Credit Risk Taking and Maturity Mismatch: the Role of the Yield Curve[1]

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[PRELIMINARY VERSION]

Abstract

We study the credit risk taking behaviour of Italian banks in response to changes in the term structure of interest rates using a confidential dataset on new loans to non-financial firms. We find that ex ante risk-taking is negatively related to the short end of the yield curve and positively to the long end. Banks' business model, as captured not only by capitalization but also by the maturity mismatch between their assets and liabilities, is key to relate these findings to the theoretical literature.

JEL classification: E30; E32; E51
Keywords: yield curve; risk-taking channel; search-for-yield

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1. Introduction

The decade preceding the global financial crisis has been characterized by a stable negative relation between the level and the slope of the yield curve in advanced economies. Since the outbreak of the financial crisis this relation has changed substantially. Decreasing natural rates of interest and unconventional monetary policies undertaken by major central banks have led to a reduction of both the short and long-term interest rates and, after the policy rates reached their effective lower bound, the slope of the yield curve progressively flattened. These are the salient features of the so-called low interest rate environment (LIRE).

Notwithstanding low interest rates are beneficial for an economy facing a deep and prolonged recession, as they reduce funding costs, ease credit conditions and expand financial wealth by increasing asset prices, there is a wide debate among policymakers about their potential side-effects, especially as far as financial stability is considered. Most of the concerns stem from pressures on banks' profitability and risk-taking incentives.

Banks issue short-term liabilities (deposits) in exchange for longer-term assets issued by households, firms and the Government. Non-credit institutions, such as pension funds and life insurance companies, instead, are characterized by long-term liabilities, whereas shares/units in funds of asset management companies are similar to bank deposits, as they are expected to be redeemable on a short-term basis. All these activities generate a maturity mismatch between the assets and the liabilities of financial institutions. As a consequence, changes in the term structure of interest rates may affect net interest margins, profitability and equity value, and the attitude toward the amount of risk they are willing to take.

The channels through which changes to the slope of the yield curve affect risk-taking have been extensively analysed in the theoretical literature. For example, Adrian and Shin (2011) develop a model of the risk-taking channel of the monetary policy transmission where a steepening of the yield curve increases net interest margins, equity value and, therefore, risk-bearing capacity of financial institutions characterized by a positive maturity mismatch between assets and liabilities. As a consequence, these firms would engage in "reach-for-yield" activities. On the other hand, the banking literature on asymmetric information and monitoring (see Allen et al., 2011) claims that an easing in credit standards – and an increase in banks' risk-taking – is typically associated with a reduction in the monitoring activity of borrowers by financial institutions. In Dell'Ariccia et al. (2014), banks' monitoring incentives depend positively on the spread between loan and deposit rates, and on the amount of equity in banks' capital structure. When a reduction in interest rates is associated with a compression of the bank spread due to a flattering of the yield curve, banks' profitability and monitoring incentives reduce, and ex-ante credit risk of their loan portfolio increases.

In this paper, we investigate the empirical relation between banks' attitude toward risk and the level and the slope of the yield curve.

Most of previous analyses have focused on the short end of the curve, finding a negative relation between banks' risk-taking and short-term interest rates. Results for the other components of the term structure are scant and inconclusive.[2] Maddaloni and Peydrò (2011) find a positive relationship between banks' lending standards, as captured by survey data, and the short-term rate both in the euro area and the US; the effect of the long-term interest rates, instead is model-dependent and not robust. Jimenez et al. (2014) use credit history information on past doubtful loans from the Spanish credit register between 2002 and 2008 as an ex ante measure of firms' creditworthiness and provide robust evidence that a reduction of the overnight rate induces lowly capitalized banks to grant more loan applications to ex ante risky firms than highly capitalized banks; the long-term interest rate, as measured by Spanish government bond yields, has no significant effect when replacing the overnight rate in the regressions. Poligorova and Santos (2017) focus on the cost of credit in the US between 1990 and 2008 and find that loan spreads applied by banks to riskier firms become relatively smaller in response to a decrease in short-term interest rates and to an increase in long-term rates. Finally, Dell'Ariccia et al (2017) use loan-level data on internal banks' ratings from the Federal Reserve's Survey of Terms of Business Lending (STBL) over the period 1997 to 2011 and find that the riskiness of banks' loan portfolio is negatively associated with short-term interest rates. The term-spread between 10-year and one-year Treasury yields is introduced as a control in the model specification and has no significant effect on banks' risk-taking. Bonfim and Soares (2018) also explored various issues related to the risk-taking channel in Portugal but focused only on the effects of changes in the short-term interest rate.

This "missing evidence" of a clear and robust effect of changes in the yield curve components other than the short-term interest rate on risk-taking, notwithstanding the insights from the theoretical literature and the relevance in the policy debate, may be related to several explanations. First, the choice of the sample period may play an important role. Studies that include contemporaneously both the short-term interest rate and the slope of the

[2] Since we are interested on how risk-taking behaviour changes in response to movements in the term structure, we refer only to the strand of the literature on ex-ante measures of risk taking.

yield curve and focus on periods in which the two components are almost perfectly collinear may not be able to identify their effects separately. For example, in the US the correlation between these two components of the term structure increased from -0.65 in the 90s to about -0.95 between the beginning of the 2000s and the outbreak of the global financial crisis (the period in which most of the empirical analyses focus). Afterwards, the correlation declined to -0.5, as a consequence of the reduction of the natural rate of interest, the policy rates reaching their effective lower bound and the implementation of unconventional monetary measures. For works focusing on euro-area countries, the issue of multicollinearity could be less relevant as the correlation between the slope – measured by the spread between the 10-year IRS and the EONIA – and the level of the yield curve declined from -0.8 in the period between the beginning of the 2000s and the outbreak of the global financial crisis, to -0.2 thereafter.

A second possible explanation is the granularity of the dataset. Analyses that cannot fully control for borrower- or loan-specific characteristics may provide unreliable results on the statistical significance of some of the estimated coefficients. A similar concern rises from the omission of bank-specific characteristics which are not fully captured by bank fixed effects. As previously mentioned, the maturity mismatch between assets and liabilities plays an important role in the relationship between the slope of the yield curve and banks' risk-taking. To the extent that (*i*) banks business model in terms of duration gap changes over time, (*ii*) the empirical analysis comprises banks with both positive and negative duration gaps and (*iii*) the model specification does not take into account the heterogeneity in business models, the effect of the long-term interest rates may be, on average, biased downward.

In this paper we address the aforementioned issues. In particular, we use a confidential loan-level dataset for Italian banks over a period (2005-2016) which includes both "normal" and "exceptional" times and allows, therefore, for very different configurations in the term structure of interest rates.

The quality and the granularity of our dataset are appealing in a number of aspects. First, we consider as the ex-ante measure of credit risk the Z-score assigned by the Cerved group – the leading Information Provider in Italy on firms credit worthiness and one of the major rating agencies in Europe – to each borrower. The Z-score is a mapping of the probability of firm default over the next two years into risk ratings and it has been previously used to assess the heterogeneity in credit supply restrictions during the financial crisis (Albertazzi and Marchetti, 2010; Albareto and Finaldi Russo, 2012; Bonaccorsi and Finaldi Russo,

2016) and to test the “zombie lending” hypothesis in the case of Italy (Schivardi, Sette and Tabellini, 2017). Compared to the ex-ante measures of risk-taking used in Jimenez et al. (2014), where “risky” firms are those that in the four previous years had one or more nonperforming loans, the Z-score is much more granular, as it is based on a larger set of balance sheet characteristics. With respect to the measure adopted in Dell’Ariccia et al (2017), the Z-score is firm-specific but not bank nor loan-specific. On the one side, this allows us to isolate the credit score from bank-specific characteristics and, therefore, it allows an easier comparison of the measure of credit risk across banks; on the other side, we are not able to directly discriminate between other risk components of the loan, by looking at the Z-score. However, recent empirical analyses, such as Dell’Ariccia et al. (2017), show that loan characteristics explain a very small portion of the variation in loan risk ratings, implying that the most relevant component is the riskiness of the borrower. Moreover, since the credit register data include information about loan-specific characteristics such as the presence of collateral, the maturity, the amount granted and the frequency of the repricing of the loan, we can control for factors that may affect ex-ante credit risk at the time the loan was granted.

Second, we rely on supervisory reports to obtain bank-specific variables that can be used to investigate the heterogeneity of the estimated effects across banks. We focus on the duration gap between assets and liabilities as the main source of bank heterogeneity. This balance sheet characteristic has not been explored in previous literature on risk-taking, although it is a crucial ingredient to assess the sensitivity of the banks’ balance sheet to changes in market interest rates.

Third, since in our dataset the borrower identity is disclosed, we can control for within-borrower variation. Moreover, in some specifications aiming at assessing the heterogeneity of the estimated effects across banks, this information allows us to better control for loan demand at firm level (see Khwaja and Mian, 2008; Jimenez et al., 2014) or for relationship lending at the bank-firm pair, thus improving the identification.

Finally, all these features of the dataset allow us to construct two different measures of ex-ante credit risk-taking and, consequently, to use two empirical approaches proposed in the previous literature: the one by Dell’Ariccia et al (2017), which focuses on the changes in the class of risk to which it belongs the creditor of the marginal loan, and the one by Jimenez et al (2014), which considers the amount of credit granted to risky vs non-risky firms. Importantly, the two measures are not directly comparable as they provide different pieces of information on credit risk-taking: the former could be interpreted as a measure of the probability that the marginal loan is provided to a riskier firm (i.e. extensive margin); the latter is a measure that allows comparing how much additional credit is provided to firms belonging to different classes of risk (i.e. intensive margin). Both information are important and complement each other.

The paper provides two important contributions to the existing empirical literature on the relationship between interest rates and banks' risk-taking.

To the best of our knowledge, the paper is the first to present robust evidence of a positive and significant relationship between the slope of the yield curve and banks' risk-taking, as measured by both the probability of providing the loan to a riskier firm and the additional amount granted to riskier firms. We corroborate the view that the level of interest rates is an important driver of the ex-ante risk taking behaviour in providing new loans but, contrary to previous analyses, we find that both the short and the long end of the yield curve matter. In particular, the former affect negatively risk-taking, the latter positively. As a consequence, a steepening or an upward (parallel) shift of the curve increases banks' credit risk-taking. The effect is stronger for banks with larger duration gap, independently from the sign of the maturity mismatch.

The second contribution concerns the role of banks' heterogeneity in relating empirical findings to the theoretical explanations provided in the literature. Previous studies have mainly focused on banks' capitalization as the source of heterogeneity.[3] Results have been mixed, potentially country- and model-dependent, and in any case inconclusive. We show that in order to validate the theories on risk taking it is crucial to take into consideration the business model, as described not only by banks' capitalization but also by their duration gap. In particular, a steepening or an upward (parallel) shift of the yield curve increases profitability and risk-bearing capacity of banks with a positive maturity mismatch. As a consequence, for these financial institutions we corroborate the view that "reach-for-yield" (Adrian and Shin, 2011) motives are the main driver of their risk-taking behaviour, rather than "risk-shifting" considerations related to asymmetric information problems (Allen et al., 2011; Dell'Ariccia et al. 2014). The opposite holds true for banks with a negative duration gap, for which a steepening of the curve reduces profitability and, therefore, the monitoring effort in credit activity.

[3] Dell'Ariccia et al. (2017) show that more capitalized banks are more engaged in risk-taking behaviour when short-term rates are lowered; Jiménez et al. (2014), instead, find that the effect of low short-term rates on risk-taking is stronger for weakly capitalized banks.

The remainder of the paper is the following. In Section 2 we describe the sources and the main features of the dataset. In Section 3 we focus on the average effect of changes in short and long-term interest rates on credit risk-taking. Section 4 concentrates on heterogeneity of banks' business model in terms of maturity mismatches between assets and liabilities and in terms of banks' capitalization, and uses such heterogeneity in order to validate theoretical explanations presented in the literature. Section 5 concludes and offers the main policy implications.

2. The data

We exploit a unique dataset at the bank-firm level which collects confidential information over the period 2005 to 2016 from different sources. In particular, we merge (*i*) ex-ante firm level credit risk measures from Cerved with (*ii*) the loan-level information from the Italian Credit register and (*iii*) a number of bank- and firm-specific characteristics from Cerved and Supervisory Reports.

The ex-ante credit risk is measured at the borrower-level. We use the Z-score indicator provided by the Cerved group, which is the leading Information Provider in Italy on firms' credit worthiness and one of the major rating agencies in Europe.[4] This indicator is a mapping from the probability of firm default over the next two years into risk ratings, which vary from 1 to 9, with the latter representing the riskiest borrowers. The score is computed annually using the methodology described in Altman (1968) and Altman et al. (1994). In order to control for unobserved characteristics at both sector- and local-level, we take from the Cerved database also the firm sector of economic activity and the zip-code of the registered office. However, since we have the identity of the borrower we can control for invariant firm-specific characteristics in the estimated regressions using a full set of firm-fixed effects.

The data on lending come from the Italian Credit Register (CR), which covers the universe of banks operating in Italy. We restrict our analysis to the *new* term loans to non-financial firms. Term loans are mainly related to firms' investment decisions in the medium-term and differ considerably from revolving credit lines, which are instead managed day-by-day by firms depending on their liquidity needs. For the construction of the dataset we consider two distinct sections of the CR, which differ for the availability of the various

[4] While larger banks may also have their own internal models for the evaluation of ex-ante credit risk, in 2008 Cerved obtained ECAI recognition (external agency for evaluation of creditworthiness) from the Bank of Italy, becoming the first Italian credit rating agency whose credit ratings can be used for the calculation, based on standard methods, of prudential capital ratios of banks based on the Basel II Accord.

terms and conditions, the frequency of the data and the number of intermediaries. Our primary source of information is the TAXIA database, which is reported at quarterly frequency and consists of granular information about the loans granted by a representative sample of Italian intermediaries (about 200 Italian banks and 10 branches and subsidiaries of foreign banks). For each bank-firm relationship we have information about the size of the granted loan, the cost and the maturity of the loan (i.e. loans with maturity up to one year versus loans with maturities over one year), the repricing date of the loan (i.e. floating-rate versus fixed-rate) and whether the loan is subsidized or not. The other source of information is recorded on a monthly basis for all banks operating in Italy. This dataset provides information about the amount and the maturity of granted credit and the amount and the type of collateral posted on each credit exposure, but has no information about the cost and the repricing date of the loan.[5] The two dataset are used separately or combined to test the robustness of our main results. The various terms and conditions are used as control variables in the estimated regressions as they may represent important factors of mitigation of the ex-ante credit risk.

The bank-level data come from the Supervisory Reports on banks' balance sheets submitted by each individual bank or banking group to the Bank of Italy. We use consolidated balance sheet items since main business strategies are usually decided by the holding of the banking group rather than by the single bank, and regulatory requirements must be computed on consolidated balance sheets. For simplicity, we refer to the banking groups as banks henceforth[6]. Since, the dataset provides information about the identity of the holding company of the banking group as well as the identity of the single intermediary, we are also able to control for bank-specific time-invariant unobserved variables by including fixed-effects at the banking group-level, or, alternatively, at the bank-level.

We construct the following bank-specific variables: *Size* is the log of bank total assets; *Tier 1 capital ratio* is the ratio of Tier 1 regulatory capital to total risk-weighted assets; *NPL ratio* is the ratio of non-performing loans to total loans; *liquidity ratio* is the ratio of cash and

[5] In the Italian CR there is a reporting threshold for the quantity of credit at 75,000 € since 2008 and 30,000 € from 2009 onwards. The threshold has marginal impact on our analysis. Indeed, the CR is a borrower-by-borrower dataset and the threshold refers to the overall exposition of a single borrower towards single intermediaries. Hence, a firm that has two distinct loans of 40,000 € each with the same bank appears in our sample with two different records.

[6] In order to construct banks' consolidated balance sheets, we carefully manage merges and acquisitions among banks. The two banks involved in each merge operation are considered as separate entities until the effective date of the operation and as a new single one afterwards. At the same time, if a firm has a relationship with a specific bank and this bank disappears from the database because of a merge or an acquisition by another intermediary, we can track whether there is a new relationship with the newly formed bank or with the acquirer. In this case we consider the relationship as a new one since both the characteristics of the "new" bank and its business model can be different from the previous ones.

short-term government bonds to total assets; *deposit ratio* is the ratio of retail deposits to total assets; *sovereign ratio* is the ratio of total euro-area government bonds to total assets; *profitability* is the ratio of gross operating profits to total assets; and, finally, the *duration gap* measures the maturity mismatch between assets and liabilities computed on the basis of both on-balance and off-balance sheet items. This indicator captures the sensitivity of the market value of the financial institution's net worth to changes in interest rates and is, therefore a measure of banks' exposure to the interest rate risk.

Following the standardized methodology described in Bank of Italy (2006), which is consistent with the main principles stated by the Basel Committee on Banking Supervision (2004, 2006) for the evaluation of interest rate risk, the *duration gap* is constructed by allocating all assets, liabilities and off-balance-sheet items in the *banking book* in 14 maturity buckets according to their remaining time to maturity or, in the case of variable rate items, according to their re-pricing schedule.[7] The duration gap can take negative or positive values. Financial institutions with long-term fixed-rate assets and short-term floating-rate liabilities have a positive duration gap and usually benefits from an increase in interest rates and/or a steepening of the yield curve; financial firms with short-term floating-rate assets and long-term fixed-rate liabilities have negative duration gap and usually benefit from a decrease in long-term interest rates and/or a flattening of the yield curve.

As for macroeconomic variables, the short-term interest rate is measured by the Euro Overnight Index Average rate (Eonia rate, afterwards) in nominal terms. The long-term interest rate is the 10-year Euro Interest Rate Swap (10-year EURIRS, afterwards), which is considered a risk-free long–term interest rate. In the various specifications, we use several macroeconomic controls for business cycle conditions in both Italy and the euro area. In particular, we consider the unemployment rate, the inflation rate and real-time coincident indicators of real economic activity. As for the latter, we use the indicator *Ita-coin* developed by Aprigliano and Bencivelli (2013) for the case of Italy and the indicator Euro-coin built by Altissimo et al. (2010).[8] Finally, to control for changes in risk premia, we also include the Italian 10-year Government bond yield.

[7] See the Appendix for technical aspects on the construction of the duration gap.

[8] Ita-coin and Euro-coin are coincident indicators of the business cycle. They condense a large number of variables that are available at different frequency in a unified framework by relying on econometric techniques in the field of dynamic factor models.

2.1 Descriptive analysis

In Table 1 we report some summary statistics for the variables used in the empirical analysis. Descriptive statistics are reported for the quarterly Taxia database. The picture is, however, very similar for the monthly database we use in the Section of robustness checks.

Table 1. Descriptive statistics

	Frequency	Observations	Mean	Standard deviation	25th percentile	75th percentile
Firm-level variables						
Risk rating	Annual	1,031,505	5.2	1.7	4.0	7.0
Macroeconomic variables						
Eonia rate (%)	Quarterly	50	1.3	1.5	0.1	2.1
10-year Eurirs rate (%)	Quarterly	50	2.8	1.4	1.7	4.1
10-year BTP - 10-year Bund spread (%)	Quarterly	50	1.4	1.2	0.3	1.6
Itacoin	Quarterly	50	0.0	0.5	-0.2	0.3
Italian inflation rate (%)	Quarterly	50	1.6	1.2	0.5	2.4
Italian unemployment rate (%)	Quarterly	50	9.2	2.3	7.3	11.6
Eurocoin	Quarterly	50	0.3	0.5	0.0	0.6
Euro-area inflation rate (%)	Quarterly	50	1.6	1.1	0.6	2.3
Expected real GDP - Italy (%)	Quarterly	50	1.1	0.5	0.8	1.4
Expected real GDP - Euro area (%)	Quarterly	50	1.6	0.4	1.3	1.8
Expected inflation rate - Italy (%)	Quarterly	50	1.7	0.4	1.5	2.0
Expected inflation rate - Euro area (%)	Quarterly	50	1.6	0.3	1.4	1.8
Loan-level variables						
Loan size (logarithm)	Quarterly	2,515,614	11.9	1.5	10.9	12.9
Loan cost (%)	Quarterly	2,515,614	5.1	2.3	3.4	6.4
Long-term loans (0/1)	Quarterly	2,515,614	0.4	0.5	0.0	1.0
Fixed-rate loans (0/1)	Quarterly	2,515,614	0.1	0.3	0.0	0.0
Subsidized loan (0/1)	Quarterly	2,515,614	0.0	0.1	0.0	0.0
Bank-level variables						
Consolidated balance sheet items						
Duration gap (%)	Bi-annual	933	-0.3	39.1	-7.6	1.9
Tier 1 capital ratio (%)	Bi-annual	933	9.9	3.8	7.3	11.4
Unconsolidated balance sheet items						
Total assets (logarithm)	Quarterly	4,360	9.0	1.3	8.0	9.8
NPL ratio (%)	Quarterly	4,360	5.9	4.9	2.4	8.1
Deposit ratio (%)	Quarterly	4,360	42.0	19.2	34.5	54.7
Liquidity ratio (%)	Quarterly	4,360	5.5	6.7	0.9	8.1
Profitability (%)	Quarterly	4,360	0.4	1.0	0.1	0.8

Notes: this table reports descriptive statistics for the variables used in the empirical analysis. The sample includes loan-specific information from the Taxia quarterly database, which is a distinct section of the Italian Credit register, from 2005Q3 to 2016Q4. The firm rating is the risk rating assigned by the Cerved Group to a given firm on an annual basis, where the rating classes are comprised from 1 (lowest credit risk) to 9 (highest credit risk). Bank-level variables are from the Supervisory reports transmitted by the intermediaries to the Bank of Italy. Size, NPL ratio. Deposit ratio and Liquidity ratio are based on unconsolidated balance sheet items; Duration gap, Tier 1 capital ratio and Profitability are based on consolidated balance sheet items. Macroeconomic variables are taken from the Statistical Data Warehouse of the ECB.

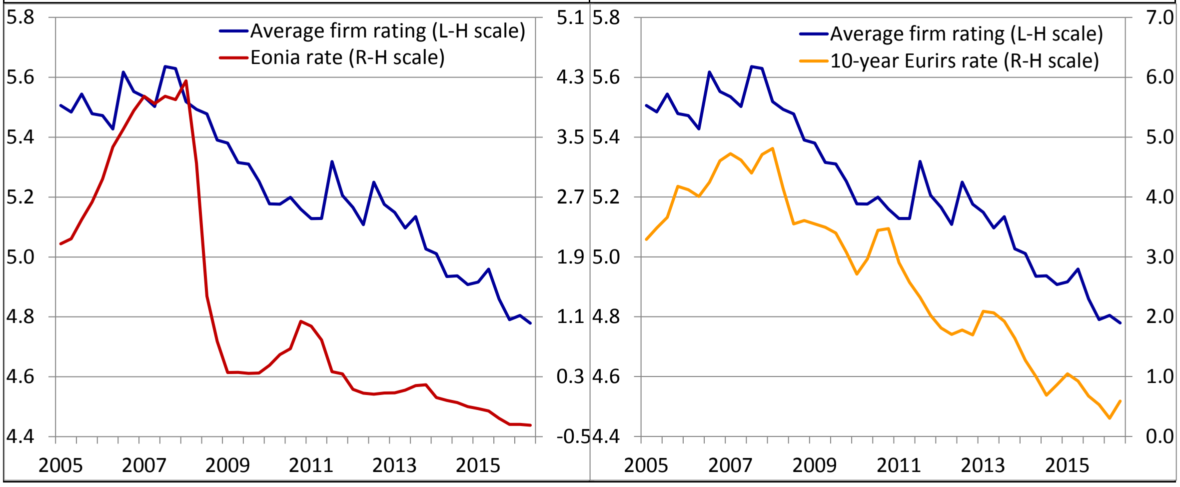
As for our variable of main interest, the table suggests that the average loan risk rating in the full sample is 5.2 with a standard deviation of 1.7, meaning that loans are, on average, granted to firms with moderate risk (rating of 5). Most of loans are granted at floating-rates and, most importantly, fixed-rate loans have all maturity up to one year. The average loan rate is about 5.1 per cent, with a standard deviation of 2.3. The average loan amount is 11.9, which corresponds to about 800,000€, with a standard deviation of 1.5 (about 39 million). This reflects the fact that the merge between the Credit register and the Cerved sample leads to a very granular dataset comprising loans to both small and large firms.

The average Tier1 capital ratio is 9.9 and the standard deviation is 1.3. Banks also markedly differ in terms of both NPL ratio and deposit ratio, thus indicating high banks' heterogeneity in terms of riskiness, business model and size.

In Figure 1 we compare developments in interest rates with the average value of firm rating, computed on all banks loans that have been granted in a given quarter. Interestingly, the picture does not suggest a systematic and negative correlation with the short-term interest rate. On the contrary, the correlation with the long-term interest rate is much stronger and positive.

FIGURE 1 – Average firm rating and interest rates
(quarterly data; simple average)

(a) Firm rating and short-term interest rates | **(b) Firm rating and long-term interest rates**



An interesting feature of our dataset is the heterogeneity in banks' duration gap. This variable is commonly used (especially in the US) to distinguish between financial firms of different nature such as commercial banks, which "lend long and borrow short", or insurance companies and pension funds, which "lend short and borrow long". In the case of Italy, the panel instead comprises banks with both a positive and a negative duration gap. Precisely, we have information about 72 banking groups. We have 6 intermediaries exhibiting a positive duration gap over the entire sample period against 15 with a persistently negative duration gap. For the majority of the banks, the sign of the duration gap changes over time. These stylized facts suggest that the inclusion of bank fixed effects in estimated regressions cannot properly capture the banks' business model, as far as the role of the interest rate risk is considered.

In Figure 2 we report the time series of the average duration gap for the entire banking system and for the two clusters of banks, namely banks with positive and negative duration gap. Banks' exposure to the interest rate risk changes considerably over time and across banks. The main reason is that the developments in this bank-specific variable reflect not only the change in banks' maturity mismatch on the on-balance sheet items but also the use of financial derivatives, which allow the intermediaries to quickly change the exposure to the interest rate risk (see Esposito et al., 2015).

Finally, it is interesting to assess the cross-section correlation between the duration gap and the other bank-specific characteristics, which have been used in banking analysis to capture some aspects of the banks' business model.

FIGURE 2. Developments in banks' duration gap
(yearly observations)

(a) Ratio of banks' exposure to interest rate risk over tier1 capital | **(b) Number of banks with positive vs. negative duration gap**

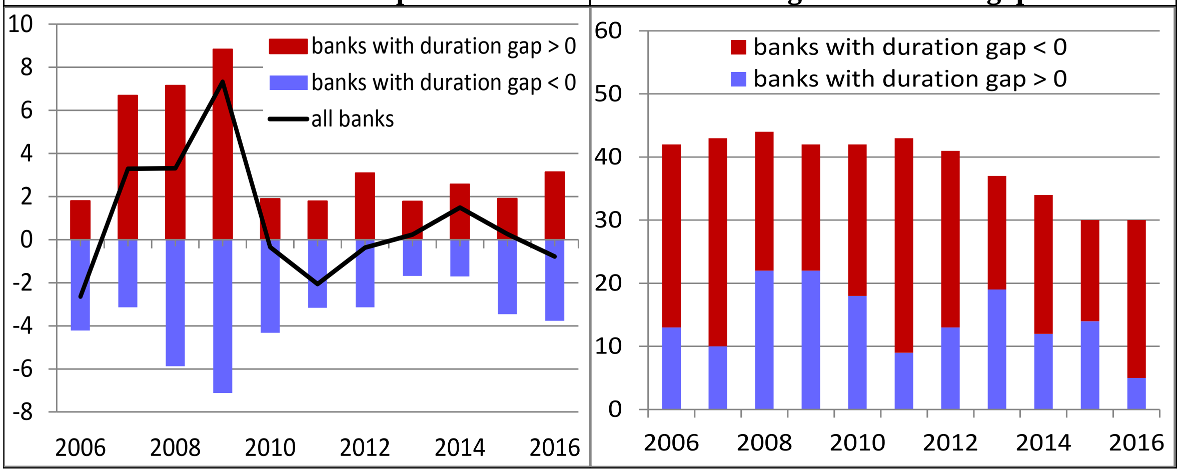
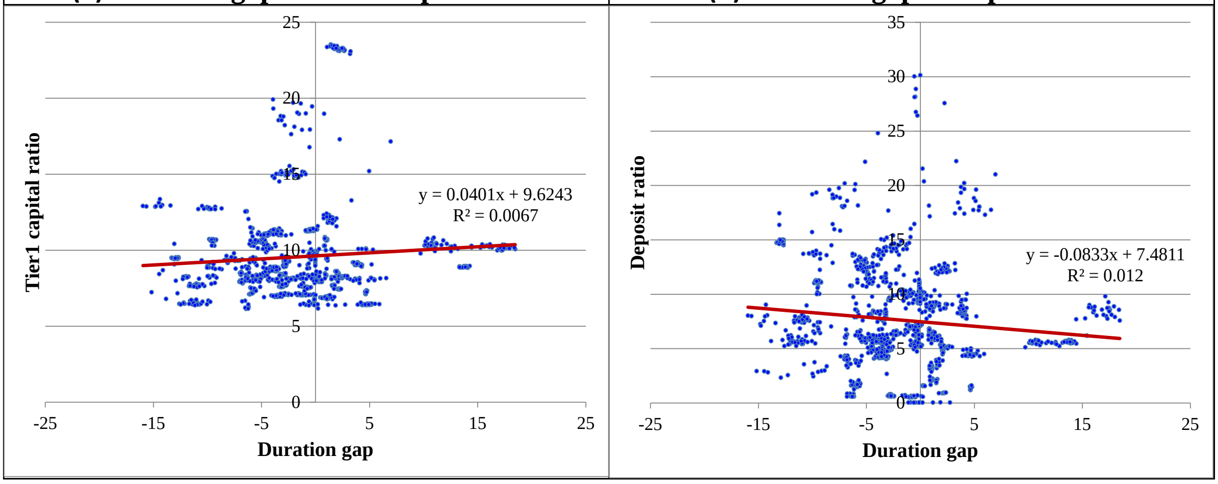


Figure 3 we report the scatter plot of the duration gap with the Tier1 capital ratio and the deposit ratio. In both cases the correlation is very low, thus suggesting that the bank duration gap has independent information content with respect to the other banks' features (similar conclusions hold for the correlation with the other bank-specific characteristics considered in this paper).

FIGURE 3. Cross-section correlation

(half-yearly observations)

(a) Duration gap vs Tier1 capital ratio	(b) Duration gap vs deposit ratio



3. Credit risk-taking and the slope of the yield curve

In this section we assess to which extent different components of the yield curve are significant drivers of banks' risk taking behaviour. We address this issue from two different perspectives.

3.1 Risk taking as the change in the rating class of the new marginal loan

The first approach draws from Dell'Ariccia et al. (2017). The dependent variable, $risk_{i(j)t}$, is the risk rating of borrower *i* reported by the Cerved group based on firm-specific developments in the *previous year*, which reflect the true information available to the loan officers at the time the *new* loan was granted. The model specification is the following:

$$risk_{i(j)t} = \omega_i + \mu_j + \beta_1 short_t + \beta_2 long_t + \gamma X_{jt-1} + \theta Y_{ijt} + \delta Z_t + \varepsilon_{ijt} \quad (1)$$

In regression (1) the rating, $risk_{i(j)t}$, is assigned to all new loans granted to the same borrower in the same year. This implies that we have repeated observations on the left-hand side of our regression (1). As for the explanatory variables, $short_t$ is the average Eonia rate in quarter *t* while $long_t$ is the average 10-year EURIRS rate in quarter *t*, ω_i is a set of firm-specific fixed-effects, μ_j is a set of bank-specific fixed-effects, X_{jt-1} is a vector of time-varying bank-specific variables, Y_{ijt} is a set of loan-specific variables, Z_t is a vector of other macroeconomic controls for developments in the Italian economy.[9] To control for

[9] We also check whether our main results are not driven by a systematic response of banks' attitude toward risk to developments in the euro area as a whole. To this end, in the various regressions we also control for current

dependence of observations across banks, firms and within quarters, standard errors are two-way clustered by bank and firm-quarter. Results are robust if we use an alternative two-way clustering scheme at bank-quarter and firm. The coefficients of main interest are β_1, which we expect to be negative and β_2, whose sign is a priori-unknown. According to this approach, these coefficients capture the effects of changes in the yield curve on changes in the rating class of the new loan. The main results are reported in Table 2.

TABLE 2 - Interest rates and credit risk-taking – Dependent variable: rating class of the new loan

	(1)	(2)	(3)	(4)	(5)
Macroeconomic variables					
Eonia rate	**-0.1204*****	**-0.1243*****	**-0.0632*****	**-0.0298*****	**-0.0196*****
10-year Eurirs rate		**0.0157**	**0.0458*****	**0.0649*****	**0.0564*****
10-year BTP-BUND spread	-0.0884***	-0.0875***	-0.0609***	-0.0465***	-0.0446***
Italian Inflation rate	0.0120**	0.0111**	0.0048	0.0027	0.0000
Italian unemployment rate	-0.0568***	-0.0539***	-0.0059	0.0248***	0.0330***
Italian business cycle	0.0192**	0.0178**	-0.0233***	-0.0477***	-0.0516***
Bank controls					
Duration gap	-0.0002	-0.0003	-0.0002*	-0.0001***	-0.0001**
Size	-0.0543	-0.0546	-0.0273	-0.0025	0.0008
Tier1 capital ratio	-0.0212***	-0.0202***	-0.0096***	-0.0037**	-0.003
NPL ratio	-0.0214***	-0.0199***	-0.0116***	-0.0040**	-0.0045**
Deposit ratio	0.0017	0.0018	0.0006	-0.0007	-0.0016
Liquidity ratio	-0.0009	-0.0009	-0.001	-0.0004	0.0004
Profitability	0.0078	0.0081	0.0043	-0.0021	-0.0018
Loan-level controls					
Loan size	-0.0139*	-0.0140*	-0.0270***	-0.0171***	-0.0128***
Loan cost	0.1818***	0.1815***	0.1015***	0.0529***	0.0469***
Loan maturity	-0.0165	-0.0165	-0.0330*	-0.0268***	-0.0151*
Fixed-rate loans	-0.1603***	-0.1600***	-0.0922***	-0.0161**	-0.0184**
Subsidized loans	-0.1364**	-0.1362**	-0.1539***	-0.0091	0.0093
Bank fixed effects	yes	yes	yes	yes	no
Firm zip-code*sector fixed effects	no	no	yes	no	no
Firm fixed effects	no	no	no	yes	no
Firm*Bank fixed effects	no	no	no	no	yes
Observations	2,498,790	2,498,790	2,446,268	2,375,238	2,131,448
Number of banks	144	144	144	144	143
Number of firms	359,111	359,111	313,917	235,559	205,307
Adjusted R-squared	0.096	0.096	0.524	0.723	0.764

Notes: panel regression estimates from 2005Q1 to 2016Q4 using the Taxia database. The dependent variable is the risk rating assigned by Cerved group to a given borrower. Standard errors are computed using a two-way clustering by bank and firm-quarter. ***,**, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

For comparability with previous studies, we begin our analysis by estimating regression (1) including neither the long-term interest rate nor the set of firm-specific fixed effects. In the specification we include a number of macroeconomic variables to control for business

and expected GDP and inflation. Main results remain unchanged, meaning that the specifications including only the Italian macroeconomic controls represent a valid benchmark to be used in the following sections.

cycle and financial conditions in Italy, which may affect banks' risk taking behaviour beyond what is captured by developments in market interest rates. Moreover, we control for several loan-specific characteristics, namely the loan size, loan interest rate, maturity, the repricing date of the loan and a dummy variable taking the value of 1 for subsidized loans, as they may act as substitutes or complements of the ex-ante credit risk when the loan application is considered by the individual bank. Since the probability to grant a loan to a specific borrower may also vary across banks depending on the internal rating model and lending technology used by loan officers, we absorb such differences by including bank-specific fixed effects.

The estimated coefficients suggest a negative and significant effect of short-term interest rate on bank risk-taking. Lower values of the short-term interest rates are associated, on average, to new loans granted to borrowers with a lower creditworthiness. A one standard deviation decrease in the Eonia rate (1.5%) would be associated to an increase in loan risk ratings of 0.18, a result coherent with the estimates of Dell'Ariccia et al (2017) for the US (where a one standard deviation decrease in the Fed fund rate implies an increase in loan risk ratings of 0.11).

The various loan characteristics are statistically significant and seem to act as mitigation factors of the ex-ante credit risk. Indeed, the value of the borrower rating declines with the loan size, increases with the price of the loan and is lower, on average, for fixed-rate contracts, meaning that the probability to grant a loan to a risky borrower declines if the bank faces a higher concentration and/or interest rate risk at the loan-level. Maturity of the loan, as captured by the dummy variable for loans with maturity over one year, does not seem to play a significant role. Most of the various bank-specific characteristics are statistically not significant, with the exception of the Tier1 capital and NPL ratios.

In column (2) we include the long-term interest rate as an additional explanatory variable. Since in the regression we control for the short-term interest rate, the estimated coefficient captures the effect of a change in the component of the long term interest rate that is orthogonal to changes in the short-term rate.[10] The long-term interest rate enters with a positive sign but it is not significant; the other coefficients remain broadly unchanged.

Results change considerably when we progressively include additional control variables in the regression and exploit with-in borrower variation. In column (3) we include a set of

[10] Since the model is linear, we may have considered directly the slope of the yield curve instead of the long-term interest rate. Results remain unchanged but the interpretation of the estimated coefficients is less direct. In particular, the effect of the long-term interest rate on bank risk taking should be computed as the sum of the coefficient for the Eonia rate and the coefficient for the slope of the yield curve.

zip-code*sector specific fixed effects (i.e. 146,968 control dummies) while in column (4) we consider a full set of firm-specific fixed-effects to control for invariant and unobserved characteristics of the borrowers (i.e. 235,559 control dummies). The role played by the short-term interest rate reduces by a factor of 4. The increase in loan risk ratings associated to a one standard deviation decrease in the Eonia rate would reduce to 0.05 (from 0.18 in specification (1)). On the contrary, the effect of the long end of the yield curve on ex-ante credit risk increases and become highly significant. A steepening of the yield curve determined by a one standard deviation increase in the long-term interest rate (1.4%) would be associated to an increase in loan risk ratings of 0.09.

Finally, in column (5) we substitute bank and firm fixed effects with the more stringent bank-firm fixed effects so to exploit the variation within the same firm-bank pair over time, thereby controlling for any time invariant relationship lending characteristics. The effects of both the short and the long-term interest rates remain statistically significant albeit they slightly attenuate in magnitude.

3.2 Risk taking as the change in new lending for the different rating classes

The model specification (1) focuses on the rating of a new loan but does not consider the amount granted to borrowers with different credit risk. In order to take into account the amount of lending we adapt the empirical approach proposed by Jimenez et al. (2014) to our framework. Accordingly, the model specification becomes the following[11]:

$$q_{ijt} = \omega_i + \mu_j + \beta_1 short_t * risk_{i(j)t} + \beta_2 long_t * risk_{i(j)t} + \gamma X_{jt-1} + \theta Y_{ijt} + \varepsilon_{ijt} \quad (2)$$

where q_{ijt} is the logarithm of the new credit flow granted by bank *i* to firm *j* at time *t*, and the effects of main interest are captured by the coefficients on the interaction terms between each interest rate and the firm rating. The coefficient β_1 is a direct empirical test of whether the *amount* of lending to risky firms increases when the short-term interest rate declines and β_2 whether the *amount* of lending to risky firms increases when long-term rates reduces. The specification (2), on top of the set of control variables used in specification (1), allows including also a full set of time fixed effects to control for unobservable macroeconomic factors that may affect banks' risk-taking behaviour, such as the impact of changes in the regulatory framework occurred during the financial crisis and more extensively with the

[11] Jimenez et al. (2014) analyse both the extensive (rejection/acceptance of loan applications) and the intensive (granted credit volume) margin of credit. However, when focusing on within-firm variation, the extensive margin is not statistically significant and the effect is entirely through the intensive margin.

adoption of the Single Supervisory Mechanism. The results reported in Table 3 confirm the broad picture obtained with the specification (1).

Ex-ante riskier firms obtain more credit following a steepening of the yield curve due to an increase of long-term interest rates. When the short term interest rate decreases, risk-taking increases, even though the effect is no longer significant when firm-specific fixed-effects are included in the set of control variables.

TABLE 3 – Interest rates and credit risk-taking – Dependent variable: (log) amount of new lending for different rating classes

	(1)	(2)	(3)	(4)	(5)
Firm rating	-0.0542***	-0.1166***	-0.0639***	-0.0431***	-0.0316***
Interactions with macroeconomic variables					
Eonia rate * Firm rating	**-0.0101*** **	**-0.0126*** **	**-0.0044*** **	**-0.0013**	**-0.0012**
10-year Eurirs rate * Firm rating		**0.0109*** **	**0.0086*** **	**0.0084*** **	**0.0081*** **
10-year BTP-BUND spread * Firm rating	0.0011	0.0009	0.0021	0.0019	0.0023*
Italian inflation rate * Firm rating	0.0058***	0.0099***	0.0028**	0.0007	0.0001
Italian unemployment rate * Firm rating	-0.0004	-0.0018	-0.0026	-0.0030**	-0.0030***
Italian business cycle * Firm rating	-0.0002	-0.0006	0.0052**	0.0053***	0.0047***
Bank controls					
Duration gap	0.0008***	0.0008***	0.0003	0.0001	-0.0001
Size	0.0984	0.0981	0.0152	-0.0234	0.0048
Tier1 capital ratio	0.0297***	0.0296***	0.0226***	0.0157***	0.0081**
NPL ratio	0.0219**	0.0220**	0.0122**	0.0098*	0.0034
Deposit ratio	-0.0070*	-0.0070*	-0.0032	-0.0012	-0.0013
Liquidity ratio	-0.0087***	-0.0087***	-0.0046***	-0.0025*	0.0007
Profitability	0.0007	0.0006	-0.0008	0.0003	0.0011
Loan-level controls					
Loan cost	-0.2672***	-0.2672***	-0.1352***	-0.0718***	-0.0642***
Loan maturity	0.1751***	0.1750***	0.3743***	0.5235***	0.4965***
Fixed-rate loans	-0.2618***	-0.2621***	-0.2279***	-0.2075***	-0.2035***
Subsidized loans	-0.2958***	-0.2961***	-0.0901	-0.0311	-0.0515
(Year:quarter) fixed effects	yes	yes	yes	yes	yes
Bank fixed effects	yes	yes	yes	yes	no
Firm zip-code*sector fixed effects	no	no	yes	no	no
Firm fixed effects	no	no	no	yes	no
Firm*Bank fixed effects	no	no	no	no	yes
Observations	2,498,790	2,498,790	2,446,268	2,375,238	2,131,448
Number of banks	144	144	144	144	143
Number of firms	359,111	359,111	313,917	235,559	205,307
Adjusted R-squared	0.192	0.192	0.547	0.672	0.754

Notes: panel regression estimates from 2005Q1 to 2016Q4 using the Taxia database. The dependent variable is the logarithm of granted loan by the individual bank to a given borrower. Standard errors are computed using a two-way clustering by bank and firm-quarter. ***,**, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Based on the estimated coefficients reported in column (4), where we control for banks and firms fixed effects, a one standard deviation (1.4 percentage points) increase in the long-term interest rate (for a given level of the short term interest rate) is associated to about a

10% increase in the amount of lending to riskiest firms (i.e., with a rating class of 9) with respect to safest firms (i.e., with a rating class of 1). When considering the interquartile range of the entire distribution (75th percentile versus 25th percentile), the differential effect is more muted (2% in the change of credit). The inclusion of the more conservative set of control variables (i.e. bank-firm fixed effects) only marginally affects the results (see column (5)).

In order to investigate the presence of a non-linear relation between the yield curve and risk-taking across different classes of rating, we include in the model specification (2) a quadratic term in the firm rating and its interactions with the level and slope of the yield curve. The estimation results are reported in Table 4. Column (1) and (2) present the results of the regression without and with firm-fixed effects. Column (3) reports the results using the set of bank-firm fixed effects.

Columns (4) and (5) consider an alternative specification to capture potential non-linear effects of changes in the level and the slope of the yield curve on each different class of rating, namely by considering a separate dummy variable for each rating class and including their interaction terms with each macroeconomic variable in the estimated regressions.

TABLE 4 – Non-linear effects of the yield curve on new lending for different rating classes

	(1)	(2)	(3)		(4)		(5)	
				Rating class	Eonia rate*Rating	10-year Eurirs	Eonia rate*Rating	10-year Eurirs
Firm rating	-0.1415**	-0.1410***	-0.1001***	rating=2	0.0009	**-0.004**	0.0053	**-0.0006**
Eonia rate*Firm rating	**-0.0261*** **	**-0.0014**	**0.0005**	rating=3	0.0053	**0.0143**	0.0067	**0.0046**
10-year Eurirs rate*Firm rating	**0.0530*** **	**0.0234*** **	**0.0172*** **	rating=4	0.0006	**0.0245***	0.0023	**0.0197**
				rating=5	0.0018	**0.0338** **	0.0032	**0.0244***
Non-linear effects in firm rating				rating=6	-0.0055	**0.0546*** **	-0.0031	**0.0528*** **
Firm rating^2	0.0025	0.0102**	0.0069**	rating=7	-0.0018	**0.0422*** **	0.0009	**0.0371** **
Eonia rate*(Firm rating)^2	**0.0014**	**0.0000**	**-0.0002**	rating=8	-0.0105	**0.0415** **	-0.0114	**0.0431** **
10-year Eurirs rate*(Firm rating)^2	**-0.0042*** **	**-0.0016***	**-0.0009**	rating=9	-0.001	**0.0362**	-0.0106	**0.0516** **
(Year:quarter) fixed effects	yes	yes	yes		yes		yes	
Bank fixed effects	yes	yes	no		yes		no	
Firm fixed effects	no	yes	no		yes		no	
Firm*Bank fixed effects	no	no	yes		no		no	
[(Other macro variables) * (Firm rating)]	yes	yes	yes		yes		yes	
[(Other macro variables) * (Firm rating)^2]	yes	yes	yes		yes		yes	
Bank controls	yes	yes	yes		yes		yes	
Loan-level controls	yes	yes	yes		yes		yes	
Observations	2,498,790	2,375,238	2,131,448		2,375,238		2,131,448	
Number of banks	144	144	143		144		143	
Number of firms	359,111	235,559	205,307		235,559		205,307	
Adjusted R-squared	0.193	0.672	0.754		0.672		0.754	

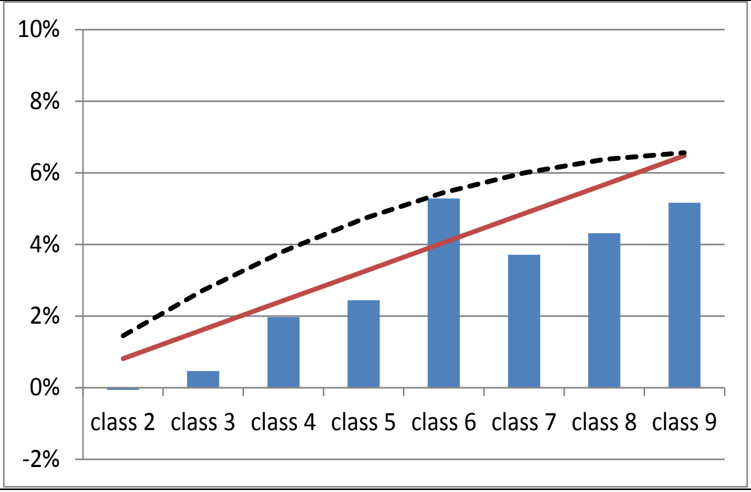
Notes: panel regression estimates from 2005Q1 to 2016Q4 using the Taxia database. The dependent variable is the logarithm of granted loan by the individual bank to a given borrower. Standard errors are computed using a two-way clustering by bank and firm-quarter. ***,**, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Figure 4 compares the change in lending for different classes of rating (in difference from the growth rate of loans to firms belonging to class 1) determined by a steepening of the yield curve as obtained from the linear estimates reported in Table 3 (solid red line) with those reported in Table 4 obtained under the quadratic specification (column (3); dashed black line) and under specification which includes the dummy variables for each rating class (column (4) and (5); blue histograms).

The only non-linearity that emerges in the risk taking behaviour for different class of rating in response to a steepening of the yield curve concerns the class of rating 6, for which the increase in loans is higher than what would be explained by the linear specification. Therefore, with this exception, both non-linear specifications provide results similar to those obtained under the linear specification, which can be considered a relevant benchmark to be used in the following sections, provided that we control for relationship lending in the regression.

Results presented in this section have important implications for policymakers since they suggest that for a comprehensive evaluation of the risk-taking behaviour of financial institutions one should look jointly at the short-term interest rate and the slope of the yield curve. In this regard, we provide reassuring answers to concerns for financial stability in a LIRE (ESRB, 2016). To the extent that a LIRE is characterized by both low short -term interest rates and a relatively flat slope of the yield curve, our estimates suggest that banks, on average, tend to reduce ex-ante risk-taking on new loans.

FIGURE 4 – Increase of loans for different classes of rating determined by a steepening of the yield curve



Notes: growth rates of loans for different classes of rating, in deviation from the growth rate of loans to firms belonging to rating class 1, determined by a steepening of the yield curve. Solid red line: linear specification in firm rating; dashed black line: quadratic specification in firm rating; blue histograms: specification using a single dummy variable for each rating class.

4. Banks' heterogeneity, the yield curve and credit risk-taking

The estimated effects of the yield curve on risk taking reported in the previous sections are *averages* across banks. In this Section we focus on potential heterogeneity across intermediaries and evaluate whether the sensitivity of banks' risk taking to interest rate changes depends on their business model.

4.1 The role of the duration gap

We start by focusing on banks' heterogeneity in terms of maturity mismatch between assets and liabilities. To this end, we consider separate regressions for banks with positive and for those with negative duration gap, using specifications (1) and (2). In Table 5 we report the estimation results.

TABLE 5 – Interest rates and credit risk-taking: the role of the duration gap

	A) Dependent variable: rating class of new loan				B) Dependent variable: (log) amount of new lending for different rating classes			
	duration gap > 0		duration gap < 0		duration gap > 0		duration gap < 0	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Eonia rate	**-0.0261*****	**-0.0182****	**-0.0291*****	**-0.0089**				
10-year Eurirs rate	**0.0665*****	**0.0612*****	**0.0675*****	**0.0531*****				
Firm rating					-0.0444***	-0.0429***	-0.0469**	-0.0356
Eonia rate * Firm rating					**0.0021**	**0.0032**	**-0.0034***	**-0.0039***
10-year Eurirs rate * Firm rating					**0.0100*****	**0.0090*****	**0.0069****	**0.0070****
Bank fixed effects	yes	-	yes	-	yes	-	yes	-
Firm fixed effects	yes	-	yes	-	yes	-	yes	-
Firm*Bank fixed effects	-	yes	-	yes	-	yes	-	yes
(Year:quarter) fixed effects	-	-	-	-	yes	yes	yes	yes
Other macro variables	yes	yes	yes	yes	-	-	-	-
[(Other macro variables) * (Firm rating)]	-	-	-	-	yes	yes	yes	yes
Bank controls	yes	yes	yes	yes	yes	yes	yes	yes
Loan-level controls	yes	yes	yes	yes	yes	yes	yes	yes
Number of banks	121	119	140	139	121	121	140	140
Number of firms	144 192	122 660	163 087	138 260	144 192	144 192	163 088	163 088
Observations	1 049 169	910 423	1 224 020	1 060 542	1 049 169	910 423	1 224 020	1 060 542
Adjusted R-squared	0.746	0.793	0.730	0.789	0.684	0.760	0.676	0.757

Notes: panel regression estimates from 2005Q1 to 2016Q4 using the Taxia database. In panel a) the dependent variable is the risk rating assigned by Cerved group to a given borrower ; in panel b) the dependent variable is the logarithm of granted loan by the individual bank to a given borrower. Standard errors are computed using a two-way clustering by bank and firm- quarter. ***,**, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

We find that the coefficients associated to the short-term interest rates are negative for both clusters of banks in both specifications. Similarly the coefficients associated to the long-term interest rates are positive. A steepening of the yield curve, determined either by a reduction of the short-term interest rate for a given level of the long-term interest rates or by an increase of the long-term interest rate for a given level of the short term rates increases risk-taking.

These results provide a direct empirical test on the various explanations presented in the theoretical literature on interest rates and banks risk taking. The economic theory has identified different channels through which interest rates may affect risk-taking. The literature on the risk-taking channel of monetary policy (see, for example, Borio and Zhu, 2008 and Gambacorta, 2009) suggests that the attitude toward risk depends negatively on short-term interest rates but positively on the slope of the yield curve. In particular, financial institutions "lending long and borrowing short" (i.e. with a balance sheet characterized by a positive duration gap between assets and liabilities)[12] benefit from low short-term interest rates and a steep yield curve. Such a configuration of the term structure, in fact, leads to an increase in net interest margins, in equity value and, therefore, in risk-bearing capacity (Adrian and Shin, 2011). As a consequence, banks would engage in "reach-for-yield". Profitability of financial institutions "lending short and borrowing long" (i.e. with a negative duration gap) instead suffer from low short rates and a steep yield curve and may be forced to take on more risks in "search-for-yield" for contractual, behavioural or institutional reasons (Rajan, 2005). Both theories, therefore, would suggest that the reduction in long-term interest rates observed in the last decade should have mitigated (or offset) financial institutions' risk-taking stemming from decreasing short-term interest rates.

On the other hand, the banking literature on asymmetric information and monitoring (Allen et al., 2011; Dell'Ariccia et al. 2014) claims that an easing in credit standards – and an increase in banks' risk-taking – is typically associated with a reduction in the monitoring activity of borrowers by financial institutions.[13] This strand of the literature usually refers to financial institutions with a positive duration gap, but similar considerations could be extended to those with a negative gap. In this case, net interest rate margins and monitoring will be negatively affected, and attitude toward risk incentivized by a steepening of the yield curve. Therefore, according to this theory, the flattening of the yield curve should mitigate risk attitude of financial institutions with negative duration gap and amplify risk-taking of those with a positive gap. In the first row of Table 6 we summarize the expected relation between banks' risk-taking and the slope of the yield curve according to the previously mentioned theories.

[12] The duration gap is a measure of maturity mismatch between the asset and liability sides of the balance-sheet that takes into account both the remaining time to maturity and the re-pricing schedule of all balance-sheet items.

[13] In Dell'Ariccia et al. (2014), banks' monitoring incentives depend positively on the spread between loan and deposit rates, and on the amount of equity in banks' capital structure. When a reduction in interest rates is associated with a compression of the bank spread due to either a flattering of the yield curve or the presence of an effective lower bound on deposit rates, banks' profitability and monitoring incentives reduce, and the credit risk of their loan portfolio increases.

For banks with a positive duration gap results reported in Table 5 corroborate the view that "reach-for-yield" motives are the main driver of their risk-taking behaviour, rather than "risk-shifting" considerations related to asymmetric information problems (that would have implied an opposite relation between the slope and risk-taking; see Table 6).

Table 6 - Expected effect of a steepening of the yield curve on risk taking, depending on banks' duration gap and capitalization, according to the theoretical literature

	Risk-taking channel of monetary policy		Banking models with asymmetric information and monitoring	
	Duration Gap>0	**Duration Gap<0**	**Duration Gap>0**	**Duration Gap<0**
Slope	+	+	-	+
Slope*capital	+	+	+	-

A positive relationship between the slope of the yield curve and ex-ante credit risk for lenders with a negative duration gap could instead be consistent with the "search-for-yield" view implicit in the model by Rajan (2005) as well as with "risk-shifting" theories involving asymmetric information between lenders and borrowers. In order to discriminate between the two explanations we further analyse banks' heterogeneity.

4.2 The role of bank capital and other characteristics

In this section we focus on the role of other sources of heterogeneity in determining the risk taking behaviour. The theory has mainly focused on the role of bank capital, suggesting that this characteristic can play a dual role in banks' risk taking.

On the one hand, it has been used as a proxy for banks capacity to increase leverage. Based on this consideration, a steepening of the yield curve would induce both types of banks, with positive and negative duration gap, to take relatively more risk if they have more capital: banks with positive duration gap in order to "reach-for-yield" (Adrian and Shin, 2010); those with negative duration gap in order to "search-for-yield" (Rajan, 2005).

On the other hand, bank capitalization is also considered as an inverse measure of exposure to asymmetric information problems (Kashyap and Stein, 2005). According to banking models with screening and monitoring banks' risk taking is inversely related to profitability. Therefore, banks with relatively less capital and positive duration gap will take more risk in response to a flattening of the yield curve; those with less capital and negative duration gap will increase relatively more risk taking in response to a steepening of the curve.

The previous literature found mixed results on the role of capital in risk taking. Dell'Ariccia et al. (2017) show that more capitalized banks are more engaged in risk-taking behaviour when short-term rates are lowered; Jiménez et al. (2014), instead, find that the effect of low short-term rates on risk-taking is stronger for weakly capitalized banks. Discrepancies in the estimation results could reflect the different econometric approach or the peculiar behaviour of banks operating in different countries. However, another potential explanation is the different composition of the panel of banks according to the bank duration gap.

As stressed in the previous section, in order to correctly test the various theories, we need to distinguish between banks with positive and negative duration gaps and take into account the potential interaction of the bank capital with the business model. For banks with a positive duration gap we expect that more capital is associated to more credit risk, when the short rate declines or the slope steepens. For banks with a negative duration gap, instead, more capital could be associated to both more and less credit risk, depending on whether the leverage channel or the moral hazard explanation dominates (second row in Table 5).

We provide a formal test of these theories by considering both measures of risk-taking and both econometric approaches and carrying out separate regressions for banks with a positive versus negative duration gap. In the case of the approach proposed by Dell'Ariccia et al. (2017) we consider the following regression:

$$risk_{i(j)t} = \omega_i + \mu_j + T_t + \beta_1 short_t * X_{jt-1} + \beta_2 long_t * X_{jt-1} + controls + \varepsilon_{ijt} \quad (3)$$

The coefficients of main interest are the interaction terms between banks characteristics, X_{jt-1}, and the market interest rates. Among the different banks characteristics we are interested on Tier1 capital ratio. For banks with positive duration gap a negative β_1 and a positive β_2 would be consistent with both the leverage and the moral hazard theories; for banks with negative duration gap a negative β_1 and a positive β_2 would corroborate the leverage theory, while a positive β_1 and a negative β_2 would be in favour of moral hazard considerations.

In equation (3), we improve the identification of the effects of bank capital on risk-taking by: i) saturating the model with time fixed effects, in order to control for macroeconomic factors affecting all banks in the panel, such as the impact of the regulatory framework on bank capital; ii) controlling for the interaction terms between bank capital and other macroeconomic variables; iii) controlling for the interaction terms between all macroeconomic variables and the other bank-specific characteristics.

In the case of the approach by Jimenez et al. (2014) we consider the regression:

$$q_{ijt} = \omega_{it} + \mu_j + \beta_1 short_t * risk_{i(j)t} * X_{jt-1} + \beta_2 long_t * risk_{i(j)t} * X_{jt-1} + controls + \varepsilon_{ijt} \quad (4)$$

In equation (4) the theories are tested by considering inference on the triple interaction terms between the firm rating, banks characteristics (among which we are mainly interested in the Tier1 capital ratio) and the market interest rates: again, the signs of β_1 and β_2 for the interacted terms that involve the Tier1 capital ratio would be consistent with the different theories as for specification (3).

We test the robustness of the effects of bank capital on risk-taking by considering alternative specifications with different sets of fixed effects for both models (3) and (4). The first specification is less conservative and comprises only time and bank*firm fixed effects. The second specification includes time and bank*firm fixed effects, thus controlling also for stable unobserved component at the bank-firm pair.

When evaluating model (4) we can have also a third specification where we saturate the model with firm-time fixed effects in order to better control for demand conditions at the firm level (see Kwajha and Mian, 2008). This approach has, however, the cost of dramatically reducing the number of observations by 2/3 and to focus on the effects in the multiple lending framework (i.e. by comparing firms getting credit from two or more banks in the same quarter). This specification also includes triple interaction terms between all the macroeconomic variables, the firm rating and the other bank-level characteristics, to further improve in identification to the extent that bank capitalization is correlated with other bank features or to detect other balance sheet characteristics that are important for the risk-taking channel. We provide the estimation results in Table 7.

Under both approaches we find that controlling for interaction terms with bank characteristics other than the Tier1 capital ratio is crucial in order to correctly assess the role of capital in risk-taking. The coefficients on the interacted terms with the interest rates and the Tier1 ratio, in fact, change significantly when we include those controls. In particular, among the banks characteristics, the duration gap is the most relevant source of heterogeneity for both clusters of banks in response to a change in the slope of the yield curve.

The estimated coefficients show that banks with a larger duration gap (in absolute value) take more credit risk. This result holds for banks with both a positive and a negative duration gap. Accordingly, banks with a positive duration gap are engaged in "reach-for-yield" and the amount of risk-taking increases with the duration gap between assets and liabilities. In the regression for banks with a negative duration, we find that the interaction term between the long-term rate and the absolute value of bank duration gap is still positive and statistically significant. Again the risk-taking channel is more pronounced for banks with a business model that implies a higher interest rate risk (i.e. a larger negative gap between the average duration of assets and the average duration of liabilities).

TABLE 7 – Interest rates and credit risk-taking: the role of bank capital

	A) Dependent variable: rating class of new loan				B) Dependent variable: (log) amount of new lending for different rating classes			
	duration gap > 0		duration gap < 0		duration gap > 0		duration gap < 0	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Eonia rate * Tier1 ratio	**-0.0010**	**0.0045**	**0.0030**	**0.0040****	-0.0215	-0.0141	0.0057	0.0083
10-year Eurirs rate * Tier1 ratio	**0.0022**	**0.0022**	**-0.0017**	**-0.0065****	0.0480***	0.0303*	-0.0054	0.0069
Eonia rate * │Duration gap│		**-0.0001**		**-0.0014*****		0.0019		-0.0053**
10-year Eurirs rate * │Duration gap│		**0.0020****		**0.0032****		-0.0069***		-0.0070
Eonia rate * NPL ratio		0.0036		0.0001		-0.0054		0.0169**
10-year Eurirs rate * NPL ratio		-0.0007		0.0015		0.009		-0.0049
Eonia rate * Deposit ratio		-0.0005		-0.0001		-0.0041		-0.0086
10-year Eurirs rate * Deposit ratio		0.0019		0.0007		-0.002		0.0037
Eonia rate * Liquidity ratio		0.0002		0.0001		-0.0001		0.0028*
10-year Eurirs rate * Liquidity ratio		-0.0002		-0.0004		-0.0049*		-0.0037*
Eonia rate * Size		-0.0017		0.0008		0.0192		0.0102
10-year Eurirs rate * Size		-0.100**		-0.0011		-0.0213		-0.0447**
Eonia rate * Firm rating * Tier1 ratio					**0.0054**	**0.0023**	**0.0002**	**-0.0003**
10-year Eurirs rate * Firm rating * Tier1 ratio					**-0.0059****	**0.0011**	**-0.0027**	**-0.0051****
Eonia rate * Firm rating * │Duration gap│						**-0.0006*****		**0.0012*****
10-year Eurirs rate * Firm rating * │Duration gap│						**0.0015*****		**0.0016***
Eonia rate * Firm rating * NPL ratio						-0.0004		-0.0015
10-year Eurirs rate * Firm rating * NPL ratio						-0.0008		-0.0009
Eonia rate * Firm rating * Deposit ratio						0.0013		0.0015*
10-year Eurirs rate * Firm rating * Deposit ratio						0.0007		-0.0010
Eonia rate * Firm rating * Liquidity ratio						0.0004		-0.0001
10-year Eurirs rate * Firm rating * Liquidity ratio						0.0003		0.0001
Eonia rate * Firm rating * Size						-0.0017		-0.0013
10-year Eurirs rate * Firm rating * Size						0.0020		0.0019
Firm*(Year:quarter) fixed effects	-	-	-	-	yes	yes	yes	yes
(Year:quarter) fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Firm*Bank fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Bank controls	yes	yes	yes	yes	yes	yes	yes	yes
Loan-level controls	yes	yes	yes	yes	yes	yes	yes	yes
[Other macro vars]*[Tier1 ratio]*[Firm rating]	-	-	-	-	yes	yes	yes	yes
[Other macro vars]*[Other bank controls]*[Firm rating]	-	-	-	-	no	yes	no	yes
Observations	910 423	910 423	1 060 542	1 060 542	323 188	323 188	381 677	381 677
Adjusted R-squared	0.793	0.761	0.790	0.790	0.677	0.679	0.688	0.688

Notes: panel regression estimates from 2005Q1 to 2016Q4 using the Taxia database. In panel A) the dependent variable is the risk rating assigned by Cerved group to a given borrower; in panel B) the dependent variable is the logarithm of granted loan by the individual bank to a given borrower. Standard errors are computed using a two-way clustering by bank and firm-quarter. ***,**, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Concerning the sign and significance of the coefficient of the interacted terms with Tier1 capital ratio, here our main interest is for banks with negative duration gap, for which in the previous section we were not able to discriminate across the different theories on risk-taking (columns (4) and (8) in Table 5). However, notice, that under both models, the more conservative specifications (which includes more controls) for banks with positive duration gap the coefficient is positive but not statistically (see columns (4) and (8) in Table 7).

For banks with negative duration gap, we find a negative and statistically significant coefficient for the interaction terms between the bank capital ratio and the slope of the yield curve when risk-taking is measured by the change in the rating class of the marginal loan (model (3)) and a negative and statistically significant coefficient for the triple interaction term between the bank capital ratio, the firm rating and the slope of the yield curve when risk-taking is measured by the change in the new lending for different rating classes (model (4)). As for the amount of lending, the estimated coefficients in column (8) imply that an increase in the long-term component of the yield curve from its 75th percentile of 4.1% to its 25th percentile of 1.7% is associated with an increase in risk taking of 9% for a bank relatively high Tier 1 capital ratio (i.e., at its 75th percentile) and of 14% for a bank with a relatively low Tier 1 capital ratio (i.e., at its 25th percentile).

All in all, for banks with negative duration gap these results corroborate the explanation that attributes the increase in risk-taking behaviour in response to a steepening of the yield curve to "risk-shifting" theories involving asymmetric information between lenders and borrowers rather than models related to the "search-for-yield" motivation.

5. Conclusions

In this paper, we have investigated the empirical relation between banks' attitude toward risk and the level and slope of the yield curve, matching a granular information on new loans to non-financial firms from the Italian Credit register with an ex-ante measure of the borrower creditworthiness over a long sample period characterized by very different configurations of the term structure of interest rates.

We corroborate the view that the short end of the yield curve is an important driver of the risk taking behaviour in providing new loans but, contrary to previous analyses, we find that also the long end matters. According to our estimates, short-term interest rates affect negatively risk-taking and long-term rates positively. Moreover, when controlling for firm-fixed effect, the role played by the short-term interest rate dramatically reduces. On the contrary , the effect of long-term interest rates on ex-ante credit risk is magnified.

We also find evidence that the effects of changes in interest rates are heterogeneous across banks, depending on the business model as captured by the maturity mismatch in their balance sheets. In particular, the larger the mismatch in absolute value, the stronger the effect of the long-term interest rates on credit risk.

This finding is used in the paper to evaluate the empirical relevance of the theoretical explanations of risk-taking behaviour developed in the literature. Our main results support the explanation that a steepening of the yield curve increases the risk-bearing capacity of banks with positive duration gap, which react by engagin in "reach-for-yield". For banks with negative duration gap, instead, looking at the impact of the yield curve on credit risk on new loans is not sufficient in order to assess whether those types of banks increase risk-taking in response to a steepening of the curve because they need to search-for-yield in order to counteract the decrease in profitability or because the negative impact on profitability reduces their incentives to monitor borrowers in presence of asymmetric information.

In order to assess which of the two theoretical explanations has a larger empirical relevance for banks with negative duration gap we have exploited another source of heterogeneity, namely bank capitalization. We find that, among banks with negative duration gap, those that are less capitalized increase relatively more their credit risk in response to a steepening of the yield curve. We interpret this result as evidence in favour of the monitoring explanation.

Our main results have important implications for policymakers since they suggest that for a comprehensive evaluation of the risk-taking behaviour of the banking sector one should look jointly at different components of the yield curve. In this regard, we provide reassuring answers to concerns for financial stability stemming from a low interest rate environment characterized by low short and long-term interest rates and a relatively flat yield curve. In such an environment our estimates suggest that banks tend to reduce ex-ante risk-taking on new loans, independently from the sign of the duration gap of their balance sheet.

From a monetary policy perspective, instead, the paper suggests that the risk-taking channel of the transmission mechanism is stronger when the changes in the slope of the yield curve are determined by policies that affect the long end. Moreover, while the literature on the risk-taking channel concludes that banks' attitude toward risk increases in response to a decrease of short-term interest rates our paper suggests that monetary policies aimed at stimulating the economy by reducing long-term interest rates do not increase banks' credit-risk; in fact, to the extent that monetary policy decisions induce a flattening or a parallel downward shift of the curve, banks' risk-taking reduces.

Future research will address the transmission of the term structure of interest rates on banks' portfolio of securities using granular information, thus providing complementary information to our findings on banks' credit allocation.

Appendix – Technical aspects on measuring the Duration Gap

According to the standardized methodology to construct the duration gap (Bank of Italy, 2006), assets and liabilities that do not have an explicit maturity have a different treatment.

The reserve requirement is classified in the “up to one month” time band, reflecting the weekly frequency of the Eurosystem’s main refinancing operations, the yield of which is used as a benchmark in determining the interest rate on the reserve requirement. Bad debts (net of value adjustments) are classified in the “5 to 7 years” band, in line with the estimated residual life of the loans based on their turnover rate. Cash is classified in the “demand and revocable” time band. The sum of overnight deposits and demand deposits are allocated as follows: a fraction of 25% (the so-called non-core component) goes into the “demand and revocable” time band while the remaining fraction of 75% (the so-called core component) goes in the next four time bands (from “up to one month” to “6 months to 1 year”) in proportion to the number of months contained in them. Derivatives are allocated to the time bands in accordance with the criteria for capital requirements in respect of market risks.

For each time band, assets are offset against liabilities to produce a net position. The net position of every time band is then multiplied by a weighting factor based on a proxy of the “modified duration” for each time band. Following the Basel Committee, the modified duration is calculated assuming that all positions in each time band have a yield of 5 per cent.

The duration gap enters additively in scenario analysis aimed at assessing the effects of given interest rate shock on banks’ net worth. The regulatory framework suggests a standardized interest rate shock, defined as a parallel shift of the yield curve by 200 basis points. The interest rate risk indicator is computed as the ratio between the overall bank exposure to such shock and supervisory capital. The alert threshold for the interest rate risk indicator is set to 20%. Esposito et al. (2015) used this indicator to provide an empirical analysis of the management of interest rate risk during the financial crisis for Italian banks.

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