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## Bank funding costs and solvency

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**Abstract**

This paper investigates the relationship between bank funding costs and solvency for a large sample of euro area banks using two proprietary ECB datasets for both wholesale funding costs and deposit rates. In particular, the paper studies the relationship between bank solvency, on the one hand, and senior bond yields, term deposit rates and overnight deposit rates, on the other. The analysis finds a significant negative relationship between bank solvency and the different types of funding costs. It also shows that this relationship is non-linear, namely convex, for senior bond yields and term deposit rates. It also identifies a positive realistic solvency threshold beyond which the effect of an increase in solvency on senior bond yields becomes positive. The paper also finds that senior bond yields are more sensitive to a change in solvency than deposit rates. Among the deposit rates, the interest rates of the overnight deposits are the least sensitive. Banks' asset quality, profitability and liquidity seem to play only a minor role in driving funding costs while the ECB monetary policy stance, sovereign risk and financial markets uncertainty appear to be material drivers.

Keywords: Banks, solvency, funding costs
JEL Classification: G15, G21

## Non-Technical Summary

High funding costs, if due to bank specific vulnerabilities, can erode banks' earnings and deplete banks' capital buffers in bad times or decelerate their build-up in good times. Thus, high funding costs, when prompted by bank vulnerabilities, can have an adverse impact on banks' ability to withstand macroeconomic shocks and endanger the overall stability of the banking sector. Indeed, the full pass-through of higher funding costs may be challenging in a non-monopolistic market if the increase in the funding costs is caused by bank idiosyncratic risks and does not reflect a general increase in interest rates. To the contrary, a sector-wide increase in funding costs prompted by a rise in monetary policy rates would generally boost the profitability of banks which can increase their lending rates more than their deposit rates. At the same time, if higher funding costs are passed through into higher lending rates, the real economy can also be adversely affected, by depressing the demand for new lending, prompting deleveraging and leading to lower economic activity. Therefore, the dynamics of funding costs, their relationship with banks' characteristics and the related potential second round effects need to be considered in regular financial stability assessments and macroprudential stress testing frameworks. Omitting them can largely underestimate banks' vulnerabilities.

The empirical literature generally shows that a negative relation between bank funding costs and solvency exists. Bank funding costs are deemed to depend largely on the market perception of counterparty credit risk, which is driven by a wide range of banks' fundamentals including solvency, asset quality, profitability and liquidity. Therefore, a worsening of banks' fundamentals and in particular weaker solvency may lead to higher funding costs.

However, a large part of the literature employs imperfect measures of bank funding costs. Most of the existing studies on the topic use market-based measures. These measures may not fairly represent the actual funding costs paid by banks. The literature employing market-based measures also does not take into account the fact that different types of banks' liabilities might exhibit different sensitivities to stress conditions. Other studies rely on balance sheet and P&L data to derive proxies of banks' funding costs.

Against this background, this paper studies the empirical relationship between banks' funding costs and their fundamentals. In particular, it focuses on the relationship between banks' funding costs and solvency. The analysis considers a large sample of euro area banks using two novel ECB proprietary datasets for banks' funding costs. These datasets contain information on bank level senior bond yields and on bank level interest rates for term deposits and overnight deposits from customers.

Our analysis generally finds a significant negative relation between banks' solvency ratio and funding costs. Moreover, it reveals that this relationship is non-linear, namely convex, for senior bond yields and interest rate for term deposits. A decrease in the solvency ratio has a stronger impact on banks' senior bond yields and interest rates for term deposits for banks with a relatively lower solvency ratio. The paper also identifies a realistic positive threshold for solvency at which the effect of solvency on senior bond yields changes sign and becomes positive. An increase in solvency leads to higher senior bond yields for banks with a relatively high solvency ratio. This result suggests that it might be inefficient for banks to accumulate excessive capital. The paper also provides evidence that banks' senior bond yields are more sensitive to a change in solvency than deposit rates. Indeed, the interest rates on the term deposits are less sensitive to changes in solvency than the senior bond yields. Furthermore, the relationship between the interest rates on overnight deposits and solvency is negative but often not significant. Banks' asset quality, profitability and liquidity seem to play only a minor role in driving funding costs while the ECB monetary policy stance, sovereign risk and financial markets uncertainty appear to be material drivers.

The contribution of this work to the literature is threefold. First, to our knowledge, this paper is the first that studies the relationship between bank solvency and funding costs using a comprehensive set of confidential bank level interest rates which provide a precise yardstick of the effective costs that banks pay to their lenders in the euro area. Second, this is the first paper which consistently studies the relationship between funding and solvency using different types of funding, namely senior bonds, term deposits and overnight deposits. This is an important contribution, as it allows us to assess the diverse sensitivities of the costs of the different types of bank funding. Third, this study is the first paper which not only finds that the relationship between solvency and funding costs is non-linear, but also shows that non-linearities are significant only for senior bond yields and term deposit rates while they are not significant for overnight deposit rates. Furthermore, it identifies a realistic solvency threshold at which the effect of an increase in solvency on senior bond yields changes sign and becomes positive.

The results of this paper substantiate the need for encompassing the relationship between funding costs and banks' solvency in financial stability analyses and in particular in macroprudential solvency stress test frameworks. Not accounting for this relationship and, thus, omitting second round effects could lead to the underestimation of banks' vulnerabilities. Furthermore, these results could also inform the calibration of macroprudential capital policy measures, such as the countercyclical capital buffer, which aim to ensure that banking sector capital requirements take account of the macro-financial environment in which banks operate and protect the banking system from periods of excess aggregate credit growth often associated with the build-up of system-wide risk.

# 1 Introduction

High funding costs, if due to bank specific vulnerabilities, can erode banks' earnings and deplete banks' capital buffers in bad times or decelerate their build-up in good times. Thus, high funding costs, when prompted by bank vulnerabilities, can have an adverse impact on banks' ability to withstand macroeconomic shocks and endanger the overall stability of the banking sector. Indeed, the full pass-through of higher funding costs may be challenging in a non-monopolistic market if the increase in the funding costs is caused by bank idiosyncratic risks and does not reflect a general increase in interest rates. To the contrary, a sector-wide increase in funding costs prompted by a rise in monetary policy rates would generally boost the profitability of banks which can increase their lending rates more than their deposit rates. At the same time, if higher funding costs are passed through into higher lending rates, the real economy can also be adversely affected, by depressing the demand for new lending, prompting deleveraging and leading to lower economic activity. Therefore, the dynamics of funding costs, their relationship with banks' characteristics and the related potential second round effects need to be considered in regular financial stability assessments and macroprudential stress testing frameworks (Budnik, Mozzanica, Dimitrov, Groß, Hansen, Kleemann, Sanna, Sarychev, Siņenko, Volk and Covi 2019; ECB 2017; Henry, Kok, Amzallag, Baudino, Cabral, Grodzicki, Gross, Hałaj, Kolb, Leber, Pancaro, Sydow, Vouldis, Zimmermann and Zochowski 2013). Omitting them can largely underestimate banks' vulnerabilities.

This paper studies the empirical relationship between banks' funding costs and their fundamentals. In particular, it focuses on the relationship between banks' funding costs and solvency.

The theoretical literature on the topic is not conclusive about the sign of the relation between bank funding costs and solvency. However, a substantial part of the literature suggests that this relationship is negative. Modigliani-Miller theorem (Modigliani and Miller 1958) proposes that, in the absence of taxes, bankruptcy costs, agency costs, asymmetric information, and in an efficient market, the liability structure of a bank does not affect its overall cost of funding. All other things being equal, a higher level of capital should lead to a decrease in the per-unit cost of debt and equity, leaving the overall cost of funding constant. Even if the conditions for the Modigliani-Miller theorem to hold are not fulfilled (see for example Calomiris and Hubbard (1995), Cornett and Tehranian (1994), Myers and Majluf (1984), Stein (1998)), a higher capital level implies a larger loss absorption capacity and, thus, should make debt less risky and, consequently, lower its costs as the compensation demanded by depositors and investors for the cost of bankruptcy should decline.

The empirical literature generally shows that a negative relation between banks' funding costs and solvency exists. For example, the literature on market discipline (Ellis and Flannery 1992; Flannery and Sorescu 1996) provides evidence that lower capital levels are associated with higher interest rates on uninsured liabilities. In general, banks' funding costs are deemed to depend largely on the market perception of counterparty credit risk, which is driven by a wide range of bank's fundamentals including solvency, asset quality, profitability and liquidity.

Therefore, a worsening of banks' fundamentals and in particular a weaker solvency may lead to higher funding costs.

Various studies suggest a wide range of sensitivities depending on the types of funding considered, the methodology adopted and the sample taken into account. A 100 bps increase in the solvency ratio is documented to lower funding costs between 0.2 bps[1] and 105 bps[2].

We can identify three main strands of literature according to the measures used for proxying banks' funding costs. The first strand employs Credit Default Swap (CDS) spreads as a measure of funding costs. A second relatively thin stream uses balance sheet and P&L data to derive proxies of funding costs. Finally, a third narrow strand of literature employs bond yields as a yardstick of bank funding costs.

Concerning the first strand, Annaert, De Ceuster, Van Roy and Vespro (2013), using panel regressions for 31 euro area (EA) banks between 2004 and 2008, find that a 100 bps drop in bank stock returns (used as a proxy for bank leverage) is associated with a 64 bps rise in the bank CDS spreads. Using a sample of 161 banks from 23 countries Hasan, Liu and Zhang (2016) regress bank's CDS spreads on bank's fundamental characteristics over for the period between 2001 and 2011 and find that a standard deviation increase in the market based leverage raises CDS spreads by an average of 110 bps. Using CDS spreads for 52 banks in 14 advanced economies between 2001 and 2012 and employing a panel Error Correction Model, Babihuga and Spaltro (2014) find that in the long run a 100 bps increase in total bank regulatory capital ratios reduces funding costs by 26 bps, but in the short run the relation is positive: an increase in capital is associated with raising costs two quarters later. The authors explain that the positive sign on the short-run coefficient may reflect adverse selection problems associated with raising capital. A different estimation method is applied by Schmitz et al. (2017) who employ a simultaneous equations framework to account for the possible simultaneity between funding costs and solvency. Using CDS spreads and two measures of banks' solvency (i.e. the common equity Tier 1 ratio and the 5-years expected default frequency), as well as a wide range of bank-specific variables for 54 banks from six countries in the period 2004-2013, they find that a 100 bps higher common equity Tier 1 ratio is associated with a decrease of 105 bps in banks' funding costs. Alternatively, they find that a 100 bps increase in a bank's CDS spreads is associated with a 32 bps reduction in its common equity Tire 1 ratio. They also find that lower implicit government guarantees (that they proxy using the 5 year CDS sovereign spread) lead to higher bank spreads. Finally, Dent, Hacioglu Hoke and Panagiotopoulos (2017) study the interrelations between banks' solvency and wholesale funding costs for the largest 4 banks in the United Kingdom using weekly market-based data and exploiting non-linear panel techniques between 2007 and 2016. In particular, they rely on the market-based leverage ratio as a proxy for banks' solvency and CDS premia as a measure of funding costs. Their results show that this relationship is non-linear. A decrease in the market based solvency is significantly associated with a rise in wholesale funding costs. More specifically, they show that when the market-

[1] Bonfim and Santos (2004).

[2] Schmitz, Sigmund and Valderrama (2017).

based leverage ratio is above a threshold equal to 2.4%, a 100 bps decrease in the market-based leverage ratio leads to an increase in CDS premia of about 6.5 bps. Instead, if the market-based leverage ratio is lower than the threshold, the impact increases in size up to about 30 bps.

On the second strand of the literature, Aymanns, Caceres, Daniel and Schumacher (2016), using balance sheet data from the Federal Deposit Insurance Corporation (FDIC) Call Reports and SNL Financial, construct two proxies of banks' funding costs: the total funding cost, proxied by the ratio of interest expenses over total liabilities, and the interbank funding cost that is proxied using the ratio of interest expenses on federal funds and repos purchased to the total stock of federal funds and repos purchased during the reporting period. The solvency measure is constructed by applying principal component analysis to a variety of measures of banks' capital. The results suggest that the relationship between funding costs and solvency is non-linear. However, the magnitude of the solvency effect is typically small, with a solvency increase of a 100 bps leading on average to a decrease in total funding costs of about 2 bps and in the interbank funding costs of 4 bps over 1993–2013. Likewise, Gambacorta and Shin (2018), relying on a measure of average cost of debt funding given by the ratio of the total interest paid over the total level of debt (excluding equity and reserves) and using a panel regression approach for a large sample of international banks, find a negative significant relationship between equity to total assets and funding costs. They show that a 100 bps increase in the ratio of equity over total assets is significantly associated with a decline in the average cost of funding of bank debt of 4 bps.

In the third strand of the literature, Bonfim and Santos (2004) use spreads (computed as the difference between the bond yield to maturity and the yield on German government bonds with the closest maturity) both at the issuance and in the secondary market for the period between 1999 and 2003 as measure of funding costs. Using a pooled OLS approach, they explore the relation between bank bond spreads and 5 groups of fundamentals: asset quality, capital structure, liquidity, solvency and profitability. They find that a 100 bps increase in the solvency ratio is associated with a 0.2 bps decrease in bank's bond spreads. Elyasiani and Keegan (2017) also take into consideration bond yield spreads. They study the relationship between the spreads on debt issued by 26 U.S. systemically important banks and their idiosyncratic risk factors, macroeconomic factors, and bond features, in the secondary market in the period between 2003 and 2014. They find that bond buyers are sensitive to changes in banks' specific risk factors by demanding higher yields and also react to business cycle developments.

Overall, a large part of the literature employs imperfect measures of banks' funding costs. Most of the existing studies on the topic use market based measures, typically, CDS spreads (Annaert et al. 2013; Hasan et al. 2016; Schmitz et al. 2017). While CDS spreads are an interesting yardstick of bank funding costs, as they exhibit a forward-looking dimension, they also embed liquidity and risk aversion premiums and, therefore, tend to be volatile, might misprice the credit risk (Annaert et al. 2013)[3] and, thus, may not fairly represent the actual

[3] In addition, only 5-years CDS spreads are generally used, thus, disregarding shorter and longer maturities.

funding costs paid by banks. The literature employing market based measures also does not take into account the fact that different types of banks' liabilities might exhibit different sensitivities to stress conditions. Also Aymanns et al. (2016), despite relying on balance sheet data, use only proxies of banks' total funding costs and interbank funding. Bonfim and Santos (2004) and Elyasiani and Keegan (2017) estimate banks' funding costs using bonds' yields for senior bonds. However, both these studies only consider wholesale funding costs and neither account for potential endogeneity of the banks' risk specific factors nor they estimate non-linearities between banks' solvency and funding costs[4]. To study the latter is particularly relevant as non-linearities in the relationship between banks' solvency and funding costs can materially amplify banks' capital losses during stress.

Against this background, this paper investigates the relation between banks' funding costs and solvency for a large sample of euro area banks using two novel and ECB proprietary datasets for banks' funding costs.[5] The paper also explores the existence of potential non-linearities in this relationship.

The first proprietary dataset, used in this study, contains information on bank level senior bond yields computed at the ECB relying on the iBoxx database provided by Markit. The second unique dataset, called Individual Monetary and Financial Institution Interest Rates, provides information on bank level interest rates for term deposits and overnight deposits from customers. In the paper, the main measure of solvency taken into consideration is the common equity Tier 1 (CET1) ratio. However, other solvency yardsticks such as the Tier 1 ratio, the total capital ratio and the leverage ratio are also taken into account as robustness checks. Measures of other bank fundamentals are also included in the analysis as controls. In particular, we consider proxies for bank asset quality, profitability and liquidity.

The analysis is conducted for the period between 2005 and 2017 for senior bond yields and for the period between 2007 and 2017 for deposit rates. To account for possible endogeneity between banks' fundamentals and funding costs, our preferred estimator to investigate this relationship is the system GMM procedure proposed by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998). To test the robustness of our results, we also estimate this relationship using pooled OLS with lagged explanatory variables and clustered standard errors.

The regression analysis generally finds a significant negative relation between banks' solvency ratio and funding costs. Moreover, our analysis reveals that this relationship is non-linear, namely convex, for senior bond yields and interest rate for term deposits. A decrease in the solvency ratio has a stronger impact on senior bond yields and interest rate for term deposits

[4]In the literature, only some papers (e.g. Aymanns et al. (2016), Schmitz et al. (2017) and Dent et al. (2017)), which study the empirical relationship between banks' funding costs and their fundamentals, also investigate the possible existence of non-linearities in this relationship.

[5]While this paper focuses on the relationship between banks' funding costs and characteristics, it is important to acknowledge that banks generally consider the Weighted Average Cost of Capital (WACC) as a relevant metric when they decide to raise new capital. The WACC includes not only debt funding costs but also the cost of equity.

for banks with a relatively lower solvency level. The paper also identifies a realistic positive threshold for solvency at which the effect of solvency on senior bond yields changes sign and becomes positive. Above this threshold, an increase in solvency leads to higher senior bond yields. This result suggests that it might be inefficient for banks to accumulate excessive capital. The paper also provides evidence that bank senior bond yields are more sensitive to a change in solvency than deposit rates. Indeed, the interest rates on the term deposits are less sensitive to changes in solvency than the senior bond yields. Furthermore, the relationship between the interest rates on overnight deposits and solvency is negative but often not significant. The estimates, including a quadratic term for solvency, suggest that, given for example an initial CET1 ratio of 7%, a reduction in solvency of 100 bps is associated with an increase in the senior bond yields of 13 bps and with a rise in the term deposit rates of 6 bps. Moreover, the results show that the sensitivity of senior bond yields to changes in solvency are significantly stronger in crisis countries than in non-crisis countries. Finally, banks' asset quality, profitability and liquidity seem to play only a particularly minor role in driving funding costs while the ECB monetary policy stance, sovereign risk and financial markets uncertainty appear to be material drivers.

Our contribution to the literature is threefold. First, to our knowledge, this paper is the first that studies the relationship between bank solvency and funding costs using a comprehensive set of confidential bank level interest rates which provide a precise yardstick of the effective costs that banks pay to their lenders in the euro area. Second, to our knowledge, this is the first paper which consistently studies the relationship between funding and solvency for different types of funding, namely senior bonds, term deposits and overnight deposits. This is an important contribution, as it allows us to assess the diverse sensitivities of the costs of the different types of bank funding. In this context, it is also worth mentioning that the types of funding we consider in this study cover on average about 85% of banks' total assets in our sample[6]. Thus, they provide a comprehensive and consistent view on bank funding-solvency nexus. Third, this study is the first paper which not only finds that the relationship between solvency and funding costs is non-linear but also shows that non-linearities are significant only for senior bond yields and term deposit rates while they are not significant for overnight deposit rates. Furthermore, we identify a solvency threshold at which the effect of an increase in solvency on senior bond yields changes sign and becomes positive.

The results of this paper substantiate the need for encompassing the relationship between funding costs and banks' solvency in financial stability analyses and in particular in macro-prudential solvency stress test frameworks. Not accounting for this relationship and, thus, omitting second round effects could lead to the underestimation of banks' losses in adverse scenarios. Furthermore, these results could also inform the calibration of macroprudential capital

[6]However, the share of total assets covered by the types of liabilities considered in this work exhibits material heterogeneity across the banks in the sample. This feature points to important differences in banks' funding mix. Moreover, over time the sample is characterised by a clear decreasing trend for the share of wholesale funding over total assets and an increasing trend for the share of deposits over total assets.

policy measures, such as the countercyclical capital buffer, which aim to ensure that banking sector capital requirements take account of the macro-financial environment in which banks operate and protect the banking system from periods of excess aggregate credit growth often associated with the build-up of system-wide risk.

The rest of this paper is organized as follows. In Section 2, we describe the dataset we use in our analysis. In Section 3, we present some stylized facts and descriptive information for the key variables of interest. Section 4 outlines the applied empirical model and the estimation strategy. Section 5 reports and discusses our main findings, and briefly describes the implemented battery of robustness checks. Section 6 concludes.

## 2 Data

This analysis uses a large unbalanced panel of yearly data which contains information on banks' funding costs, banks' characteristics, and macroeconomic and financial conditions. The data for banks' funding costs are sourced from two ECB proprietary datasets.

The first dataset (hereafter iBoxx) relies on Markit iBoxx bond indexes and provides information on senior bond yields at the bank level at the measurement time. These yields are computed as the weighted average of the yields of the outstanding euro denominated senior bonds for each issuer[7]. The bond level yields are computed as the discounted sum of the expected cash flows divided by the price of the bond in the secondary market and indicate the interest rate banks would have to pay if they were willing to issue new bonds. The data for senior bonds yields used in the regression analysis cover up to 57 banks from 10 euro area countries for the period between 2005 and 2017 (Table 2). The iBoxx dataset also provides information on the remaining time to maturity for each bond.

The second dataset, called Individual Monetary and Financial Institution Interest Rates (IMIR), contains information on individual deposit rates charged by banks for different types of deposits and maturities. More specifically, this dataset encompasses interest rate data on new business for overnight deposits and term deposits[8] from customers. The IMIR dataset also provides information on the original time to maturity of term deposits.

Our dataset includes interest rates for overnight deposits for 115 banks from 14 euro area countries and interest rates for term deposits for 112 banks from 16 euro area countries for the period between 2007 and 2017 (Table 2).

The literature (Aikman, Alessandri, Eklund, Gai, Kapadia, Martin, Mora, Sterne and Willison 2009; Aymanns et al. 2016; Bonfim and Santos 2004) has identified solvency, asset quality,

[7]Bank level yields are computed relying on data for both investment grade as well as sub-investment grade bonds. Various types of bonds (floating rate, callable, etc.) are used to build the yield index but neither convertible bonds nor structured notes are employed. The minimum required outstanding amount of a bond to enter the database is EUR 150mn, all bonds must have a remaining time to maturity of at least one year at the index calculation date, and there must be at least 3 bonds on the market to compute the bank level index since bonds with the highest and the lowest yield are not considered.

[8]Term deposits refer to deposits with an agreed maturity.

profitability and liquidity as the main bank characteristics that have an impact on bank funding costs. In line with these findings, our work considers the following bank specific characteristics as explanatory variables in the regression analysis: CET1 ratio[9], Tier 1 capital ratio, total capital ratio and common equity over total assets for solvency; provisions over total loans to customers and reserves over total loans to customers for asset quality; return over equity (ROE) and return over assets (ROA) for profitability and wholesale funding over total assets and deposits over total assets for liquidity. The data for these bank-level balance sheet items and profit and loss accounts are sourced from SNL.[10]

The data on macroeconomic and financial conditions, which are used in the regression analysis as control variables to account for cross-country variation in economic factors, are sourced from the ECB Statistical Data Warehouse (SDW). More specifically, the regression analysis includes as macro-financial control the EONIA rate, which captures the ECB monetary policy stance and is one of the main drivers of interest rates in the euro area. Another important explanatory variable is the spread between the 10-year sovereign yield and the German 10-year Bund yield. This variable accounts for sovereign risk, i.e. for the implicit guarantee provided by governments to banks and the related sovereign risk (Albertazzi, Ropele, Sene and Signoretti 2014; BIS 2011), and is computed for each bank according to its country of incorporation. Indeed, as revealed by the European sovereign crisis, bank and sovereign risks are highly intertwined. Even for deposits, the sovereign risk must be priced in as the states provide the ultimate guarantee for deposits (Acharya, Drechsler and Schnabl 2014; Cooper and Nikolov 2017; Farhi and Tirole 2017). Finally, to capture the possible relation between global risk aversion and funding costs, the volatility index of the Euro Stoxx (VSTOXX) is included among our macro-financial controls.

Descriptive statistics for all variables used in this analysis are available in the Appendix in Table 1.

## 3 Stylized facts

This section first presents some stylized facts on the evolution over time of the main variables of interest, namely senior bond yields, term deposit rates, overnight deposit rates and bank solvency.

The average senior bond yields and the average interest rates on term deposits (Figure 1, panel (a) and panel (b)) featured a sharp decline in 2009 and 2010 following the loosening of the euro area monetary policy. Then, both these rates increased in 2011 reflecting the tightening of

[9] Common equity Tier 1 comprises bank's core capital and includes common shares, stock surpluses resulting from the issue of common shares, retained earnings, common shares issued by subsidiaries and held by third parties, and accumulated other comprehensive income. The common equity Tier 1 ratio is computed as the ratio between common equity Tier 1 and risk weighted assets.

[10] The SNL data providing information on bank characteristics were matched with the data on cost of funding from iBoxx and IMIR relying on two sets of bank identifiers, i.e. the Monetary Financial Institution (MFI) identifiers and Legal Entity Identifiers (LEI).

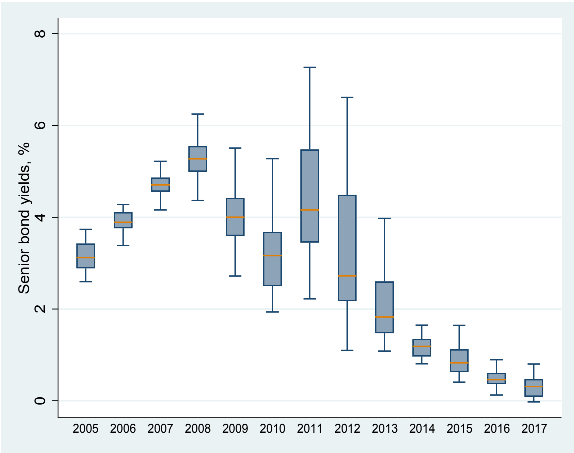
funding conditions due to the European sovereign crisis. Thereafter, likely thanks to the ECB unconventional monetary policy and the establishment of the banking union, they both started declining reaching record low levels in 2017. At the same time, the dispersion of the senior bond yields and partly of the interest rates on the term deposits increased between 2010 and 2013. This widening reflected the heterogeneity of funding conditions across euro area banks due to the on-going euro-area sovereign crisis, subdued economic growth and raising concerns about banks' solvency positions. In this period, access to wholesale and, to a lesser extent, to retail funding for some banks was significantly constrained as well. Also the remaining maturity of the outstanding stock of senior euro-denominated bonds issued by euro area banks declined over time reaching a trough in 2012. Thereafter, it started to gradually increase. This shortening of bonds' remaining maturity might also reflect an increase in markets' risk aversion and a decline in investors' willingness to lend to financial institutions. In contrast, interest rates on overnight deposits (Figure 1, panel (c)) followed more closely the evolution of the euro area monetary policy stance. On average, they decreased sharply in 2009 and then they continued to decline slowly before reaching the zero lower bound in 2015. Interestingly, some banks also started charging negative interest rates on term and overnight deposits in 2016 and 2015, respectively.

Finally, as shown in Figure 1, panel (d), the average CET1 ratio has gradually increased since the start of the Great Recession in 2007. At the same time, the dispersion of the ratio across banks has increased. The CET1 ratio increase has been particularly material between 2009 and 2013.

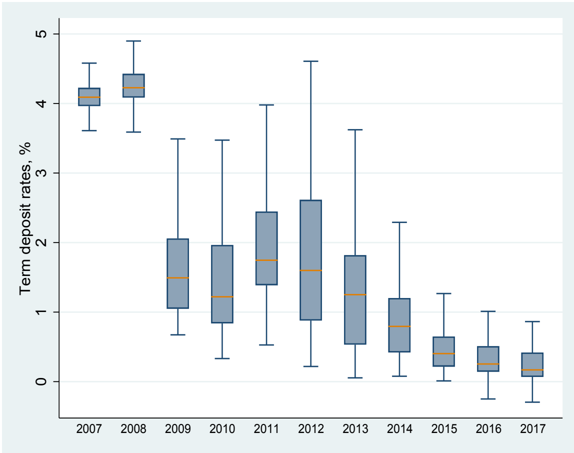
Furthermore, while a rigorous evaluation of our key research questions is deferred to the empirical analysis, it is helpful to consider in this section the link between bank solvency and different types of funding costs descriptively. We do so by plotting in Figure 2 the funding costs for the three liability segments considered in our study, i.e. senior bonds, term and overnight deposits, against solvency. Without prejudice to the formal econometric verification, the plots seem to indicate that the relationship between funding costs and solvency is non-linear, namely convex. When common equity Tier 1 ratio is relatively low, the relationship between funding costs and solvency appears to be negative while it turns positive for larger values of the common equity Tier 1 ratio.

This descriptive evidence seems to suggest that higher bank's solvency is associated with lower bank's funding costs as long as the CET1 ratio is not too high. Higher solvency for lower levels of CET1 ratio reduces funding costs as it strengthens the capacity of the bank to reimburse its creditors. However, beyond a certain threshold, this relationship may turn positive due to the costs related to the excessive accumulation of capital, i.e. due to the potential loss of income that banks may suffer from using capital to excessively improve solvency as the cost of equity is higher than the cost of debt.

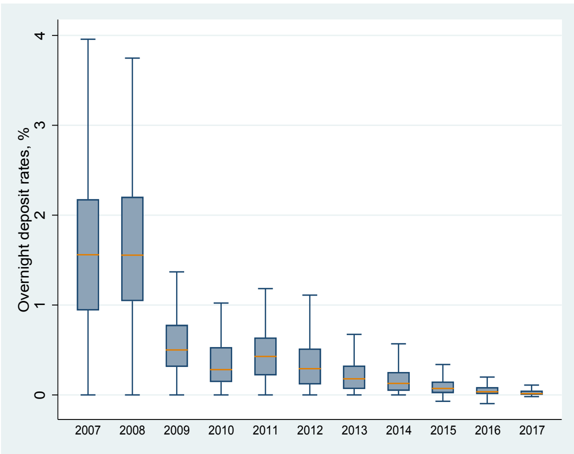
Figure 1: Distribution over time of senior bond yields, term deposit rates, overnight deposit rates and common equity Tier 1 ratio, in %.



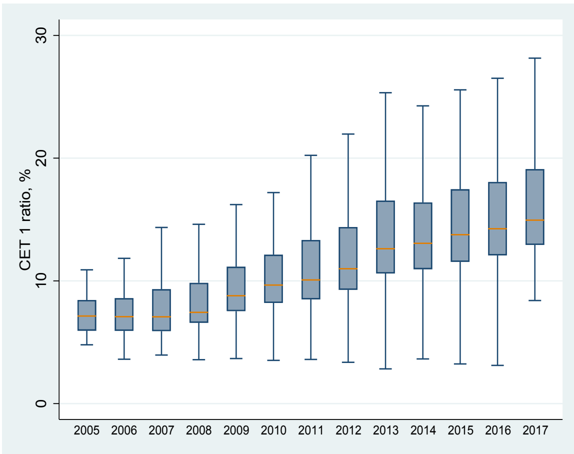

(a) Senior bond yields




(b) Term deposit rates




(c) Overnight deposit rates




(d) Common equity Tier 1 ratio

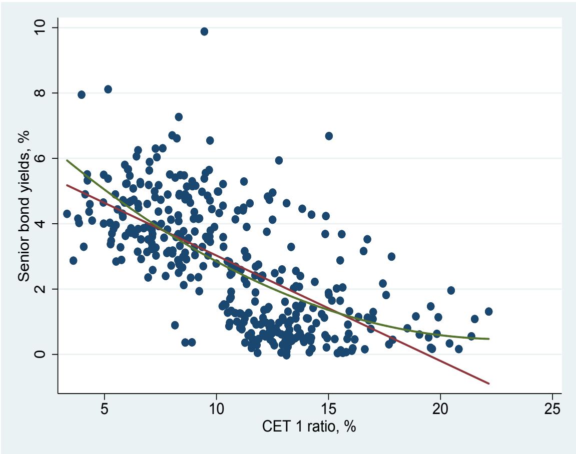
# 4 Empirical model and estimation strategy

Our empirical strategy, which aims at investigating the relationship between banks' funding costs and fundamentals, mainly relies on the estimate of the following linear dynamic panel data model:

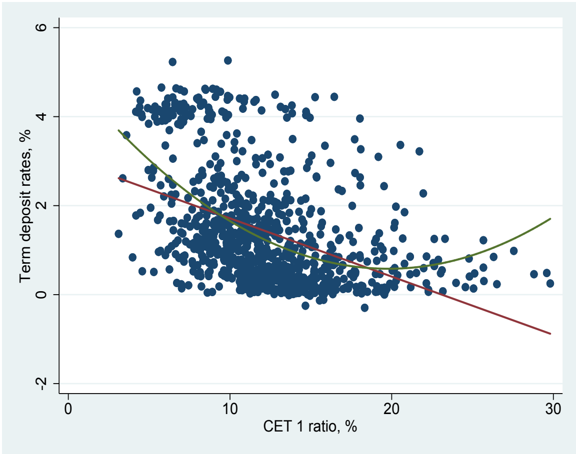
$$y_{i,t} = \alpha_i + \phi y_{i,t-1} + \mathbf{X}_t \beta + \epsilon_{i,t} \tag{1}$$

where the dependent variable $y_{i,t}$ is the funding cost measure of interest (i.e. either senior bond yields or term deposits rates or overnight deposit rates) for bank $i$ for period $t$, $y_{i,t-1}$ is the

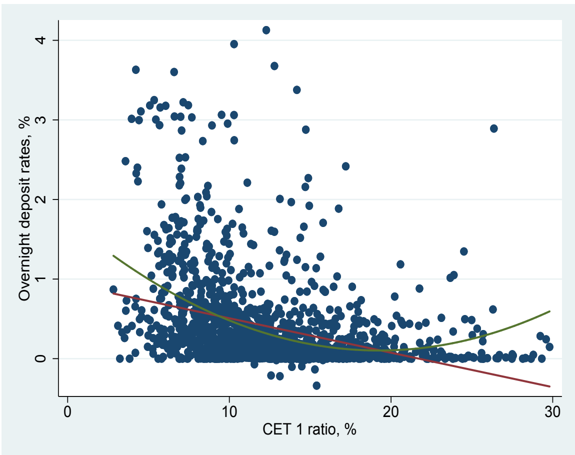
Figure 2: Senior bond yields, term deposit and overnight deposit rates against common equity Tier 1 ratio, with fitted linear (red) and quadratic (green) regression lines, in %.




(a) Senior bond yields




(b) Term deposit rates




(c) Overnight deposit rates

lagged dependent variable[11] and $\mathbf{X}_t$ is a $[1 * m]$ vector of explanatory variables including bank-specific characteristics, macroeconomic and financial conditions. More specifically, as mentioned in Section 2, the bank-specific variables included as regressors in the various estimates, in addition to the lag of the dependent variable, are: (i) the CET1 ratio, Tier 1 capital ratio, total capital ratio and common equity over total assets for solvency; (ii) the provisions over total loans to customers and reserves over total loans to customers for asset quality; (iii) the ROE and ROA for profitability; (iv) wholesale funding over total assets and deposits over total assets for liquidity[12]. The macroeconomic variables included in the estimated models as independent

[11]The models estimated for term deposit rates and overnight deposit rates include both the first and the second lag of the dependent variable.

[12]The models estimated for senior bond yields also include as control the remaining time to maturity while the

variables are: (i) the EONIA rate, (ii) the spread between the 10-year sovereign yield and the German 10-year Bund yield and (iii) the volatility index of the Euro Stoxx. The model also includes bank individual fixed effects $\alpha_i$ to capture bank specific characteristics constant over time. Finally, in equation 1, $\epsilon_{i,t}$ is the zero-mean bank-specific error term.

In this context, one empirical concern is the possible endogeneity in the relationship between banks' fundamentals and funding costs. Indeed, endogeneity can be a source of concern in regressions of this type, as banks' fundamentals and costs of funding are mutually intertwined. For example, current and past realizations of funding costs can be important factors in driving solvency and, vice-versa, it is simple to think of arguments that may explain why a higher solvency can lead to lower funding costs. Additionally, the inclusion in a panel framework of a lagged dependent variable, which accounts for the potential time persistence of funding costs, might yield biased and inconsistent estimates owing to the correlation between the lagged dependent variables and the error terms. This is referred to as dynamic panel bias (Kiviet 1995; Nickell 1981). To address this issue and to tackle the possible endogeneity, equation 1 is estimated using a system generalised method of moments (GMM) estimator based on the work of Arellano and Bover (1995) and Blundell and Bond (1998) that combines the regression in differences with the regression in levels.[13] In this context, the explanatory variables are instrumented by using "internal" instruments.[14]

# 5 Estimation results and discussion

## 5.1 Baseline regressions

In this section, we report and discuss the results for our benchmark specifications for senior bond yields, term deposit rates and overnight deposit rates. In particular, in Table 3, Table 4 and Table 5, we report, for each dependent variable, eight different specifications which include various combinations of bank controls. For the interpretation of the results, we mainly focus on regression 8 which encompasses all the main control variables under consideration.

The results for the senior bond yields, reported in Table 3, show that all macro-financial controls are significant and have the expected signs. In particular, an increase in the EONIA, in the Euro Stoxx volatility and in the sovereign spreads is positively associated with banks' bond yields. As the EONIA reflects the ECB monetary policy stance and is the reference rate

models estimated for term deposit rates also include the average original maturity.

[13]A similar empirical strategy is adopted by Aymanns et al. (2016) and Gambacorta and Shin (2018).

[14]While we base our empirical strategy on the well-established system GMM estimator, which addresses the potential endogeneity concerns by using internal instruments, another possible empirical strategy would be to estimate a system of simultaneous equations as in Schmitz et al. (2017) which would allow investigating the two-way interlinkages between funding costs and solvency. We exploit a system GMM estimator due to the challenges related to the identification of reliable exogenous external instruments which are needed to identify the endogenous variables in a simultaneous equation framework. Indeed, in this context, the identification strategy requires finding exogenous sources of variation of bank solvency and funding costs and relying on two-stage-least squares or three-stage-least squares estimators. On the other side, however, the system GMM approach does not allow analysing the two-way interaction between funding cost and solvency.

for most of the banks' financial contracts, its increase naturally leads to a rise in bank funding costs. Similarly, a rise in markets' risk aversion measured by VSTOXX is associated with a higher risk premium and, as a result, leads to higher bank senior bond yields. Finally, the positive significant relationship between the sovereign spreads and banks' bond yields is the reflection of the relatively strong bank-sovereign nexus in the euro area as the sovereign spreads can be considered a measure of sovereign risk. Among the bank specific controls, only the yardsticks for solvency and profitability result to be significant in regression 8. In particular, an increase of the CET1 ratio by 100 bps leads on average to a decrease in the senior bond yields of about 6 bps.[15] The results also show that more profitable banks seem to benefit from lower yields on senior bonds, i.e. the higher the ROE, the lower the yields. These regressions also find that asset quality and bank liquidity do not seem to influence bank senior bond yields as the respective estimated coefficients are not significant. Finally, the estimated coefficient of the lagged dependent variable is always positive and significant proving the persistence of bank bond yields. The results for senior bond yields are comparable to some extent with those of Bonfim and Santos (2004), who use bond spreads as the measure of costs of debt issuance. Using a pooled OLS approach the authors find that a 100 bps increase in the solvency ratio is associated with a 0.2 bps decrease in the spread between the banks' bond and German bunds. The economic magnitude of our estimates speaks for a substantially stronger solvency-funding nexus for yields on senior bond debt, even if accounting for the spread to German bunds. This may be related to the different time horizons of the two studies, whereby most of our sample covers the global financial crisis while Bonfim and Santos (2004) focus on the period between 1999 and 2003. This finding could support the hypothesis that the nexus could have become stronger during the crisis.

The results for the term deposit rates, reported in Table 4, show that, as for the bond yields, all macro-financial control variables are significant and have the expected signs. It is, however, worth noticing that the sovereign spread has a weaker influence on the term deposit rates than on the senior bond yields. This result could possibly be explained by the fact that insured deposits are protected by deposit guarantee schemes, while senior bonds are not. Moreover, while senior bond holders have normally been pari passu to uninsured depositors in resolutions, recent bank resolutions (e.g. in Ireland and Cyprus) have shown that the authorities are more determined to bail-out domestic depositors than they are to bail-out senior bond holders. This attitude also provides an implicit guarantee for uninsured depositors. At the same time, the EONIA rate is passed through to deposit rates to a larger extent than to senior bond yields as, in line with the bank lending channel, monetary policy operates primarily by influencing

[15] In Appendix A, in Table A.1, we report also the long-term effects (and the related statistics of significance) of the CET1 ratio on senior bond yields and term deposit rates respectively. These long term effects are computed relying on the results of the regressions reported in column 8 in Table 3 and Table 4. More specifically, the long term effects are computed as the ratio of the estimated coefficients of the CET1 ratio over one minus the estimated coefficients of the autoregressive terms. The same results are not reported for overnight deposit rates as the estimated coefficient of the CET1 ratio is not significant in the baseline regression reported in column 8 in Table 5.

the cost of deposits (Bernanke and Blinder 1988). Instead, stock market volatility has weaker influence on deposit rates than on senior bond yields. Furthermore, all bank specific controls but the CET1 ratio are insignificant and, thus, do not play any role in influencing the term deposit rates. More specifically, concerning the solvency-funding relation, we find that an increase of the CET1 ratio by 100 bps, leads to a decrease in the term deposit rates by about 3 bps on average. This coefficient is lower than for senior bond yields, as, for the reasons explained above, depositors benefit from an effective more comprehensive protection than senior bond holders. The explicit and implicit deposit guarantees can also explain the lack of significance of the other bank controls. Indeed, these guarantees effectively release the depositors, unlike the bond holders, from the obligation of monitoring banks' (creditors') credit conditions. Furthermore, while the remaining time to maturity was an insignificant explanatory for bond yields, the original time to maturity of term deposits is positively and significantly associated with term deposit rates, i.e. the higher the maturity, the higher the deposit rates. This finding is in line with common pricing practices by banks, whereby longer term deposits pay higher rates. Finally, the first and the second lag of the dependent variable are always significant and their long term multiplier is positive proving the persistence of bank term deposit rates.

The results for the overnight deposit rates, reported in Table 5, show that while the EONIA and the volatility of the Euro Stoxx are positively and significantly associated with these interest rates, the sovereign spreads are largely not[16]. Concerning the solvency-funding relation, the analysis finds that an increase of the CET1 ratio by 100 bps is associated with a decrease in the overnight deposit rate of less than 1 bp on average. However, this relationship is often not significant. The insignificance of the sovereign spreads and the limited significance of the CET1 ratio can also be explained by the fact that overnight deposits are demandable instruments and, thus, they hardly bear any credit risk. Also overnight deposits, which are primarily held for transaction purposes, have a zero duration further reducing their risk-premium component. Finally, as in the case of term deposits and for the same reasons, all bank specific controls are insignificant. The first lag of the dependent variable is always positive and significant proving the persistence of bank overnight deposit rates.

### 5.2 Models capturing non-linearities

In addition to our baseline specifications discussed above, we consider a few extensions.

First, we formally investigate whether a non-linear relationship between funding costs and solvency exists by adding to the baseline specifications the CET1 ratio squared. The estimated models for this extended specification are reported in column 1 of Table 6, Table 7 and Table 8 for senior bond yields, term deposit rates and overnight deposit rates, respectively. The results

[16]Using data for the Italian banking system's costs of funding, Albertazzi et al. (2014) find a similar result, i.e. the sovereign spread (in their work the BTP-Bund spread) has no significant effect on the overnight deposit rates. In line with our results, they also find that there is a positive significant relationship between the sovereign spread, the term deposit rates and the bond yields and the effect of the spread is larger on the bond yields than on the term rates.

show that the estimated coefficient of the squared solvency measure is positive and significant for senior bond yields and term deposit rates while it is not significant for overnight deposit rates. In addition, the coefficients of all other variables are to a large extent qualitatively unaffected in the regressions for senior bond yields and term deposit rates. Furthermore, the CET1 ratio is not significant in the overnight deposit rate regression. These results indicate the existence of a non-linear convex relationship between, senior bond yields, term deposit rates and the CET1 ratio.[17] These estimates suggest that, given for example an initial CET1 ratio of 7%, a reduction in solvency of 100 bps is associated with an increase in the senior bond yields of 13 bps and with a rise in the term deposit rates of only 6 bps.

To draw further conclusions from these estimates we determine turning points in the CET1 ratio levels at which the total effect of a change in the CET1 ratio on funding costs changes the sign. In light of the findings reported in column 1 of Table 6, Table 7 and Table 8, namely that the squared CET1 ratio term is insignificant for overnight deposit rates, we limit the considerations hereafter to the regressions including senior bond yields and term deposit rates as dependent variables.

The total effect of a change in the CET1 ratio on funding costs is the sum of the estimated coefficient on the CET1 ratio and the first derivative of the related squared term. As a result, a CET1 ratio threshold can be identified, separately for senior bond yields and term deposit rates, below which a bank can benefit from a marginal increase in the CET1 ratio in terms of a reduction in funding costs.[18] The Wald test is applied to determine the joint significance of the total effect. Moreover, we compute joint standard errors for the CET1 ratio and CET1 ratio squared, and use them to determine confidence bands around the turning points. Table 9 presents the turning points calculated for each of the two relevant regressions, along with their corresponding 10 percent confidence intervals. The table also reports Wald test results for the joint significance of the CET1 ratio and its squared term. The Wald test statistics (column 3, Table 9) indicate that the total effect of solvency on funding costs is statistically significant at the 90% level or higher for both senior bond yields and term deposit rates.[19] Table 9 also shows the share of the CET1 ratio observations in our sample above the turning points. Having computed joint standard errors for the two variables in question in order to determine

[17] It is important to mention that these findings hinge on the assumed non-linear functional form.

[18] The turning point can be identified by setting the total effect of CET1 ratio on funding costs to zero, that is, by taking $\beta_1 + 2 * \beta_3 * CET1ratio = 0$, and solving for the value of CET1 ratio for which the relationship holds.

[19] In Appendix A, in Figure A.1, we report also the plots of the non-linear long-term effects of the CET1 ratio on senior bond yields and term deposit rates respectively. These effects are computed relying on the results of the regressions reported in column 1 in Table 6 and Table 7. More specifically, the long term effects are computed as the sum of the estimated coefficients on the CET1 ratio and the first derivatives of the related squared terms over one minus the estimated coefficients of the autoregressive terms. The same results are not reported for overnight deposit rates as the estimated coefficients of the CET1 ratio are not significant in the regression reported in column 1 in Table 8. In Table A.2, we also show the joint significance of the non-linear long term effects and the boundaries of the confidence intervals around the turning points both for senior bond yields and term deposit rates. Overall, it can be noticed that the slope of the non-linear long term effects is steeper than that of the non-linear short term effects. This implies that as the CET1 ratio moves away from the turning points, the long-term impacts of a given CET1 ratio on the senior bond yields and term rates are stronger than the short-term impacts.

confidence intervals, we can plot confidence bands around the total effect of solvency on funding costs. Figure 3 presents the related plots.

Figure 3 shows that the impact of a variation of the CET1 ratio on senior bond yields is significantly lower than zero as long as banks have a CET1 ratio lower than about 9.9% (Table 9). The effect gradually increases and changes sign (turning point) at about 10.9%. In contrast, above a value of about 12.6%, the impact of CET1 ratio on senior bond yields is significantly positive. This result is particularly interesting when considering that about 49% of CET1 ratio observations in our whole sample exhibit a higher value than the threshold, i.e. a higher value than 10.9%.The relation between senior bond yields and the CET1 ratio may be positive for high capital ratios as accumulating capital beyond a certain threshold may turn to be inefficient and hamper banks' profitability. Increasing capital ratios by issuing equity, reducing the growth of assets or via retained earnings could be more costly than raising other source of funding. The most notable cost stems from the fact that deposits and other debt liabilities often benefit from subsidized safety net protections, including deposit insurance and too-big-to-fail subsidies that benefit bank debt more than bank equity (Kane 1989). Junior debt-holders and uninsured depositors suffered minimal losses during the recent crisis, especially when compared with shareholders.

In the case of the term deposit rates, we see a somehow different picture. The total effect of solvency on term deposit rates is again significant, and the system GMM estimator points to a turning point that lies at 22% (Table 9). The impact of a change in the CET1 ratio on term deposit rates is significantly lower than zero as long as banks have a CET1 ratio lower than about 19.7%. In contrast, above a value of about 25.3%, the impact of CET1 ratio on term deposit rates is significantly positive. Against this background, it is worth mentioning that only about 8% of CET1 ratio observations in our sample exhibit a higher value than the identified threshold. Therefore, we could easily conclude that the relationship between term deposit rates and solvency despite being non-linear is, in practical terms, mainly negative.

### 5.3 Further extensions and robustness checks

In addition to the non-linear specifications just discussed above, we consider some further extensions of the baseline model. These extensions are also estimated using the system GMM estimator.

First, we investigate if the sensitivity of funding costs to solvency changes according to the country of incorporation of a bank. In particular, we distinguish between banks established in crisis and non-crisis countries. This question is investigated estimating a further regression for the three different types of funding costs where the explanatory variable for the CET1 ratio has been substituted by two interaction terms of the same variable with a dummy for crisis countries (that takes a value equal to 1 if the country of incorporation of the bank is Cyprus, Greece, Ireland, Italy, Portugal, Spain and Slovenia ) and a dummy for non-crisis countries (that takes a value equal to 1 if the country of incorporation of the bank is Austria, Belgium, Finland, France, Germany, Luxembourg, Malta, the Netherlands, Slovakia). The results, which are presented in column 6 in Table 6, Table 7 and Table 8 respectively for senior bond yields, term deposit rates and overnight deposit rates, show that the negative solvency-funding relation is stronger for crisis countries than for non-crisis countries for senior bond yields. For term deposit rates, the solvency-funding nexus is negative and significant but the difference between the estimated coefficients for crisis and non-crisis countries is not statistically significant. For overnight deposit rates, the relationship with solvency is not significant neither for crisis nor for non-crisis countries.

Furthermore, as an additional robustness check, we re-estimate the benchmark model using different measures of solvency. In particular, we consider the Tier 1 ratio, the total capital ratio and the leverage ratio. The results are reported in columns 3, 4, and 5 in Table 6, Table 7 and Table 8. The baseline results are largely confirmed.

To further check the validity of our results, we estimate a different version of our benchmark model now also including time fixed effects which allow accounting for unobserved time-varying factors. In these estimates, we omit from the explanatory factors the EONIA and the VSTOXX as these variables also capture time-varying common factors. These results are reported in column 2 in in Table 6, Table 7 and Table 8 and generally support the findings obtained from the estimate of the baseline models.

Moreover, to control for the possible effects of the non-standard monetary policy measures implemented by the ECB over the sample period on the relationship between bank funding costs and solvency, we estimate an additional regression where the EONIA is replaced by the shadow rate[20] developed by Wu and Xia (2017). The results of these further estimates are reported in column 7 in Table 6, Table 7 and Table 8 and support our baseline findings. Also, as expected, the estimated coefficient of the shadow rate is positive and significant confirming that a monetary policy loosening is associated with a decline in bank costs of funding.

As a final robustness check, we re-estimate all the regressions reported in in Table 3, Table 4 and Table 5 using a pooled OLS estimator with clustered standard errors at bank level (that allows for intra-group correlations) and lagged bank specific explanatory variables to address possible endogeneity concerns. Additionally, the dynamic term is omitted from these regressions to avoid the possible dynamic bias. The results of these regressions are reported in Table 10, Table 11 and Table 12 and qualitatively confirm our benchmark findings. All key coefficients are significant and exhibit the correct signs. In particular, concerning the solvency-funding nexus, the estimated coefficient of the CET1 ratio is negative and significant for senior bond yields and term deposit rates but it is not significant for overnight deposit rates. In terms of the magnitude, the estimated coefficient on the CET1 ratio is in absolute terms higher for senior bond yields, lower for term deposit rates and rather low for overnight deposit rates (similarly to the regressions estimated using the GMM estimator).

[20]The shadow rate is a concept originally introduced by Black (1995) and is a yardstick which measures the monetary policy stance when nominal interest rates hit the zero lower bound.

### 5.4 Decomposition of funding costs

To better assess, for the banks in our sample, the relative importance of the different drivers of funding costs we plot their decomposition in Figure 4. To this end, we decompose the models' predicted yields or rates into bank specific characteristics, namely solvency, credit quality, profitability, and liquidity and macro-financial factors, i.e. sovereign spread, VSTOXX and EONIA rate. The plotted predicted yields are based on the results of the non-linear regressions for senior bond yields and term deposit rates and of the linear benchmark regression for overnight interest rates.

The plots show that the macro-financial variables play the most relevant role in driving banks' funding costs. On average, macro-financial conditions explain about 50% of the predicted senior bond yields and term deposit rates and about 70% of the predicted overnight deposit rates. Their role is particularly prominent in the first part of the represented time sample due to the sovereign crisis and the higher level of the policy rate. Their contribution then slightly declines over time. Solvency is the second most important driver of funding costs. Its contribution has consistently been negative and on average explained about one-third of the predicted senior bond yields and term deposit rates. Its role has been much less material in explaining overnight deposit rates. Its weight has slightly increased over time. Other banks' fundamentals are the least material drivers.

Finally, it is interesting to mention that, as expected, banks' specific characteristics, i.e. solvency and other banks' fundamentals, are more important determinants of senior bond yields than of deposit rates. This result can be explained by the greater capacity of market investors than of depositors to understand banks' characteristics and resilience.

## 6 Conclusions

This paper investigates the relationship between bank funding costs and solvency. To this end, this analysis relies on two ECB proprietary datasets containing information on senior bond yields and deposit rates at the individual bank level. More specifically, based on panels of up to 115 euro area banks, the paper empirically tests the link between senior bond yields, term deposit rates, overnight deposit rates and solvency and other bank fundamentals.

The analysis finds significant negative relationships between bank funding costs and solvency for senior bonds and term deposits. The relationship is negative but often not significant for overnight deposit rates.

The paper also finds evidence that this relationship is non-linear, namely convex, for senior bond yields and term deposit rates. Furthermore, it identifies a positive realistic solvency threshold beyond which the effect of an increase in solvency on senior bond yields becomes positive.

It also shows that the sensitivity of funding costs to changes in solvency ratios increases with the degree of riskiness of the funding instrument: senior bond yields are the most sensitive to changes in solvency, while overnight deposit rates are almost insensitive to these changes, if at all. The estimates, including a quadratic term for solvency, suggest that, given for example an initial CET1 ratio of 7%, a reduction in solvency of 100 bps is associated with an increase in the senior bond yields of 13 bps and with a rise in the term deposit rates of 6 bps.

The decomposition analysis reveals that banks' funding costs appear to be mainly driven by the macro-financial variables, i.e. the ECB main refinancing rate proxied by the EONIA, sovereign risk and financial market uncertainty. Solvency is the second most important driver of funding costs while other banks' fundamentals are the least material drivers. Finally, the paper shows that belonging to a core or a periphery country significantly affects the sensitivity of senior bond yields.

# References


Acharya, V. V., I. Drechsler and P. Schnabl, “A pyrrhic victory? Bank bailouts and sovereign credit risk,” *Journal of Finance* 69 (2014), 2689–2739.

Aikman, D., P. Alessandri, B. Eklund, P. Gai, S. Kapadia, E. Martin, N. Mora, G. Sterne and M. Willison, “Funding liquidity risk in a quantitative model of systemic stability,” Bank of England Working Paper 372, 2009.

Albertazzi, U., T. Ropele, G. Sene and F. M. Signoretti, “The impact of the sovereign debt crisis on the activity of Italian banks,” *Journal of Banking and Finance* 46 (2014), 387–402.

Annaert, J., M. De Ceuster, P. Van Roy and C. Vespro, “What determines Euro area bank CDS spreads?,” *Journal of International Money and Finance* 32 (2013), 444–461.

Arellano, M. and S. Bond, “Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations,” *The Review of Economic Studies* 58 (Apr. 1991), 277–297.

Arellano, M. and O. Bover, “Another look at the instrumental variable estimation of error-components models,” *Journal of Econometrics* 68 (1995), 29–51.

Aymanns, C., C. Caceres, C. Daniel and L. B. Schumacher, “Bank Solvency and Funding Cost,” IMF Working Paper 16/64, 2016.

Babihuga, R. and M. Spaltro, “Bank Funding Costs for International Banks,” IMF Working Paper 14/71, 2014.

Bernanke, B. and A. Blinder, “Credit, Money, and Aggregate Demand,” *American Economic Review* 78 (1988), 435–439.

BIS, “The impact of sovereign credit risk on bank funding conditions,” 43 (Committee on the Global Financial System Papers, 2011).

Black, F., “Interest rates as options,” *Journal of Finance* 50 (1995), 1371–1376.

Blundell, R. and S. Bond, “Initial conditions and moment restrictions in dynamic panel data models,” *Journal of Econometrics* 87 (1998), 115–143.

Bonfim, D. and C. Santos, “Determinants of Banks’ Financing Costs in the Bond Market,” Banco de portugal, financial stability report, 2004.

Budnik, K., M. B. Mozzanica, I. Dimitrov, J. Gross, I. Hansen, M. Kleemann, F. Sanna, A. Sarychev, N. Siņenko, M. Volk and G. Covi, “Macroprudential stress test of the euro area banking system,” Occasional Paper Series 226, European Central Bank, 2019.

Calomiris, C. W. and R. G. Hubbard, “Internal Finance and Investment: Evidence from the Undistributed Profits Tax of 1936-37,” *The Journal of Business* 68 (1995), 443–482.

Cooper, R. and K. Nikolov, “Government debt and banking fragility: The spreading of strategic uncertainty,” NBER Working Paper 19278, 2017.

Cornett, M. M. and H. Tehranian, “An examination of voluntary versus involuntary security issuances by commercial banks: The impact of capital regulations on common stock returns,” *Journal of Financial Economics* 35 (1994), 99–122.

Dent, K., S. Hacioglu Hoke and A. Panagiotopoulos, "Solvency and wholesale funding cost interactions at UK banks," Working Paper 681, Bank of England, 2017.

ECB, "STAMPE: Stress-Test Analytics for Macroprudential Purposes in the euro area," (ECB, 2017).

Ellis, D. M. and M. J. Flannery, "Does the debt market assess large banks, risk? : Time series evidence from money center CDs," *Journal of Monetary Economics* 30 (1992), 481–502.

Elyasiani, E. and J. Keegan, "Market Discipline in the Secondary Bond Market: The Case of Systemically Important Banks," Working Papers 17-5, Federal Reserve Bank of Philadelphia, 2017.

Farhi, E. and J. Tirole, "Deadly embrace: Sovereign and financial balance sheets doom loops," *The Review of Economic Studies* (2017).

Flannery, M. J. and S. M. Sorescu, " Evidence of Bank Market Discipline in Subordinated Debenture Yields: 1983-1991," *Journal of Finance* 51 (1996), 1347–1377.

Gambacorta, L. and H. S. Shin, "Why bank capital matters for monetary policy," *Journal of Financial Intermediation* 35 (2018), 17–29.

Hasan, I., L. Liu and G. Zhang, "The Determinants of Global Bank Credit-Default-Swap Spreads," *Journal of Financial Services Research* 50 (2016), 275–309.

Henry, J., C. Kok, A. Amzallag, P. Baudino, I. Cabral, M. Grodzicki, M. Gross, G. Hałaj, M. Kolb, M. Leber, C. Pancaro, M. Sydow, A. Vouldis, M. Zimmermann and D. Zochowski, "A macro stress testing framework for assessing systemic risks in the banking sector," ECB Occasional Paper Series 152, 2013.

Kane, E., "How incentive-incompatible deposit-insurance funds fail," Working Paper 2836, NBER, 1989.

Kiviet, J., "On bias, inconsistency, and efficiency of various estimators in dynamic panel data models," *Journal of Econometrics* 68 (1995), 53–78.

Modigliani, F. and M. Miller, "The cost of capital, corporation finance and the theory of investment," *American Economic Review* 48 (1958), 261–297.

Myers, S. C. and N. S. Majluf, "Corporate financing and investment decisions when firms have information that investors do not have," *Journal of Financial Economics* 13 (1984), 187–221.

Nickell, S., "Biases in dynamic models with fixed effects," *Econometrica* (1981), 1417–1426.

Schmitz, S. W., M. Sigmund and L. Valderrama, "Bank Solvency and Funding Cost: New Data and New Results," IMF Working Paper 17/116, 2017.

Stein, J. C., "An Adverse-Selection Model of Bank Asset and Liability Management with Implications for the Transmission of Monetary Policy," *RAND Journal of Economics* 29 (1998), 466–486.

Windmeijer, F., "A Finite Sample Correction for the Variance of Linear Efficient Two-Step GMM Estimators," *Journal of Econometrics* 126 (2005).

Wu, J. C. and F. D. Xia, "Time Varying Lower Bound of Interest Rates in Europe," Chicago Booth Research Paper 17/06, 2017.

# Appendix

Table 1: Summary statistics for the key variables

| Variable | Observations | Mean | Median | Standard deviation |
|---|---|---|---|---|
| Senior bond yields | 423 | 2.86 | 2.92 | 2.01 |
| Remaining time to maturity of senior bonds | 423 | 3.74 | 3.45 | 1.90 |
| Term deposit rates | 704 | 1.50 | 1.01 | 1.38 |
| Original maturity of term deposits | 705 | 0.82 | 0.67 | 0.41 |
| Overnight deposit rates | 1276 | 0.44 | 0.15 | 0.70 |
| Common equity Tier 1 ratio | 1149 | 12.04 | 10.98 | 12.87 |
| Tier 1 ratio | 1259 | 12.49 | 11.21 | 13.03 |
| Total capital ratio | 1271 | 15.58 | 13.65 | 18.76 |
| Common equity over total assets | 1381 | 5.08 | 4.80 | 2.93 |
| Loan loss provisions over gross customer loans | 1135 | 0.54 | 0.39 | 0.61 |
| Loan loss reserves over gross customer loans | 1287 | 1.74 | 1.09 | 2.03 |
| Return over equity | 1248 | 5.61 | 5.49 | 7.71 |
| Return over assets | 1268 | 0.56 | 0.26 | 6.49 |
| Deposits over total assets | 1375 | 40.38 | 40.94 | 20.43 |
| Wholesale funding over total assets | 866 | 42.70 | 37.89 | 21.19 |
| Sovereign spread | 1671 | 0.71 | 0.23 | 1.40 |
| Euro Stoxx volatility index | 1674 | 21.51 | 18.12 | 7.99 |
| EONIA | 1674 | 1.21 | 0.63 | 1.43 |
| Shadow rate | 1547 | -0.26 | -0.12 | 2.70 |

Table 2: Number of banks by country for senior bond yields, term deposit rates and overnight deposit rates

| Country | Senior bond yields | Term deposit rates | Overnight deposit rates |
|---|---|---|---|
| AT | 9 | 9 | 4 |
| BE | 2 | 8 | 6 |
| CY | 0 | 2 | 1 |
| DE | 15 | 27 | 31 |
| ES | 6 | 17 | 17 |
| FI | 1 | 4 | 3 |
| FR | 6 | 12 | 15 |
| GR | 0 | 4 | 4 |
| IE | 2 | 3 | 3 |
| IT | 10 | 5 | 17 |
| LU | 0 | 4 | 5 |
| MT | 0 | 2 | 0 |
| NL | 4 | 1 | 3 |
| PT | 2 | 4 | 5 |
| SI | 0 | 6 | 1 |
| SK | 0 | 4 | 0 |
| Total number of banks | 57 | 112 | 115 |
| Total number of countries | 10 | 16 | 14 |

Table 3: Baseline System GMM regressions for senior bond yields

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| L.Senior bond yields | 0.391*** | 0.405*** | 0.414*** | 0.426*** | 0.419*** | 0.377*** | 0.240 | 0.311*** |
| | (0.0564) | (0.0502) | (0.0571) | (0.0813) | (0.0527) | (0.0607) | (0.150) | (0.112) |
| Remaining time to maturity of senior bonds | -0.00101 | -0.0317 | -0.0267 | -0.0448 | 0.0122 | -0.00142 | -0.139 | -0.0245 |
| | (0.0636) | (0.0660) | (0.0711) | (0.0747) | (0.0755) | (0.0629) | (0.123) | (0.100) |
| Sovereign spread | 0.972*** | 0.951*** | 0.958*** | 0.979*** | 1.046*** | 0.978*** | 1.086*** | 1.150*** |
| | (0.179) | (0.193) | (0.168) | (0.198) | (0.199) | (0.180) | (0.228) | (0.187) |
| Euro Stoxx volatility index | 0.0499*** | 0.0473*** | 0.0488*** | 0.0483*** | 0.0511*** | 0.0481*** | 0.0702*** | 0.0708*** |
| | (0.00696) | (0.00652) | (0.00722) | (0.00786) | (0.00754) | (0.00610) | (0.0191) | (0.0143) |
| EONIA | 0.612*** | 0.654*** | 0.622*** | 0.613*** | 0.587*** | 0.624*** | 0.726* | 0.679** |
| | (0.0631) | (0.0858) | (0.0730) | (0.0894) | (0.0646) | (0.0748) | (0.380) | (0.318) |
| Common equity Tier 1 ratio | -0.0647*** | -0.0557*** | -0.0610*** | -0.0616*** | -0.0670*** | -0.0623* | -0.0679** | -0.0633** |
| | (0.0200) | (0.0182) | (0.0191) | (0.0219) | (0.0218) | (0.0353) | (0.0336) | (0.0263) |
| Return over equity | | -0.00537 | | | | | | -0.0104*** |
| | | (0.00361) | | | | | | (0.00290) |
| Return over assets | | | 0.0103 | | | | | |
| | | | (0.168) | | | | | |
| Loan loss provisions over gross customer loans | | | | 0.0729 | | | | -0.397 |
| | | | | (0.284) | | | | (0.467) |
| Loan loss reserves over gross customer loans | | | | | -0.0915 | | | |
| | | | | | (0.107) | | | |
| Deposits over total assets | | | | | | 0.00145 | | |
| | | | | | | (0.00951) | | |
| Wholesale funding over total assets | | | | | | | 0.00419 | -0.00405 |
| | | | | | | | (0.0120) | (0.0128) |
| Wald $\chi^2$ | 7586.7 | 9805.2 | 7111.8 | 7153.3 | 6504.1 | 8333.1 | 703.9 | 1345.3 |
| Hansen J test (p-value) | 0.153 | 0.148 | 0.183 | 0.183 | 0.121 | 0.195 | 0.172 | 0.246 |
| AR(2) Arellano-Bond test (p-value) | 0.912 | 0.51 | 0.89 | 0.889 | 0.964 | 0.897 | 0.34 | 0.27 |
| Number of instruments | 42 | 43 | 43 | 43 | 44 | 44 | 31 | 43 |
| Number of banks | 57 | 57 | 57 | 57 | 57 | 57 | 53 | 53 |
| Number of observations | 315 | 301 | 302 | 290 | 307 | 313 | 222 | 215 |

The symbols ***, **, and * denote significance at the 1%, 5% and 10% level, respectively. Heteroskedasticity and autocorrelation-robust (asymptotic) Windmeijer (2005)-corrected standard errors reported in parentheses. Below the parameter estimates, the number of instruments, the number of individual banking groups in the sample and the number of observations are provided. Further, the Wald $\chi^2$ statistic to test for the joint significance of the estimated parameters is given. Finally, for the GMM approach the p-value based on the Arellano-Bond statistic to test for second-order autocorrelation and on the Hansen J statistic to test the validity of the over-identifying restrictions are shown.

Table 4: Baseline System GMM regressions for term deposits

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| L.Term deposit rates | 0.291*** | 0.293*** | 0.301*** | 0.313*** | 0.308*** | 0.291*** | 0.449*** | 0.306*** |
| | (0.0218) | (0.0231) | (0.0254) | (0.0251) | (0.0256) | (0.0265) | (0.0406) | (0.0248) |
| L2.Term deposit rates | -0.162*** | -0.156*** | -0.162*** | -0.153*** | -0.166*** | -0.142*** | -0.145*** | -0.148*** |
| | (0.0217) | (0.0193) | (0.0203) | (0.0215) | (0.0207) | (0.0232) | (0.0209) | (0.0255) |
| Sovereign spread | 0.181*** | 0.186*** | 0.181*** | 0.190*** | 0.177*** | 0.190*** | 0.146*** | 0.213*** |
| | (0.0168) | (0.0221) | (0.0195) | (0.0238) | (0.0180) | (0.0207) | (0.0193) | (0.0285) |
| Euro Stoxx volatility index | 0.0189*** | 0.0185*** | 0.0183*** | 0.0178*** | 0.0175*** | 0.0223*** | 0.0207*** | 0.0202*** |
| | (0.00287) | (0.00289) | (0.00310) | (0.00277) | (0.00294) | (0.00278) | (0.00272) | (0.00306) |
| EONIA | 0.889*** | 0.852*** | 0.876*** | 0.871*** | 0.907*** | 0.812*** | 0.708*** | 0.814*** |
| | (0.0752) | (0.0779) | (0.0745) | (0.0741) | (0.0784) | (0.0821) | (0.0969) | (0.0833) |
| Original maturity of term deposits | 0.622*** | 0.619*** | 0.584*** | 0.586*** | 0.578*** | 0.667*** | 0.454*** | 0.580*** |
| | (0.121) | (0.142) | (0.162) | (0.148) | (0.153) | (0.133) | (0.129) | (0.172) |
| Common equity Tier 1 ratio | -0.0309*** | -0.0310*** | -0.0281*** | -0.0285*** | -0.0269*** | -0.0245** | -0.0299*** | -0.0288*** |
| | (0.00828) | (0.00897) | (0.0100) | (0.00816) | (0.00943) | (0.00989) | (0.00670) | (0.0108) |
| Return over equity | | -0.00159 | | | | | | -0.000123 |
| | | (0.00106) | | | | | | (0.00376) |
| Return over assets | | | -0.0118 | | | | | |
| | | | (0.0287) | | | | | |
| Loan loss provisions over gross customer loans | | | | -0.0596 | | | | -0.0428 |
| | | | | (0.0543) | | | | (0.0618) |
| Loan loss reserves over gross customer loans | | | | | 0.00231 | | | |
| | | | | | (0.00811) | | | |
| Deposits over total assets | | | | | | -0.00402* | | -0.00141 |
| | | | | | | (0.00233) | | (0.00259) |
| Wholesale funding over total assets | | | | | | | -0.00144 | |
| | | | | | | | (0.00374) | |
| Wald $\chi^2$ | 1453.9 | 1387.3 | 1305.5 | 1117.4 | 1439.8 | 1354.3 | 2261.0 | 1602.0 |
| Hansen J test (p-value) | 0.159 | 0.190 | 0.147 | 0.207 | 0.150 | 0.114 | 0.206 | 0.238 |
| AR(2) Arellano-Bond test (p-value) | 0.312 | 0.436 | 0.403 | 0.627 | 0.476 | 0.446 | 0.748 | 0.596 |
| Number of instruments | 91 | 92 | 92 | 92 | 92 | 92 | 95 | 88 |
| Number of banks | 112 | 110 | 111 | 110 | 111 | 112 | 112 | 109 |
| Number of observations | 656 | 637 | 642 | 615 | 643 | 655 | 609 | 612 |

The symbols ***, **, and * denote significance at the 1%, 5% and 10% level, respectively. Heteroskedasticity and autocorrelation-robust (asymptotic) Windmeijer (2005)-corrected standard errors reported in parentheses. Below the parameter estimates, the number of instruments, the number of individual banking groups in the sample and the number of observations are provided. Further, the Wald $\chi^2$ statistic to test for the joint significance of the estimated parameters is given. Finally, for the GMM approach the p-value based on the Arellano-Bond statistic to test for second-order autocorrelation and on the Hansen J statistic to test the validity of the over-identifying restrictions are shown.

Table 5: Baseline System GMM regressions for overnight deposits

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| L.Overnight deposit rates | 0.238*** | 0.235*** | 0.239*** | 0.273*** | 0.255*** | 0.242*** | 0.619*** | 0.277*** |
| | (0.0355) | (0.0381) | (0.0375) | (0.0448) | (0.0402) | (0.0328) | (0.0644) | (0.0445) |
| L2.Overnight deposit rates | -0.00521 | 0.00470 | 0.00215 | -0.0277 | -0.0288 | -0.000414 | -0.0541** | -0.0261 |
| | (0.0352) | (0.0480) | (0.0445) | (0.0434) | (0.0373) | (0.0327) | (0.0237) | (0.0387) |
| Sovereign spread | 0.00722* | 0.00136 | 0.00755 | 0.00957** | 0.000313 | 0.00596 | 0.00254 | 0.00923 |
| | (0.00417) | (0.0144) | (0.00512) | (0.00423) | (0.00376) | (0.00402) | (0.00289) | (0.00595) |
| Euro Stoxx volatility index | 0.0101*** | 0.00918*** | 0.00876*** | 0.00890*** | 0.00905*** | 0.00894*** | 0.00807*** | 0.00912*** |
| | (0.00175) | (0.00144) | (0.00156) | (0.00191) | (0.00161) | (0.00120) | (0.00159) | (0.00126) |
| EONIA | 0.107** | 0.133*** | 0.133** | 0.140** | 0.154*** | 0.127*** | 0.0532 | 0.145*** |
| | (0.0497) | (0.0464) | (0.0550) | (0.0568) | (0.0547) | (0.0476) | (0.0403) | (0.0501) |
| Common equity Tier 1 ratio | -0.00689** | -0.00486** | -0.00478* | -0.00472 | -0.00588** | -0.00655 | -0.00897*** | -0.00494 |
| | (0.00296) | (0.00237) | (0.00271) | (0.00301) | (0.00288) | (0.00433) | (0.00231) | (0.00349) |
| Return over equity | | -0.000831 | | | | | | 0.000283 |
| | | (0.00243) | | | | | | (0.000629) |
| Return over assets | | | 0.00609 | | | | | |
| | | | (0.0152) | | | | | |
| Loan loss provisions over gross customer loans | | | | -0.0100 | | | | -0.0142 |
| | | | | (0.0183) | | | | (0.0122) |
| Loan loss reserves over gross customer loans | | | | | 0.00865*** | | | |
| | | | | | (0.00161) | | | |
| Deposits over total assets | | | | | | 0.000426 | | 0.000101 |
| | | | | | | (0.000900) | | (0.000764) |
| Wholesale funding over total assets | | | | | | | 0.000137 | |
| | | | | | | | (0.000975) | |
| Wald $\chi^2$ | 323.8 | 325.7 | 352.5 | 330.7 | 423.4 | 369.5 | 972.8 | 358.4 |
| Hansen J test (p-value) | 0.102 | 0.105 | 0.124 | 0.138 | 0.198 | 0.147 | 0.103 | 0.490 |
| AR(2) Arellano-Bond test (p-value) | 0.178 | 0.140 | 0.136 | 0.168 | 0.190 | 0.161 | 0.744 | 0.165 |
| Number of instruments | 93 | 96 | 98 | 91 | 98 | 98 | 87 | 101 |
| Number of banks | 115 | 114 | 115 | 112 | 112 | 115 | 114 | 111 |
| Number of observations | 793 | 771 | 777 | 725 | 756 | 788 | 725 | 721 |

The symbols ***, **, and * denote significance at the 1%, 5% and 10% level, respectively. Heteroskedasticity and autocorrelation-robust (asymptotic) Windmeijer (2005)-corrected standard errors reported in parentheses. Below the parameter estimates, the number of instruments, the number of individual banking groups in the sample and the number of observations are provided. Further, the Wald $\chi^2$ statistic to test for the joint significance of the estimated parameters is given. Finally, for the GMM approach the p-value based on the Arellano-Bond statistic to test for second-order autocorrelation and on the Hansen J statistic to test the validity of the over-identifying restrictions are shown.

Table 6: Further system GMM regressions for senior bond yields

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| L.Senior bond yields | 0.283*** | 1.073*** | 0.284** | 0.283*** | 0.236*** | 0.134 | 0.323*** |
| | (0.0725) | (0.286) | (0.114) | (0.0952) | (0.0704) | (0.116) | (0.121) |
| Remaining time to maturity of senior bonds | -0.0876 | 0.320** | -0.00941 | -0.0264 | -0.0206 | -0.0752 | -0.00742 |
| | (0.153) | (0.133) | (0.109) | (0.120) | (0.0871) | (0.100) | (0.0873) |
| Sovereign spread | 0.855*** | 0.710*** | 1.098*** | 1.110*** | 1.174*** | 1.466*** | 1.172*** |
| | (0.227) | (0.232) | (0.191) | (0.212) | (0.197) | (0.198) | (0.161) |
| Euro Stoxx volatility index | 0.0977*** | | 0.0653*** | 0.0660*** | 0.0711*** | 0.0567*** | 0.0669*** |
| | (0.0187) | | (0.0124) | (0.0126) | (0.0108) | (0.0119) | (0.0129) |
| EONIA | 0.612* | | 0.825*** | 0.755*** | 0.715*** | 0.855*** | |
| | (0.333) | | (0.305) | (0.279) | (0.222) | (0.286) | |
| Common equity Tier 1 ratio | -0.359*** | -0.0448* | | | | | -0.0652** |
| | (0.130) | (0.0249) | | | | | (0.0301) |
| Common equity Tier 1 ratio squared | 0.0164*** | | | | | | |
| | (0.00635) | | | | | | |
| Loan loss provisions over gross customer loans | 0.895** | -0.299 | -0.236 | -0.231 | 0.0358 | 0.0886 | -0.598 |
| | (0.443) | (0.500) | (0.481) | (0.511) | (0.577) | (0.511) | (0.591) |
| Return over equity | -0.0102*** | -0.00441 | -0.0112*** | -0.0103*** | -0.00443** | -0.00960*** | -0.0140*** |
| | (0.00196) | (0.00385) | (0.00292) | (0.00285) | (0.00215) | (0.00152) | (0.00286) |
| Wholesale funding over total assets | -0.00199 | -0.00736 | -0.00713 | -0.000185 | 0.00409 | 0.00871 | 0.00764 |
| | (0.00791) | (0.0115) | (0.0117) | (0.0143) | (0.0101) | (0.00873) | (0.0120) |
| Tier 1 ratio | | | -0.0467* | | | | |
| | | | (0.0240) | | | | |
| Total capital ratio | | | | -0.0521** | | | |
| | | | | (0.0235) | | | |
| Common equity over total assets | | | | | -0.229*** | | |
| | | | | | (0.0619) | | |
| Common equity Tier 1 ratio x crisis country | | | | | | -0.191*** | |
| | | | | | | (0.0436) | |
| Common equity Tier 1 ratio x non-crisis country | | | | | | -0.0503** | |
| | | | | | | (0.0199) | |
| Shadow rate | | | | | | | 0.124** |
| | | | | | | | (0.0591) |
| Wald $\chi^2$ | 1151.4 | 2853.7 | 1451.6 | 1356.1 | 1593.2 | 2440.4 | 1903.3 |
| Hansen J test (p-value) | 0.236 | 0.185 | 0.234 | 0.203 | 0.211 | 0.233 | 0.492 |
| AR(2) Arellano-Bond test (p-value) | 0.674 | 0.137 | 0.374 | 0.294 | 0.488 | 0.549 | 0.204 |
| Number of instruments | 45 | 49 | 43 | 43 | 43 | 45 | 50 |
| Number of banks | 53 | 53 | 53 | 53 | 54 | 53 | 53 |
| Number of observations | 215 | 215 | 223 | 223 | 234 | 215 | 215 |

The symbols ***, **, and * denote significance at the 1%, 5% and 10% level, respectively. Heteroskedasticity and autocorrelation-robust (asymptotic) Windmeijer (2005)-corrected standard errors reported in parentheses. Below the parameter estimates, the number of instruments, the number of individual banking groups in the sample and the number of observations are provided. Further, the Wald $\chi^2$ statistic to test for the joint significance of the estimated parameters is given. Finally, for the GMM approach the p-value based on the Arellano-Bond statistic to test for second-order autocorrelation and on the Hansen J statistic to test the validity of the over-identifying restrictions are shown.

Table 7: Further system GMM regressions for term deposits

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| L.Term deposit rates | 0.309*** | 0.583*** | 0.309*** | 0.315*** | 0.326*** | 0.312*** | 0.208*** |
| | (0.0251) | (0.0882) | (0.0248) | (0.0247) | (0.0285) | (0.0261) | (0.0261) |
| L2.Term deposit rates | -0.155*** | -0.0784 | -0.150*** | -0.153*** | -0.162*** | -0.158*** | -0.0541** |
| | (0.0288) | (0.0770) | (0.0234) | (0.0234) | (0.0244) | (0.0291) | (0.0233) |
| Sovereign spread | 0.213*** | 0.114*** | 0.205*** | 0.197*** | 0.217*** | 0.211*** | 0.219*** |
| | (0.0279) | (0.0213) | (0.0292) | (0.0289) | (0.0247) | (0.0298) | (0.0325) |
| Euro Stoxx volatility index | 0.0246*** | | 0.0215*** | 0.0227*** | 0.0195*** | 0.0204*** | 0.0356*** |
| | (0.00292) | | (0.00277) | (0.00271) | (0.00286) | (0.00318) | (0.00241) |
| EONIA | 0.825*** | | 0.820*** | 0.839*** | 0.890*** | 0.846*** | |
| | (0.0803) | | (0.0760) | (0.0702) | (0.0719) | (0.0900) | |
| Original maturity of term deposits | 0.701*** | 0.284** | 0.475*** | 0.500*** | 0.451*** | 0.630*** | 0.712*** |
| | (0.171) | (0.131) | (0.155) | (0.179) | (0.125) | (0.175) | (0.156) |
| Common equity Tier 1 ratio | -0.0887*** | -0.0180** | | | | | -0.0315*** |
| | (0.0282) | (0.00724) | | | | | (0.0107) |
| Common equity Tier 1 ratio squared | 0.00201*** | | | | | | |
| | (0.000682) | | | | | | |
| Loan loss provisions over gross customer loans | -0.0419 | -0.00726 | -0.0367 | -0.0432 | -0.0632 | -0.0521 | -0.0558 |
| | (0.0575) | (0.0436) | (0.0717) | (0.0692) | (0.0912) | (0.0596) | (0.0683) |
| Return over equity | 0.000606 | -0.00110 | -0.000168 | -0.000820 | -0.00217 | 0.000230 | -0.00184 |
| | (0.00344) | (0.00268) | (0.00368) | (0.00361) | (0.00406) | (0.00362) | (0.00481) |
| Deposits over total assets | 0.00230 | 0.000401 | -0.00166 | -0.00178 | -0.00709** | -0.00208 | -0.00305 |
| | (0.00338) | (0.00184) | (0.00272) | (0.00277) | (0.00302) | (0.00251) | (0.00280) |
| Tier 1 ratio | | | -0.0221** | | | | |
| | | | (0.00942) | | | | |
| Total capital ratio | | | | -0.0207** | | | |
| | | | | (0.00934) | | | |
| Common equity over total assets | | | | | 0.0144 | | |
| | | | | | (0.0143) | | |
| Common equity Tier 1 ratio x crisis country | | | | | | -0.0251** | |
| | | | | | | (0.0103) | |
| Common equity Tier 1 ratio x non-crisis country | | | | | | -0.0300*** | |
| | | | | | | (0.0104) | |
| Shadow rate | | | | | | | 0.113*** |
| | | | | | | | (0.0156) |
| Wald $\chi^2$ | 1851.3 | 5463.7 | 1701.4 | 1745.4 | 2062.6 | 1783.0 | 1401.8 |
| Hansen J test (p-value) | 0.241 | 0.303 | 0.126 | 0.108 | 0.177 | 0.239 | 0.234 |
| AR(2) Arellano-Bond test (p-value) | 0.447 | 0.937 | 0.645 | 0.613 | 0.986 | 0.491 | 0.483 |
| Number of instruments | 90 | 94 | 88 | 88 | 88 | 90 | 88 |
| Number of banks | 109 | 109 | 111 | 111 | 110 | 109 | 109 |
| Number of observations | 612 | 612 | 632 | 634 | 646 | 612 | 612 |

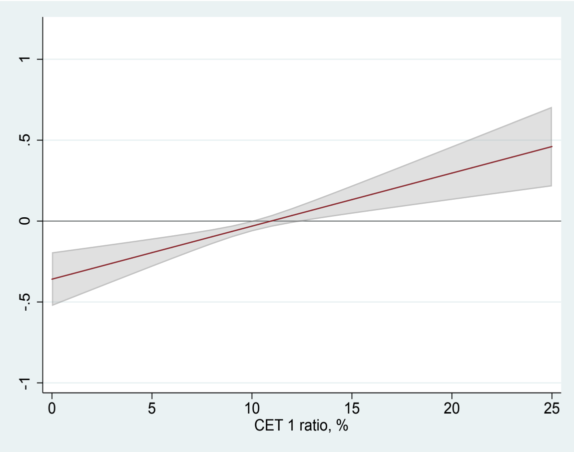
The symbols ***, **, and * denote significance at the 1%, 5% and 10% level, respectively. Heteroskedasticity and autocorrelation-robust (asymptotic) Windmeijer (2005)-corrected standard errors reported in parentheses. Below the parameter estimates, the number of instruments, the number of individual banking groups in the sample and the number of observations are provided. Further, the Wald $\chi^2$ statistic to test for the joint significance of the estimated parameters is given. Finally, for the GMM approach the p-value based on the Arellano-Bond statistic to test for second-order autocorrelation and on the Hansen J statistic to test the validity of the over-identifying restrictions are shown.

Table 8: Further system GMM regressions for overnight deposits

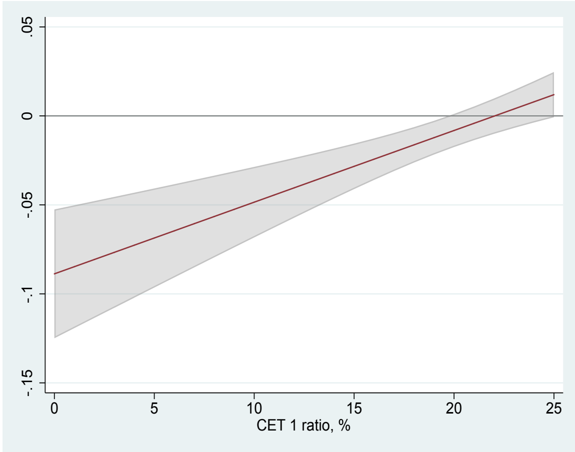
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| L.Overnight deposit rates | 0.379*** | 0.317*** | 0.287*** | 0.281*** | 0.270*** | 0.256*** | 0.345*** |
| | (0.0731) | (0.0833) | (0.0397) | (0.0450) | (0.0430) | (0.0395) | (0.0749) |
| L2.Overnight deposit rates | -0.0654 | 0.0560 | -0.0122 | -0.00910 | -0.0118 | -0.0184 | -0.0320 |
| | (0.0485) | (0.0604) | (0.0351) | (0.0285) | (0.0270) | (0.0292) | (0.0412) |
| Sovereign spread | 0.0159 | 0.00292 | 0.0141 | 0.00992 | 0.0178** | 0.0180** | 0.0115 |
| | (0.0104) | (0.00876) | (0.00949) | (0.00777) | (0.00810) | (0.00796) | (0.00942) |
| Euro Stoxx volatility index | 0.00667*** | | 0.00992*** | 0.00948*** | 0.00816*** | 0.00866*** | 0.00728*** |
| | (0.00161) | | (0.00167) | (0.00146) | (0.00122) | (0.00152) | (0.00173) |
| EONIA | 0.162*** | | 0.138*** | 0.145*** | 0.180*** | 0.146*** | |
| | (0.0476) | | (0.0492) | (0.0371) | (0.0285) | (0.0413) | |
| Common equity Tier 1 ratio | -0.00973 | -0.00573 | | | | | -0.00388 |
| | (0.00868) | (0.00399) | | | | | (0.00400) |
| Common equity Tier 1 ratio squared | 0.000185 | | | | | | |
| | (0.000220) | | | | | | |
| Loan loss provisions over gross customer loans | -0.0450 | 0.000117 | -0.0349* | -0.0253 | -0.0168 | -0.0141 | -0.0272* |
| | (0.0313) | (0.0157) | (0.0188) | (0.0186) | (0.0173) | (0.0150) | (0.0160) |
| Return over equity | 0.000416 | 0.00167** | 0.000858 | 0.000725 | 0.00132 | 0.00122 | 0.0000639 |
| | (0.00201) | (0.000850) | (0.00134) | (0.00124) | (0.00100) | (0.00123) | (0.00172) |
| Deposits over total assets | 0.00161 | 0.00106 | 0.000571 | 0.000187 | -0.00159* | -0.000553 | 0.00156 |
| | (0.00130) | (0.00114) | (0.000862) | (0.000749) | (0.000861) | (0.00122) | (0.00115) |
| Tier 1 ratio | | | -0.00738** | | | | |
| | | | (0.00310) | | | | |
| Total capital ratio | | | | -0.00531*** | | | |
| | | | | (0.00186) | | | |
| Common equity over total assets | | | | | 0.00353 | | |
| | | | | | (0.00514) | | |
| Common equity Tier 1 ratio x crisis country | | | | | | -0.00490 | |
| | | | | | | (0.00512) | |
| Common equity Tier 1 ratio x non-crisis country | | | | | | -0.00219 | |
| | | | | | | (0.00328) | |
| Shadow rate | | | | | | | 0.0267*** |
| | | | | | | | (0.00742) |
| Wald $\chi^2$ | 396.7 | 701.2 | 271.7 | 226.7 | 195.1 | 291.4 | 428.2 |
| Hansen J test (p-value) | 0.214 | 0.163 | 0.110 | 0.252 | 0.198 | 0.224 | 0.185 |
| AR(2) Arellano-Bond test (p-value) | 0.136 | 0.114 | 0.170 | 0.163 | 0.175 | 0.169 | 0.120 |
| Number of instruments | 98 | 93 | 92 | 91 | 91 | 92 | 96 |
| Number of banks | 111 | 111 | 111 | 112 | 115 | 111 | 111 |
| Number of observations | 721 | 721 | 747 | 748 | 796 | 721 | 721 |

The symbols ***, **, and * denote significance at the 1%, 5% and 10% level, respectively. Heteroskedasticity and autocorrelation-robust (asymptotic) Windmeijer (2005)-corrected standard errors reported in parentheses. Below the parameter estimates, the number of instruments, the number of individual banking groups in the sample and the number of observations are provided. Further, the Wald $\chi^2$ statistic to test for the joint significance of the estimated parameters is given. Finally, for the GMM approach the p-value based on the Arellano-Bond statistic to test for second-order autocorrelation and on the Hansen J statistic to test the validity of the over-identifying restrictions are shown.

Figure 3: Total effects of CET1 ratio on senior bond yields and term deposit rates.




(a) Senior bond yields




(b) Term deposit rates

Table 9: Turning points with corresponding error bands for regressions using senior bond yields and term deposit rates as dependent variables

| | Turning point | Joint significance | Confidence interval | Share |
|---|---|---|---|---|
| Senior bond yields | 10.95 | 7.73*** | [9.94, 12.58] | 49% |
| Term deposit rates | 22.06 | 9.90*** | [19.71, 25.29] | 8% |

Note: The symbols ***, **, and * denote significance at the 1%, 5% and 10% level, respectively.

Table 10: OLS regressions for senior bond yields

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| L.Remaining time to maturity of senior bonds | 0.0439 | 0.0373 | 0.0189 | 0.0327 | 0.0640 | 0.0443 | -0.0386 | -0.0286 |
| | (0.0512) | (0.0428) | (0.0471) | (0.0563) | (0.0475) | (0.0480) | (0.0591) | (0.0614) |
| Sovereign spread | 1.120*** | 1.063*** | 1.023*** | 1.084*** | 1.156*** | 1.147*** | 1.013*** | 1.016*** |
| | (0.169) | (0.145) | (0.138) | (0.150) | (0.174) | (0.172) | (0.140) | (0.163) |
| Euro Stoxx volatility index | 0.0956*** | 0.0903*** | 0.0894*** | 0.0881*** | 0.0984*** | 0.101*** | 0.0517*** | 0.0684*** |
| | (0.00573) | (0.00560) | (0.00596) | (0.00818) | (0.00630) | (0.00695) | (0.0100) | (0.0165) |
| EONIA | 0.787*** | 0.888*** | 0.932*** | 0.817*** | 0.759*** | 0.807*** | 1.803*** | 1.618*** |
| | (0.0591) | (0.0494) | (0.0609) | (0.0585) | (0.0517) | (0.0622) | (0.240) | (0.195) |
| L.Common equity Tier 1 ratio | -0.0951*** | -0.0831*** | -0.0643*** | -0.0902*** | -0.0960*** | -0.0765*** | -0.0452*** | -0.0424** |
| | (0.0199) | (0.0164) | (0.0179) | (0.0190) | (0.0214) | (0.0273) | (0.0164) | (0.0176) |
| L.Return over equity | | -0.0247*** | | | | | | -0.0195*** |
| | | (0.00361) | | | | | | (0.00151) |
| L.Return over assets | | | -0.621*** | | | | | |
| | | | (0.194) | | | | | |
| L.Loan loss provisions over gross customer loans | | | | 0.277 | | | | -0.155 |
| | | | | (0.186) | | | | (0.270) |
| L.Loan loss reserves over gross customer loans | | | | | -0.0765 | | | |
| | | | | | (0.111) | | | |
| L.Deposits over total assets | | | | | | -0.00973 | | |
| | | | | | | (0.00791) | | |
| L.Wholesale funding over total assets | | | | | | | 0.0107* | 0.00339 |
| | | | | | | | (0.00620) | (0.00451) |
| $R^2$ | 0.884 | 0.919 | 0.899 | 0.879 | 0.885 | 0.886 | 0.871 | 0.910 |
| Number of observations | 297 | 284 | 286 | 275 | 292 | 296 | 190 | 182 |

***, **, and * denote significance at the 1%, 5% and 10% level, respectively. Clustered standard errors at bank level are used.

Table 11: OLS regressions for term deposit rates

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Sovereign spread | 0.191*** | 0.183*** | 0.192*** | 0.191*** | 0.189*** | 0.191*** | 0.203*** | 0.191*** |
| | (0.0151) | (0.0148) | (0.0151) | (0.0168) | (0.0149) | (0.0152) | (0.0197) | (0.0181) |
| Euro Stoxx volatility index | 0.0161*** | 0.0176*** | 0.0173*** | 0.0152*** | 0.0153*** | 0.0164*** | 0.00894* | 0.0171*** |
| | (0.00474) | (0.00478) | (0.00474) | (0.00487) | (0.00464) | (0.00428) | (0.00489) | (0.00430) |
| EONIA | 1.256*** | 1.234*** | 1.238*** | 1.276*** | 1.272*** | 1.254*** | 1.148*** | 1.237*** |
| | (0.0649) | (0.0656) | (0.0652) | (0.0680) | (0.0627) | (0.0639) | (0.116) | (0.0677) |
| L.Original maturity of term deposits | 0.522*** | 0.551*** | 0.552*** | 0.508*** | 0.518*** | 0.524*** | 0.564*** | 0.533*** |
| | (0.108) | (0.110) | (0.110) | (0.111) | (0.108) | (0.125) | (0.114) | (0.129) |
| L.Common equity Tier 1 ratio | -0.0130** | -0.0177*** | -0.0179*** | -0.0108* | -0.0123** | -0.0136** | -0.0100 | -0.0158*** |
| | (0.00567) | (0.00512) | (0.00508) | (0.00577) | (0.00581) | (0.00614) | (0.00612) | (0.00595) |
| L.Return over equity | | 0.000274 | | | | | | 0.00210 |
| | | (0.000565) | | | | | | (0.00162) |
| L.Return over assets | | | 0.0185 | | | | | |
| | | | (0.0163) | | | | | |
| L.Loan loss provisions over gross customer loans | | | | -0.0131 | | | | 0.000854 |
| | | | | (0.0334) | | | | (0.0339) |
| L.Loan loss reserves over gross customer loans | | | | | 0.00460 | | | |
| | | | | | (0.00666) | | | |
| L.Deposits over total assets | | | | | | -0.0000445 | | -0.000293 |
| | | | | | | (0.00195) | | (0.00209) |
| L.Wholesale funding over total assets | | | | | | | 0.00262 | |
| | | | | | | | (0.00222) | |
| $R^2$ | 0.889 | 0.886 | 0.886 | 0.884 | 0.888 | 0.889 | 0.858 | 0.884 |
| Number of observations | 729 | 699 | 705 | 674 | 713 | 727 | 572 | 669 |

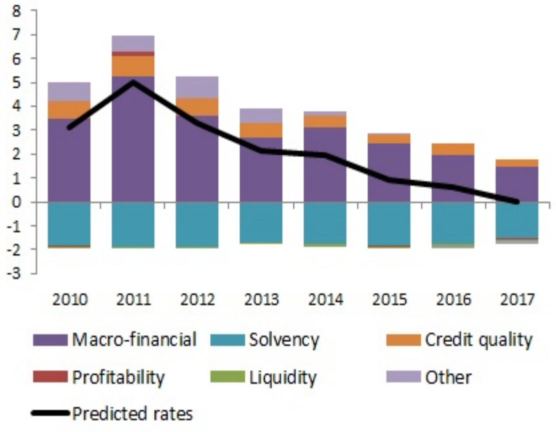
***, **, and * denote significance at the 1%, 5% and 10% level, respectively. Clustered standard errors at bank level are used.

Table 12: OLS regressions for overnight deposit rates

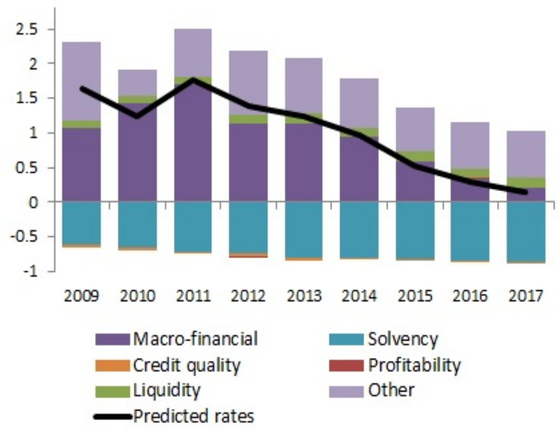
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Sovereign spread | -0.00298 | -0.00357 | -0.00369 | -0.000235 | -0.00705 | -0.000897 | 0.00811 | -0.00474 |
| | (0.00561) | (0.00595) | (0.00626) | (0.00648) | (0.00603) | (0.00547) | (0.00507) | (0.00678) |
| Euro Stoxx volatility index | 0.0131*** | 0.0129*** | 0.0126*** | 0.0139*** | 0.0130*** | 0.0141*** | 0.0100*** | 0.0150*** |
| | (0.00140) | (0.00139) | (0.00139) | (0.00167) | (0.00144) | (0.00138) | (0.00173) | (0.00179) |
| EONIA | 0.383*** | 0.386*** | 0.390*** | 0.356*** | 0.387*** | 0.381*** | 0.267*** | 0.357*** |
| | (0.0359) | (0.0384) | (0.0373) | (0.0364) | (0.0389) | (0.0356) | (0.0390) | (0.0379) |
| L.Common equity Tier 1 ratio | -0.00439** | -0.00401** | -0.00361* | -0.00564*** | -0.00509** | -0.00244 | -0.00225 | -0.00425 |
| | (0.00190) | (0.00198) | (0.00190) | (0.00217) | (0.00207) | (0.00277) | (0.00192) | (0.00266) |
| L.Return over equity | | -0.000490 | | | | | | -0.00254** |
| | | (0.000471) | | | | | | (0.00107) |
| L.Return over assets | | | -0.0103 | | | | | |
| | | | (0.0117) | | | | | |
| L.Loan loss provisions over gross customer loans | | | | -0.00421 | | | | -0.0251 |
| | | | | (0.0105) | | | | (0.0161) |
| L.Loan loss reserves over gross customer loans | | | | | 0.00674*** | | | |
| | | | | | (0.00197) | | | |
| L.Deposits over total assets | | | | | | -0.00106 | | -0.000343 |
| | | | | | | (0.000825) | | (0.000832) |
| L.Wholesale funding over total assets | | | | | | | 0.000257 | |
| | | | | | | | (0.000738) | |
| $R^2$ | 0.680 | 0.679 | 0.682 | 0.667 | 0.677 | 0.681 | 0.474 | 0.667 |
| Number of observations | 981 | 952 | 959 | 889 | 938 | 978 | 745 | 884 |

***, **, and * denote significance at the 1%, 5% and 10% level, respectively. Clustered standard errors at bank level are used.

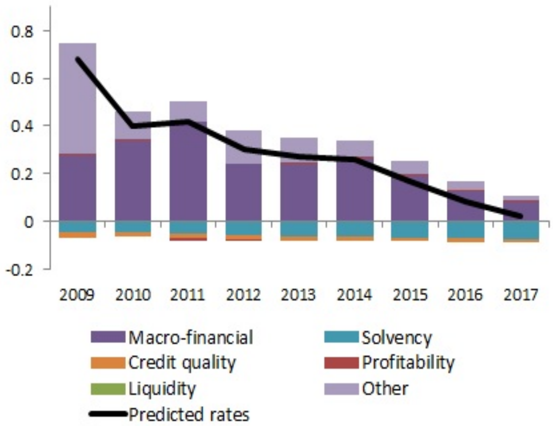
Figure 4: Decomposition of predicted senior bond yields, term deposit rates and overnight deposit rates.




(a) Senior bond yields




(b) Term deposit rates




(c) Overnight deposit rates

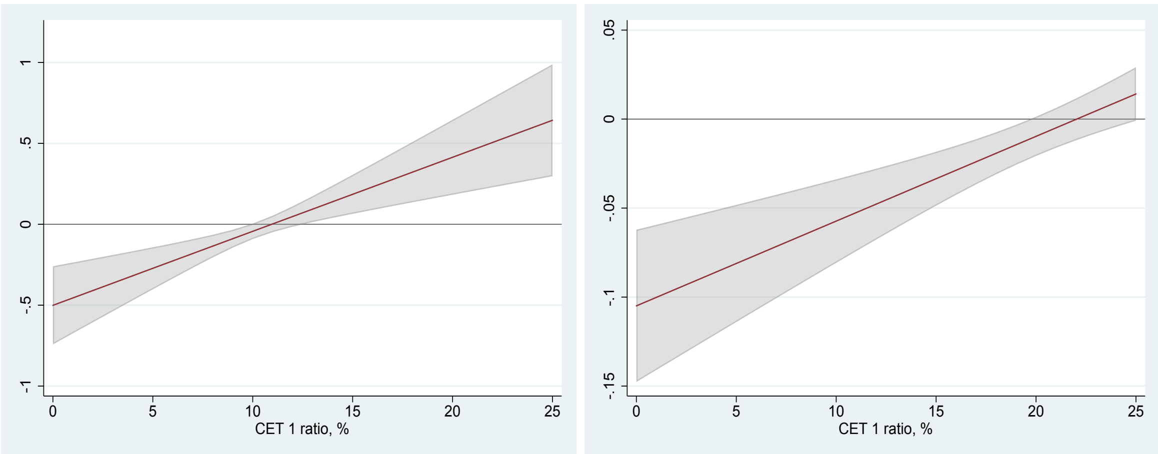
# Appendix A

Table A.1: Long-term effects of the CET1 ratio on senior bond yields and term deposit rates and related test statistics of significance based on the results of the baseline models

| | Long-term effect | Statistic of significance |
|---|---|---|
| Senior bond yields | -0.092 | 4.23** |
| Term deposit rates | -0.034 | 7.10*** |

Note: The effects and the test statistics are based on the results of the regressions reported in column 8 in Table 3 and Table 4. The symbols ***, **, and * denote significance at the 1%, 5% and 10% level, respectively.

Figure A.1: Total long-term effects of CET1 ratio on senior bond yields and term deposit rates.




(a) Senior bond yields (b) Term deposit rates

Table A.2: Turning points with corresponding error bands for regressions using senior bond yields and term deposit rates as dependent variables and relying on total long term effects

| | Turning point | Joint significance | Confidence interval |
|---|---|---|---|
| Senior bond yields | 10.95 | 7.11*** | [9.89, 12.53] |
| Term deposit rates | 22.06 | 9.91*** | [19.91, 25.28] |

Note: The effects and the test statistics are based on the results of the regressions reported in column 1 in Table 6 and Table 7. The symbols ***, **, and * denote significance at the 1%, 5% and 10% level, respectively.

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