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Abstract

In a recent line of research the low interest-rate environment of the early to mid 2000s is viewed as an element that triggered increased risk-taking appetite of banks in search for yield. This paper uses approximately 18,000 annual observations on euro area banks over the period 2001-2008 and presents strong empirical evidence that low interest rates indeed increase bank risk-taking substantially. This result is robust across a number of different specifications that account, *inter alia*, for the potential endogeneity of interest rates and/or the dynamics of bank risk. Notably, among the banks of the large euro area countries this effect is less pronounced for French institutions, which held on average a relatively low level of risk assets. Finally, the distributional effects of interest rates on bank risk-taking due to individual bank characteristics reveal that the impact of interest rates on risk assets is diminished for banks with higher equity capital and is amplified for banks with higher off-balance sheet items.

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1. Introduction

Excess bank risk-taking is nowadays considered the *bête noire* of financial markets and quite deservedly so. A recent line of debate has placed the spotlight on whether the relatively low interest rates of the early to mid 2000s increased the risk-taking appetite of banks. Briefly stated, it is argued that a low interest-rate environment drives, *ceteris paribus*, bank margins and informational asymmetries down. As a consequence, banks react by softening their lending standards, thus raising the level of risk assets in their portfolios and worsening the equilibrium risk of failure. This paper analyzes empirically whether such a negative relationship between the level of interest rates and bank risk-taking is prevalent in the 16 euro area countries over the period 2001-2008.

The theory that backs up the empirical analysis can be traced in the theoretical propositions of Keeley (1990) and Dell' Ariccia and Marquez (2006). These studies suggest that certain exogenous shocks that lead to lower informational asymmetries, trigger intensified competition and credit expansion, and create incentives for banks to search for higher yield in more risky projects. If, thereby, lending standards are relaxed and risk assets of banks as a share of their total assets are substantially increased, this will probably cause a deterioration of banks' charter value and an increase in the likelihood of crises. Rajan (2006) goes on to state explicitly that the source of such bank behavior could be an environment of low interest rates. For instance, a prolonged period of low interest rates, and the associated decline in the volatility of these rates, releases risk budgets of banks and encourages higher risk positions. In addition, very low nominal rates are usually coupled with a reduction in the margin between the lending and the deposit rate of banks (i.e. bank margins) and this raises incentives of banks to search for yield through the mechanism implied in Dell' Ariccia and Marquez (2006). The mechanisms described so far sound sensible, but unavoidably this discussion also concerns expansionary monetary policy. Borio and Zhu (2008) introduce the term "risk-taking channel of monetary policy

transmission" to characterize the potential relationship between an expansionary monetary policy and increased bank risk-taking.

In the period following the terrorist attack of 9/11 on the World Trade Center, the nominal interest rates reached very low historical levels. For example, the money-market rate went down from 6.24% in 2000 to 1.13% and 1.35% in 2003 and 2004, respectively. This policy was primarily led by fears related to an economic slowdown owing to hurt consumer confidence. The accompanied reduction in the euro area was equally important, given analogies. The money-market rate in the euro area decreased from 4.38 in 2001 to 2.05% and 2.09% in 2004 and 2005, respectively. In addition, the level of interest rates since 2002 remained particularly low, lower than any other period of equivalent length in the last three decades. Given these theoretical considerations and empirical facts, this study asks how banks reacted to these developments. Did they perceive the low level of interest rates as threatening to their profitability? And if yes did they increase their risk-taking appetite in search for yield?

Empirical evidence on the relationship between interest rates and bank risk is limited to the recent work of Jimenez *et al*. (2008), Ioannidou *et al*. (2009) and Brissimis and Delis (2009). All three papers focus on the impact of monetary policy changes on bank risk, in other words on the risk-taking channel of monetary policy. Jimenez *et al.* (2008) employ data on Spanish banks over a relatively long period and find that an expansionary monetary policy is indeed associated with higher credit risk. Ioannidou *et al.* (2009) use the Bolivian case as a quasi-natural experiment of exogenously-taken monetary policy and find very similar results. Finally, Brissimis and Delis (2009) are more concerned with whether monetary policy fluctuations cause differential bank behavior towards their lending and risk-taking decisions on the basis of internal bank characteristics.

Clearly, more research is needed on the interest rates-bank risk nexus and the present study aims to contribute to this literature in three ways. First, we are more concerned with the

specific developments on the level of interest rates in the period after the terrorist attack of 9/11, since observers and analysts link these developments to the recent financial turmoil that unfolded to a recession. Apparently, we are interested in the level of interest rates, and not on monetary policy changes, even though we also carry out sensitivity analyses on this front. We believe that an empirical analysis on the level of interest rates is closer to the theoretical propositions of Dell' Ariccia and Marquez (2006) and Rajan (2006) because an expansionary monetary policy could still imply relatively high levels of interest rates. Second, instead of focusing on a single economy, we use a large international dataset that covers a total of 3628 banks operating in the euro area during the period 2001-2008 (the total number of observations is a bit over 18000). The richness of this dataset allows drawing general conclusions about the theoretical considerations discussed above and relating these conclusions to the economic downturn. Third, the stance we take towards the relationship in hand is more from the side of bank behavior and less from the side of the central bank's policy goals. That is, we estimate risk equations that follow directly from the literature on the determinants of bank risk, where the impact of the regulatory and supervisory environment is directly controlled for. We view this amendment as particularly important, since lack of controls pertaining to capital regulation, official supervisory power and market discipline of banks in risk equations is more than likely to lead to omitted-variable bias.

The euro area seems an ideal setting to provide empirical evidence that will help identifying a link between interest rates and bank risk-taking. In forming the central bank rates, the European Central Bank (ECB) pursues, more clearly than the Federal Reserve, the objective of price stability above all potential other objectives. Therefore, monetary policy in the euro area has not been viewed by the ECB, at least until recently, as a mechanism that could potentially impair the performance of the banking sector, or change the structure of its risk-taking activities. In fact, the direct responsibility for banking supervision and financial stability remains mainly

with the competent authorities in each EU Member State, and the Treaty of Rome has only assigned to the European System of Central Banks the task of "contributing to the smooth conduct of policies pursued by the competent authorities relating to the prudential supervision of credit institutions and the stability of the financial system". Therefore, interest-rate decisions have not been affected during our sample period by developments in the banking sector in the euro area and the ECB has viewed, until the recent past, monetary policy and supervision of banks as two distinctively different tasks.

Alas, identification problems in the nexus between interest rates and bank risk-taking may still be present if one considers that (i) both these variables are affected by the general macroeconomic conditions and (ii) interest rates charged by individual banks may be endogenous in the risk-taking decisions of these banks. Furthermore, existing studies of the determinants of bank risk suggest that bank risk-taking behavior is highly persistent. We tackle the first and third problems by means of appropriate estimation methods and through various sensitivity analyses and the second problem by using a large bank panel dataset as in related studies of the bank-lending channel (see e.g. Kashyap and Stein, 2000; Ashcraft, 2006).

In a nutshell, the findings exhibit a strong negative relationship between the level of interest rates and bank risk-taking. This holds irrespective of the variable used to proxy interest rates (short- or long-term, industry- or bank-level) and irrespective of whether the level or the change in interest rates is considered. The findings are robust to (i) the estimation method and (ii) the use of annual or quarterly data. Therefore, the theoretical considerations of Dell' Ariccia and Marquez (2006), Rajan (2006) and Borio and Zhu are confirmed, as banks seem to have increased substantially their risk-taking appetite during the low-interest rates period under consideration. Finally, we find that the distributional effects of interest rates on bank risk-taking due to individual bank characteristics reveal that the impact of interest rates on risk assets is

diminished for banks with higher equity capital and is amplified for banks with higher off-balance sheet items.

The remainder of the paper is organized as follows. Section 2 provides the general empirical model to be estimated and discusses the dataset. Section 3 describes the specific identification frameworks used in the empirical analysis and presents the empirical results. Finally, Section 4 provides policy implications and concludes the paper.

2. Econometric model and data

The general empirical model to be estimated is of the following form:

$$r_{it} = \alpha + \beta_1 ir_{it} + \beta_2 b_{it} + \beta_3 c_t + u_{it} \quad (1)$$

where the risk variable, *r*, of bank *i* at time *t* is written as a function of the interest rate variable, *ir*, that may or may not have a cross-sectional dimension according to the measure employed; a set of bank-level control variables, *b*; and a set of regulatory, macroeconomic and structural control variables, *c*, which are common to all banks. This general model will be augmented with specific theoretical and empirical elements as the empirical analysis goes on. Yet, prior to carrying out the empirical analysis we should discuss the dataset and the variables used.

We build a large unbalanced panel dataset to examine the relationship between various interest rates and bank risk-taking. Annual bank-level data are collected from the Bankscope database. The panel includes commercial banks, savings banks, cooperative banks and bank-holding companies that were operating in the 16 euro area countries over the period 2001-2008.[1] Investment banks are not included because they do not take deposits and, therefore, do not fall into the theoretical discussion provided above. We use data from consolidated accounts if available and otherwise from unconsolidated accounts. The original dataset includes 19121 bank-year observations. However, the final sample is smaller as we apply an outlier rule to the main

[1] The countries are Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Malta, Netherlands, Portugal, Slovak Republic, Slovenia and Spain.

variables, which allows dropping the banks for which data on some variables are either not available or contain extreme values for certain variables. The final sample consists of 18067 bank year observations.

An immediate question that arises is whether an analysis of the interest rates-bank risk nexus is possible using annual data. An excellent discussion of this issue is offered in Ashcraft (2006, pp. 760): "Kashyap and Stein (2000) use a two-step procedure on quarterly data where they first run a sequence of regressions by cross-section and then use the estimated coefficients in a time-series regression. Newey and McFadden (1994) point out that standard errors from the second stage of a two-step estimator are generally inconsistent. Only when the consistency of the first-stage does not affect the consistency of the second stage will the estimated second-stage standard errors be appropriate. If one combines both steps into one using a generalized difference-in-difference estimation strategy, however, this issue can be entirely avoided. The sacrifice here practically is that one must use a lower frequency of data. As this one-step approach requires that all variables and their potential interactions with macro-variables be present in the regression it is simply not practical to use quarterly data". Note that in estimating risk equations we will be dealing with distributional effects of the interest-rate variables and thus the above discussion applies directly to our study. Yet, also note that the spotlight here is placed first and foremost on the level of interest rates and only secondarily in their change. This is an additional reason on why annual data on bank- or industry-level interest rates is probably sufficient to analyze the relationship in hand, as by nature an analysis of the level of interest rates considers a longer-term phenomenon compared to monetary policy changes. Still, both Ashcraft (2006) and Gambacorta (2005) compare the results obtained from annual data with those obtained from quarterly data of similar samples and find that annual data is sufficient to explain the impact of monetary policy rates on bank lending. To ensure robustness, we also build in Section 6 below a secondary dataset with quarterly bank data (obtained from Bloomberg) to

examine the sensitivity of our results. Since this dataset includes a significantly lower number of banks, we only use it for comparative purposes.

Table 1 provides summary statistics for all the variables used in this study. Table 2 reports correlation coefficients between these variables, showing that correlations are higher than acceptable levels only between the interest-rate variables (discussed below) to be used in alternative specifications. In what follows, we analyze the choice of our dependent and explanatory variables.

2.1. Bank risk-taking

We proxy the risk-taking behavior of banks using primarily the ratio of risk assets to total assets (denoted as *risk assets*) and secondarily the ratio of non-performing loans to total loans (denoted as *non-performing loans*). Data for both these variables is obtained from Bankscope and descriptive statistics are reported in Table 1. The first measure reflects the riskiness of bank portfolios at any point in time and corresponds directly to the term "bank risk-taking". Bank risk assets include all bank assets except cash, government securities (at market value) and balances due from other banks. In other words, all bank assets subject to change in value due to changes in market conditions or changes in credit quality at various re-pricing opportunities are included as risk assets. Naturally, an increase in *risk assets* demonstrates a more risky position of banks. In our sample the mean value of *risk assets* equals 0.776; the lower average value is reported in 2002 (0.740) and the highest in 2006 (0.791). This 5% increase from 2002 to 2006 cannot go unnoticed, as it represents a substantial shift in the average risk-taking behavior of banks. In light of the building of the financial bubble that led to the crisis, the average *risk assets* decreased to 0.775 in 2007 and reached a value of 0.745 in 2008, when the financial crisis has unfolded to a recession.

In turn, *non-performing loans*, reflects the quality of bank assets, i.e., the potential adverse exposure to earnings and asset market values due to deteriorating loan quality. In other words, *non-performing loans* is a proxy for credit risk. Since a portion of non-performing loans will result in losses for the bank, a high value for this ratio is associated with higher credit risk. The total number of observations for this variable is 14218, with a mean value of 0.031. Relatively high values are observed in 2001 (0.039) and in 2008 (0.037), while the lowest average value is observed in 2005 (0.280). Given that *non-performing loans* represents credit risk this measure is likely to be inferior to *risk assets* because of two reasons. First, credit risk may or may not be the result of bank managerial practices. For example, part of the non-performing loans may be due to adverse macroeconomic developments that lead to systemic risk and borrowers' default, and not due to the increased risk-taking appetite of banks that would be reflected in a higher *risk assets* ratio. Second, the *non-performing loans* ratio reflects credit risk, while the *risk assets* ratio encompasses other forms of assets besides loans (e.g. maturing bank CDs) and hence represents a more universal measure of risk-taking. Thus, in the present analysis we favor *risk assets* as our measure of bank risk-taking and we conduct sensitivity analyses using the *non-performing loans* ratio.[2]

2.2. Interest rates

The present study is concerned with the relationship between the general level of interest rates and bank risk-taking. To this end, we experiment with various interest rates, including a short-term rate, a long-term rate, the central-bank rate and a bank-level lending rate.[3] Data for the first three country-level interest-rate variables is obtained from Eurostat and concerns annual averages (summary statistics are provided in Table 1). In particular, the short-term rate is the

[2] Note that related studies proxy bank risk using a number of other measures, such as the Z-index, the variance in bank profits etc. Yet, these measures are better viewed as insolvency risk, not "bank risk-taking" and therefore they are only loosely related to the theoretical considerations set out in the introduction.

[3] We also used other measures for the interest-rate variable with a lower maturity (overnight, one month). Our estimation results remained practically unchanged.

annual average of the 3-month interbank rate; the long-term rate is the annual average of the 10-year government bond yield; and the central-bank rate is the European Central Bank policy rate for the euro area countries and the official refinancing operation rate for some of the countries in our sample before these adopted the euro (i.e. Slovenia before 2007, Cyprus and Malta before 2008 and Slovakia for the full period). The first two measures are richer in information as they vary between countries. Using various country-level measures allows us to potentially capture different aspects of the impact of interest rates and check the robustness of our estimation results. The average values of all these rates have been declining up to 2005 and rising again afterwards. A slight exception concerns the central bank rate, which significantly falls in 2008 compared to 2007 owing to the adverse economic developments and the associated effort of the European Central Bank to pursue expansionary monetary policy.

The bank panel dataset also allows utilizing a bank-level lending rate, which significantly increases the number of observations on the interest-rate variable. Following the bulk majority of the banking literature (see e.g. Goddard *et al.*, 2001 and references therein), we use Bankscope data to proxy bank-level rates by the ratio of interest income to total customer loans. This ratio shows the average price of loans that each bank charges on its customers.[4] After some trimming of the original dataset (see discussion above), we are left with a total of 18067 observations for this variable. The average value in our sample equals 0.092 and the trend is diminishing up to 2005 (the average value in 2001 is 0.107 going down to 0.080 in 2005), then rising up to 0.093 in 2008.

Figure 1 presents a simple non-parametric regression on the relationship between the bank-level lending rate and *risk assets*. In the first regression we use almost the full array of observations, while in the second we restrict the values of both the dependent (risk assets) and the independent (bank-level lending rate) variables. The regression clearly points out to a

[4] As a robustness check we additionally used the ratio of total bank revenue to total earning assets, which reflects the more general average interest rate of banks. The results remained practically unchanged and are available on request.

negative relationship, which is the first evidence that low rates are associated with higher bank risk-taking. It remains to examine whether this relationship is altered when a number of control variables are included in the usual parametric regressions.

2.3. Control variables

The highly sophisticated technology and the new risk management techniques introduced into banking in the 1990s and 2000s allowed banks to increase the level of risk assets as a share of total assets and thereby raise their profitability. If we do not control for technology changes, then an increase in risk assets as a share of total assets may not be due to "real" increases in bank risk-taking but rather reflect the more sophisticated risk-related technology available to banks. Therefore, in all estimations we include a time trend or time effects among the regressors. In addition, we control for cross-country differences using country dummy variables. Besides these baseline control variables, we include numerous bank- and country-level controls in our estimated equations so as to avoid omitted-variables bias. These variables are defined and discussed below, while summary statistics are reported in Table 1.

At the bank-level we control for a number of bank characteristics that may affect risk-taking (all required data is collected from Bankscope). First, we use the ratio of equity capital to total assets as a measure of bank capitalization and the ratio of profits before tax to total assets as a measure of bank profitability. Banks are expected to tradeoff higher levels of equity capital for risk assets, this relationship clearly being endogenous. In turn, the impact of profitability on bank risk-taking is ambiguous. On the one hand, a higher level of risk assets may be associated with higher profits, especially in good times, and higher levels of profits may be used to make new loans in the next period. In contrast, too high risks may lead to problem loans and lower profitability that will eventually imply fewer risk assets in the next period. To this end, profitability is also endogenous and enters the estimated equations lagged once. In addition, bank

size, specialization and efficiency are also potentially important elements in shaping bank risk. Technically efficient banks may be more capable in managing risks; however, higher risks may also explain technical efficiency levels if they are responsible for the level of bank income. Clearly, efficiency (measured by the ratio of total revenue to total expenses) should also be treated as an endogenous variable in risk equations. Another bank-level control variable is the level of non-traditional activities, which have seen a sharp increase over the last decade. We control for these activities using the ratio of off-balance sheet items to total bank assets. Finally, in all estimated equations we control for bank size using the natural logarithm of real total assets. Since banks at any given point in time are aware of their relative size when they make risk decisions, we do not consider this variable as endogenous, but rather as predetermined (for a discussion on this issue, see Athanasoglou *et al*., 2008). For a similar set of bank-level controls in risk equations, see e.g. Laeven and Levine (2009) and Demirguc-Kunt *et al*. (2008).

Furthermore, it is well-known that bank risk is driven by the regulatory, macroeconomic and structural conditions prevailing in each country examined (see e.g. Laeven and Levine, 2009). Failing to control for the regulatory conditions will most likely lead to a serious omitted-variable bias. Using the dataset of Barth *et al.* (2008) and previous versions, we construct three regulatory indices pertaining to capital stringency, official supervisory power and market discipline.[5] The first index shows the extent of both initial and overall capital stringency. Initial capital stringency refers to whether the sources of funds counted as regulatory capital can include assets other than cash or government securities and borrowed funds, as well as whether the regulatory or supervisory authorities verify these sources. Overall capital stringency indicates whether risk elements and value losses are considered while calculating the regulatory capital. Theoretically, the capital stringency index can take values between 0 and 8, with higher values indicating more stringent capital requirements. The second index reveals the power of the

[5] These indices are constructed on the basis of information obtained in three points in time that correspond to updates in the Barth *et al.* database. Many other studies that have used this database across a number of years followed a similar approach (e.g. Fernandez and Gonzalez, 2005; Pasiouras *et al*., 2006).

supervisory agencies to take specific actions in relation to their authority against bank management and directors, shareholders, and bank auditors. The supervisory power index can take values between 0 and 14, with higher values denoting higher supervisory power. The third regulatory index reflects the degree to which banks are forced to disclose accurate information to the public (e.g. disclosure of off-balance sheet items, risk management procedures, etc.) and whether there are incentives to increase market discipline. A thorough description of the way these indices are constructed is provided in the Appendix.[6]

At the country-level we also control for the state of the macroeconomic environment using the GDP growth rate and the importance of the banking sector in providing credit to the economy using the ratio of domestic credit provided by banks to GDP. During more favorable macroeconomic conditions banks tend to increase their lending in search for higher yield and therefore a positive relationship is expected between GDP growth and risk assets. In turn, the share of credit provided by banks can be viewed as a proxy for alternative sources of finance within a country and, therefore, a higher ratio reflects higher credit constraints. We expect that in countries with higher credit constraints banks inherently take on higher risks so as to meet the demand for credit. Finally, we control for banking industry concentration using a 3-bank concentration ratio. Boyd *et al*. (2006), among others, find that banks' probability of failure is positively related with concentration, while other studies (e.g. Jimenez *et al*., 2007) suggest that problem loans and concentration are uncorrelated.

3. Econometric analysis and results

Empirical estimation of Eq. (1) presents a number of identification challenges, the main two being the potential endogeneity of the interest-rate variable and the persistence of bank risk. In addition, in the banking literature, it is well-known that bank characteristics such as

[6] As a robustness check we used alternatively the composite economic freedom index, obtained from the Heritage Foundation database. Since this index (or its sub-indices) is not directly linked to regulations in the banking sector, we only report the results on the basis of the Barth *et al*. (2008) indices.

capitalization, profitability, etc., are also endogenous in risk equations. We start by considering a simple econometric model, where only interest rates are endogenous. Subsequently, we estimate a dynamic panel data model that accounts for risk persistence and endogeneity of the bank-specific controls. Based on our theoretical considerations, we view this model as more sensible and thus we also use it to examine the distributional effects of interest rates on bank risk due to certain bank characteristics. Finally, we examine whether our main results hold (i) separately for the major euro area countries, (ii) if we consider models of changes in the risk and interest-rate variables and (iii) if we employ a quarterly dataset. All estimated equations include time and country effects (dummies) that have been found to be jointly statistically significant, but are not reported to save space.

3.1. Endogenous interest rates

Ioannidou *et al*. (2009) and Jimenez *et al*. (2008) use data on the Bolivian and Spanish banking sectors, respectively, and suggest that both interest rates and risk are endogenous to the macroeconomic conditions in these countries. In our empirical setting, the use of an international bank panel dataset probably mitigates this type of endogeneity. Differently phrased, the assumption that bank-level risk of each and every bank in the euro area shapes the general level of interest rates seems to be particularly strong. Especially in the period under consideration, we have no evidence that the ECB determines policy rates by looking into bank risk-taking. However, the bank-level lending rates may still be endogenously determined with the level of bank risk-taking if one considers that banks shape their own lending rate by discounting the expected level of risk in their portfolios. Hence, we have to instrument. A clever choice for an instrument on euro area interest-rate variables is made by di Giovanni *et al*. (2009). In particular, they argue that interest rates in the European Union are directly affected by German short-term nominal interest rates. They extend the analysis of Clarida *et al*. (1998), and show that the

German interest rate plays an important role in the reaction function of major euro area countries. In our dataset, we verified statistically that the German short-term interest rate (annual average of one month rate) is a good instrument by using a Sargan test for overidentifying restrictions.[7] We also verify that the instrumental variables (IV) method is preferable to OLS by using a Hausman test. Based on these considerations and tests, we use this particular German rate as an instrument for the interest rates of other euro area countries.[8]

The results obtained from the estimation of Eq. (1) using the panel data IV method are presented in Table 3. All interest rates employed bear a negative and strongly significant coefficient, showing that lower interest rates increase bank risk-taking. This result holds irrespective of the variable used to proxy bank risk-taking, which is *risk assets* in regressions I-IV and *non-performing loans* in regressions V-VI and irrespective of the interest-rate variable chosen. The bank-level lending rate is also a negative and highly significant determinant of bank risk, yet it somewhat changes the effect of some of the control variables. However, it still remains unanswered whether the dynamic nature of bank risk-taking and the potential endogeneity of some of the control variables affect the results. Below we estimate a dynamic panel data model to stress these issues.

3.2. Dynamic risk and endogenous controls

An essential concern in estimating Eq. (1) above using an IV method is that bank risk persists and thus will deviate from equilibrium in the short run. At least four theoretical reasons can be provided to explain the dynamic nature of bank risk. First, persistence may reflect the existence of intense competition, which tends to alleviate the risk-taking of banks (e.g., Keeley, 1990; Cordella and Yeyati, 2002). Second, relationship-banking with risky borrowers will have a

[7] In addition, we identify a strong correlation between the instrument (i.e. the German one-month rate) and the various interest rates used as independent variables (equal to 0.84) and a relatively weak correlation between this instrument and the bank risk-taking variables (equal to -0.13).

[8] We also experimented with the first lags of the various interest rates variables employed as instruments. The results were quantitatively similar but the tests for overidentifying restrictions were weaker.

lasting effect on the levels of bank risk-taking, despite the fact that dealing repeatedly with the same customer will improve efficiency. A similar mechanism would prevail given bank networks or if the banking industry is opaque. Third, to the extent that bank risk is associated with the phase of the business cycle, banks may require time to smooth the effects of macroeconomic shocks. Fourth, risks may persist due to regulation. In particular, deposit guarantees or capital requirements may exacerbate moral hazard issues, leading to inefficient and risky investments over a considerable period of time. Finally, above and beyond the aforementioned theoretical considerations, the potential impact of stock variables on flow variables may be better approximated by a dynamic formulation. All in all, if risk indeed persists a static model is biased, the choice of a dynamic empirical model (i.e., one including a lagged dependent variable) is well-justified, and the coefficient on the lagged risk variable may be viewed as the speed of convergence to equilibrium. These considerations lead to the estimation of the following variant of Eq. (1):

$$r_{it} = \alpha + \delta(r_{i,t-1}) + \beta_1 ir_{it} + \beta_2 b_{it} + \beta_3 c_t + u_{it} \qquad (2)$$

Eq. (2) can be estimated using the generalized method of moments for dynamic panel data put forward by Arellano and Bover (1995) and Blundell and Bond (1998). A value of δ statistically equal to 0 implies that bank risk is characterized by a high speed of adjustment, while a value statistically equal to 1 means that the adjustment is very slow. Values between 0 and 1 suggest that risk persists, but will eventually return to its normal (average) level. Finally, δ takes implausible (negative) values if convergence to equilibrium cannot be achieved, which probably indicates a problem with the dataset (e.g. a very small time dimension of the panel).[9] Besides accounting for the specified dynamics, the Blundell-Bond estimator has two additional virtues. First, it does not break down in the presence of unit roots (for a proof see Binder *et al.*, 2003).

[9] For more on these issues, see Nerlove (2002, pp. 273-304).

Second, and most important, it accommodates the possible endogeneity between the risk and some of the right-hand side variables by means of appropriate instruments.

In particular, besides the interest-rate variables, we treat as endogenous the variables reflecting capitalization, lagged profitability, efficiency, and off-balance sheet items.[10] The theoretical reasons suggesting that these variables are endogenous are traced in Section 2 above. Econometrically, endogeneity implies that these variables are correlated with u_{it} and earlier shocks but uncorrelated with $u_{i,t+1}$ and subsequent shocks. Then, these variables enter the estimated equations by treating them symmetrically with the dependent variable. In other words the set of instruments is given by $(r_{i1},\ldots,r_{i,t-3},\ x_{i1},\ldots,x_{i,t-3})$, where x is the set of endogenous variables.[11] In addition, all the regulatory indices and bank size are treated as predetermined variables. Thus, we assume that in determining the level of risk-taking, banks are aware of the regulatory environment and their size. Econometrically, this implies that for predetermined variables z, their second lag $z_{i,t-2}$ is also a valid instrument. Therefore, the full set of instruments is given by the vector $(r_{i1},\ldots,r_{i,t-3},\ x_{i1},\ldots,x_{i,t-3},\ z_{i1},\ldots,z_{i,t-2})$.

The empirical results are reported in Table 4. First-order autocorrelation, AR1, could be expected in the first differences of the errors; however, higher order autocorrelation would indicate that some lags of the dependent variable are in fact endogenous, thus bad instruments. In all estimated equations the test for AR2 rejects the presence of second-order autocorrelation. Moreover, the Sargan test indicates that the model is not over-identified. The coefficients on the lagged dependent variables suggest that bank risk-taking is highly persistent. We also experimented with a higher order of lags for the dependent variables and we found no persistence beyond the first year. Therefore, and given the discussion on δ above, bank risk persists but will eventually return to its equilibrium level.

[10] The discussion on instrumental variables that follows is based, among others, on Arellano and Bover (1995), Blundell and Bond (1998) and Bond (2002).

[11] We do not use the second lags $r_{i,t-3},\ x_{i,t-3}$ as instruments because the validity of the lagged levels dated t-2 as instruments is rejected by the Sargan test of overidentifying restrictions.

The coefficients on the various interest-rate variables remain negative and highly significant. Therefore, the dynamics do not affect the significance of the results compared to the IV estimates. However, the impact of the control variables is more explanatory in the dynamic setting. Bank size is negative and highly significant (insignificant in the IV regressions) confirming the theory that larger banks are more risk averse. In addition, the impact of the off-balance sheet ratio is now positive, while it was negative in the IV regressions. This positive effect implies that banks engaging more in non-traditional activities also tend to take on higher risks in their traditional activities. In contrast, a higher level of off-balance sheet items does not seem to increase the level of problem loans, as the relevant coefficient in columns V-VI is insignificant. In both Tables 3 and 4, bank capitalization is negatively related with both measures of risk-taking, which is intuitive since higher equity capital (that could be the result of stricter capital requirements) implies more prudent bank behavior. The impact of lagged profitability on risk assets is insignificant, while it substantially raises the non-performing loans ratio. This is a very interesting result, which shows, that at least in the period examined, euro area banks used the profits of the previous period not to increase risk assets but to fund qualitatively more risky projects.

Concerning the impact of the country-level variables, we first notice that from the regulatory variables only the market discipline index restricts the level or risk assets in bank portfolios (see relevant coefficients in columns I-IV). Therefore, regulations aiming at increasing subordinated debt as part of capital and improving the transparency of the banking system are important in containing the risk-taking appetite of banks. In contrast, all regulation policies improve the quality of portfolios as shown in the relevant coefficients on the three regulatory indices in columns V-VI. Concerning the structural and macroeconomic variables, financial systems that rely extensively in banking to fund projects are associated with significantly higher levels of bank risk-taking, while in periods of high GDP growth risk assets somewhat rise and

non-performing loans rise substantially. Finally, concentration is statistically insignificant in all specifications, confirming the findings of e.g. Jimenez *et al*. (2007).

Table 5 reports the coefficient estimates on the bank-level lending rates obtained from the dynamic panel data method, using separately the panels of the four largest euro area countries (i.e. France, Germany, Italy and Spain). In all countries but France the coefficients are negative and highly significant. In France the coefficient is significant only at the 10% level, which suggests that French banks did not increase considerably the level of risk assets in their portfolios. Notably, French banks have on average the lower risk assets ratio among the four banking sectors (0.69 in France, compared to 0.83 in Germany, 0.78 in Italy and 0.76 in Spain) and the higher average bank-level lending rate (0.096, compared to 0.092 in Germany, 0.078 in Italy and 0.080 in Spain). This shows that lending-rate stickiness and risk aversion is higher among French banks, and this partially explains why French banks were proven more resilient to the global financial crisis (see also Xiao, 2009).

3.3. Distributional effects of interest rates due to bank characteristics

Following (i) the extensive literature on the relationship between policy interest rates and bank lending (i.e. the bank lending channel of monetary policy transmission) and (ii) the part of the study of Brissimis and Delis (2009) that concerns the risk-taking channel, we examine here whether interest rates have a differential effect on bank risk owing to certain characteristics of bank balance sheets. To carry out this exercise we re-formulate Eq. (2) as follows:

$$r_{it} = \alpha + \delta(r_{i,t-1}) + \beta_1 ir_{it} + \beta_2 b_{it} + \beta_3 c_t + \beta_4 ir_{it} * b_{it} + u_{it} \qquad (3)$$

We experiment with interaction effects that include all the bank-level control variables used above, but we only show the results of the ones that have a significant effect. These variables are capitalization, size and off-balance items. A problem with the inclusion of interaction effects is the severe multicollinearity between the multiplicative term and its

constituents. We deal with this issue by "mean centering" the relevant *ir* and *b* variables. This procedure consists of transforming the values of *ir* and *b* to deviations from their means, and then forming the product term from these deviations. After applying mean centering to all the interest-rate variables and to the bank-level variables reflecting size, capitalization and off-balance sheet items, the correlation coefficients, that were as high as 0.98,[12] fall to the levels reported in Table 6. Thus, we are now ready to estimate Eq. (3).

The estimation results are presented in Table 7. Estimations are carried out using the dynamic panel data method and, to save space, we only report the results from equations that include the short-term rate and the bank-level lending rate. The findings suggest that the impact of interest rates on risk assets is diminished for banks with higher equity capital and is amplified for banks with higher off-balance sheet items (see columns I and II). In other words, banks with high capital are able to absorb the impact of interest rates on bank risk, whilst for banks that are highly exposed to non-tradition activities this impact is more severe. The same holds for capitalization in the *non-performing loans* equations (columns III-IV), while the level of off-balance sheet activities does not have a direct or a distributional effect in these equations. Bank size seems to have a distributional effect only when *non-performing loans* are used as a proxy for bank risk-taking. This implies that very large banks are able to buffer the impact of interest rates on problem loans. Note that, as problem loans may be the result of systemic risk and not higher risk-taking, this result shows that the distributional effect of size on the interest rates-bank risk nexus is probably better captured in the *risk assets* equations, which show no significant role for bank size.

The specifications with interaction terms allow us to examine whether the total effect of interest rates can change sign depending on the value of bank characteristics. This is particularly interesting in the case of capitalization, where a negative and significant coefficient is found on

[12] The initial correlation coefficients between these variables are available on request.

the interest rate variables and a positive and significant coefficient is found on the interaction term of these variables with capitalization. To calculate the value of capitalization, where the impact of interest rates on bank risk turns positive, we take the derivative of the estimated equations with respect to capitalization. These calculations for the equations presented in columns I-IV yield 0.115, 0.121, 0.128 and 0.148, respectively.[13] Hence, for example, we find that for banks with equity capital ratios higher than 0.121, the impact of the bank-level lending rate on *risk assets* turns positive and this happens for 2434 observations in our sample. Similarly, for banks with equity capital ratios higher than 0.148, the impact of the bank-level lending rate on *non-performing loans* turns positive; this occurs for 1545 observations in our sample.

3.4. Changes in interest rates and bank risk-taking

As discussed above, existing studies of the relationship between interest rates and bank risk focus on monetary policy changes. These studies follow the approach of the bank-lending channel literature (see e.g. Kashyap and Stein, 2000, and the collective volume of Angeloni *et al*., 2003) and regress changes in bank risk variables on changes in monetary policy rates. This is clearly an assessment of the so-called risk-taking channel of monetary policy that we discussed in the introduction. To assess the impact of changes in interest rates on changes in bank risk-taking we estimate the equation:

$$\Delta r_{it} = \alpha + \delta(\Delta r_{i,t-1}) + \beta_1 \Delta ir_{it} + \beta_2 b_{it} + \beta_3 \Delta c_t + u_{it} \qquad (4)$$

where Δ reflects change from the previous period (year).[14] Estimation is carried out using the dynamic panel data method described above and the results are reported in Table 8.

[13] Note that the short-term rate is in percentage points and, thus, to carry out the calculations we multiply its coefficient by 100.

[14] Also, the well-known identification problem of the bank-lending channel (i.e. distinguishing shifts in loan demand from shifts in loan supply in reduced-form lending equations) is probably not present here, as information on the risk assets variable clearly reflects the level of bank risk that each and every bank in the sample takes on and has nothing to do with the borrowers. This may not be as accurate in the case of the non-performing loans ratio, as this variable also reflects the side of borrowers.

The coefficients on the various interest-rate variables remain negative and highly significant. These results are equivalent to the existence of a risk-taking channel of monetary policy transmission in the euro area. As Borio and Zhu (2008) suggest a risk-taking channel may be at work because of two reasons. The first reason is the same with what we discussed about the level of interest rates, and suggests that reductions in interest rates may cause reduced volatility and lower interest rate margins. The former effect tends to release risk budgets and encourage positions of higher risk, wile the latter puts pressure on banks to search for yield in more risky projects. The second reason concerns perceptions on central bank commitment to future policy decisions. By increasing the degree of transparency or commitment accompanying monetary policy, the central bank essentially reduces uncertainty. Once more, this allows banks to redistribute budgets that were previously related to forecasting towards risk-taking activities. It seems very likely that both mechanisms prevailed in the euro area during the period under consideration and, thus, explain the strong negative coefficients on the interest-rate variables. Note, however, that much like with the estimates obtained from Eq. (2), French banks do not seem to change their risk-taking behavior following a change in the interest rates (see second column of Table 5).

Concerning the impact of the control variables, we do not observe significant changes from those of the regressions presented in the tables above. The only exception is the impact of economic growth, which is found to be positive and strongly significant in the equations of Table 8, implying that in periods (and countries) where the economy is booming, banks tend to substantially increase their risk assets and face higher problem loans. Yet, this may be highly problematic if the accumulated problem loans lead to financial distress in the next period.

3.5. Evidence from quarterly data

A potential criticism on the analysis above is that annual data may be not sufficient to properly identify the impact of interest rates on bank risk-taking. Even though this study is primarily concerned with whether the low interest rates of the 2000s contributed to excess risk-taking of banks and only secondarily with the impact of short-term responses of risk-taking to monetary policy changes, we additionally build a quarterly dataset to inquire into the robustness of our main results. We collect quarterly bank-level data for the same set of euro area countries and for the same time frame. Data is obtained from Bloomberg, which unfortunately contains information only on listed companies. Admittedly, this may signal a data-selection bias, but still this is our best choice. Applying the same selection criteria with the annual data, we end up with 503 banks and 5081 bank-level observations. We re-estimate Eqs. (2) and (3) using the dynamic panel data method, however this time we have to use the first three lags of the dependent variable among the regressors. The set of instruments is also formatted accordingly.

Estimation results are reported in Table 9. We report four equations, the first two including basic estimations on the short-term and bank-level rates and the other two including interaction terms as in Table 7. The findings are surprisingly similar to those observed above at an annual frequency. The short-term rates lose on statistical significance but remain significant at the 5% level. In contrast, the bank-level rate remains significant at the 1% level. Previous findings regarding the distributional effect of capitalization continue to hold when bank-level rates are used (see column V), however this effect weakens when the short-term rate is used (column IV). The impact of the control variables also remains very similar to those presented in the various tables above. Therefore, we argue that when it comes to the examination of the relationship between interest rates and bank risk-taking, there is no loss of information with the use of annual data.

4. Summary of findings and policy implications

The 2000s have seen a prolonged period of low levels of interest rates in market-based economies, matched with liberalized banking systems and considerable expansion of credit. Mainstream economic theory and policy aligned with the adoption of free market policies, has viewed these developments as a recipe for accelerated growth and economic prosperity (see e.g. Shleifer, 2009). This belief is probably true if one considers the macroeconomic and technological advancement of the last three decades. However, the strength and the nature of the recent global financial crisis that unfolded to a recession in 2008, reminded us once again that the efficient functioning of the banking system is not only a matter of liberalization and integration; it also requires a comprehensive assessment of bank risk and a restraint of associated risk-taking incentives of banks.

Using a recent line of theoretical and empirical literature as a springboard, this study has aimed to isolate the impact of the long-drawn-out period of low levels of interest rates on the risk-taking behavior of banks. The empirical analysis, conducted on a large panel of euro area banks, revealed a strong negative relationship between bank risk-taking and interest rates. Thus, the low interest-rate environment unambiguously increased risk-related bank assets and altered the composition of euro area bank portfolios toward a more risky position. We also found that this negative relationship is stronger for banks that engage in non-traditional banking activities (higher volume of off-balance sheet items) and weaker (but still significant) for banks with high levels of capitalization.

We contend that these findings point out to policy considerations toward three main directions. First and foremost, central banks should consider the risk-loving bank behavior within a low interest-rate environment when setting monetary policy. All in all, an aftermath of this crisis may be that monetary policy and financial stability are interrelated and this necessitates the development of a new theoretical framework, where financial stability enters into the Taylor rule

framework. Second, given that non-traditional bank activities and capitalization seem to play a central role in banks' risk-taking behavior, institution-building and the restoration of competent and effective regulatory and supervisory power over these bank characteristics may hold the key to a more prudent bank behavior. Finally, and related to the above, it seems apparent that discussions surrounding the revitalization of a Glass-Steagal type of separation of bank activities, or banks internalizing the cost of regulation especially during good times, may be interrelated with decisions concerning the demand and the supply of credit in general and the level of interest rates in particular.

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Appendix. Construction of regulatory variables

Variable	Description
Capital requirements index (caprq)	This variable is determined by adding 1 if the answer is yes to questions 1-6 and 0 otherwise, while the opposite occurs in the case of questions 7 and 8 (i.e. yes=0, no =1). (1) Is the minimum required capital asset ratio risk-weighted in line with Basle guidelines? (2) Does the ratio vary with market risk? (3-5) Before minimum capital adequacy is determined, which of the following are deducted from the book value of capital: (a) market value of loan losses not realized in accounting books? (b) unrealized losses in securities portfolios? (c) unrealized foreign exchange losses? (6) Are the sources of funds to be used as capital verified by the regulatory/supervisory authorities? (7) Can the initial or subsequent injections of capital be done with assets other than cash or government securities? (8) Can initial disbursement of capital be done with borrowed funds?
Supervisory power index (offpr)	This variable is determined by adding 1 if the answer is yes and 0 otherwise, for each one of the following fourteen questions: (1) Does the supervisory agency have the right to meet with external auditors to discuss their report without the approval of the bank? (2) Are auditors required by law to communicate directly to the supervisory agency any presumed involvement of bank directors or senior managers in illicit activities, fraud, or insider abuse? (3) Can supervisors take legal action against external auditors for negligence? (4) Can the supervisory authorities force a bank to change its internal organizational structure? (5) Are off-balance sheet items disclosed to supervisors? (6) Can the supervisory agency order the bank's directors or management to constitute provisions to cover actual or potential losses? (7) Can the supervisory agency suspend director's decision to distribute dividends? (8) Can the supervisory agency suspend director's decision to distribute bonuses? (9) Can the supervisory agency suspend director's decision to distribute management fees? (10) Can the supervisory agency supersede bank shareholder rights and declare bank insolvent? (11) Does banking law allow supervisory agency or any other government agency (other than court) to suspend some or all ownership rights of a problem bank? (12) Regarding bank restructuring and reorganization, can the supervisory agency or any other government agency (other than court) supersede shareholder rights? (13) Regarding bank restructuring & reorganization, can supervisory agency or any other government agency (other than court) remove and replace management? (14) Regarding bank restructuring & reorganization, can supervisory agency or any other government agency (other than court) remove and replace directors?
Market discipline index (mdisc)	This variable is determined by adding 1 if the answer is yes to questions 1-7 and 0 otherwise, while the opposite occurs in the case of questions 8 and 9 (i.e. yes=0, no =1). (1) Is subordinated debt allowable (or required) as part of capital? (2) Are financial institutions required to produce consolidated accounts covering all bank and any non-bank financial subsidiaries? (3) Are off-balance sheet items disclosed to public? (4) Must banks disclose their risk management procedures to public? (5) Are directors legally liable for erroneous/misleading information? (6) Do regulations require credit ratings for commercial banks? (7) Is an external audit by certified/licensed auditor a compulsory obligation for banks? (8) Does accrued, though unpaid interest/principal enter the income statement while loan is non-performing? (9) Is there an explicit deposit insurance protection system?

Note: The individual questions and answers were obtained from the World Bank database developed by Barth *et al.* (2001, 2006, 2008).

Table 1
Summary statistics

Variable	Mean	Std.dev.	Min.	Max.
risk assets	0.776	0.191	0.050	1.000
non-performing loans	0.031	0.052	0.004	0.348
capitalization	0.087	0.105	-0.198	1.000
profitability	0.007	0.058	-5.787	1.815
size	13.711	1.699	6.215	21.513
efficiency	1.093	3.058	-31.500	209.723
off-balance sheet items	0.127	0.736	-0.008	37.914
capital stringency	5.460	1.551	2.000	12.000
supervisory power	8.686	1.740	6.000	14.000
market discipline	5.711	0.682	2.000	8.000
economic growth	1.593	1.409	-2.300	10.423
importance of banks	127.347	24.862	42.857	280.317
concentration	62.539	12.831	30.251	98.760
short-term rate	3.323	1.046	2.106	13.542
long-term rate	4.250	0.706	2.414	16.789
central-bank rate	3.762	0.846	2.900	12.000
bank-level lending rate	0.092	0.046	0.000	0.397

The table reports summary statistics for the variables used in the empirical analysis. The variables are as follows: risk assets is the ratio of risk assets to total assets, non-performing loans is the ratio of non-performing loans to total loans, capitalization is the ratio of equity capital to total assets, profitability is the ratio of profits before tax to total assets, size is the natural logarithm of real total assets, efficiency is the ratio of total revenue to total expenses, off-balance sheet items is the ratio of off-balance sheet items to total assets, capital stringency is the index of capital requirements, supervisory power is the index of official disciplinary power of the supervisor, market discipline is the index of market discipline and monitoring of the banking sector, economic growth is GDP growth, importance of banks is the domestic credit provided by the banking sector as a share of GDP, concentration is the 3-bank concentration ratio, short-term rate is the annual average of the 3-month interbank rate, long-term rate is the annual average of the 10-year government bond yield, central-bank rate is the central bank interest rate, and bank-level lending rate is the ratio of interest income to total customer loans.

Table 2
Correlation matrix

	capital.	lagged profit.	size	effic.	off-bal. items	cap. stringency	super. power	market discip.	econ. growth	import. of banks	conc.	short-term rate	long-term rate	central bank rate	bank lending rate
capitalization	1.000														
lagged profitability	0.160	1.000													
size	-0.247	0.032	1.000												
efficiency	0.113	0.206	0.019	1.000											
off-balance sheet items	0.106	0.040	0.064	0.015	1.000										
capital stringency	-0.073	-0.022	0.181	-0.044	0.054	1.000									
supervisory power	-0.083	-0.031	0.039	-0.001	0.029	0.442	1.000								
market discipline	0.111	0.088	0.164	0.064	0.033	0.375	-0.270	1.000							
economic growth	0.122	0.066	0.110	0.036	0.068	0.261	0.138	0.473	1.000						
importance of banks	-0.246	-0.096	0.119	-0.012	-0.069	0.211	0.206	0.059	-0.201	1.000					
concentration	-0.263	-0.137	0.168	-0.079	0.014	0.578	0.479	-0.002	0.278	0.363	1.000				
short-term rate	0.009	-0.007	0.000	0.011	0.011	-0.072	0.116	-0.099	0.352	-0.048	0.078	1.000			
long-term rate	-0.012	-0.044	-0.032	-0.009	0.009	-0.140	0.248	-0.371	-0.061	-0.035	-0.011	0.718	1.000		
central-bank rate	0.073	0.045	0.013	0.039	0.023	0.012	0.017	0.195	0.605	-0.156	0.086	0.885	0.462	1.000	
bank-level lending rate	0.059	-0.023	-0.023	-0.009	-0.004	-0.040	0.049	-0.170	-0.061	0.016	0.091	0.125	0.186	0.043	1.000

The table reports correlation coefficients for the variables used in the empirical analysis. The variables are as follows: risk assets is the ratio of risk assets to total assets, non-performing loans is the ratio of non-performing loans to total loans, capitalization is the ratio of equity capital to total assets, lagged profitability is the ratio of profits before tax to total assets in year t-1, size is the natural logarithm of real total assets, efficiency is the ratio of total revenue to total expenses, off-balance sheet items is the ratio of off-balance sheet items to total assets, capital stringency is the index of capital requirements, supervisory power is the index of official disciplinary power of the supervisor, market discipline is the index of market discipline and monitoring of the banking sector, economic growth is GDP growth, importance of banks is the domestic credit provided by the banking sector as a share of GDP, concentration is the 3-bank concentration ratio, short-term rate is the annual average of the 3-month interbank rate, long-term rate is the annual average of the 10-year government bond yield, central-bank rate is the central bank interest rate, and bank-level lending rate is the ratio of interest income to total customer loans.

Table 3
Interest rates and bank risk-taking: Instrumental variables regressions

	I	II	III	IV	V	VI
capitalization	-0.171***	-0.176***	-0.168***	-0.098***	-0.549*	-0.668***
	(-8.259)	(-8.496)	(-8.082)	(-4.174)	(-1.898)	(-2.243)
lagged profitability	0.083*	0.077*	0.087*	0.242***	-1.132***	-1.288***
	(1.772)	(1.656)	(1.853)	(4.676)	(-9.926)	(-9.594)
size	-0.001	-0.002	-0.001	0.002	-0.030**	-0.025*
	(-0.742)	(-1.392)	(-0.716)	(0.966)	(-2.490)	(-1.731)
efficiency	0.004***	0.004***	0.004***	0.003**	0.002**	0.002**
	(3.075)	(3.149)	(3.074)	(2.353)	(2.181)	(2.012)
off-balance sheet items	-0.008***	-0.008***	-0.008***	-0.005**	-0.003	-0.002
	(-2.877)	(-3.026)	(-2.830)	(-2.137)	(-0.642)	(-0.163)
capital stringency	0.000	0.002	0.001	-0.000	-0.005	-0.014
	(0.343)	(1.539)	(0.873)	(-0.311)	(-0.237)	(-1.316)
supervisory power	-0.001	-0.001	-0.002	-0.000	0.011	0.005
	(-0.376)	(-0.370)	(-1.391)	(-0.264)	(0.673)	(0.297)
market discipline	-0.006*	-0.013***	-0.006*	-0.013***	-0.042***	-0.037***
	(-1.855)	(-3.628)	(-1.873)	(-3.712)	(-3.892)	(-3.482)
economic growth	0.005***	0.003***	0.007***	0.002***	0.053***	0.057***
	(5.852)	(3.964)	(7.000)	(3.845)	(2.632)	(2.714)
importance of banks	0.001***	0.001***	0.001***	0.001***	0.003***	0.003***
	(16.898)	(16.511)	(16.706)	(21.076)	(4.621)	(4.721)
concentration	-0.000	-0.001	-0.000	-0.000	-0.003	-0.003
	(-0.457)	(-1.358)	(-0.645)	(-0.858)	(-1.330)	(-1.530)
short-term rate	-0.008***				-0.046**	
	(-10.099)				(-2.129)	
long-term rate		-0.018***				
		(-10.154)				
central bank rate			-0.011***			
			(-10.065)			
bank-level lending rate				-1.524***		-0.085***
				(-14.593)		(-3.652)
obs	18067	18067	18067	18067	14218	14218
Wald-test	513.88	514.26	513.21	704.73	3130.30	3625.10
p-value	0.000	0.000	0.000	0.000	0.000	0.000
Hausman	0.002	0.004	0.004	0.003	0.002	0.002

The table reports coefficients and t-statistics (in parentheses). In regressions I-IV dependent variable is the ratio of risk assets to total assets and in regressions V-VI the ratio of non-performing loans to total loans. The explanatory variables are as follows: capitalization is the ratio of equity capital to total assets, lagged profitability is the ratio of profits before tax to total assets in year t-1, size is the natural logarithm of real total assets, efficiency is the ratio of total revenue to total expenses, off-balance sheet items is the ratio of off-balance sheet items to total assets, capital stringency is the index of capital requirements, supervisory power is the index of official disciplinary power of the supervisor, market discipline is the index of market discipline and monitoring of the banking sector, economic growth is GDP growth, importance of banks is the domestic credit provided by the banking sector as a share of GDP, concentration is the 3-bank concentration ratio, short-term rate is the annual average of the 3-month interbank rate, long-term rate is the annual average of the 10-year government bond yield, central-bank rate is the central bank interest rate, and bank-level lending rate is the ratio of interest income to total customer loans. obs is the number of observations, the Wald-test and its associated p-value denote the goodness of fit of the regressions and Hausman is the p-value of the Hausman test for the validity of the instrumental variables method (over the GLS alternative). *,** and *** denote statistical significance at the 1, 5 and 10% level, respectively.

Table 4
Interest rates and bank risk-taking: Dynamic panel regressions

	I	II	III	IV	V	VI
Lagged risk assets	0.711***	0.708***	0.709***	0.617***		
	(57.282)	(56.830)	(54.505)	(46.958)		
Lagged non-perf. loans					0.418	0.471
					(7.190)	(7.847)
capitalization	-0.175***	-0.206***	-0.188***	-0.109***	-0.491***	-0.348***
	(-7.051)	(-8.420)	(-7.504)	(-3.921)	(-4.090)	(-3.319)
lagged profitability	0.129	0.124	0.194*	0.027	-2.649***	-1.254***
	(1.146)	(1.102)	(1.722)	(0.224)	(-5.183)	(-2.801)
size	-0.012***	-0.017***	-0.016***	-0.015***	-0.012***	-0.013***
	(-5.319)	(-7.352)	(-6.371)	(-6.813)	(-3.141)	(-3.075)
efficiency	0.003	0.004**	0.004**	0.002	-0.059***	-0.055**
	(1.607)	(2.066)	(1.990)	(0.943)	(-2.714)	(-2.502)
off-balance sheet items	0.032***	0.032***	0.034***	0.038***	0.037	0.021
	(5.829)	(5.696)	(6.030)	(7.128)	(0.407)	(0.066)
capital stringency	0.000	0.002*	0.000	0.002**	-0.015***	-0.012***
	(0.320)	(1.757)	(0.282)	(2.288)	(-3.422)	(-2.792)
supervisory power	-0.001	0.000	-0.001	-0.006***	-0.002***	-0.002***
	(-1.340)	(0.124)	(-1.082)	(-5.213)	(-3.829)	(-3.732)
market discipline	-0.006***	-0.007***	-0.006***	-0.008***	-0.003**	-0.004***
	(-2.651)	(-2.683)	(-2.606)	(-3.032)	(-2.225)	(-2.822)
economic growth	0.001	0.001*	0.003**	0.001	0.002***	0.003***
	(0.566)	(1.682)	(2.324)	(1.122)	(3.978)	(5.381)
importance of banks	0.000***	0.000***	0.000***	0.001***	0.001***	0.001***
	(6.035)	(6.087)	(4.677)	(10.919)	(4.272)	(4.931)
concentration	-0.000	-0.001	-0.001	0.000	-0.001	-0.001
	(-0.931)	(-1.144)	(-1.435)	(0.999)	(-1.085)	(-0.988)
short-term rate	-0.005***				-0.010***	
	(-8.619)				(-3.235)	
long-term rate		-0.013***				
		(-10.561)				
central bank rate			-0.006***			
			(-6.639)			
bank-level lending rate				-0.479***		-0.227***
				(-8.531)		(-8.212)
obs	14607	14607	14607	14607	12289	12289
Wald-test	5635.96	5700.51	5006.56	4936.16	251.71	1115.09
p-value	0.000	0.000	0.000	0.000	0.000	0.000
AR1	0.000	0.000	0.001	0.000	0.000	0.000
AR2	0.236	0.205	0.252	0.217	0.322	0.302
Sargan	0.108	0.121	0.098	0.117	0.305	0.303

The table reports coefficients and t-statistics (in parentheses). In regressions I-IV dependent variable is the ratio of risk assets to total assets and in regressions V-VI the ratio of non-performing loans to total loans. The explanatory variables are as follows: capitalization is the ratio of equity capital to total assets, lagged profitability is the ratio of profits before tax to total assets in year t-1, size is the natural logarithm of real total assets, efficiency is the ratio of total revenue to total expenses, off-balance sheet items is the ratio of off-balance sheet items to total assets, capital stringency is the index of capital requirements, supervisory power is the index of official disciplinary power of the supervisor, market discipline is the index of market discipline and monitoring of the banking sector, economic growth is GDP growth, importance of banks is the domestic credit provided by the banking sector as a share of GDP, concentration is the 3-bank concentration ratio, short-term rate is the annual average of the 3-month interbank rate, long-term rate is the annual average of the 10-year government bond yield, central-bank rate is the central bank interest rate, and bank-level lending rate is the ratio of interest income to total customer loans. obs is the number of observations, the Wald-test and its associated p-value denote the goodness of fit of the regressions, AR1 and AR2 are the tests for first and second order autocorrelation and Sargan is the test for overidentifying restrictions. *,** and *** denote statistical significance at the 1, 5 and 10% level, respectively.

Table 5
Interest rates and bank risk-taking in the large euro area banking systems: Dynamic panel regressions

	bank-level lending rate		change in bank-level lending rate	
	Coef.	t-stat.	Coef.	t-stat.
France	-0.201*	(-1.65)	-0.072	(-0.77)
Germany	-0.448***	(-7.98)	-0.528***	(-7.81)
Italy	-1.026***	(-8.38)	-0.644***	(-2.80)
Spain	-2.004***	(-9.21)	-0.502***	(-4.61)

The table reports coefficient estimates and associated t-statistics on the relationship between bank-level lending rate and bank risk-taking for the four largest euro area countries. The first estimated equation is the equivalent of regression IV in Table 4, carried out for each country separately. The second estimated equation is the equivalent of regression IV in Table 5, carried out for each country separately. *,** and *** denote statistical significance at the 1, 5 and 10% level, respectively.

Table 6
Correlations between distributional characteristics, interest-rate variables and their products after "mean centering"

	sir	bir	cap'	obs'	size'	cap'*sir'	cap'*bir'	size'*sir'	size'*bir'	obs'*bir'	obs'*sir'
short-term rate' (sir)	1.000										
bank-level lending rate' (bir)	0.095	1.000									
capitalization' (cap)	-0.002	0.075	1.000								
off-balance sheet items' (obs)	-0.002	-0.008	0.100	1.000							
size'	0.038	-0.010	-0.253	0.059	1.000						
cap' * sir'	-0.162	-0.014	-0.151	-0.028	0.004	1.000					
cap' * bir'	-0.005	0.167	0.358	0.074	-0.042	0.026	1.000				
size' *sir'	-0.018	-0.004	0.011	0.000	0.026	-0.242	-0.029	1.000			
size' * bir'	-0.004	0.097	-0.076	-0.015	0.007	-0.046	-0.305	0.108	1.000		
obs' * bir'	-0.002	0.035	0.105	-0.136	-0.013	-0.041	0.271	0.016	-0.029	1.000	
obs' * sir'	-0.068	-0.003	-0.037	0.116	-0.003	0.120	-0.037	0.074	0.024	-0.239	1.000

The table reports correlation coefficients for the variables that have been obtained from the mean centering procedure described in the text and the products of these variables. The variables are as follows (a ' distinguishes the centered variables from the original ones): capitalization is the ratio of equity capital to total assets, size is the natural logarithm of real total assets, off-balance sheet items is the ratio of off-balance sheet items to total assets, short-term rate is the annual average of the 3-month interbank rate, and bank-level lending rate is the ratio of interest income to total customer loans.

Table 7
Interest rates and bank risk-taking: Distributional effects due to bank characteristics

	I	II	III	IV
Lagged risk assets	0.723***	0.622***		
	(10.865)	(10.822)		
Lagged non-performing loans			0.365***	0.370***
			(5.182)	(5.692)
capitalization	-0.138***	-0.265***	-0.340***	-0.335**
	(-9.509)	(-9.062)	(-4.760)	(-4.555)
lagged profitability	-0.019	0.006	-2.035***	-2.398***
	(-0.168)	(0.053)	(-4.485)	(-5.320)
size	-0.003***	-0.008***	-0.011***	-0.014***
	(-5.864)	(-6.223)	(-4.609)	(-5.779)
efficiency	0.002	-0.001	-0.049***	-0.034***
	(0.817)	(-0.279)	(-4.197)	(-2.709)
off-balance sheet items	0.021***	0.028***	-0.011	-0.012
	(5.391)	(5.491)	(-0.576)	(-0.913)
capital stringency	0.000	0.000	-0.008**	-0.008**
	(0.254)	(0.238)	(-1.980)	(-2.189)
supervisory power	-0.001	-0.004***	-0.021***	-0.018***
	(-1.543)	(-3.230)	(-4.715)	(-3.663)
market discipline	-0.007***	-0.005**	-0.022*	-0.045***
	(-2.748)	(-2.181)	(-1.916)	(-3.807)
economic growth	0.002***	0.002***	0.012***	0.016***
	(2.658)	(3.147)	(2.896)	(4.197)
importance of banks	0.000***	0.001***	0.001***	0.001***
	(5.386)	(10.895)	(4.382)	(5.247)
concentration	-0.001	0.000	-0.001	-0.001
	(-0.330)	(-0.678)	(-0.858)	(-0.960)
short-term rate	-0.005***		-0.009***	
	(-8.608)		(-3.327)	
bank-level lending rate		-0.585***		-0.159***
		(-11.848)		(-6.512)
capitalization*short-term rate	0.012***		0.056***	
	(3.603)		(4.954)	

size*short-term rate	0.000		0.010***	
	(0.202)		(5.335)	
off-balance sheet*short-term rate	-0.014***		-0.009	
	(-4.188)		(-0.510)	
capitalization*bank-level lending rate		2.193***		-0.025
		(9.161)		(-0.167)
size*bank-level lending rate		0.036*		0.062***
		(1.669)		(5.281)
off-balance sheet*bank-level lending rate		-0.237***		-0.008
		(-3.739)		(-0.287)
obs	14607	14607	12289	12289
Wald-test	8174.89	6274.34	359.48	1099.52
p-value	0.000	0.000	0.000	0.000
AR1	0.000	0.000	0.002	0.004
AR2	0.134	0.120	0.205	0.210
Sargan	0.207	0.193	0.422	0.400

The table reports coefficients and t-statistics (in parentheses). In regressions I-IV dependent variable is the ratio of risk assets to total assets and in regressions V-VI the ratio of non-performing loans to total loans. The explanatory variables are as follows: capitalization is the ratio of equity capital to total assets, lagged profitability is the ratio of profits before tax to total assets, size is the natural logarithm of real total assets in year t-1, efficiency is the ratio of total revenue to total expenses, off-balance sheet items is the ratio of off-balance sheet items to total assets, capital stringency is the index of capital requirements, supervisory power is the index of official disciplinary power of the supervisor, market discipline is the index of market discipline and monitoring of the banking sector, economic growth is GDP growth, importance of banks is the domestic credit provided by the banking sector as a share of GDP, concentration is the 3-bank concentration ratio, short-term rate is the annual average of the 3-month interbank rate, long-term rate is the annual average of the 10-year government bond yield, central-bank rate is the central bank interest rate, and bank-level lending rate is the ratio of interest income to total customer loans. obs is the number of observations, the Wald-test and its associated p-value denote the goodness of fit of the regressions, AR1 and AR2 are the tests for first and second order autocorrelation and Sargan is the test for overidentifying restrictions. *,** and *** denote statistical significance at the 1, 5 and 10% level, respectively.

Table 8
Changes in interest rates and bank risk-taking: Dynamic panel regressions

	I	II	III	IV	V	VI
Lagged risk assets	0.699***	0.698***	0.600***	0.714***		
	(9.647)	(9.557)	(9.719)	(11.169)		
Lagged non-perf. loans					0.463***	0.432***
					(8.336)	(8.035)
capitalization	-0.127***	-0.108***	-0.150***	-0.128***	-0.493***	-0.462***
	(-5.001)	(-4.336)	(-5.932)	(-4.938)	(-3.068)	(-2.887)
lagged profitability	0.487***	0.435***	0.515***	0.504***	-2.433***	-3.327***
	(4.269)	(3.816)	(4.499)	(4.316)	(-6.833)	(-9.365)
size	-0.009***	-0.008***	-0.011***	-0.016***	-0.066***	-0.057***
	(-4.337)	(-3.880)	(-4.930)	(-7.871)	(-5.868)	(-4.825)
efficiency	-0.000	0.000	-0.000	-0.003	-0.028**	-0.028**
	(-0.058)	(0.060)	(-0.203)	(-1.173)	(-2.036)	(-2.095)
off-balance sheet items	0.013**	0.014**	0.015**	0.013**	0.004	0.008
	(2.116)	(2.378)	(2.426)	(2.164)	(0.397)	(0.991)
capital stringency	0.000	-0.000	0.000	0.001	0.002	0.001
	(0.121)	(-0.208)	(0.167)	(0.983)	(0.221)	(0.074)
supervisory power	0.004**	0.005***	0.002	0.001	-0.007	-0.004
	(2.100)	(2.899)	(1.276)	(0.325)	(-0.797)	(-0.366)
market discipline	-0.006*	-0.006*	-0.007**	-0.009***	-0.005*	-0.007**
	(-1.748)	(-1.852)	(-2.201)	(-2.874)	(-1.861)	(-2.363)
economic growth	0.004***	0.007***	0.007***	0.002**	0.007***	0.007***
	(6.164)	(9.607)	(9.301)	(2.483)	(4.951)	(4.209)
importance of banks	0.001***	0.001***	0.001***	0.001***	0.006***	0.006***
	(3.435)	(3.730)	(3.332)	(5.410)	(5.985)	(5.804)
concentration	0.000	-0.001	-0.001	0.000	0.000	-0.001
	(0.294)	(-0.105)	(-0.824)	(0.207)	(0.155)	(-0.322)
short-term rate	-0.009***				-0.007***	
	(-12.930)				(-7.123)	

long-term rate		-0.015***				
		(-13.834)				
central bank rate			-0.012***			
			(-11.139)			
bank-level lending rate				-0.592***		-0.603***
				(-9.171)		(-12.707)
obs	8770	8770	8770	8538	8464	8325
Wald-test	401.73	417.98	359.36	359.82	1444.59	7224.63
p-value	0.000	0.000	0.000	0.000	0.000	0.000
AR1	0.000	0.000	0.000	0.000	0.000	0.000
AR2	0.071	0.068	0.073	0.077	0.122	0.116
Sargan	0.139	0.141	0.107	0.115	0.202	0.194

The table reports coefficients and t-statistics (in parentheses). In regressions I-IV dependent variable is the annual change in the ratio of risk assets to total assets and in regressions V-VI the annual change in the ratio of non-performing loans to total loans. The explanatory variables are as follows (some of them are also in annual changes as shown in Eq. 3): capitalization is the ratio of equity capital to total assets, lagged profitability is the ratio of profits before tax to total assets, size is the natural logarithm of real total assets in year t-1, efficiency is the ratio of total revenue to total expenses, off-balance sheet items is the ratio of off-balance sheet items to total assets, capital stringency is the index of capital requirements, supervisory power is the index of official disciplinary power of the supervisor, market discipline is the index of market discipline and monitoring of the banking sector, economic growth is GDP growth, importance of banks is the domestic credit provided by the banking sector as a share of GDP, concentration is the 3-bank concentration ratio, short-term rate is the annual average of the 3-month interbank rate, long-term rate is the annual average of the 10-year government bond yield, central-bank rate is the central bank interest rate, and bank-level lending rate is the ratio of interest income to total customer loans. obs is the number of observations, the Wald-test and its associated p-value denote the goodness of fit of the regressions, AR1 and AR2 are the tests for first and second order autocorrelation and Sargan is the test for overidentifying restrictions. *,** and *** denote statistical significance at the 1, 5 and 10% level, respectively.

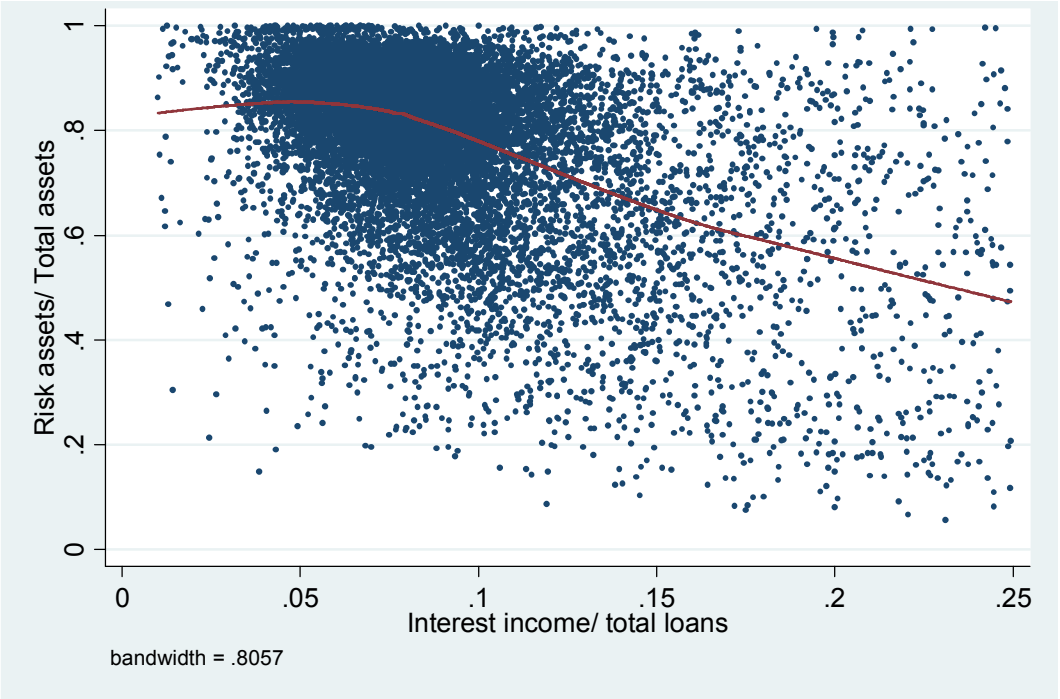
Table 9
Interest rates and bank risk-taking: Evidence from quarterly data

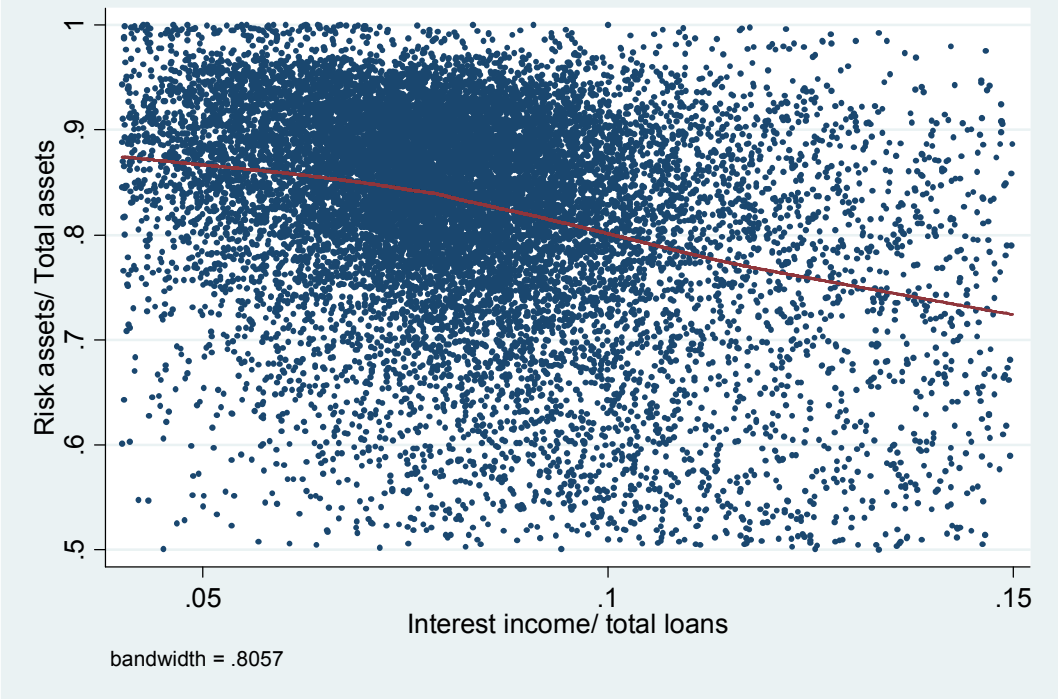
	I	II	III	IV
Lagged risk assets	0.669***	0.550***	0.649***	0.561***
	(34.77)	(26.64)	(35.05)	(29.92)
capitalization	-0.125***	-0.085***	-0.100***	-0.207***
	(-3.28)	(-2.20)	(-4.85)	(-5.01)
profitability	0.246	0.140	0.208	0.203
	(1.621)	(0.85)	(1.39)	(1.42)
size	-0.011***	-0.007*	-0.001	-0.003*
	(-3.24)	(-1.95)	(-1.34)	(-1.86)
efficiency	0.001	-0.000	0.000	-0.005**
	(0.56)	(-0.12)	(0.08)	(-2.15)
off-balance sheet items	0.027***	0.034***	0.032***	0.027***
	(3.85)	(5.35)	(6.18)	(4.45)
capital stringency	0.001	0.001	0.001	0.001
	(0.75)	(1.12)	(0.58)	(0.67)
supervisory power	0.002	0.001	0.003**	0.002
	(1.36)	(1.12)	(2.40)	(0.98)
market discipline	-0.012**	-0.013**	-0.012**	-0.012**
	(-2.26)	(-2.45)	(-2.24)	(-2.26)
economic growth	0.009***	0.010***	0.009***	0.011***
	(4.44)	(4.84)	(5.06)	(5.38)
importance of banks	0.000***	0.001***	0.000***	0.001***
	(3.61)	(6.91)	(3.33)	(6.46)
concentration	-0.000	-0.000	-0.000	-0.000
	(-0.98)	(-1.04)	(-1.12)	(-1.04)
short-term rates	-0.107**		-0.093**	
	(-2.40)		(-2.07)	
bank-level lending rate		-0.438***		-0.441***
		(-5.01)		(-6.13)
capitalization*short-term rate			0.018	
			(1.25)	
size*short-term rate			0.001	
			(1.57)	

off-balance sheet*short-term rate			0.013***	
			(2.67)	
capitalization*bank-level lending rate				1.043**
				(2.43)
size*bank-level lending rate				-0.045
				(-1.42)
off-balance sheet*bank-level lending rate				0.177**
				(2.46)
obs	5081	5081	5081	5081
Wald-test	2071.77	1551.17	2314.86	2131.06
p-value	0.000	0.000	0.000	0.000
AR1	0.001	0.003	0.001	0.000
AR2	0.103	0.114	0.128	0.148
Sargan	0.182	0.240	0.140	0.262

The table reports coefficients and t-statistics (in parentheses). In regressions I-IV dependent variable is the ratio of risk assets to total assets and in regressions V-VI the ratio of non-performing loans to total loans. The explanatory variables are as follows: capitalization is the ratio of equity capital to total assets, profitability is the ratio of profits before tax to total assets, size is the natural logarithm of real total assets, efficiency is the ratio of total revenue to total expenses, off-balance sheet items is the ratio of off-balance sheet items to total assets, capital stringency is the index of capital requirements, supervisory power is the index of official disciplinary power of the supervisor, market discipline is the index of market discipline and monitoring of the banking sector, economic growth is GDP growth, importance of banks is the domestic credit provided by the banking sector as a share of GDP, concentration is the 3-bank concentration ratio, short-term rate is the annual average of the 3-month interbank rate, long-term rate is the annual average of the 10-year government bond yield, central-bank rate is the central bank interest rate, and bank-level lending rate is the ratio of interest income to total customer loans. obs is the number of observations, the Wald-test and its associated p-value denote the goodness of fit of the regressions, AR1 and AR2 are the tests for first and second order autocorrelation and Sargan is the test for overidentifying restrictions. *,** and *** denote statistical significance at the 1, 5 and 10% level, respectively.

Figure 1
Bank-level interest rates and risk-taking





The figures report the non-parametric (local) regression between bank risk-taking, measured by the ratio of risk assets to total assets, and the bank-level lending rate, measured by the ratio of interest income to total assets. For expositional brevity, the first figure considers values of the bank-level lending rate up to 0.25 and the second figure values of up to 0.15. The regression line reflects the negative relationship between risk assets and the bank-level lending rate.