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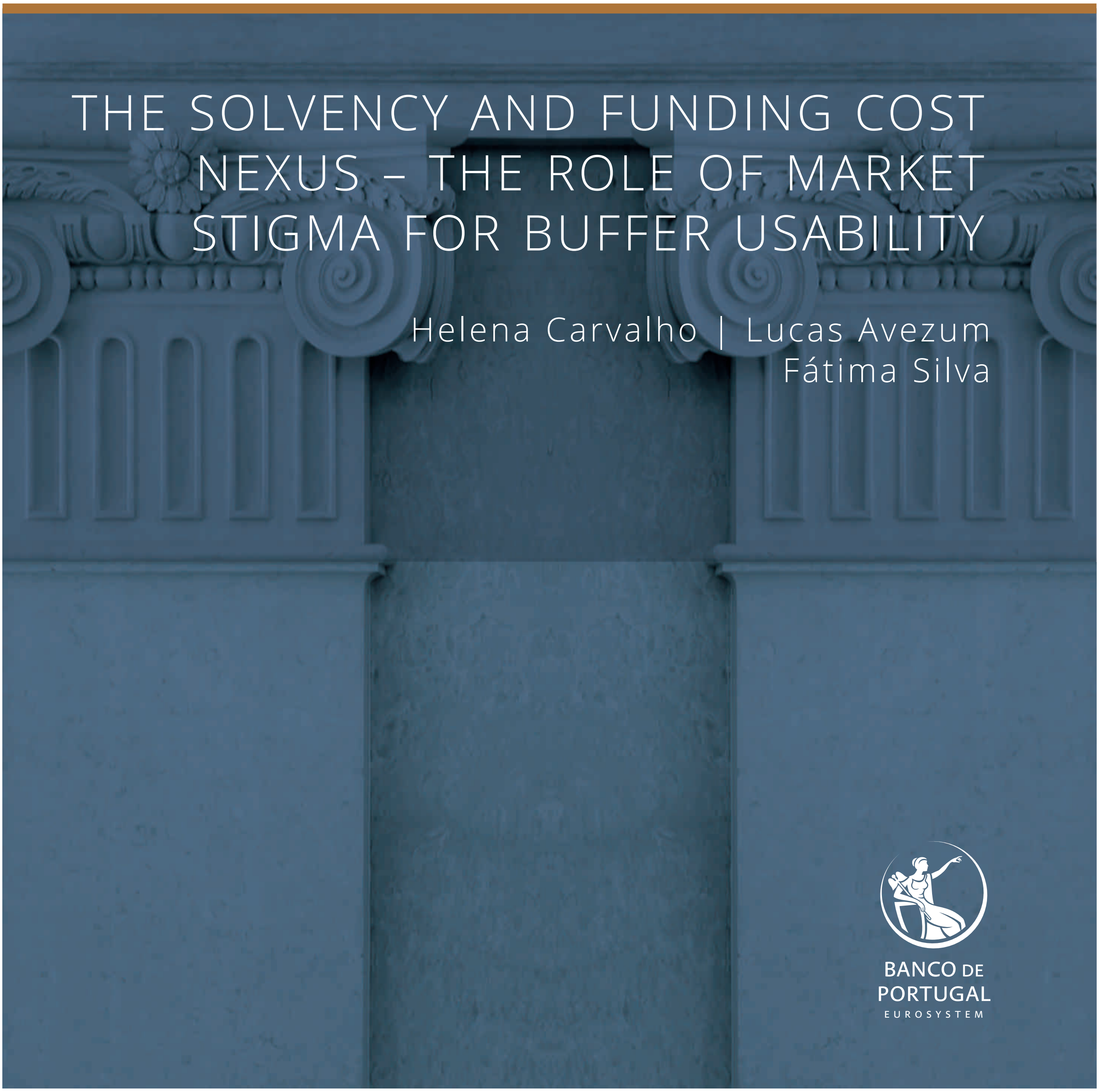

THE SOLVENCY AND FUNDING COST NEXUS – THE ROLE OF MARKET STIGMA FOR BUFFER USABILITY

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The solvency and funding cost nexus - the role of market stigma for buffer usability

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Abstract
In this paper, we investigate the relationship between the banks' solvency ratio and their funding costs using a proprietary dataset from Banco de Portugal for 21 Portuguese banks from 2006 to 2020. In light of the discussion on impediments to capital buffer usability by banks, we focus on the importance of market discipline to this relationship. Our results suggest that the relationship between solvency and funding costs is negative and state-dependent, i.e. market participants become more sensitive to changes in solvency during economic downturns. The relationship is stronger for market-based financing sources in comparison to deposits. Finally, we use a breakpoint analysis and find that investors are more likely to penalize the same absolute deterioration in solvency levels when banks are already in a fragile position. Our findings support the hypothesis that fear of market stigma may make banks reticent to use buffers in times of stress.

JEL: G00, G21, G28

Keywords: solvency, funding costs, capital requirements, market stigma.

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1. Introduction

The Great Financial Crisis exposed vulnerabilities in the quality and quantity of banks' capital. It was the catalyst for increasing regulatory capital requirements, including the introduction of macroprudential buffers that can be used during economic downturns to incentivize banks to continue providing credit to the economy instead of engaging in excessive de-leveraging or de-risking behaviors. However, market pressure to maintain or even increase capital ratios can constrain banks in using their buffers during economic downturns. Hence, concerns with higher funding costs can be one of the reasons why capital ratios in Europe did not decrease meaning that banks did not dip into their buffers during the onset of the COVID-19 crisis despite a large release of regulatory capital buffer (Couaillier *et al.* 2021).

Understanding the relationship between banks' solvency and funding costs is crucial for prudential policy. It has been argued that increasing capital requirements is costly for banks, as they are forced to change their funding composition towards more expensive sources of funding. However, higher solvency levels also make the bank safer leading to lower risk premiums being demanded. The effect of solvency on funding costs depends on both the effect it has on the rates of individual funding sources and on the funding composition. A rise in funding costs erodes banks' profitability which might impair banks' ability to generate the required capital levels internally, an essential tool for withstanding unexpected shocks. In order to preserve capital, banks might respond by curtailing credit provision to the real economy either by passing the costs to customers (price channel) and/or by reducing the supply of credit (quantity channel). A higher cost of credit could impact negatively on overall economic activity as the number of borrowers that become unable to repay their loans may rise too. Moreover, excessive de-leveraging or de-risking strategies could have severe adverse effects on the real economy.

In this paper, we investigate the relationship between the solvency ratio and funding costs using a proprietary dataset from Banco de Portugal for 21 Portuguese banks from 2006 to 2020. Our measure for funding cost is the ratio between the interest paid to the stock of interest-bearing liabilities and it does not include equity financing. The empirical literature studying the determinants of funding costs points towards a negative relationship, i.e. better solvency, asset quality, profitability, or liquidity are cost reducing. In light of the discussion on the effectiveness of the current regulatory capital framework, we focus in particular on the importance of market discipline to this relationship. First, we expect the relationship to be state-dependent as market participants become more risk-averse during economic downturns and may require banks to maintain higher capital ratios to reduce default risk. The long time span of our dataset and the fact that it is on a quarterly basis means that we can investigate if the relationship is stronger during crisis periods. Second, our detailed balance sheet dataset allows us to calculate the funding costs for different financing sources. We expect a stronger relationship between solvency and market-based financing sources in comparison to deposits.

Finally, investors are more likely to penalize the same absolute deterioration in solvency levels when banks are already in a fragile position. To test this hypothesis, we use breakpoint analysis to study if the relationship is non-linear. Importantly, to account for the possible endogeneity between solvency and funding costs, besides using standard panel OLS estimation and fixed effects, we use an instrumental variable strategy. The use of multiple specifications in each section of the paper works as a robustness check.

We find that solvency, measured as the ratio of tier 1 capital to risk-weighted assets, is negatively associated with funding costs. A reduction in the *Solvency Ratio* of 100 bps is associated with an increase in *Funding Cost* of between 1 and 10 bps, depending on the estimator and specification used. We also find that the relationship is state-dependent. During a crisis, the effect of a 100bps increase in the *Solvency Ratio* is 15bps more negative compared to normal periods. The impact of changes in solvency on the cost of each individual funding component (deposits, interbank, claims on central banks, or debt) is also more pronounced during crisis periods. We observe a stronger relationship for funding sources more sensitive to market pressure, such as interbank lending and debt securities than for deposits. The paper also provides evidence that the marginal benefit on funding costs of increasing capital ratio is not constant for all levels of capital. Above a certain level of solvency - depending on the specification, between 11% and 16% - the estimated coefficient of the *Solvency Ratio* on *Funding Cost* is substantially smaller or even positive, depending on the estimator and specification used.

We contribute to the literature that studies the interaction between funding costs and solvency. Several papers find a negative association between solvency and funding costs (Aldasoro *et al.* 2022; Arnould *et al.* 2021; Aymanns *et al.* 2016; Babihuga *et al.* 2014; Elyasiani and Keegan 2017; Gambacorta and Shin 2016; Hasan *et al.* 2016; Schmitz *et al.* 2017). Most research looks at the determinants of market-based debt funding cost rates. Market-based rates have the advantage of capturing best the marginal effect on funding costs from changes in bank fundamentals; investors monitor banking indicators and quickly adjust their investment positions accordingly. However, banks have several sources of funding with prices that react differently to changes in fundamentals. If the cost of one funding source changes, banks can optimize their funding composition. As such, studies focusing on the cost of an individual source of funding may over- or under-estimate the effect of solvency. Arnould *et al.* (2021) find that senior bond yields are the most sensitive to changes in solvency, and that deposit rates are the least sensitive. Aymanns *et al.* (2016) also find that solvency is negatively related to both the average and wholesale funding cost; the coefficient is larger in magnitude for wholesale funding, pointing to the higher credit risk sensitivity of wholesale investors. Conversely, our approach allows us to decompose the overall funding cost measure according to the funding source. However, ideally, we would like to relate the solvency level to the effective interest rate of each funding source.

Market participants' sensitivity to risk is dependent upon the phase of the economic cycle, as shown by Elyasiani and Keegan (2017) that find that the importance of market discipline is stronger during periods of crisis and post-crisis. In Babihuga *et al.* (2014), the interaction of the subprime crisis dummy with the capital variable suggests that changes in bank capital matter more for funding costs during and after the crisis. In our analysis, we find similar results for the funding cost and contribute to the literature by showing that the state dependency also holds for the relationship between solvency and the cost of each funding source. The existence of a state-dependent effect has implications for our understanding of the degree of complementarity between regulatory action and market discipline. The release of buffers may not be effective if market forces work in the opposite direction, by tightening scrutiny and punishing banks that make use of the reduced requirements to decrease their level of solvency.

The marginal effect on funding costs of increasing solvency is not linear. The effect of a unit increase in solvency on funding costs is larger when solvency levels are low, as observed by Aymanns *et al.* (2016) and Schmitz *et al.* (2017). Arnould *et al.* (2021) also noticed the existence of threshold beyond which the effect of an increase in solvency on the chosen measure of funding cost changes. Our findings show that, only below a certain level of solvency, an increase in solvency decreases the funding costs, increasing the banks' profitability and their ability to internally generate short-term capital.

The paper proceed as follows: Section 2 presents the dataset used in our analysis, related descriptive statistics, and stylized facts. Section 3 presents the main results and Section 4 includes robustness and extensions. Finally, Section 5 concludes.

2. Data

The paper considers quarterly time series data for 21 Portuguese banking groups over the period from the first quarter of 2006 to the last quarter of 2020. We restrict the sample to financial institutions with their main activity in Portugal that accept deposits. The sample corresponds to the Portuguese banking system excluding branches of credit institutions having their head office in other European Union Member-States, to ensure that they have agency over their funding decisions. Bank-specific information is taken from 'Séries Longas para o Setor Bancário Português', a panel dataset produced by Banco de Portugal (Couchinho *et al.* 2019). Furthermore, we used internal supervisory data sources to extend the dataset with more granular information on balance sheet and P&L items. We complement the bank-specific information with macro-financial variables from the ECB Statistical Data Warehouse (SDW). All the variables were winsorized at 1% level to minimize the influence of outliers.

Table 1 provides descriptive statistics of our main explanatory and dependent variables. There is significant variation in funding cost rates, as well as in bank-specific characteristics. This reflects the long time span of the sample as well as the heterogeneous features of each financial institution and provides a diverse setting to test our main hypothesis of a negative relationship between solvency and the funding costs faced by the institution. Detailed variable definitions and sources are provided in Table A.1 of the Appendix.

Variable	Num. Obs.	Mean	Std. Dev.	Pctl. 25	Pctl. 75
Funding Cost	1155	0.018	0.015	0.008	0.025
Deposits Funding Cost	1159	0.014	0.010	0.005	0.021
Central Bank Funding Cost	699	0.011	0.021	0.001	0.011
Interbank Funding Cost	1114	0.016	0.022	0.001	0.021
Debt Funding Cost	697	0.030	0.019	0.016	0.043
Solvency Ratio	1147	0.203	0.123	0.112	0.269
Provisions to Assets	1164	0.003	0.005	0.000	0.005
Loan Loss Reserves Ratio	1162	0.057	0.050	0.025	0.077
Average Risk Weight (RW)	1147	0.581	0.161	0.473	0.663
Liquidity Ratio	1164	0.038	0.043	0.014	0.043
Return on Equity (ROE)	1164	0.024	0.079	0.006	0.058
Total assets (€10^9)	1164	19.001	30.459	0.264	31.055
Size	1164	7.560	2.526	5.575	10.343
EONIA	1185	0.006	0.014	-0.004	0.008
Dow Jones Euro Stoxx 50 Index	1185	3.255	0.582	2.718	3.733
V2TX	1185	0.228	0.080	0.168	0.263
Deposits Annualized Agreed Rate	1168	0.017	0.014	0.004	0.027

Table 1. Summary Statistics

This table presents summary statistics for our sample, which comprises 21 Portuguese financial institutions. The data span the period from the first quarter of 2006 to the last quarter of 2020. Variable definitions and sources are provided in table A.1 of the appendix.

The main dependent variable, *Funding Cost*, is annualized interest and other similar charges divided by total interest-bearing liabilities. Implicit measures of funding costs from accounting data might not be as marginally responsive as market-based metrics, such as Credit Default Swap (CDS) spreads or bond yields, but provide a more accurate view of banks' actual funding costs, given its funding mix composition. Furthermore, our choice allows us to compute the cost of each source of non-equity funding and understand the effect of funding mix adjustments on the overall funding cost.

For this purpose, we compute measures of the funding costs for the main liabilities components using the ratio of interest paid for that component to the respective stock of liabilities: *Deposit Funding Cost* for deposits from households, non-financial corporations, government, and other financial corporations, *Central Bank Funding Cost* for liquidity provided by central banks, *Interbank Funding Cost* for deposits from credit institutions, and *Debt Funding Cost* for funding from issuing bonds or other debt instruments. We expect different sensitivities of each funding cost measure, with deposit funding being the least sensitive and interbank/debt funding being the most sensitive.

Figures 1 and 2 present the evolution of the non-equity funding costs and the aggregate funding mix composition. Over the sample period, funding costs substantially decreased from an average funding cost of 3% in the first quarter of 2006 to an average of 0.5% in the last quarter of 2020. It is possible to distinguish four stages in the evolution of the funding costs of Portuguese banks. From 2006 to the GFC of 2008-09, funding costs were rising and displayed significant heterogeneity across the banks in the sample. Debt and deposit funding dominated aggregate bank funding expenses, and interbank funding also played a significant role, even though relatively smaller than the previous sources. From the GFC to the onset of the Portuguese sovereign debt crisis in 2010 there was a marked decrease in funding costs, and Portuguese banks reduced their reliance on interbank funding. Instead, there was an increase in central bank funding expenses while the relative importance of debt and deposit funding was kept. From 2010 to the end of 2012, funding costs started to increase again. It was during this period that Portuguese banks most relied on central bank funding and shifted their funding model towards more traditional sources of funding, like deposits. From 2012 onwards, the trend has been for a continuous decrease in funding costs, in line with the decrease in interest rates. Overall, the stress from the GFC exacerbated by the tumultuous years of the sovereign debt crisis led to a change in the funding structure of Portuguese banks. They reduced their reliance on interbank and debt funding sources and turned to more traditional sources of funding like deposits. The ratio of customer loans to deposits decreased from an average of 142% in the first quarter of 2006 to 79% in the last quarter of 2020. Recently, Portuguese banks have maintained their reliance on deposit funding but have also started to rely more on debt funding, which could be linked to new regulatory requirements like the MREL (Minimum Requirement for own funds and Eligible Liabilities).

Overall, the developments of the last fifteen years are the product of a series of structural developments. The financial crisis changed the funding model of Portuguese banks. We see an effort to hedge against abrupt changes in wholesale market rates and conditions that may take place during a crisis, reflected in a higher share of deposit funding. The advantages of flexible sources of funding like debt and interbank lending, however, are its downfall during periods of crisis when these sources are less reliable in terms of market access and conditions. Indeed, over-reliance on short-term wholesale funding was proven detrimental to financial stability (Oura *et al.* 2013). The low-interest-rate environment from an accommodative monetary policy stance is the main driver in the continuous decrease in funding costs. Notwithstanding the generalized structural development, there is significant heterogeneity between the financial institutions in the sample. We investigate the role of bank-specific characteristics in explaining this variation and also compare their relative importance against broader macro-financial factors.

To test our measure of implicit funding cost, we have also collected observed interest rates that are individually agreed between the monetary institution and the customer for each new deposit (Deposits Annualized Agreed Rate), per bank and per quarter. The correlation between the observed deposit rates for new operations and our implicit *Deposit Funding Cost* is 0.82.

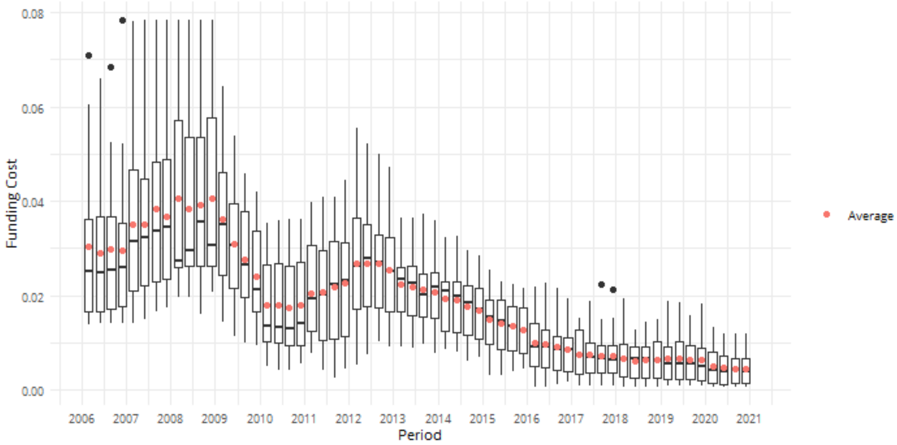

Figure 1: Evolution of funding costs.

Funding Cost is computed as annualized interest and other similar charges divided by total interest bearing liabilities. The graph shows a boxplot for the distribution of Funding cost for the banks in the sample in each quarter. The lower and upper hinges correspond to the 25th and 75th percentiles, the lower/upper whisker extends 1.5 * inter-quartile range from the hinge. Data beyond the whisker are plotted individually.

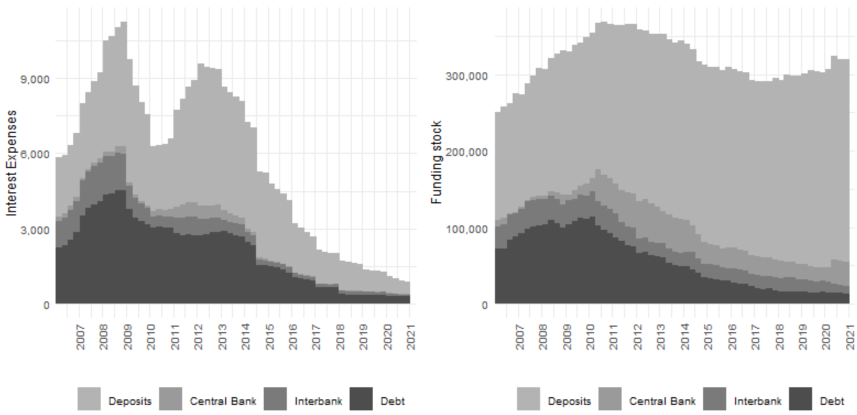

Figure 2: Evolution of the composition of funding costs, in terms of interest expenses and correspondent liability stock.

The panel on the left shows the composition of interest expenses by source of funding (in M€). The panel on the right shows the composition of funding liabilities (in M€). The non-equity funding sources considered were Deposits from households, non-financial corporations, government, other financial corporations, deposits from Central Banks, Interbank deposits from credit institutions, Debt securities.

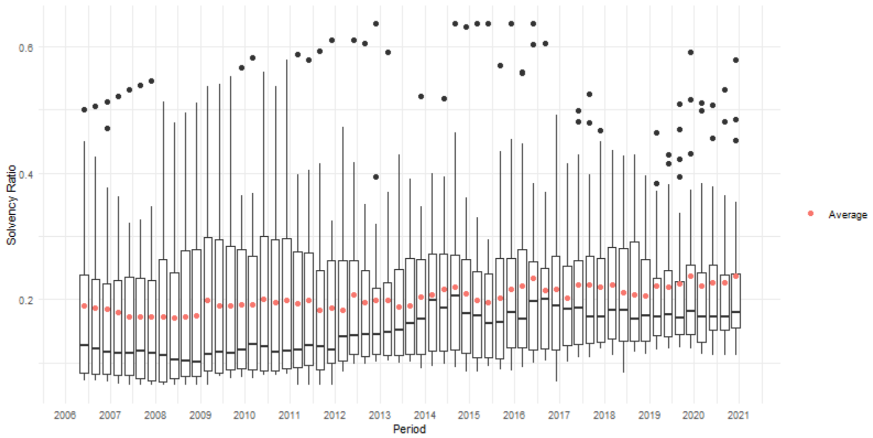

Figure 3: Evolution of the Solvency Ratio.

Solvency Ratio is computed as Tier 1 Capital divided by total risk-weighted assets. The graph shows a boxplot for the distribution of *Solvency Ratio* for the banks in the sample in each quarter. The lower and upper hinges correspond to the 25th and 75th percentiles, the lower/upper whisker extends 1.5 * inter-quartile range from the hinge. Data beyond the whisker are plotted individually.

The main explanatory variable, *Solvency Ratio*, is the Tier 1 Own Funds ratio, which is a measure of high-quality regulatory capital in relation to risk-weighted assets. Tier 1 capital is going concern capital comprising Common Equity Tier 1 and Additional Tier 1 capital – it includes common shares and stock surplus, retained earnings, other comprehensive income, capital instruments meeting the criteria for Additional Tier 1 and related surplus, qualifying minority interests, and regulatory adjustments. We selected the Tier 1 ratio as our measure of solvency because it only considers capital instruments, share premiums, and retained profits that are available to absorb losses. A possible alternative would have been to use the total capital ratio as the measure for solvency. In our view, doing so would be inappropriate because the measure includes subordinated loans that from an accounting point of view are classified as debt obligations and thus simultaneously included in our funding cost measure. Over the sample period, the banks strengthened their *Solvency Ratio* from an average of 19% (median 13%) in the first quarter of 2006 to an average of 24% (median 18%) in the last quarter of 2020. The average increase in the *Solvency Ratio* is also the result of the change in the regulatory landscape that raised minimum capital requirements.

We control for size, liquidity, asset quality, and profitability. The size of banking groups is measured by the logarithm of total assets. We expect to observe a negative relationship between bank size and funding costs which might be related to monitoring costs, meaning that smaller institutions may face difficulties in accessing funding from the market. In turn, more liquidity, captured by the cash ratio (cash and deposits in central banks divided by total assets), enhances the ability to meet short-term liabilities and thus should be perceived favorably by the markets. Asset quality is measured by the loan loss reserve ratio. A lower share of impaired loans in total customer loans should be priced positively by the market. Finally, we use the return on equity as a measure of profitability. The expected relationship between profitability and funding costs is ambiguous because lower profitability levels may call into question the sustainability of the institution, while extremely high levels may also be perceived as indicating excessive risk-taking.

Some specifications also use the Euro Overnight Index Average (EONIA). We prefer EONIA because it is anchored in actual financial transactions to obtain the weighted average of unsecured overnight interbank lending, whereas Euribor relies on quotes issued by the panel banks which has raised concerns about its reliability. In robustness checks, not presented for brevity sake, we re-estimated all specifications using Euribor but the results do not change materially. Additionally, we include the Dow Jones Euro Stoxx 50 Price Index to capture the market sentiment. For market volatility, we use V2TX, the VSTOXX index.

3. The relationship between solvency and funding costs

In this section, we analyze: (i) the sign of the solvency and funding costs relationship; (ii) state-dependency, to assess whether the economic and financial cycle position affects the relationship causing it to be different in normal times versus crisis times; (iii) the sensitivity of different funding sources to changes in solvency; (iv) the existence of non-linearity in the relationship with respect to the level of solvency.

As a whole, the different specifications address the shortcomings identified by the literature, including possible endogeneity due to second order effects between solvency and funding costs. We examine the relationship between the *Solvency Ratio* and the *Funding Cost*, using three specifications:

$$FC_{it} = \beta_0 + \beta_1 solv_{it} + \beta X_{it} + \gamma Y_t + \varepsilon_{it} \tag{1}$$

$$FC_{it} = \beta_0 + \beta_1 solv_{it} + \beta X_{it} + b_i + f_t + \varepsilon_{it} \tag{2}$$

$$solv_{it} = \beta_0 + \beta_1 RW_{it} + \beta X_{it} + b_i + f_t + \varepsilon_{it} \tag{3.1}$$

$$FC_{it} = \beta_0 + \beta_1 \widehat{solv}_{it} + \beta X_{it} + b_i + f_t + \varepsilon_{it} \tag{3.2}$$

where FC_{it} is the *Funding Cost* for each bank in each quarter. The independent variable of interest is $solv_{it}$, the *Solvency Ratio*. Specification (1) corresponds to a linear panel data model with vector X_{it} for time-varying bank-specific variables for Size, the Loan Loss Reserves Ratio, the Liquidity Ratio, and the Return on Equity Ratio and vector Y_t for the macro-financial controls EONIA, Dow Jones, and V2TX for volatility. Specification (2) includes fixed effects b_i and f_t for bank and quarter, respectively. The simultaneous inclusion of time and bank fixed effects controls for any remaining variability not being captured by the model. Specification (3.1) and (3.2) decompose the instrumental variable estimation into its two stages, where (3.1) obtains predicted values for the possibly endogenous regressor $solv_{it}$ using risk-weights (RW_{it}) as the instrument and (3.2) regresses the dependent variable on the predicted values of $solv_{it}$ and other control variables. There might be a significant nexus of second order effects not captured by the specifications used so far. To account for endogeneity, we use instrumental variables. Standard errors are corrected for heteroscedasticity in most specifications.

Table 2 results show a negative relationship between the *Solvency Ratio* and *Funding Cost*. Column (1) shows the results of specification (1) including bank-level control variables. We obtain a statistically significant coefficient of -0.042 suggesting a negative relationship between solvency and funding costs. Column (2) includes global market variables: the Euro Overnight Index Average rate (EONIA), the quarterly Dow Jones Euro Stoxx Price Index, and a volatility index (V2TX). The use of macro-financial controls provides insights on the relative importance of bank-specific characteristics vis-à-vis global market influences. In this specification, controlling for overall market conditions reduces the magnitude of the coefficient on solvency but it remains significant and negative. The sensitivity of overall funding cost to changes in EONIA behaves as expected. Better overall market performance, as measured by the Dow Jones index, also has the effect of reducing the funding costs of banks. Higher market wide volatility, captured by the V2TX, decreases banks' funding costs. In times of market stress, funding providers may display a 'flight to safety' behavior and lean towards instruments with less uncertainty.

To account for omitted variable bias, specifications in columns (3), (4), and (5) introduce bank and year-quarter fixed effects. The simultaneous inclusion of time and bank fixed effects causes the coefficient on solvency to lose significance, visible in column (5). However, as noted by on Banking Supervision (2015) and Schmitz *et al.* (2017) the relationship between solvency and funding costs may not be unilateral and there might be a significant nexus of second-order effects not captured by fixed effects. Indeed, high funding costs erode profitability with an effect on the solvency indicator.[1]

To account for the possible source of endogeneity, we use instrumental variable estimators. An instrument is considered valid if it fulfills two conditions: (i)

1. A variable addition regression-based test provides evidence of endogeneity of *Solvency Ratio* supporting the use of 2SLS.

exogeneity and (ii) relevance. We tested two instruments, Provisions to Assets in columns (6) and (7) similarly to Schmitz *et al.* (2017) and the Risk Weight (RW) in columns (8) and (9). While the rationale for the exogeneity of *Provisions to Assets* seems valid – provisions directly reduce solvency but will only affect funding costs through its effect on the solvency ratio and, in turn, provisions are not directly affected by financing costs – the instrument does not fulfill the relevance condition. The instrument relevance test indicates a weak instrument.[2] Conversely, the F-statistic in column (8) indicates that the *Risk Weight* has explanatory power in regard to the *Solvency Ratio*. Moreover, the *Risk Weight* fulfills the exogeneity condition because it directly affects the *Solvency Ratio* but only affects funding costs through its effect on solvency and, in turn, we don't expect financing costs to affect risk-weights contemporaneously. Implicit is also the assumption that the average risk weight of the banks' is not widely monitored by market participants, a reasonable assumption considering the time span of the sample and the nature of the banks in it. In the last specification using the IV estimator (9), to a 100 bps increase in the *Solvency Ratio* reduces *Funding Cost* by approximately 9.9 bps.

Overall, Table 2 suggests that when faced with a negative solvency shock, debtholders' (and depositors') reaction to the implicit increase in default probability is to demand higher yields. This result is in line with the estimates obtained in the literature, which suggest that a 100 bps increase in solvency is associated with a decrease in funding costs of between 2 bps (Aymanns *et al.* 2016) and 23 bps (Aldasoro *et al.* 2022).[3]

2. We consider a case with one endogenous variable and one instrument k. When k=1, $F^{E}ff = F^{R}$ can be compared to Stock and Yogo (2005) critical values, as suggested in Andrews *et al.* (2019).

3. The estimates have a wide range and use different proxies for solvency and for funding costs. Notwithstanding the limitations of comparing estimators from very distinctive analysis, the existing literature finds that, all other factors constant, banks with a higher solvency level benefit from lower funding costs.

Dependent Variable: Funding Cost	Pooled OLS			FE		IV			
	(1)	(2)	(3)	(4)	(5)	(6)[1] 1SLS	(7) 2SLS	(8)[1] 1SLS	(9) 2SLS
Solvency Ratio	-0.042***	-0.016***	-0.014***	-0.010*	-0.004		0.121		-0.099***
	(0.004)	(0.002)	(0.002)	(0.004)	(0.004)		(0.275)		(0.017)
Size	0.001**	0.002***	0.002***	0.006***	0.008***	-0.062***	0.015	-0.081***	0.002
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.010)	(0.017)	(0.010)	(0.002)
Loan Loss Reserves Ratio	-0.030***	-0.004	-0.011*	-0.007	-0.018***	0.018	-0.021*	-0.129*	-0.016*
	(0.007)	(0.004)	(0.005)	(0.005)	(0.005)	(0.050)	(0.010)	(0.053)	(0.007)
Liquidity Ratio	-0.094***	-0.005	0.004	-0.008	0.008	-0.077	0.017	-0.126*	0.001
	(0.008)	(0.005)	(0.005)	(0.007)	(0.008)	(0.055)	(0.023)	(0.050)	(0.010)
ROE	0.011+	-0.007+	-0.012**	-0.007	-0.012***	0.070*	-0.023	0.122***	-0.004
	(0.006)	(0.004)	(0.004)	(0.004)	(0.003)	(0.028)	(0.024)	(0.025)	(0.005)
EONIA		0.713***		0.730***					
		(0.028)		(0.028)					
Dow Jones		-0.010***		-0.010***					
		(0.001)		(0.001)					
V2TX		-0.018***		-0.019***					
		(0.005)		(0.004)					
Provisions to Assets						-0.295			
						-0.426			
RW								-0.188***	
								-0.021	
Bank fixed effects	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Year-Quarter fixed effects	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Num. Obs.	1138	1138	1138	1138	1138	1145	1138	1145	1138
R^2	0.269	0.654	0.696	0.739	0.787	0.849	0.626	0.87	0.692
R^2 Adj.	0.266	0.651	0.678	0.733	0.77	0.837	0.597	0.86	0.668
F-Test statistic for instrument significance						0.4813		77.925	

Table 2. Negative relationship between solvency and funding costs

This table reports regressions of *Funding Cost* on the *Solvency Ratio*, controlling for bank-specific characteristics. The time period is from the first quarter of 2006 to the last quarter of 2020. Variable definitions and sources are provided in table A.1 of the appendix. Column (1) to (2) provide estimates for model specification (1). Column (1) is a baseline estimate for *Funding Cost* dependent on the *Solvency Ratio* and other bank-characteristics. Column (2) adds controls for macro-financial variables that vary each quarter but not for each bank. Columns (3) to (5) provide estimates for model specification (2). Column (3) includes year-quarter fixed effects, column (4) includes bank fixed effects, and column (5) includes both. Columns (6) and (7) provide estimates for model specification (3.1) and (3.2) using Provisions to Assets as the instrument. Column (6) presents the first stage least square estimation. From the F-Test statistic for instrument significance we conclude that the instrument does not fulfill the relevance condition. As such, the estimates in column (7) that use this instrument are not valid. Column (8) and (9) provide estimates for model specification (3.1) and (3.2) using Risk Weight (RW) as the instrument. From the F-Test statistic for instrument significance in column (8) we conclude that the instrument is relevant. Column (9) is the second stage least square estimation. + $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ | Standard errors in brackets | [1] The dependent variable is the *Solvency Ratio*.

3.1. The state-dependent relationship between solvency and funding costs

In this section, we test the hypothesis of the relationship between the *Solvency Ratio* and the *Funding Cost* being different during moments of crisis relative to normal times. We extend the prior analysis of Table 2 by interacting a crisis indicator variable with solvency using the following specifications:

$$FC_{it} = \beta_0 + \beta_1 solv_{it} + \beta_2 crisis_t + \beta_3 solv_{it} * crisis_t + \beta X_{it} + \gamma Y_t + \varepsilon_{it} \quad (4)$$

$$FC_{it} = \beta_0 + \beta_1 solv_{it} + \beta_2 crisis_t + \beta_3 solv_{it} * crisis_t + \beta X_{it} + b_i + f_t + \varepsilon_{it} \quad (5)$$

$$solv_{it} = \beta_0 + \beta_1 RW_{it} + \beta_2 crisis_t + \beta_3 RW_{it} * crisis_t + \beta X_{it} + b_i + f_t + \varepsilon_{it} \quad (6.1)$$

$$FC_{it} = \beta_0 + \beta_1 \widehat{solv}_{it} + \beta_2 crisis_t + \beta_3 \widehat{solv}_{it} * crisis_t + \beta X_{it} + b_i + f_t + \varepsilon_{it} \quad (6.2)$$

where the variable $crisis_t$ takes the value of one if the year-quarter falls into a crisis period, and zero otherwise. The definition of the crisis period uses the reference business cycle chronology for the Portuguese economy based on the monthly coincident indicator disclosed by Banco de Portugal and developed by Rua (2017). The monthly coincident indicator incorporates information from real GDP and other relevant economic variables that capture the overall state of the economy. From 2006 to 2020, there were two recessions in Portugal. The first from the last quarter of 2007 to the second quarter of 2009, associated with the Great Financial Crisis. The second recession occurred from the third quarter of 2010 to the second quarter of 2013, corresponding to the period of the sovereign debt crisis in Portugal.

Table 3 shows that the association between the *Solvency Ratio* and *Funding Cost* of banks is stronger during periods of crisis. Column (3), our preferred specification using *RW* as the instrument, confirms that during periods of crisis, funding costs are more sensitive to changes in solvency. Indeed, during a crisis, the effect of a 100bps increase in the *Solvency Ratio* is 15bps more negative during a crisis compared to normal periods. Additionally, higher levels of solvency also help reduce the financing costs even in periods without crisis, albeit to a less extent. Our results are consistent with the hypothesis that market participants' sensitivity to risk is dependent upon the phase of the economic cycle. For instance, Elyasiani and Keegan (2017) find that the sensitivity of the yield of bonds issued by US systemically important banks to time-varying bank-specific variables is lower in the pre-crisis period compared with the crisis and post-crisis period.

The negative link between solvency and funding costs differs in normal times versus crisis times. Understanding the variation in the relationship between funding costs and solvency throughout the cycle has an important implication to understand the degree of complementarity between regulatory action and market discipline. One of the main novelties of the macroprudential framework created in the aftermath of the financial crisis was the introduction of a countercyclical buffer that is released during downturns to incentivize banks to dip into their capital buffers and continue providing credit to the economy instead of engaging in excessive de-leveraging or de-risking behaviors. This channel of transmission may be impaired if market forces work in the opposite direction, by tightening scrutiny and punishing banks that make use of the reduced requirements to decrease their level of solvency. If banks are aware that investors in general attribute higher importance to high levels of solvency during periods of stress, they act rationally by being more reluctant to tap into their capital buffers.

Dependent Variable: Funding Cost	Pooled OLS (1)	FE (2)	IV (3)
Solvency Ratio	-0.008**	0.004	-0.039*
	(0.003)	(0.004)	(0.020)
Crisis	0.004**		
	(0.001)		
Solvency Ratio × Crisis	-0.024***	-0.022***	-0.151***
	(0.005)	(0.004)	(0.045)
Size	0.002***	0.007***	-0.003
	(0.000)	(0.001)	(0.003)
Loan Loss Reserves Ratio	0.003	-0.011*	0.031*
	(0.004)	(0.005)	(0.015)
Liquidity Ratio	0.001	0.013+	0.035**
	(0.005)	(0.007)	(0.013)
ROE	-0.006+	-0.010**	0.008
	(0.004)	(0.003)	(0.007)
EONIA	0.735***		
	(0.031)		
Dow Jones	-0.010***		
	(0.001)		
V2TX	-0.019***		
	(0.005)		
Bank fixed effects	No	Yes	Yes
Year-Quarter fixed effects	No	Yes	Yes
Num.Obs.	1138	1138	1138
R^2	0.662	0.793	0.504
R^2 Adj.	0.659	0.777	0.465

Table 3. Relationship between solvency and funding costs in crisis times

This table reports regressions of *Funding Cost* on the *Solvency Ratio*, with an interaction term for periods of crisis and controlling for bank-specific characteristics. The time period is from the first quarter of 2006 to the last quarter of 2020. Variable definitions and sources are provided in table A.1 of the appendix. Column (1) provides estimates for model specification (4) and shows that the effect of solvency on funding costs has a larger magnitude during periods of crisis. Column (2) provides estimates for model specification (5). The result of state-dependency is robust to the inclusion of fixed effects. Column (3) provides estimates for the IV model specification (6.1) and (6.2). + p <0.1, * p <0.05, ** p <0.01, *** p <0.001 | Standard errors in brackets.

3.2. Sensitivity of funding sources to changes in solvency

In this section, we look at the relationship between the *Solvency Ratio* and the funding cost of each funding source. We estimate the state-dependency econometric specifications (4), (5), (6.1.), and (6.2.) but change the dependent variable to capture the individual funding cost sources. The overall funding cost measure FC_{it} is decomposed according to the funding source (deposits, interbank, central banks, or debt) using the ratio of interest paid for that component to the respective stock of liabilities.

Table 4 presents the results of each specification for each of the funding source components. The first three columns have *Deposit Funding Cost* as the dependent variable. The results show that during a crisis, solvency and funding cost from depositors have a negative relationship. Relative to the other sources of funding, the coefficient for the relationship between the *Solvency Ratio* and *Deposit Funding Cost* is the smallest, both in normal and in crisis times. Economic rationale suggests that deposits should indeed be the least sensitive and interbank/debt funding the most sensitive to changes in solvency. The deposit guarantee scheme works as an implicit subsidy (Bahaj and Malherbe 2020). Its existence creates a funding advantage, depositors' funds are insured in the event of bank default. Trust from depositors makes it easier to capture deposits and these are a cheaper source of financing. The safety net enjoyed by depositors reduces their incentive to monitor the health of the financial institution where they chose to deposit funds (Boot *et al.* 1993; Demirgüç-Kunt and Huizinga 2004).

Columns (4)-(6) have the *Central Bank Funding Cost* as the dependent variable. We use the information for deposits from central banks to compute the ratio between annualized interest and the stock of deposits. The coefficients for normal times are not statistically significant . The lack of sensitivity of this funding rate to solvency reflects that central banks' financing operations make liquidity available in exchange for adequate collateral with a haircut according to the type of collateral. Conversely, during a crisis, the coefficient is statistically significant in column (6). The negative association during a crisis is compatible with the euro area monetary policy framework to lend freely against good collateral in moments of crisis but only to solvent banks.

The columns (7)-(9) and (10)-(12) examine the relationship between the *Solvency Ratio* and *Interbank* and *Debt Funding Cost*, respectively. For *Interbank Funding Cost*, we use data for deposits from credit institutions to compute the ratio between annualized interest and the stock of deposits. For *Debt Funding Cost*, we use the ratio of annualized interest pertaining to debt securities and the stock of these instruments. Columns (7)-(9) show that *Interbank Funding Cost* is highly sensitive to changes in *Solvency Ratio* both in normal and even more so during crisis times. Column (8), in particular, shows that during a crisis the effect of an increase of 100bps in the *Solvency Ratio* reduces the *Interbank Funding Cost* by approximately 2.5bps more in comparison to calmer periods. The magnitude of this difference is substantial since during normal times the effect of a 100bps increase in the *Solvency Ratio* on the *Interbank Funding Cost* is already a reduction of 2.9bps. Column (12) paints a similar picture, the sensitivity of *Debt Funding Cost* during periods of crisis is of a similar magnitude albeit with lower statistical significance.

As expected, the magnitude of the coefficient is highest in the case of *Interbank* and *Debt Funding Cost* – especially so during moments of crisis. Our results lend empirical weight to the hypothesis put forward by King (2008) that the effect of market discipline on the interbank market would constitute an upper bound among other liabilities. Banks benefit from a comparative advantage given their expertise in the activity and are better equipped to monitor other credit institutions. Investors and other banks alike can be considered the most sophisticated market participants and carefully monitor banking fundamentals.

Regarding the statistical significance of the coefficients, our approach has a meaningful drawback. Our measures of *Interbank* and *Debt Funding Cost* are implicit average rates from accounting data that are not quite as marginally responsive. The rigidity of our selected proxies is a limitation for the study of this relationship. This limitation is of particular importance in the case of *Debt Funding Cost*, especially because Portuguese banks have greatly reduced their reliance on debt funding over the sample period. The reduction in the stock of debt funding means that our proxy measure of funding cost is less reflective of the marginal cost of this source of funding, which might explain our somewhat weak result.

	Deposits			Central Bank			Interbank			Debt		
	Pooled OLS	FE	IV	Pooled OLS	FE	IV	Pooled OLS	FE	IV	Pooled OLS	FE	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Solvency Ratio	-0.017***	-0.001	0.022*	-0.003	0.031	0.208	-0.019**	-0.029*	-0.159**	-0.078***	-0.010	0.047
	(0.002)	(0.002)	(0.011)	(0.012)	(0.019)	(0.168)	(0.007)	(0.014)	(0.058)	(0.014)	(0.014)	(0.088)
Crisis	0.002+			0.000			0.010**			0.002		
	(0.001)			(0.003)			(0.003)			(0.003)		
Solvency Ratio × Crisis	-0.007*	-0.009***	-0.100***	-0.023	-0.056***	-0.365*	-0.033***	-0.025**	-0.121	-0.006	-0.020	-0.143*
	(0.003)	(0.002)	(0.026)	(0.015)	(0.017)	(0.149)	(0.008)	(0.009)	(0.075)	(0.020)	(0.014)	(0.060)
Size	0.000***	-0.001+	-0.005*	0.000	-0.010**	-0.023*	0.001*	-0.009**	-0.022**	0.001**	-0.006+	-0.010
	(0.000)	(0.001)	(0.002)	(0.000)	(0.004)	(0.012)	(0.000)	(0.003)	(0.008)	(0.000)	(0.003)	(0.008)
Loan Loss Reserves Ratio	0.011**	-0.006	0.023*	0.006	0.017	0.024	0.029+	-0.007	0.020	-0.009	-0.029	-0.039
	(0.004)	(0.004)	(0.009)	(0.029)	(0.031)	(0.047)	(0.018)	(0.018)	(0.028)	(0.022)	(0.019)	(0.029)
Liquidity Ratio	-0.006	0.022***	0.042***	0.139***	0.164***	0.193***	-0.031*	0.026	0.011	0.022	-0.025	-0.018
	(0.004)	(0.005)	(0.008)	(0.032)	(0.038)	(0.043)	(0.013)	(0.017)	(0.026)	(0.021)	(0.032)	(0.032)
ROE	-0.011***	-0.003	0.005	0.005	-0.002	-0.006	-0.005	0.008	0.032*	-0.057***	-0.014	-0.014
	(0.003)	(0.002)	(0.004)	(0.006)	(0.007)	(0.015)	(0.009)	(0.008)	(0.015)	(0.011)	(0.010)	(0.011)
EONIA	0.463***			0.995***			0.437***			0.254***		
	(0.017)			(0.149)			(0.068)			(0.068)		
Dow Jones	-0.010***			-0.006*			0.000			-0.001		
	(0.001)			(0.003)			(0.002)			(0.002)		
V2TX	-0.023***			-0.039**			0.017			-0.021+		
	(0.003)			(0.014)			(0.014)			(0.012)		
Bank fixed effects	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Year-quarter fixed effects	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Num.Obs.	1141	1141	1141	694	694	694	1098	1098	1098	685	685	685
R^2	0.642	0.871	0.635	0.276	0.446	0.257	0.172	0.335	0.194	0.205	0.55	0.512
R^2 Adj.	0.639	0.861	0.606	0.266	0.376	0.162	0.164	0.281	0.127	0.193	0.492	0.449

Table 4. Sensitivity of different funding cost sources to changes in the level of solvency

This table reports regressions of each individual funding cost source rate on the *Solvency Ratio*, with an interaction term for periods of crisis and controlling for bank-specific characteristics. The time period is from the first quarter of 2006 to the last quarter of 2020. Variable definitions and sources are provided in table A.1 of the appendix. The first main column titled 'Deposits' looks at deposits from households, non-financial corporations, government, and other financial corporations and uses the ratio between annualized interest expenses and the stock of deposits as the dependent variable. The second main column titled 'Central Bank' uses as dependent variable the ratio between annualized interest expenses from deposits from Central Banks and the correspondent stock of deposits. The third main column titled 'Interbank' uses as dependent variable the ratio between annualized interest expenses from deposits from credit institutions and the correspondent stock of deposits. The fourth main column titled 'Debt' uses as dependent variable the ratio of annualized interest pertaining to debt securities and the stock of these instruments. The specifications in column (1) to (12) refer to models analogous to those in Table 3. + $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ | Standard errors in brackets.

3.3. Non-linearity depending on the level of solvency

In this section, we test the hypothesis of non-linearity in the relationship between the *Solvency Ratio* and the *Funding Cost*. We use two different types of models. First, we extend our baseline specifications (1) and (2) by employing a segmented or broken-line model as in (7) and (8):

$$FC_{it} = \beta_0 + \beta_1 solv_{it} + \beta_2(solv_{it} - \varphi)_+ + \beta X_{it} + \gamma Y_t + \varepsilon_{it} \tag{7}$$

$$FC_{it} = \beta_0 + \beta_1 solv_{it} + \beta_2(solv_{it} - \varphi)_+ + \beta X_{it} + b_i + f_t + \varepsilon_{it} \tag{8}$$

where $(solv_{it} - \varphi)_+ = (solv_{it} - \varphi)I(solv_{it} > \varphi)$ and $I(\cdot)$ is the indicator function equal to one when the statement is true. The parameter φ is the breakpoint, in our case it is the level of solvency upon which the relationship between solvency and funding costs changes. Thus, in this model we estimate a coefficient for the effect of solvency on funding costs for values of solvency below the estimated breakpoint and another for values above the breakpoint. The advantage of this methodology is both its interpretability and its ability to provide the breakpoint estimate. We follow Muggeo (2003) approach that reduces the problem to an iterative fitting of linear models.[4]

Table 5 shows that there exists a significant difference-in-slope regarding the effect on *Funding Cost* of a change in the *Solvency Ratio* between banks that in a given quarter have solvency above the breakpoint and those with solvency below. We performed Davies' test for the specifications in all columns to conclude that there exists a breakpoint, which is evidence of non-linearity.[5] Column (1) presents the results of estimating model (7). The breakpoint is estimated at a *Solvency Ratio* of 12.5%. The funding costs of banks with a *Solvency Ratio* below 12.5% are highly sensitive to changes in solvency – a 100bps increase in the *Solvency Ratio* reduces the *Funding Cost* by approximately 22bps. For banks with a *Solvency Ratio* above 12.5%, the effect has a smaller magnitude - a 100bps increase in the *Solvency Ratio* reduces the *Funding Cost* by approximately 0.9bps. Next, in column (2), we add bank and year-quarter fixed effects to account for possible omitted variable bias. The estimation yields a breakpoint estimate of 15.7%. Again we see the same pattern of higher sensitivity of *Funding Cost* to changes in the *Solvency Ratio*

4. For more information about the method see Muggeo (2003) for a discussion of the estimation method, Muggeo (2008) for an illustration, Muggeo (2016) for an approach to hypothesis testing, and Muggeo (2017) for a discussion of interval estimation for the breakpoint.

5. Muggeo proposes employing the Davies (1987) test for testing the hypothesis of the difference-in-slopes parameter being equal to zero. More information about the test in Muggeo (2008).

for banks with lower solvency. Banks that have solvency above the breakpoint face a small but statistically significant increase in *Funding Cost* suggesting that the investors no longer place as much importance on changes in solvency when evaluating banks with an already high solvency position.

	Piecewise regression	
	Pooled OLS	FE
	(1)	(2)
Solvency Ratio below Breakpoint	-0.220***	-0.160***
	(0.028)	(0.018)
Solvency Ratio above Breakpoint	-0.009*	0.008+
	(0.003)	(0.004)
Size	0.001***	0.004***
	(0.000)	(0.001)
Loan Loss Reserves Ratio	0.003	-0.011**
	(0.005)	(0.005)
Liquidity Ratio	-0.001	0.018**
	(0.006)	(0.007)
ROE	-0.006	-0.008**
	(0.003)	(0.003)
EONIA	0.619***	
	(0.023)	
Dow Jones	-0.009***	
	(0.001)	
V2TX	-0.019***	
	(0.005)	
Bank fixed effects	No	Yes
Year-quarter fixed effects	No	Yes
Num.Obs.	1138	1138
R^2	0.6784	0.8063
R^2 Adj.	0.6756	0.7907
Breakpoint Estimation	0.125	0.157
	(0.005)	(0.006)
Davies Test for a change in the slope	0	0

Table 5. Non-linear relationship between solvency and funding cost

This table reports non-linear regressions of the *Funding Cost* on the *Solvency Ratio*, controlling for bank-specific characteristics. The time period is from the first quarter of 2006 to the last quarter of 2020. Variable definitions and sources are provided in table A.1 of the appendix. In the estimation we used piecewise regression to estimate the *Solvency Ratio* at which the breakpoint occurred and estimate slopes before and after the breakpoint. Segmented regression was implemented using the R package 'segmented' developed by Vito M. R. Muggeo. The methodology tests for the presence of an inflection point and estimates its location. Column (1) presents the results of estimating specification (7) and column (2) the results of estimating model (8). The first row includes the coefficient for the slope before the breakpoint and the second row provides the coefficient for the slope after the breakpoint. The estimated breakpoint is also provided in the table. + p <0.1, * p <0.05, ** p <0.01, *** p <0.001 | Standard errors in brackets

The second step of the analysis is to test the existence of non-linearity in model (3), in which we used 2SLS. At the moment, to our knowledge, there is not a proven robust way to apply segmented models in an instrumental variable setting. Instead, we use a parametric change point analysis. Scheines *et al.* (2001) propose a method for creating a piecewise linear IV-estimator (PL-IV*) that consists of identifying the breakpoint location in the explanatory variable and then applying the IV estimator separately in each region. To identify the change-point in solvency, we use the Schwarz Information Criteria (SIC) as in Chen and Gupta (2012) informational approach. We compute the SIC for the null hypothesis H_0 of the model being linear and for the alternative hypothesis Ha containing the set of non-linear models with a change point k at positions 2, 3, to n-2. The decision rule for selecting the model is to select the model with a change at k for which $SIC(k) = min(SIC(H_a))$ if $min(SIC(H_a)) < SIC(H_0)$. After identifying the change point, we divided the sample into two regions – one above the change point and another below the change point. A downside of the PL-IV* methodology is that it may underestimate the standard error of the other parameters since it does not capture the uncertainty in the change point estimation.

Table 6 presents the results of applying the PL-IV*. First, this method also favors the existence of a non-linear relationship with an estimated solvency change point of 11%. We divide the sample by the change point and separately use Risk Weight as instruments to 2SLS estimate each region. The *Funding Cost* of banks with a *Solvency Ratio* below 11% are highly sensitive to changes in solvency – a 100bps increase in the *Solvency Ratio* reduces *Funding Cost* by approximately 58.5 bps. For banks with a *Solvency Ratio* above 11%, the effect has a smaller magnitude - a 100bps increase in the *Solvency Ratio* reduces *Funding Cost* by approximately 5.4 bps. The results are consistent with Aymanns *et al.* (2016) who also find that the effect of an additional increase in solvency on wholesale funding costs is more than twice as large for poorly capitalized banks relative to well-capitalized banks.

	PL-IV*	
	Solvency Ratio below Breakpoint	Solvency Ratio above Breakpoint
Solvency Ratio	-0.585+	-0.054***
	(0.351)	(0.011)
Size	0.013	0.000
	(0.009)	(0.002)
Loan Loss Reserves Ratio	0.035	0.011+
	(0.058)	(0.006)
Liquidity Ratio	0.007	0.014+
	(0.045)	(0.007)
ROE	-0.017	-0.009*
	(0.013)	(0.005)
Bank fixed effects	Yes	Yes
Year-quarter fixed effects	Yes	Yes
Num.Obs.	259	879
R^2	0.824	0.710
R^2 Adj.	0.768	0.680
Breakpoint Estimation	0.110	

Table 6. Non-linear relationship between solvency and funding cost using PL-IV*

This table reports regressions of the *Funding Cost* on the *Solvency Ratio*. *Solvency Ratio* is instrumented using Risk Weights. The time period is from the first quarter of 2006 to the last quarter of 2020. Variable definitions and sources are provided in table A.1 of the appendix. At the moment, to our knowledge, there isn't a proven robust way to apply segmented models in an instrumental variable setting. Instead, we use parametric change point analysis, as proposed in Scheines *et al.* (2001). + p <0.1, * p <0.05, ** p <0.01, *** p <0.001 | Standard errors in brackets

The existence of capital requirements helps explain the non-linearity in the relationship. Banks seek to maintain a positive distance between their capital ratio and the overall capital requirement, i.e., a voluntary buffer, to avoid distribution restrictions and market stigma. Our estimated breakpoints, between 11% and 16%, are around the average tier 1 capital requirement ratio in our sample (12.2%), which supports the relevance of market stigma in explaining why capital buffers were not used during crisis times. The findings suggest that investors penalize more the same absolute deterioration in solvency levels when the bank's capital ratio is below or close to the overall capital requirement.

4. Robustness and Extensions

4.1. Deposits Annualized Agreed Rate

In our main analysis, we use the ratio between the interest paid to the stock of interest-bearing liabilities as the measure of funding cost. This approach has the advantage of allowing us to also calculate measures of the funding cost rates of the different funding sources. However, ideally, we would like to relate the solvency level to the effective interest rate of each funding source.

As a robustness test of our main dependent variables, we use an alternative measure of funding costs that reflects the interest rate banks pay. On a monthly basis, Banco de Portugal computes the average, weighted by their amounts, of interest rates that are individually agreed between the credit institution and the customer for each new deposit. While this measure should better capture the sensitivity of funding costs to solvency, it has the disadvantage of being only available for deposit funding. Nevertheless, because deposits are the largest funding source for Portuguese banks, the results of this test are meaningful for the overall *Funding Cost*. After averaging the monthly data to obtain year-quarter observations, we re-estimate the state-dependency specifications using *Deposits Annualized Agreed Rate* as the dependent variable.

Table 7 provides the results. In column (3) we observe that in normal times, depositors are not sensitive to changes in the level of solvency; as previously stated. During a crisis, the effect of a 100bps increase in the *Solvency Ratio* reduces *Deposits Annualized Agreed Rate* by approximately 5.2bps more in comparison to normal periods. This effect is equal in sign but smaller in magnitude than that registered for our computed implicit measure of *Deposits Funding Cost*.

	Deposits (Deposits Annualized Agreed Rate)		
	Pooled OLS	FE	IV
	(1)	(2)	(3)
Solvency Ratio	-0.017***	-0.007*	0.001
	(0.002)	(0.003)	(0.010)
Crisis	0.009***		
	(0.001)		
Solvency Ratio × Crisis	-0.016***	-0.019***	-0.052*
	(0.004)	(0.003)	(0.021)
Size	-0.001***	-0.002**	-0.004**
	(0.000)	(0.001)	(0.001)
Loan Loss Reserves Ratio	-0.001	-0.004	0.006
	(0.004)	(0.004)	(0.008)
Liquidity Ratio	0.010*	0.020***	0.028***
	(0.004)	(0.006)	(0.008)
ROE	-0.001	0.003	0.006*
	(0.003)	(0.002)	(0.003)
EONIA	0.741***		
	(0.019)		
Dow Jones	-0.009***		
	(0.001)		
V2TX	-0.032***		
	(0.003)		
Bank fixed effects	No	Yes	Yes
Year-quarter fixed effects	No	Yes	Yes
Num.Obs.	1136	1136	1136
R^2	0.793	0.897	0.881
R^2 Adj.	0.791	0.889	0.872

Table 7. Sensitivity of Deposits Annualized Agreed Rate to changes in solvency

This table reports regressions of the Deposits Annualized Agreed Rate on the *Solvency Ratio*, with an interaction term for periods of crisis and controlling for bank-specific characteristics. In column (3) the *Solvency Ratio* is instrumented using *RW*. The time period is from the first quarter of 2006 to the last quarter of 2020. Variable definitions and sources are provided in table A.1 of the appendix. + p <0.1, * p <0.05, ** p <0.01, *** p <0.001 | Standard errors in brackets.

4.2. The interaction with non-conventional monetary policy

The period studied coincided with an environment of economic recovery and decreasing interest rates driven by increasingly loose monetary policy stances. Monetary policy is a global factor that we control for through the use of year-quarter fixed effects in our main specifications. Even so, we are interested in better understanding how the non-conventional monetary policy decisions of the period, like large scale asset purchase programs, can affect the relationship between solvency and funding cost. To capture all dimensions of monetary policy, we use the shadow rate developed by Wu and Xia (2020) that reflects conventional and non-conventional monetary policy tools when an economy reaches the effective lower bound.

	Average Funding Cost		Deposit Funding Cost	Deposits Annualized Agreed Rate
	FE	IV	IV	IV
	(1)	(2)	(3)	(4)
Solvency Ratio	-0.014***	-0.082***	-0.013+	-0.020*
	(0.004)	(0.014)	(0.007)	(0.009)
Solvency Ratio × Shadow Rate	-0.570***	-1.821***	-0.460**	-0.403*
	(0.046)	(0.378)	(0.169)	(0.179)
Size	0.005***	-0.002	-0.003*	-0.003*
	(0.001)	(0.002)	(0.001)	(0.001)
Loan Loss Reserves Ratio	-0.009+	0.013+	-0.001	-0.003
	(0.005)	(0.008)	(0.004)	(0.005)
Liquidity Ratio	0.026***	0.063***	0.035***	0.029***
	(0.007)	(0.015)	(0.008)	(0.008)
ROE	-0.011***	-0.005	-0.003	0.003
	(0.003)	(0.004)	(0.002)	(0.002)
Num.Obs.	1138	1138	1141	1136
R^2	0.809	0.68	0.849	0.899
R^2 Adj.	0.794	0.655	0.837	0.891

Table 8. Interaction with monetary policy

This table reports the results of introducing the *Shadow Rate* in the specification as an interaction term with *Solvency Ratio* and controlling for bank-specific characteristics. In column (1) and (2) the dependent variable is the *Funding Cost*. In column (3) the dependent variable in the *Deposit Funding Cost* and in column (4) the dependent variable is the *Deposits Annualized Agreed Rate*. The time period is from the first quarter of 2006 to the last quarter of 2020. Variable definitions and sources are provided in table A.1 of the appendix. + $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ | Standard errors in brackets.

Table 8 presents the results. As the *Shadow Rate* decreases, i.e. monetary policy loosens, the *Funding Cost* becomes less sensitive to changes in solvency. The loss of sensitivity of deposit funding costs to solvency as monetary policy loosens is visible in column (3) and (4) both for the *Deposit Funding Cost* and for the *Deposits Annualized Agreed Rate*. Proximity to the Zero Lower Bound may create an accumulation of deposit rates offered at a near zero level if banks are not allowed to pass on that negative rate to clients. The loss in sensitivity to solvency is stronger for overall funding costs than for deposit funding costs, as visible by comparing column (1) and (2) with columns (3) and (4). Additional to deposits, *Funding Cost* encompasses interbank and debt funding sources. In this case, the loss of funding cost's sensitivity to fundamentals like solvency is compounded by the documented search-for-yield behavior.

5. Conclusion

Promoting a banking sector with an adequate level of solvency is key for macroprudential policy. Adequacy presupposes that the banking system is able to increase the solvency level during the upside of the business/financial cycle and, in turn, use the capital to absorb the effects of a shock during a stress event. The signal and magnitude of the relationship between solvency and funding costs have received increased attention as a potential impediment to capital buffer usability.

Using data for the Portuguese banking system, we find that the relationship between funding costs and solvency is negative and stronger during a crisis than in normal times. Market funding sources, notably interbank lending and debt securities, are more sensitive to changes in solvency than deposits. This finding has an important implication to assess the degree of complementarity between regulatory action and market discipline. Evidence of heightened perceived risk during crisis – especially in market funding sources – helps explain why, despite the large capital requirements release during the Covid-19 crisis, banks were reluctant to use the capital buffers. The effectiveness of a release of a capital buffer may be impaired if market forces work in the opposite direction, by tightening scrutiny and punishing banks that make use of the reduced requirements to reduce their level of solvency.

We also find evidence of non-linearity of funding costs with respect to the level of solvency. Indeed, only below a certain level of solvency, an increase in solvency decreases the funding costs, increasing the banks' profitability and their ability to internally generate short-term capital. This result validates the current minimum capital requirements regulatory design that works as a floor that protects banks from going below the optimal level that would leave them exposed to harsh investors' oversight and large penalization in the case of further decreases.

The existence of state dependency and non-linearity in the negative relationship between funding costs and solvency supports the relevance of market stigma in explaining why capital buffers were not used during crisis times.

6. Appendix

Variable	Definition and source
Funding Cost rate (FC)	Annualized interest and other similar charges divided by total interest bearing liabilities. Each bank records the amount of interest paid up to each quarter. To annualize the data, we divide by the number of quarters that have passed and then multiply by four to obtain the yearly equivalent. Séries Longas para o Setor Bancário Português, Banco de Portugal
Deposits Funding Cost rate (Dep)	Annualized interest and other similar charges from deposits from households, non-financial corporations, government, and other financial corporations divided by total deposits from customers. Internal supervisory data, Banco de Portugal; Séries Longas para o Setor Bancário Português, Banco de Portugal

Central Bank Funding Cost rate (CB)	Annualized interest and other similar charges from Central Bank resources divided by total deposits from Central Banks. Internal supervisory data, Banco de Portugal; Séries Longas para o Setor Bancário Português, Banco de Portugal
Interbank Funding Cost rate (IB)	Annualized interest and other similar charges from deposits from credit institutions divided by total deposits from credit institutions. Internal supervisory data, Banco de Portugal; Séries Longas para o Setor Bancário Português, Banco de Portugal
Debt Funding Cost rate (Debt)	Annualized interest and other similar charges from debt securities issued and other financial liabilities divided by total liabilities represented by debt titles. Internal supervisory data, Banco de Portugal; Séries Longas para o Setor Bancário Português, Banco de Portugal
Solvency Ratio	Tier 1 Capital divided by total risk-weighted assets. Tier 1 capital is the sum of common shares and stock surplus, retained earnings, other comprehensive income, qualifying minority interest, capital instruments meeting the criteria from AT1 and related surplus, additional qualifying minority interest and regulatory adjustments. Risk-weighted assets are all assets held by the bank weighted by the respective credit risk. Séries Longas para o Setor Bancário Português, Banco de Portugal
Provisions to Assets	Provisions and impairments (net of reversals) divided by total assets. Séries Longas para o Setor Bancário Português, Banco de Portugal
Loan Loss Reserves	Impairments and value adjustments in customer loans divided by gross carrying amount of customer loans. Séries Longas para o Setor Bancário Português, Banco de Portugal
Risk-weights (RW)	Average risk-weight of exposure amount. Risk-weighted assets are all assets held by the bank weighted by the respective credit risk. Séries Longas para o Setor Bancário Português, Banco de Portugal
Liquidity Ratio	Cash and cash balances/loans to central banks divided by total assets. Séries Longas para o Setor Bancário Português, Banco de Portugal
Return on Equity (ROE)	Net profit or loss divided by total equity. Séries Longas para o Setor Bancário Português, Banco de Portugal
Size	Logarithm of total assets. Séries Longas para o Setor Bancário Português, Banco de Portugal
Euro OverNight Index Average (EONIA)	Closing rate for the overnight maturity of the 1-day interbank interest rate for the Euro zone. Statistical Data Warehouse, ECB
Dow Jones	Dow Jones Euro Stoxx Price Index. Historical close, average of observations through period. Divided by 100 for easier interpretation. Statistical Data Warehouse, ECB
V2TX	Euro Stocc Volatility (VSTOXX) index computed by QONTIGO. Divided by 100 for easier interpretation. STOXX, QONTIGO, Deutsche Börse Group
Deposits Annualized Agreed Rate	Observed annualised agreed rates for new deposits (TAA, taxa acordada anualizada in its Portuguese denomination). "Estatísticas de balanço e de taxas de juro das instituições financeiras monetárias", Banco de Portugal

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