0.78)	−0.117** (−2.55)
Derivative liabilities to total liabilities (and equity)	0.029 (0.78)	−0.008 (−0.25)	0.039 (0.72)	0.107 (1.22)	0.175 (1.65)	0.187* (1.74)
Net interest income to operating revenue	−0.016*** (−7.37)	−0.002 (−0.13)	−0.015*** (−5.04)	−0.011 (−0.93)	0.002 (0.09)	−0.008 (−0.45)
Net fee income to RWA	−0.246 (−0.89)	0.140 (0.27)	−0.078 (−0.20)	0.365 (1.12)	0.476 (0.68)	0.394 (1.00)
Return on average assets	−0.468** (−2.61)	−1.072 (−1.65)	−0.488*** (−3.05)	−0.377** (−2.15)	−1.649** (−2.55)	−0.275 (−1.53)

TABLE 4 (Continued)

Regressors	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
	Full period	2005–2009	2010–2014	Full period	2005–2009	2010–2014
Net customer loans minus deposits to total assets	0.069*** (3.17)	0.026 (1.06)	0.046* (1.78)			
Loan loss reserves to gross customer loans	−0.118 (−1.55)	0.430 (1.18)	−0.169* (−1.71)	−0.124* (−1.92)	0.275 (0.54)	−0.142 (−1.50)
Size	0.004 (1.50)	0.004 (1.56)	0.003 (1.07)	0.002 (0.72)	0.002 (0.60)	−0.001 (−0.34)
Sensitivity to slope changes	0.118*** (3.75)	−0.071 (−0.97)	0.165*** (4.49)	0.128*** (4.26)	−0.034 (−0.41)	0.172*** (5.11)
Sensitivity to curvature changes	−0.055*** (−3.32)	−0.105** (−2.50)	−0.004 (−0.14)	−0.041* (−1.94)	−0.090* (−1.83)	−0.011 (−0.35)
Sensitivity to market factor changes	0.026*** (5.38)	0.025*** (4.23)	0.015*** (2.80)	0.019*** (4.12)	0.022*** (3.10)	0.014*** (3.02)
Observations	235	82	153	204	73	131
R ²	0.72	0.85	0.71	0.73	0.86	0.73
R ² (within country)	0.52	0.65	0.54	0.52	0.72	0.58

pronounced. The overall R^2 values as well as the within-country R^2 values confirm that the explanatory power of all models is sufficiently large.

Regression results are mostly in line with the expectations explained in Section 4.2: While the coefficients for total financial assets and for securities are insignificant, the ratio of net customer loans to total assets is positively related to banks' sensitivity to level changes, which corresponds with the expected effect on earnings. The negative relation of deposits to total liabilities (and equity) is also in line with our expectation because compared to other funding sources, a relatively smaller portion of a rate shock is passed onto customers. Given that, in particular, the second half of the sample period was characterized by rate cuts and deposit gathering—meaning that the difference between the market rate and the deposit rate became smaller or even reversed—the effect is significantly stronger from 2010 onwards. An exception is term deposits which prove to be unrelated to level swings.

We observe a significantly negative relation of total debt to total liabilities (and equity) and confirm this finding when we apply the breakdown of debt into subordinated and senior debt. Banks with a lower amount of marketable debt on the liability side of their balance sheets are more sensitive to changes in the level of the yield curve. These findings are in line with our expectations.

The significant negative coefficients for the ROAA indicate that less profitable banks are more exposed to changes in the level of the term structure. On the one hand, this negative relation may result from rising long-term interest rates that translate into immediate capital losses on the long-term assets and thus lower profitability. On the other hand, more profitable banks are more resilient in absorbing these potential losses. Thus, higher ROAA, which to

some extent serves as a cushion against adverse market scenarios, is linked to lower sensitivity to level swings in the yield curve. The same rationale applies to the risk-reducing function of the net interest income to operating revenue: Banks which rely more heavily on interest income as an earnings source are less exposed to level changes in the yield curve, possibly because they apply effective hedging strategies.

Further, our regression results hint towards a negative relation of credit risk and interest rate risk: Banks with higher ratios of loan loss reserves to gross customer loans are, on average, less exposed towards interest rate risk. The coefficients for bank size are very small and insignificant. One empirical finding that does not correspond with our expectations is represented by the positive coefficients for the Core Tier capital ratio. This indicates that banks with less capital and, hence, a lower risk-bearing capacity are also less exposed to level changes in the yield curve. The contrary effect that has been identified in the literature (Au Yong et al., 2009; Fraser et al., 2002; Saporoschenko, 2002). However, one might also argue that banks with lower capital ratios are better hedged or engage in less risky business and are, thus, less exposed to interest rate risk.

Finally, the coefficients for banks' sensitivities to slope and curvature swings as well as banks' sensitivity to market factor changes reveal that banks which are more exposed to changes in the slope of the yield curve or changes in the overall stock market are also more sensitive to changes in the level of the yield curve. However, there appears to be a negative relationship between curvature and level sensitivities: the more sensitive banks are to curvature swings, the less their stock prices react to level swings in the yield curve. This underlines the importance of including all three yield curve parameters in our study.

We conduct three additional tests as explained in Section 4.2 to check our results for robustness in alternative model specifications. First, while the regressions shown in Table 4 include year-specific time FE that control for the general macroeconomic situation in each year, we also conduct a pooled regression analysis without time FE. Our results are overwhelmingly confirmed in the robustness check with excluded time FE. Second, we re-estimate the same regressions as shown in Table 4 but consider end-year values for the explanatory variables (see Section 4.2), while averages over two subsequent years have been used in our baseline model (Table 4). With very few exceptions, we can confirm all of our results. Third, we calculate the annual sensitivities by taking the median of the daily sensitivities, instead of taking the mean as in the baseline model, and our results are also confirmed by this robustness check.²⁰

4.3.2 | Exposure to slope swings

As explained in Section 3.2, more than 75% of all interest rate variability can be attributed to level shifts. Hence, the factors that explain banks' sensitivity to changes in the level of the yield curve should be considered as *primary* bank-specific factors for interest rate risk exposure, which we analyzed in Section 4.3.1. However, irrespective of a banks' sensitivity to level shifts, it may still have exposure to nonparallel changes in the yield curve. This sensitivity and the associated *secondary* bank-specific factors are analyzed in this section.

²⁰These results are available upon request.

TABLE 5 Explaining single supervisory mechanism banks' sensitivity to slope swings

This table reports regression results. The dependent variable states banks' interest rate risk exposure to slope changes in the euro area yield curve. RWA refers to risk-weighted assets. Core Tier capital ratio is defined as a ratio of a bank's core equity capital to risk-weighted assets. Size is calculated as a logarithm of banks' total assets. The details of the items included in other positions are provided in the Supporting Information: Internet Appendix. All the data is collected on an annual basis from the SNL Financial database. Time period: 2005–2014. In each case, the regression is run while controlling for time- and country-fixed effects. Standard errors are clustered at bank level; *t* statistics are shown in brackets. *, ** and *** indicate significance at the 10%, 5% and 1% levels.

Regressors	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
	Full period	2005–2009	2010–2014	Full period	2005–2009	2010–2014
Total financial assets to total assets	−0.013 (−0.07)	−0.033 (−0.32)	−0.021 (−0.06)			
Securities to total assets				−0.027 (−0.21)	−0.089 (−0.60)	−0.008 (−0.05)
Net customer loans to total assets				−0.016 (−0.13)	−0.248 (−1.66)	0.069 (0.43)
Core Tier capital ratio	−0.242** (−2.37)	−0.707*** (−3.14)	−0.350* (−1.84)	−0.164 (−1.26)	−0.494* (−1.89)	−0.262 (−1.25)
Deposits to total liabilities (and equity)				0.072 (1.14)	0.151 (1.70)	0.056 (0.55)
Term deposits to deposits				−0.017 (−0.52)	−0.090* (−1.74)	0.025 (0.81)
Total debt to total liabilities (and equity)	0.021 (0.47)	0.067 (0.97)	−0.008 (−0.12)			
Subordinated debt to total liabilities (and equity)				0.331 (1.08)	0.636 (1.25)	0.242 (0.50)
Senior debt to total liabilities (and equity)				0.040 (0.52)	0.182* (1.76)	0.026 (0.23)
Derivative liabilities to total liabilities (and equity)	0.014 (0.36)	−0.059 (−1.58)	−0.014 (−0.15)	0.126 (1.13)	0.127 (0.62)	0.003 (0.02)
Net interest income to operating revenue	−0.009* (−1.90)	0.010 (0.24)	−0.003 (−0.41)	−0.025 (−1.36)	0.034 (0.83)	−0.028 (−1.05)
Net fee income to RWA	−0.543 (−0.83)	0.825 (1.24)	−1.356 (−1.53)	−1.306 (−1.59)	0.663 (0.71)	−2.074* (−1.81)
Return on average assets	−0.338 (−0.93)	1.481 (1.60)	0.016 (0.05)	−0.374 (−0.91)	1.337 (1.20)	−0.072 (−0.19)

(Continues)

TABLE 5 (Continued)

Regressors	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
	Full period	2005–2009	2010–2014	Full period	2005–2009	2010–2014
Net customer loans minus deposits to total assets	−0.000 (−0.00)	−0.041 (−0.82)	0.032 (0.83)			
Loan loss reserves to gross customer loans	−0.068 (−0.36)	−0.121 (−0.22)	−0.135 (−0.52)	−0.011 (−0.07)	−0.238 (−0.40)	−0.076 (−0.40)
Size	0.001 (0.34)	−0.001 (−0.31)	0.006 (1.57)	−0.000 (−0.06)	−0.003 (−0.68)	0.007* (1.88)
Sensitivity to level changes	0.543*** (2.79)	−0.281 (−0.90)	0.866** (2.67)	0.637*** (2.80)	−0.131 (−0.40)	0.984** (2.47)
Sensitivity to curvature changes	0.372*** (10.65)	0.293** (2.54)	0.310*** (4.87)	0.366*** (10.53)	0.361*** (3.06)	0.307*** (4.51)
Sensitivity to market factor changes	−0.007 (−1.17)	−0.003 (−0.18)	−0.004 (−0.43)	−0.005 (−0.83)	−0.014 (−0.78)	−0.005 (−0.57)
Observations	235	82	153	204	73	131
R ²	0.83	0.67	0.73	0.83	0.69	0.72
R ² (within country)	0.35	0.41	0.42	0.39	0.50	0.47

To investigate which bank-level indicators can explain SSM banks' interest rate risk exposure to slope swings in the yield curve, we run separate regressions of banks' estimated exposures to changes in the slope of the yield curve on the same set of explanatory variables as in the previous section for level changes. The results are provided in Table 5. Again, the overall R^2 values, as well as the within-country R^2 values, confirm that the explanatory power of all models is sufficiently large.

Two specificities are worth noting when drawing conclusions from these coefficients. First, there is uncertainty in the type of the slope change, as an increase in the slope parameter could be triggered either by decreased short-term rates or by increased long-term rates. For example, in 2009, short-term rates decreased while the long term rates did not change too much, while in 2014, short term rates were rather stable and long term rates decreased. In both cases, the term structure became steeper, but the effect on the present value of banks' interest-sensitive positions may be very different.²¹ Second, the majority of banks has on average a positive exposure to steepening yield curves (see Table 2). However, as Figure 4c and Table A1 show, this finding is mostly driven by

²¹From a present value perspective, a flattening of the term structure triggered by the long term (like in 2014) means that banks' long-term assets have to be discounted less, which leads to a significant increase in the market value of interest-sensitive positions. Instead, a flattening of the term structure triggered by the short term (like in 2009) means that short-term positions, in particular, liabilities, are discounted more strongly, which increases the present value of interest-sensitive positions. The latter effect is much weaker than the impact of a long-term flattening in the yield curve.

sensitivities to slope changes from 2010 onwards, which are significantly positive, while sensitivities are near zero and partly negative during the years 2005–2009.

Hence, a positive coefficient in Table 5 means—in particular, during the second half of the sample period—that increasing values of regressors go along with higher values of the dependent variable $\beta_{pc_2,t}^{(i)}$ and, thus, expose the bank more strongly to slope swings. In contrast, a negative coefficient pulls $\beta_{pc_2,t}^{(i)}$ closer to zero and, thus, reduces the sensitivity to slope swings.

Again, results are in line with our expectations as explained in Section 4.1 with one exception: the coefficient for banks' senior debt to total liabilities is significantly positive for the subperiod 2005–2009. Compared to the results for banks' exposure to level shifts in the yield curve (see Section 4.3.1), some coefficients shown in Table 5 point however in a different direction. While banks with a high Core Tier capital ratio exhibit a higher exposure to level shifts, their sensitivity to changes in the slope of the yield curve is lower. While banks with a higher ratio of senior debt to total liabilities (and equity) are less exposed to level shifts, their sensitivity to slope fluctuations in the yield curve is higher (in the subperiod 2005–2009). These different findings underscore the need to include several parameters of the yield curve in our study. However, it is also important to recall that the sensitivity to level shifts accounts for the vast majority of banks' interest rate risk exposure, meaning that these effects should only be regarded as *secondary* relative to the results explained in Section 4.3.1.

With regard to the interaction between banks' sensitivity to slope swings and other parameters of the interest rate structure, we observe that banks with a higher exposure to level and curvature changes also react more sensitively to slope swings of the yield curve. As for level swings in yield curves, results for the pooled regression without time FE, for the end-year values of the explanatory variables and for median sensitivities confirm the results.²²

4.3.3 | Exposure to curvature swings

To investigate the determinants of SSM banks' interest rate risk exposure to curvature swings in the yield curve, we implement the same models as in Sections 4.3.1 and 4.3.2, but with curvature exposure $\beta_{pc_3,t}^{(i)}$ as the dependent variable. The general disclaimer that exposure to slope and curvature swings in the term structure should only be regarded as *secondary* relative to banks' *primary* sensitivity to level swings applies to this section, too. Estimated coefficients are shown in Table 6. Again, the overall R^2 values, as well as the within-country R^2 values, confirm that the explanatory power of all models is sufficiently large.

When comparing the coefficient estimates for curvature exposure shown in Table 6 with our expectations as explained in Section 4.1 and the results for both level and slope exposure (Sections 4.3.1 and 4.3.2), we detect a few differences: First, as in the case of level changes, banks with a higher Core Tier capital ratio are more exposed to curvature swings.

Second, banks with a higher ratio of net interest income to operating revenue exhibit a higher sensitivity to changes in the curvature of the yield curve. It is also noteworthy that some of the coefficients (e.g., for term deposits, loan loss reserves and bank size) differ between the first and second subperiods, so that there is no completely consistent picture in these cases. However, given that sensitivity towards curvature swings accounts for only a small portion of

²²These results are available upon request.

TABLE 6 Explaining single supervisory mechanism banks' sensitivity to curvature swings

This table reports the dependent variable corresponding to banks' interest rate risk exposure to curvature changes in the euro area yield curve. RWA refers to banks' risk-weighted assets. Core Tier capital ratio is defined as a ratio of a bank's core equity capital to RWA. Banks' size is calculated as a logarithm of total assets. The details of the items included in other positions are provided in the Supporting Information: Internet Appendix. All the data is collected on an annual basis from the SNL Financial database. Time period: 2005–2014. In each case the regression is run while controlling for time- and country-fixed effects. Standard errors are clustered at bank level; *t* statistics are shown in brackets. *, ** and *** indicate significance at the 10%, 5% and 1% levels.

Regressors	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
	Full period	2005–2009	2010–2014	Full period	2005–2009	2010–2014
Total financial assets to total assets	0.034 (0.28)	0.169* (1.75)	0.045 (0.20)			
Securities to total assets				0.053 (0.45)	−0.034 (−0.18)	0.117 (0.72)
Net customer loans to total assets				0.297** (2.30)	0.274 (1.46)	0.156 (0.96)
Core Tier capital ratio	0.878*** (7.40)	0.669* (1.77)	0.948*** (7.04)	0.785*** (6.64)	0.394 (0.79)	0.942*** (6.14)
Deposits to total liabilities (and equity)				−0.303*** (−3.94)	−0.246** (−2.26)	−0.144 (−1.59)
Term deposits to deposits				−0.039 (−1.23)	0.135*** (2.96)	−0.114** (−2.61)
Total debt to total liabilities (and equity)	−0.222*** (−3.02)	−0.215** (−2.24)	−0.240*** (−3.53)			
Subordinated debt to total liabilities (and equity)				−0.571* (−1.92)	−0.948 (−1.33)	−0.267 (−0.55)
Senior debt to total liabilities (and equity)				−0.433*** (−4.34)	−0.351*** (−2.87)	−0.287** (−2.59)
Derivative liabilities to total liabilities (and equity)	0.208** (2.27)	0.060 (0.47)	0.395*** (3.23)	0.046 (0.24)	0.068 (0.24)	0.261 (0.73)
Net interest income to operating revenue	0.018** (2.27)	0.013 (0.33)	0.024** (2.17)	0.058 (1.45)	−0.000 (−0.00)	−0.007 (−0.11)
Net fee income to RWA	−1.214 (−1.40)	−1.841 (−1.67)	−1.069 (−1.07)	−3.796*** (−3.17)	−3.058*** (−3.07)	−3.386** (−2.44)
Return on average assets	0.055 (0.12)	−2.192 (−1.63)	−0.032 (−0.07)	0.340 (0.71)	−1.637 (−0.89)	0.059 (0.12)

TABLE 6 (Continued)

Regressors	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
	Full period	2005–2009	2010–2014	Full period	2005–2009	2010–2014
Net customer loans minus deposits to total assets	0.142** (2.18)	0.153* (1.81)	0.132** (2.15)			
Loan loss reserves to gross customer loans	0.315* (1.99)	−0.835 (−1.39)	0.623*** (3.12)	0.294* (1.87)	−1.101* (−1.85)	0.683*** (2.80)
Size	0.000 (0.03)	0.020*** (3.18)	−0.015*** (−2.94)	0.005 (1.10)	0.015*** (3.79)	−0.009 (−1.13)
Sensitivity to level changes	−0.458*** (−3.45)	−0.912** (−2.47)	−0.036 (−0.14)	−0.360* (−2.03)	−0.803 (−1.68)	−0.110 (−0.35)
Sensitivity to slope changes	0.672*** (5.21)	0.638** (2.41)	0.507*** (3.00)	0.640*** (4.31)	0.839*** (3.12)	0.527*** (2.82)
Sensitivity to market factor changes	0.023*** (2.99)	−0.007 (−0.49)	0.045*** (4.92)	0.026*** (3.88)	0.014 (0.57)	0.039*** (3.66)
Observations	235	82	153	204	73	131
R ²	0.84	0.82	0.77	0.85	0.83	0.77
R ² (within country)	0.45	0.51	0.50	0.50	0.59	0.51

banks' sensitivity to interest rate changes, these factors should not be seen as *primary* for banks' overall interest rate risk.

With regard to the interaction between banks' sensitivity to curvature swings and other risk parameters, it turns out that banks with a higher exposure to slope changes and market factor changes are also more sensitive to curvature swings of the yield curve, while there is an opposite effect for banks with a higher sensitivity towards level shifts of the yield curve. These results are consistent with the observations made above. Finally, as in the previous cases, the pooled regression without time FE, the regressions on the end-year values and the regressions based on median sensitivities corroborate the results.²³

5 | CONCLUSIONS

In this paper, we investigate the interest rate risk exposure of listed European banks, which fall under the ECB's SSM in the euro area. This sample covers the most relevant banks in the euro area. The analysis indicates that banks' stock prices react to various types of movements in the yield curve. Moreover, banks' sensitivity to level, slope and curvature swings in the yield curve varies over time. We also find that level shifts explain more than 76% of total interest rate

²³These results are available upon request.

variation. Hence, they are clearly more relevant than slope or curvature changes in terms of economical relevance.

On average, banks' stock prices exhibit a positive sensitivity to level, slope and curvature increases. This observation holds true for various frequencies of the underlying data (i.e., daily and weekly), different proxies of risk-free interest rates and also if we add a factor explicitly controlling for credit risk or if we use an OLS model instead of the Bayesian DCC M-GARCH model. More precisely, out of 36 banks, all exhibit a significantly positive coefficient to level changes, which indicates that their stock prices tend to increase if interest rate levels rise, 35 banks have a positive coefficient to slope changes (i.e., a steepening yield curve), and 31 banks show a positive coefficient to curvature changes. The economic impact is large as well. A 25-basis points parallel upward shift of the yield curve would result in an increase in an average bank's stock prices of 3.65%.

One further contribution of our work compared to previous studies is the inclusion of curvature swings. For our data set which covers several crises, curvature swings amount to more than 8% of the total variation of the yield curve; this is more than usually attributed to this type of interest rate movement. This high attribution together with the most significant coefficients makes curvature risk economically relevant. Further, regulators have increased the requirements on the selection of interest rate scenarios for banks' internal risk measurement systems and want banks to consider changes in tilts as well (BCBS, 2016, pp. 44–47). Both aspects emphasize the importance of considering curvature movements.

The positive sensitivity is consistent with Ballester et al. (2009). This suggests that euro area banks may, at least during a low-interest-rate environment, be exposed in the opposite direction to interest rate shocks than US banks (English et al., 2018). In terms of the underlying theoretical rationale, the prospect for banks to earn an increased interest income after an increase in the yield curve seems to dominate the negative impact on the net present value.

At the onset of the financial crisis, interest rate risk exposure to changes in the euro area yield curve increased for almost all banks in the sample. In the subsequent years, banks maintained a high level of interest rate risk sensitivity regarding level swings, while the sensitivity to slope and curvature swings increased in particular from end-2012/early-2013 when the ECB began to take nonstandard monetary policy measures with its active balance sheet expansion.

Our analysis of the bank-specific factors that influence their interest rate risk exposure indicates that the market price of equity of banks with higher capital ratios, higher proportions of customer loans and lower proportions of deposits is more sensitive to interest rate swings. Knowledge about these factors which make a bank more vulnerable to interest rate risk provides valuable information for supervisory decision making and market analysts' assessment of bank stocks.

In summary, our results give fundamentally new insights into European banks' interest rate risk and their risk management practices in times of crises and very low interest rates. This is particularly important given the challenges for banks in the current crisis environment, their need to adjust to regulatory reforms and new technologies, and the clear financial stability implications of both developments.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the third party providers Thomson Reuters Datastream, Moody's CreditEdge and SNL Financial as well as from public domain resources. Restrictions apply to the availability of these data, which were used under license for this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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APPENDIX A

Testing the risk factors for normality

Figure A1

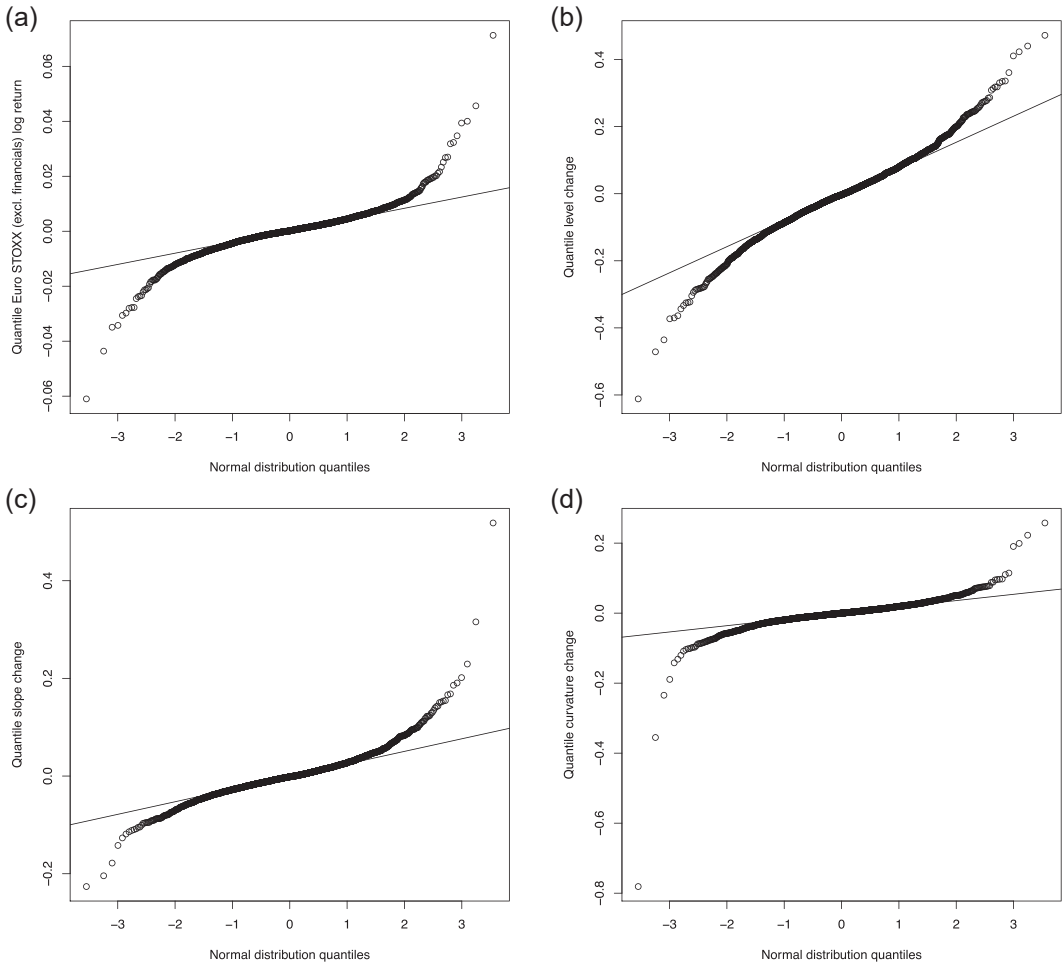


FIGURE A1 Normal QQ plots: Interest rate risk factors (a) Normal QQ plot: r_m ; (b) Normal QQ plot: pc_1 ; (c) Normal QQ plot: pc_2 ; (d) Normal QQ plot: pc_3 . The figures present tests for evidence of whether the market risk factor and the interest rate risk factors used in the analysis are normally distributed. The parameter r_m represents the log-returns of the EURO STOXX 50 excluding financials index, whereas pc_1 , pc_2 and pc_3 represent the first three principal components of changes in the euro area yield curve (see Section 3.1.1). Sample quantiles are plotted against theoretical quantiles of the normal distribution. The time period for which the data has been collected is 1/2005–12/2014. The plot indicates that the distribution of log-returns of the market risk factors as well as the changes in the yield curve slope, level and curvature parameters deviates from normality.

Robustness check: OLS regressions

Figure A2

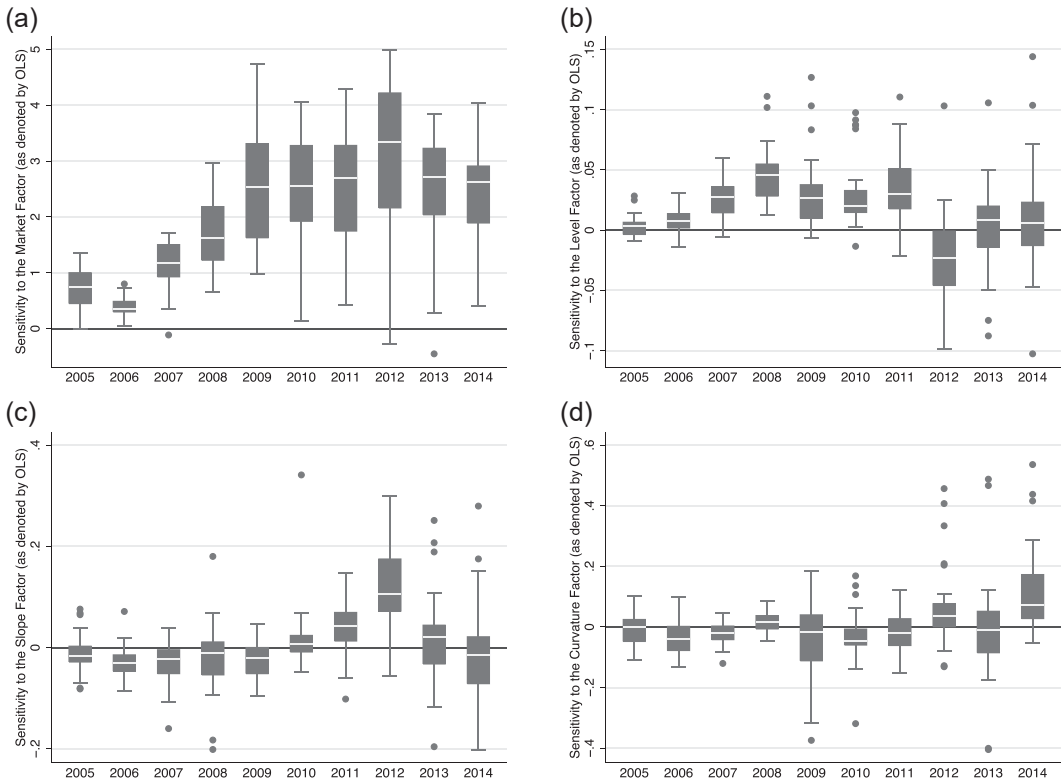


FIGURE A2 Single supervisory mechanism (SSM) banks' exposure to the market risk factor as well as to level, slope and curvature swings in the euro area yield curve using an OLS regression—yearly data (a) Sensitivity to the market risk factor (r_m); (b) Sensitivity to level swings (pc_1); (c) Sensitivity to slope swings (pc_2); (d) Sensitivity to curvature swings (pc_3). These figures present the variation in the market risk exposure and in the interest rate risk exposure to swings in the euro area yield curve observed among the SSM banks. (a) shows a positive relation between banks' stock prices and the market risk factor. (b) shows that banks' stock prices are, particularly between 2005 and 2011, positively associated with the first principal component which goes along with interest rate increases. Interestingly, this relationship weakens from the year 2012 to 2014. (c) reveals that banks have been barely sensitive to slope changes from the year 2005 to 2010. However, a positive sensitivity can be observed for the years 2011–2014. The sensitivity to curvature is depicted in (d). It turns out that the sensitivity is around zero or slightly negative in the years 2005–2013 but becomes positive for 2014. The dots visualize outliers.

Banks' interest rate risk exposure in subperiods
Table A1

TABLE A1 Banks' interest rate risk exposure to level, slope and curvature swings in the yield curve (subperiods)

This table reports the single supervisory mechanism (SSM) banks' average daily exposure to changes in the respective risk factors during 1/2005–12/2014. 'Market' corresponds to banks' exposure to market risk (known as 'market beta'), 'Level', 'Slope' and 'Curvature' denote banks' exposure to swings in the level, slope and curvature of the euro area yield curve (see Section 3.1.1 for details). All the exposures are given as a percentage change in a bank's stock price associated with a 1 percentage point change in the corresponding interest rate risk factor. *** indicates statistical significance at the 1% level.

SSM bank	Country	2005–2009				2010–2014			
		Market	Level	Slope	Curvature	Market	Level	Slope	Curvature
Erste Group Bank AG	AT	1.3704***	0.0680***	-0.0128	-0.0810***	1.5258***	0.0596***	0.0914***	0.0768***
Dexia SA	BE	0.5413***	0.0579***	-0.0354***	-0.0522***	0.7172***	0.0990***	0.0573***	0.0654
KBC Group NV	BE	0.9755***	0.0625***	-0.0186***	-0.0382***	1.1338***	0.0736***	0.0788***	0.1053***
Hellenic Bank	CY	0.3689***	0.0382***	-0.0517***	-0.0258***	0.2608***	0.0311***	0.0123***	0.0473*
Aareal Bank AG	DE	1.4306***	0.0562***	-0.0270***	-0.0740***	1.7046***	0.0559***	0.0481***	0.0682**
Commerzbank AG	DE	1.5126***	0.0695***	-0.0117	-0.0230***	1.6767***	0.0679***	0.0787***	0.1093***
Deutsche Bank AG	DE	1.5553***	0.0565***	-0.0085***	-0.0418***	1.6856***	0.0616***	0.0567***	0.0567
IKB Deutsche Industriebank AG	DE	0.9169***	0.0369***	-0.0161***	-0.0336***	0.5615***	0.0375***	0.0599***	0.0854***
Bankinter SA	ES	1.0588***	0.0482***	0.0054***	-0.0346***	1.3959***	0.0635***	0.0915***	0.1152***
BBVA SA	ES	1.4302***	0.0545***	-0.0083***	-0.0520***	1.7584***	0.0665***	0.0919***	0.0780*
Banco de Sabadell SA	ES	0.8613***	0.0336***	-0.0051***	-0.0338***	1.0826***	0.0411***	0.0739***	0.0619***
Banco Popular Español SA	ES	1.0650***	0.0440***	0.0006	-0.0481***	1.2383***	0.0570***	0.0800***	0.0649***
Banco Santander SA	ES	1.7504***	0.0567***	-0.0031	-0.0445***	2.0664***	0.0700***	0.0791***	0.0731***
BNP Paribas SA	FR	0.8599***	0.0577***	-0.0002	-0.0543***	1.0216***	0.0744***	0.0921***	0.1020***

TABLE A1 (Continued)

SSM bank	Country	2005–2009				2010–2014			
		Market	Level	Slope	Curvature	Market	Level	Slope	Curvature
Crédit Agricole SA	FR	1.3326***	0.0651***	-0.0300***	-0.0768***	1.6701***	0.0765***	0.1001***	0.1043
Société Générale SA	FR	1.0507***	0.0563***	-0.0039	-0.0646***	1.3642	0.0842	0.0836***	0.0790
Alpha Bank AE	GR	0.7581***	0.0514***	0.0145***	-0.0205***	1.0517***	0.0920***	0.1468***	0.2045***
Eurobank Ergasias SA	GR	0.7698***	0.0645***	-0.0198**	-0.0355***	0.7157***	0.1017***	0.1435***	0.2376***
National Bank of Greece SA	GR	0.4703***	0.0187***	0.0070***	-0.0106***	0.4731***	0.0457***	0.0571***	0.0532***
Piraeus Bank SA	GR	0.9090***	0.0513***	-0.0068*	-0.0340***	1.2333	0.0888	0.1293***	0.1912***
Bank of Ireland	IE	1.2669***	0.0589***	-0.0396***	-0.1021***	1.4289***	0.0748***	0.0639***	0.0492***
Allied Irish Banks. Plc	IE	0.9230***	0.0537***	-0.0494***	-0.0829***	0.9319***	0.0764***	0.0931***	0.1024
Banca Carige SpA	IT	0.7938***	0.0332***	-0.0086***	-0.0425***	1.1243	0.0518	0.0450***	0.0374***
Banca Monte dei Paschi di Siena SpA	IT	1.0671***	0.0369***	0.0090**	-0.0388***	1.7002	0.0806***	0.1307***	0.0656
Banca Popolare di Milano Scarl	IT	1.4434***	0.0388***	-0.0407***	-0.0854***	2.1033	0.0707***	0.1145***	0.0721***
Banco Popolare Società Cooperativa	IT	1.1889***	0.0486***	0.0299***	-0.0286***	1.7302	0.0739***	0.1293***	0.0446
Banca Popolare dell'Emilia Romagna SC	IT	0.6195***	0.0188***	-0.0034	-0.0023***	2.2073	0.0565***	0.1163***	0.0973***
Banca Popolare di Sondrio SCpA	IT	0.4988***	0.0160***	0.0013	0.0226***	1.4728	0.0451	0.0923	0.0607***
Credito Emiliano SpA	IT	1.0813***	0.0378***	-0.0145***	-0.0369***	1.4853	0.0643***	0.0531	0.0518
Credito Valtellinese Società Cooperativa	IT	0.6001***	0.0272***	0.0194***	-0.0099***	0.8546	0.0456	0.0907***	0.0609***
Intesa Sanpaolo SpA	IT	1.2818***	0.0485***	0.0064***	-0.0083***	1.9378	0.0826	0.1173	0.0949
Mediobanca SpA	IT	0.9883***	0.0376***	-0.0139**	-0.0198	1.6535	0.0687***	0.0915	0.0643
UniCredit SpA	IT	1.0961***	0.0589***	0.0027**	-0.0263***	1.4121	0.0902***	0.1304	0.1085
Unione di Banche Italiane SCpA	IT	1.0156***	0.0382***	0.0064***	-0.0123***	1.7929	0.0664***	0.1068	0.0687***
Banco BPI SA	PT	0.7268***	0.0337***	-0.0053	-0.0242	1.1973	0.0616	0.0823	0.0902
Banco Comercial Português SA	PT	0.9811***	0.0335***	-0.0100**	-0.0129***	1.8250	0.0522	0.0596	0.1110

The interest rate risk exposure of the biggest banks

Figure A3

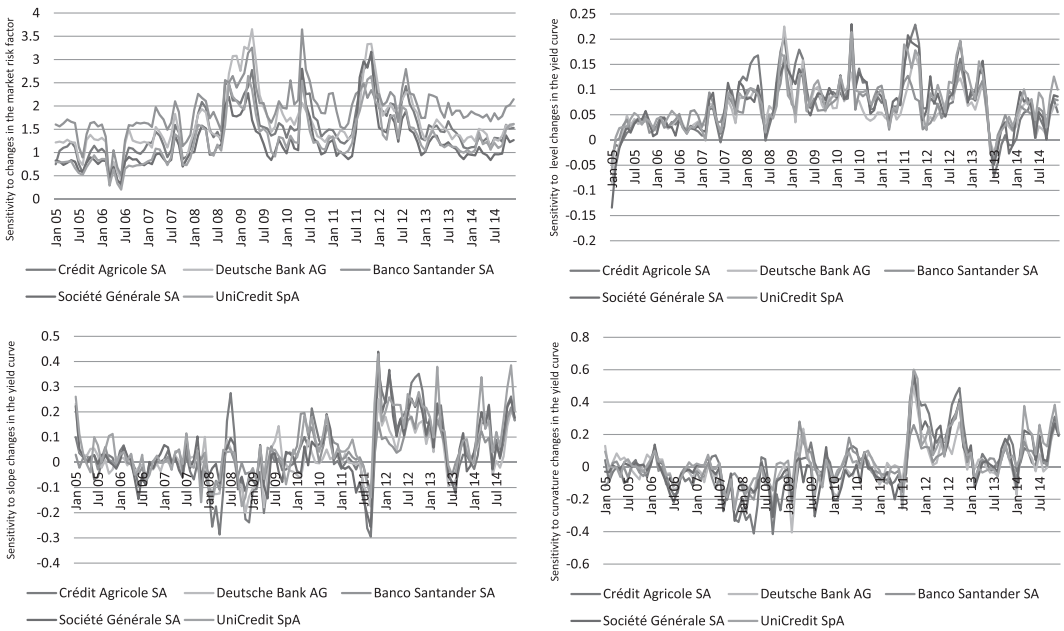


FIGURE A3 Single supervisory mechanism banks' exposure to the market risk factor as well as to level, slope and curvature swings in the euro area yield curve—five biggest banks. These figures present the market risk and interest rate risk exposure of the five biggest banks included in our sample based on monthly averages of sensitivities. It shows the exposure to market risk changes (upper left figure), level changes (upper right figure), slope changes (bottom left figure) and curvature changes (bottom right figure). It turns out that the banks' sensitivities change over time and that some banks tend to be stronger exposed to interest rate risk than other banks.

Bank characteristics in a representative balance sheet

Table A2

TABLE A2 A representative balance sheet

This table reports the single supervisory mechanism banks' representative balance sheet reconstructed from the data available in the SNL Financial database. The bold positions sum-up to the balance sheet sum. The following positions are assumed to be interest rate risk-sensitive on the asset side: net loans to customers and securities, which combine into financial assets. From the liability side, deposits, term deposits, total debt (with subordinated debt and senior debt as subcomponents) and total financial liabilities with all subcomponents are rate-sensitive. The details of each position are reported in the Supporting Information: Internet Appendix.

Assets	Liabilities
Cash and cash equivalents	Total equity
of which: Cash and balances with central banks	Deposits
of which: Net loans to banks	of which: Deposits from banks
Net loans to customers	of which: Term deposits from banks
of which: Gross loans to customers	of which: Deposits from customers
of which: Reserve on loans to customers	of which: Term deposits from customers
Securities	Total debt
Total financial assets	of which: Subordinated debt
Equity accounted investments	of which: Senior debt
Other investments	Securities sold, not yet purchased
Unit-linked investments	Other financial liabilities
Insurance assets	Derivative liabilities
Noncurrent assets HFS and discontinued operations	Total financial liabilities
Tangible and intangible assets	Unit-linked insurance and investment contracts
Tax assets	Insurance liabilities
Total other assets	Noncurrent liabilities HFS & discontinued operations
	Tax liabilities
	Noncurrent asset retirement obligations
	Other provisions
	Total other liabilities
Total assets	Total liabilities (and equity)