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Abstract

We assess if capital ratios reduced the occurrence of banking crises in the European Union from 1998 to 2017. We use a Probit model and estimate the effect of two measures: the bank capital to total assets ratio and the bank regulatory capital to Risk Weighted Assets (RWA). We found that both measures affect negatively the probability of crisis. This result is robust to the exclusion of outliers, to the inclusion of various control variables for banking, financial and macroeconomic risks. Finally, we show that while the bank regulatory capital to RWA has always a negative effect on the probability of crisis, the bank capital to total assets ratio is only significant above a threshold, estimated between 10% and 12%.

Keywords: Banking regulation, Leverage ratio, Risk-weighted capital requirement, Banking crisis.

JEL Classification: G21, E44

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1. Introduction

Banking crises are a major concern for monetary, fiscal and regulatory authorities. They trigger huge economic costs (Reinhart and Reinhart, 2010; Taylor, 2015; Levieuge et al., 2018). It is also demonstrated that financial crises recessions are more costly than other recessions in terms of output losses (Jordà et al., 2013). During the last two decades, the European Union (EU) experienced two major episodes of banking crisis (the so-called Great Financial Crisis and the Sovereign Debt Crisis). Relying on the work of Laeven and Valencia (2020), output losses in the EU during recent banking crises are estimated around 40% of GDP and the public debt increased by more than 20% of GDP.[1]

Meanwhile, several modifications occurred in the regulatory environment. While the macro-finance literature points out that rapid credit growth increases the occurrence of banking crises (Schularick and Taylor, 2012), macroprudential regulators are extensively using capital ratios to prevent them. In particular, the successive implementation of Basel II and Basel III Agreements lead to tighter capital requirements. More specifically, Basel II enforced an accurate risk assessment of banks' assets, possibly through internal models. This risk-weighted asset (RWA) calculation allowed a more refined estimate of the capital required. Basel III enhances the quality of the regulatory capital (increasing the percentage of equity and reducing the percentage of subordinate debt), increases the level of capital by the creation of a conservation buffer and establishes a leverage ratio (independent from the level of banks' risk). Basel II was translated into the European laws through the CRD (Capital Requirements Directive) II in 2008 and CRD III in 2009. Basel III was adopted via CRD IV and the Capital Requirements Regulation (CRR) in June 2013. The EU also created in 2014 a banking union which gave the European Central Bank (ECB) a new task. The ECB is now in charge of the supervision of the larger banks in the EU and therefore responsible of banks' resilience. As a matter of fact, during the last two banking crises, non-performing loans rose sharply and deteriorated the health of the banking sector (see Table 1). As a consequence, monetary policy transmission channels were weakened so as the ability of central banks to fulfil their objectives. It is therefore crucial that the ECB promotes effective regulations to improve banking sector's resiliency. Although the use of capital ratios has been extensively investigated in the empirical literature, to our knowledge, there is no study focused on their impact on the resilience of the banking sector in the EU.[2] Our paper aims at examining the relationships between banks' level of capital and the probability of banking crises in the EU between 1998 and 2017.

From a theoretical view point, there is no consensus on the ability of capital ratios to prevent banking crises as several effects are at work. First of all, the implementation of a higher equity ratio mechanically leads to a stronger solvency since debts are lower in relation to the value of assets (Acosta-Smith et al., 2020). Second, an increase in the share of equity in total liabilities should lead shareholders to be more careful since they have more to lose. Actually, it is argued that if bankers have "more skin in the game", they would be more cautious not to engage their banks in highly risky activities and it would reduce the probability of crisis (Diamond and Rajan, 2000; Mehran and Thakor, 2011). Higher capital ratio requirements decrease the benefit

[1] Table 1 summarizes the recent episodes of banking crisis in the European Union and their outcomes.
[2] Table A in the appendix presents the empirical literature on this topic.

that shareholders derive from limited liability (Kashyap et al. 2020). Furthermore, their risk aversion increases and their incentive to take risks is reduced (Agur, 2010; Martinez-Miera and Suarez, 2012). The implementation of a RWA ratio should particularly lead banks to be more cautious. A fall of their risk-taking – that reduces their RWA – makes possible either a decrease of the level of capital required, or simply an increase of the volume of business for a given level of capital (Martynova, 2015). In this line Repullo and Suarez (2013) show that Basel II made banks more prudent than Basel 1. Capital requirements may also reduce the occurrence of a bank run, leading banks to reduce the share of deposits in the total liabilities (Kashyap et al., 2020). However, capital requirements may not be sufficient to prevent banks to choose highly risky strategies and even may lead them to take more risky portfolios to achieve target rates of return (Rochet, 1992; Gale, 2010). As a lower leverage reduces the Return on Equity, shareholders may increase risk assets in order to restore financial rentability. Acosta-Smith et al. (2020) show that banks bounded by the capital requirements may increase their risk-taking. Another adverse effect exists: if the cost of equity is high, an increased requirement of capital raises the cost of capital, reducing the franchise value. As the loss in case of failure is lower, banks have an incentive to increase their risk (Hellman et al. 2000).

Empirical papers are then useful to assess how capital ratios may affect banking stability in any given context and ours contributes to this literature. A growing number of studies provide evidence that capital ratios actually reduce the probability of a banking crisis (Basel Committee on Banking Supervision (BCBS), 2010; Almenberg et al., 2017; Barth and Miller, 2018; Corbae and D'Erasmo, 2019). Acosta-Smith et al. (2020) show that while a leverage ratio leads banks to increase their risks if the cost of capital is high, the global effect improves bank sector resilience. Berger and Bouwman (2013) show that higher levels of capital always reduce small banks probability of default, while this benefice only occurs during banking crisis for medium and large banks. Boissay et al. (2019) find through a meta-analysis that on average, a 1 percentage point increase in capital ratios is associated with a 1 percentage point reduction of the crisis probability. In contrast, studies are more sceptical about the performance of these tools alone to mitigate banking risks (Barth et al., 2008; Čihák and Schaeck, 2010; Jordà et al., 2021). More broadly, our paper contributes to the literature on the determinants of banking crises that has shown that rapid domestic credit expansion is a robust indicator of financial crises (Gourinchas and Obstfeld, 2012; Schularick and Taylor, 2012; Aikman et al., 2015). It is also argued that bank-specific characteristics can have a large impact on the functioning of this sector (Gambacorta and Marques-Ibanez, 2011; Jutasompakorn et al., 2014). Others point out that macroeconomic factors, such as slowdown of GDP, low interest rates or inflation are crucial determinants of banking crises (Demirgüç-Kunt and Detragiache, 1998; Von Hagen and Ho, 2007; Pedro et al., 2018).

In this paper, we build on the aforementioned literature. We rely on the methodology used by Jordà et al. (2021). They use a Probit model and found that higher capital ratios are unlikely to prevent a financial crisis. Their study is based on a panel of 17 advanced countries between 1870 and 2015. We use this study as a benchmark to verify if their result is robust in the EU. We assess whether two variables of capital ratios – the bank capital to total assets ratio which can be considered as a proxy of the leverage ratio and the bank regulatory capital to RWA - reduce the occurrence of banking crises from 1998 to 2017 in the EU. Banking crises are identified by Laeven and Valencia (2020). We find that both ratios affect negatively this

occurrence in the EU. This result is robust to the exclusion of outliers, to the inclusion of various control variables for banking, financial and macroeconomic risks. Finally, we show that while the bank regulatory capital to RWA has always a negative effect on the probability of crisis, the bank capital to total assets ratio is only significant above a threshold estimated between 10% and 12%. These results suggest that capital requirements under Basel III will likely strengthen financial stability through their negative impact on the likelihood of banking crises. While it exists more granular data than country level data, we believe that our approach is interesting for at least two reasons. First, microeconomic data are generally not exhaustive as all banks are not always providing their information. So here we gain in exhaustivity what we lose in granularity. Second, as macroprudential policies are developing, more results at the macroeconomic level are needed.[3] In this paper, we document the link between aggregate capital ratios and banking crises and show that these tools can reduce the occurrence of banking crises.

The paper is organized as follows. Section 2 describes the data and provides summary statistics. Section 3 presents the empirical model, our main results and discusses some robustness. Section 4 concludes.

2. Data

EU member states composed our sample, from 1998 to 2017. Our data are annual and country-level. They are extracted from the World Bank Global Financial Development Database (GFDD). We consider the 28 countries that were members of the EU in 2017. Our sample contains 560 observations. All variables used in this article are described in Table B in the Appendix and descriptive statistics are presented in Table C.

2.1 Banking Crisis

The dependent variable is the occurrence of a banking crisis. We use the binary variable built by Laeven and Valencia (2020) gathered in the GFDD. They consider that a banking crisis happens if two conditions are met. First, significant signs of financial distress appear in the banking system (for instance significant bank runs, losses in the banking system, or bank liquidations). Second, significant banking policy interventions are implemented in response to significant losses in the banking system. The variable equals one as long as the crisis continues and zero otherwise. The first year of the crisis is when both criteria are met. The end of a crisis is defined the year before real GDP growth and real credit growth are both positive for at least two consecutive years. Table 1 presents the banking crisis episodes in the EU and their outcomes. The occurrences of crisis represent 82 out of 560 observations (14.64%). According to this measure, 21 EU countries experienced a banking crisis over the period, and 13 of them suffered from a crisis which lasted 5 years (See Figure 1). As expected, the events are concentrated during the Great Financial Crisis and the sovereign debt crisis, but some countries also experienced banking crises at the beginning of our sample (See Figure 2). From 2008 to 2010, 53% of the sample suffered from of a banking crisis, almost 40% during the period 2011-2012.

[3] See for instance the impact study ran by the Basel Committee on Banking Supervision (2021) or the review of the macroeconomic level literature reported by Birn et al. (2020).

2.2 Capital ratio

We consider two actual ratios of capital, reflecting the implementation of the two main regulatory capital ratios of Basel requirements: the leverage ratio and the minimum capital requirement. First, Bank capital to total assets is the ratio of banks' capital and reserves to their total assets. Capital consists in tier 1 capital and total regulatory capital, which includes several specified types of subordinated debt instruments (tier 2 and tier 3 capital). The average Bank capital to total assets is 7.37%. Bank capital to total assets is a proxy of the leverage ratio and we can see that its average level is above the 3% required by the regulatory leverage ratio implemented by the Basel III Agreements. We also consider Bank regulatory capital to RWA defines as the ratio of total regulatory capital of banks to their assets held, weighted according to those assets' risk. It's mean is 15.05%. This level complies with the 10.5% required by the Capital Adequacy Ratio under Basel III Agreements (Minimum total capital plus conservation buffer). However, at the beginning of the period, some countries presented low level of capital ratios. Actually, we can observe in Figures 3 and 4 that the average ratios slightly decreased from 2001 to 2008. The decrease is smaller for the Bank regulatory capital to RWA. During this period, banks implemented their internal valuation model, anticipating the Basel II Agreements. Internal models reduced the ratio RWA to Total Assets, leading to a decrease in the Bank capital to total assets ratio. On the contrary, both ratios increased from 2009 to 2017 and the rise is sharper for the Bank regulatory capital to RWA. These expansions may be explained by the necessity to fulfil the tighter level of capital requirements. The difference of dynamics can be justified by the fact that the gap between the actual ratio and the required level was higher for Bank regulatory capital to RWA.

2.3. Control variables

First, we include the credit to GDP ratio, as it widely used in the literature as a determinant of crises (Schularick and Taylor, 2012). More precisely, we use the 5-year average annual growth rate of the ratio of private credit to GDP. On average, the credit to GDP increased by 3%, with a range from -42% to 31%.

Second, we consider a set of variables in order to control for banks characteristics (Bank Controls thereafter). While assessing the effects of capital regulation on the probability of banking crises, we include in our model some control variables that are likely to explain crises. First, we include measures of banks default risk. Several default measurements are traditionally used in literature: distance to default (following Merton option model, Merton, 1974, or KMV – Kealhofer, McQuown and Vasicek – model), Z-score, CAMEL or non-performing loans.[4] In order to consider variables that are both country-level and consistent across countries, we use the measures available in the World Bank GFDD: banks' default risk is assessed by the Z-score and by the non-performing loans ratio. On average, the Z-score equals to 11.84%, corresponding to a probability of default quite null. The minimal value

[4] The distance to default estimates the probability that the value of the bank's assets (assumed to follow a stochastic process) will become less than the value of the debt. The Z-score considers that default occurs when losses exceed capital (See for instance Hannan and Hanweck, 1988); $Z-Score = \frac{Mean(RoA)+{Capital}/{Assets}}{Standard\ Deviation(RoA)}$. CAMEL is a rating system taking into account Capital adequacy, Asset quality, Management, Earnings, Liquidity, and Sensitivity. Importance of non-performing loans is often assessed as the ratio of defaulting loans (payments of interest and principal past due by 90 days or more) to total gross loans.

(0.02%) corresponds to a probability of default almost equals to 50%, reflecting the difficulties of some countries during the period. The mean value of the non-performing loans ratio is 6.28%. As expected, the maximum value and the last decile are high, respectively 46.68% and 14.80%. We include several other bank control variables. Bank net interest margin (on average equals to 2.39% of the interest-bearing assets) and Bank noninterest income to total income (40.45% on average) report both the profitability and the business model of banks. During the last years of the period, the flat yield curve reduces the banks' net interest margin and may give them incentives to increase their risk taking. We also include return on assets (RoA) as a proxy for banks 'profitability, its mean is 0.55%.[5] More than 10% of the observations are negative. Bank credit to bank deposits is the ratio between the financial resources provided to the private sector by domestic money banks as a share of total deposits. The business model of banks is also taken into account by the ratio Bank credit to bank deposits (118.88% on average). Berger and Bouwman (2013) underline the importance of access to financial markets in the relationships between capital ratio and risk level. We complete this measure by Liquid assets to deposits and short-term funding, quite near to the Basel III Liquidity Coverage Ratio (LCR). Liquid assets include for instance cash and due from banks, trading securities loans and advances to banks. Deposits are total customer deposits: current, savings and term. A low level of liquid assets to deposits and short-term funding undermines the banking sector and can lead to a banking crisis. The mean of this ratio is 37.41%, far from complying with the 100% required by the LCR rule and reflecting the liquidity crisis of the Great Financial Crisis. Liquid liabilities to GDP, the ratio between M3 aggregate and GDP, controls for global access to liquidity. Our sample shows a great heterogeneity: from 3.69% to 938.72%, with a mean of 99%. At last, the concentration of the banking sector may play a role. Goetz (2018) shows that a low concentration (a high level of competition) pushes banks to achieve efficiency gains, thus increasing profits and assets' quality and decreasing the likelihood of a banking crisis. Concentration is the share of the assets of the five largest banks in total commercial banking assets. European banking sector is concentrated as the mean value is 80.40%.

Third, we consider two variables in order to control for financial market characteristics (Financial Controls thereafter) as most of European banks cumulate credit activities and market activities. Stock market returns and Stock market volatility allow us to take into account the impact of financial turbulence on the banking sector. The volatility is quite high (21.6 on average) as shown in particular by the wide gap between the minimal stock return (-74.62%) and its maximal value (125.05%).

Fourth, we control for macroeconomic conditions (Macro Controls thereafter). We include the ratio of central bank assets to GDP. One can expect that a higher ratio is a sign that the central banks act as lenders of last resort. We also control for the macroeconomic environment by using the GDP growth and the Inflation.

3. Empirical strategy and results

How bank capital ratios affect the likelihood of banking crises in the EU? The GFDD dataset allows us to study this question in a panel setting with annual data from 1998 to 2017. More

[5] Alternatively, the RoA is replaced by the return on equity (RoE). The results are not modified and are available from the authors upon request.

precisely, we follow the literature (Barth and Miller, 2018; Jordà et. al., 2021) and estimate Probit regressions that assume that the probability of a banking crisis is conditional on a set of explanatory variables and can be seen in terms of the normal cumulative distribution function:

$$\Pr [Crisis_{i,t} = 1 \mid \mid \alpha_i, X_{i,t-1}] = \Phi(\alpha_i + \beta X_{i,t-1}) \quad (1)$$

$Crisis_{i,t}$ stands for the indicator of banking crisis for all years t and countries i in our sample. We follow Jordà et al. (2021) and gauge the quality of classification against another one by focusing on the AUC statistics (area under the ROC curve). This statistic measures how a model accurately sorts the data between banking crisis and non-banking crisis episodes. The AUC is close to 0.5 when a model does not classify correctly and higher when the classification is improved. As a benchmark, we estimate a model with only the country-fixed effects and obtain an AUC = 0.56. To complement the information provided by the AUC, we also propose in each Table the area under the precision-recall curve (AUC-PR) statistics. When the AUC-PR score is higher, the classification is better. In our benchmark, we obtain an AUC-PR = 0.16.

3.1 Baseline estimates

We begin by including in the vector $X_{i,t-1}$ of equation (1) the 5-year average annual growth rate of the ratio of credit to GDP (Δ_5Credit/GDP). The literature has extensively documented that increases in the quantity of credit proxied by Δ_5Credit/GDP are a major determinant of banking crisis (Schularick and Taylor, 2012; Jordà et al., 2013; Mian et al., 2017; Jordà et al., 2021).[6] We then introduce capital ratios variables and assess their additional explanatory power. A country fixed effect α_i is also used to control for the cross-country heterogeneity. All explanatory variables are lagged by one period.

Table 2 presents our baseline estimates. First, the 5-year annual average credit growth rate (column 1) affects positively the probability of crisis as in Schularick and Taylor (2012) and Jordà et al. (2021). The AUC and the AUC-PR are respectively equal to 0.68 and 0.24, indicating that the rate of accurate classifications is significantly higher than in the benchmark (with country-fixed effects only). Second, we alternatively introduce our two variables of interest, the two bank capital ratios, in levels and their 5-year annual growth rate. The levels of Bank capital to total assets and bank regulatory capital to RWA (columns 2 and 4) are both associated with lower banking crisis risk. This is line with most results from the empirical literature (e.g. BCBS, 2010, Mikkelsen and Pedersen, 2017, or Boissay et al., 2019). We also estimate the marginal effects. They are computed from predictions of the model for each independent variable when all other covariates are set to their average values. They are smaller than the average effect. We find that an increase of one point of bank capital to totals assets reduces the probability of crisis of 0.04 point. The marginal effect is smaller for the weighted ratio: an increase of one point of bank regulatory capital to RWA reduces the probability of crisis of 0.02 point.[7] Turning to columns 3 and 5, the coefficients associated with the evolution

[6] Among others, Beck and Levine (2004) pointed out that using data averaged over five-years instead of annual or quarterly data help removing business-cycle influences and focusing on structural determinants.

[7] These marginal effects indicate that when the bank capital to total assets ratio is 1 point higher, the average probability of crisis is reduced by 0,27% and when the bank regulatory capital to RWA ratio is 1 point higher the average probability of crisis is reduced by 0,14%.

of the banking capital ratios are not significant. These results suggest that what is important to enhance the resilience of the banking sector in the EU is the level of capital ratios rather than their variation. That implies that these macroprudential tools have perennial effects on banking stability, in line with the theoretical arguments that state that the impact of capital ratios on banks' risk taking is permanent.

3.2 Sensitivity analysis

We assess the robustness of these baseline estimates in several ways. First, we use of a Logit model instead of a Probit model. Second, we run our estimations on subsamples. We make sure that the results are not sensitive neither to the exclusion of outliers nor to the fact that our dataset is imbalanced between ones and zeros in the dependent variable. To test this latter point, our estimations are carried out on the sample 2008-2010. The proportion of 1 (banking crisis) over this period is 53%. Third, we check if our estimates are sensitive to the exclusion of the 5-year average annual growth rate of credit-to-GDP ratio. We also replace this traditional variable in the literature by the 1-year average annual growth rate of credit-to-GDP ratio and by its level. These robustness tests are presented in Table D in the appendix and confirm that bank capital ratios are associated with a lower banking crisis probability.[8]

Moreover, our baseline specification might suffer from an omitted variable(s) bias. Bank capital might capture the effects of alternative variables. We test this issue by adding controls in $X_{i,t-1}$ as defined in the previous section. We test bank controls, financial controls and macro controls. Results are presented in Table 3. Control variables improve the rate of classification provided by the model (The AUC ranges from 0.75 to 0.88 and the AUC-PR ranges from 0.33 to 0.55). This is particularly true when we include additional banking variables. Among others, we can underline the fact that the concentration of the banking sector strengthens its resilience, in spite of Goetz (2018) (see columns 1, 2, 7 and 8). The short-term liquidity requirements (as the LCR) also seem to reduce the probability of a banking crisis (see columns 1 and 7). As expected, the banks' default risk (assessed by the Z-score) increases the crisis probability. Furthermore, our results support the idea that lower net interest margins may lead banks to take risk in order to restore their profitability. Looking at the effects of bank capital ratios, the results are robust and quite the same than in the baseline.

3.3 Threshold estimations

We study more thoroughly the role played by the level of bank capital ratios in order to prevent banking crises. Theoretical literature shows that banks' behaviour may differ whether they are bounded by the requirements or not. We decompose our sample according to the distribution of bank capital ratios. More precisely, we estimate whether the results are affected if we only look at the bottom of the distribution of each ratio (below the median) or at the top

[8] The only coefficient that is not statistically significant is the one associated with the bank capital to total assets during the 2008-2010 subsample, but it is comparable to the baseline. Two explanations can be provided: first, this result is obtained on a smaller number of observations. Second, this variable is only significant above a certain threshold that has not been reached over this sample. We explore this point latter on.

(above the median).[9] Table 4 shows the results. Bank regulatory capital to RWA has a negative effect on the probability of crisis whether we consider the values higher or lower than the median – columns (5) to (8). Interestingly, while the bank capital to total assets ratio is not significant if we only keep its values below its median – columns (1) and (2) – it is negative and significant above its median – columns (3) and (4) – whether we add controls or not.

This last result is explored by splitting the sample at different percentiles of the bank capital to total assets ratio to identify thresholds for which this effect is at work. Results are summarized in Table E in the appendix, in which we run the regressions with and without controls for each subsample. We do find a threshold effect for the capital to total assets ratio: this ratio has a significant negative effect on banking crises between the 85th and the 90th percentile following the specification. In other words, it seems that in the EU, the negative effect of capital to total assets ratio on banking crisis is at work for values above 10.11% (for an estimation without control) and 12.25% (for a specification with all controls). This threshold is far higher than the 3% recommended by the BCBS.

We therefore can consider that the required level of leverage ratio is not high enough. This is consistent with Barth and Miller (2018) who realized a cost-benefit analysis of a raise of the leverage ratio from 4 to 15 percent for nearly 4000 US banks between 1892 and 2014 and with Almenberg et al. (2017), who conclude that the optimal capital ratio should lie between 5% and 12%. At the opposite, our results suggest that the risk weighed capital requirement is sufficiently high, as this capital ratio always has a negative impact on the probability that a banking crisis occurs.

4. Conclusion

We study if the bank capital to total assets ratio and the bank regulatory capital to RWA affect the probability of banking crises in the EU between 1998 and 2017. We find that capital ratios are associated with lower probabilities of a banking crisis. Our results are robust to various specifications which include control variables related to banking, financial and macroeconomic risks. The bank capital to total assets ratio has a significant effect only for high levels, around 11%.

It could suggest that the leverage ratio implemented by Basel III at a 3% level may be insufficiently high to prevent a banking crisis. Our results also show that the ratio of bank capital to RWA is effective to reduce the probability of a banking crisis. This could mean that the discretionary use of internal models by banks does not conflict with the objective of improving resilience, despite the willingness of Basel Committee of reducing their usage in the finalised version of the Basel III agreement, in 2017. In sum, our results show that capital requirements under Basel III will likely strengthen financial stability through their negative impact on the likelihood of banking crises.

[9] We use linear regressions instead of non-linear ones to estimate these thresholds for sake of simplicity and transparency. Moreover, non-linear approaches such as panel smooth transition regression also have their drawbacks as they may converge slowly and are uncertain (Teräsvirta, 1994).

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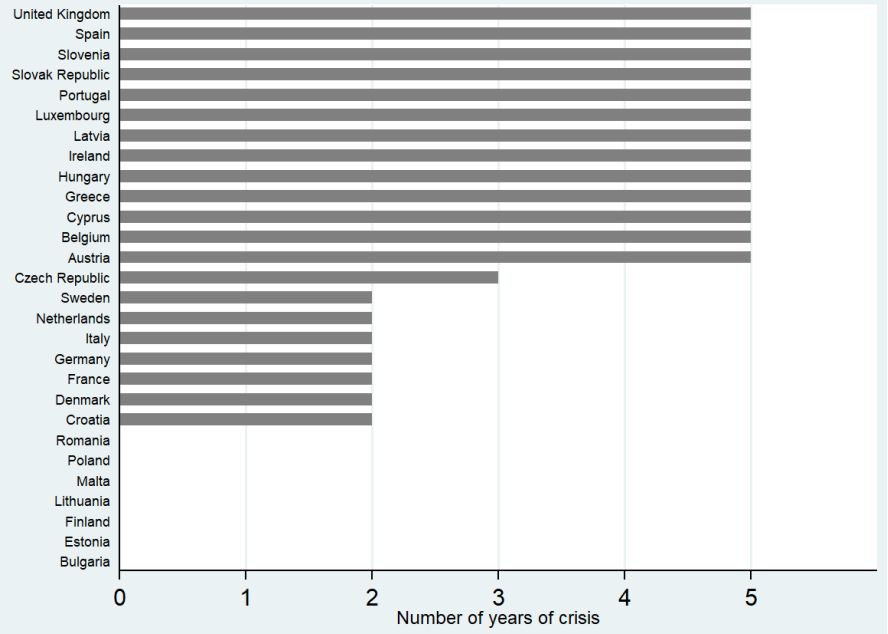
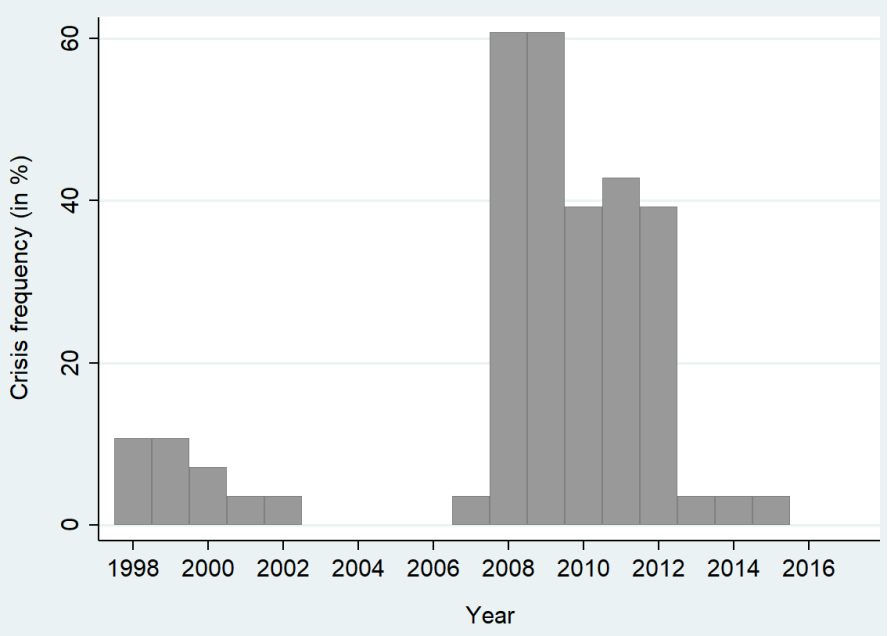
Figure 1. Occurrence of a banking crisis by country



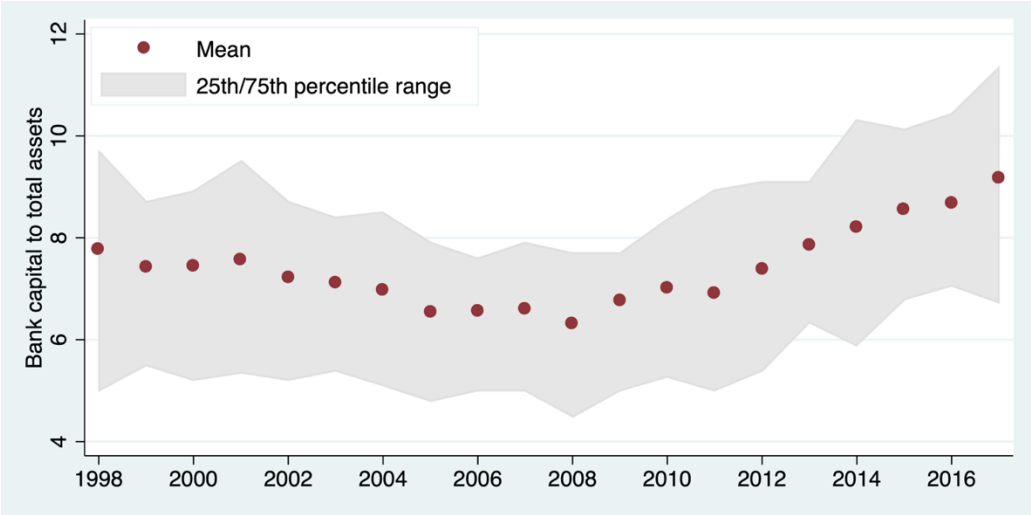
Source: World Bank Global Financial Development Database

Figure 2. Occurrence of a banking crisis by year



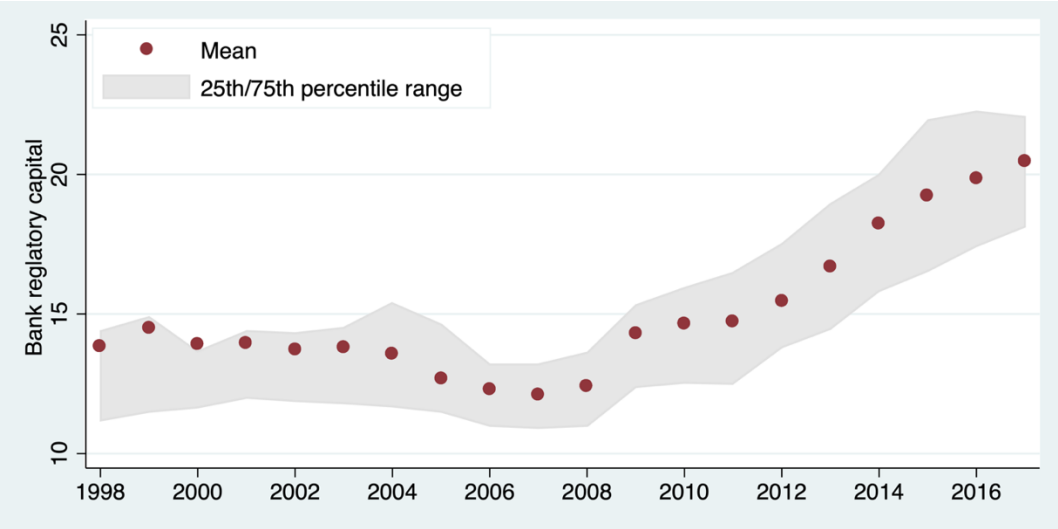
Source: World Bank Global Financial Development Database

Figure 3. Bank capital to total assets in the European Union



Source: World Bank Global Financial Development Database

Figure 4. Bank regulatory capital to RWA



Source: World Bank Global Financial Development Database

Table 1. Banking crises in the European Union and their outcomes

Country	Crisis dates		Output loss (% of GDP)	Fiscal Costs (% of GDP)	Non Performing loans (% loans)	Increase in public debt (% of GDP)
	Start	End				
Austria	2008	2012	19.2	5.2	4.1	19.8
Belgium	2008	2012	15.7	6.2	4.2	22.2
Croatia	1998	1999	...	6.9	10.5	14.1
Czech Republic	1996	2000	...	6.8	18.0	1.8
Cyprus	2011	2015	76.5	18.0	47.8	21.3
Denmark	2008	2009	35.0	5.9	5.95	32.8
France	2008	2009	23.3	1.3	4.5	15.9
Germany	2008	2009	12.3	2.7	3.7	16.2
Greece	2008	2012	64.9	28.7	37.1	43.9
Hungary	2008	2012	37.3	2.9	17.3	3.8
Ireland	2008	2012	107.7	37.6	25.7	76.5
Italy	2008	2009	32.2	0.7	18.0	8.6
Latvia	2008	2012	93.9	8.1	15.9	27.6
Luxembourg	2008	2012	43.3	7.2	1.7	12.7
Netherlands	2008	2009	26.1	14.3	3.2	24.9
Portugal	2008	2012	35.0	11.1	12.9	38.5
Slovak Republic	1998	2002	0.0	...	35.0	15.4
Slovenia	2008	2012	39.1	9.9	18.0	20.9
Spain	2008	2012	38.8	5.4	9.4	31.8
Sweden	2008	2009	25.5	0.2	2.0	12.8
United Kingdom	2007	2011	25.3	8.8	4.0	27.0
Mean			39.5	9.4	14.2	23.3

Note: Output losses are computed as the cumulative sum of the differences between actual and trend real GDP over the period [T, T+3], expressed in percent of trend real GDP, with T denoting the starting year of the crisis. The trend is computed by applying an HP filter (λ=100) to the GDP series over [T-20, T-1]. Fiscal costs refer to outlays directly related to the restructuring of the financial sector. For episodes starting in 2007 and later, the increase in public debt is measured as the change in debt projections, over [T-1, T+3], relative to the pre-crisis debt projections, where T is the starting year of the crisis. Source of the data: Laeven and Valencia (2020).

Table 2. Baseline estimations

	(1)	(2)	(3)	(4)	(5)
Δ_5 Credit/GDP	2.77**	2.87**	11.77***	1.37	6.52***
	[1.22]	[1.39]	[2.67]	[1.40]	[2.50]
Bank capital to total assets		-0.19***			
		[0.05]			
Bank regulatory capital to RWA				-0.10***	
				[0.04]	
Δ_5 Bank capital to total assets			1.47		
			[2.20]		
Δ_5 Bank regulatory capital RWA					-0.88
					[3.00]
N	472	428	308	444	325
AUC	0.68	0.72	0.79	0.71	0.74
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
AUC-PR	0.24	0.27	0.51	0.26	0.36

Note: The Table presents Probit models where the dependent variable is the banking crisis and the regressors are lagged by one period. Country fixed effects are included. Clustered (by country) standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3. Controlling for bank characteristics, financial environment and macroeconomic dynamics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ5 Credit/GDP	-0.46	-1.58	2.09	0.58	1.70	-0.19	-2.94	-5.00*
	[1.53]	[1.73]	[1.45]	[1.46]	[1.63]	[1.62]	[2.41]	[2.70]
Bank capital to total assets	-0.17**		-0.21***		-0.15***		-0.22***	
	[0.07]		[0.06]		[0.05]		[0.08]	
Bank regulatory capital to RWA		-0.13**		-0.11***		-0.15***		-0.20***
		[0.07]		[0.04]		[0.05]		[0.07]
Bank Controls								
Bank net interest margin (%)	-0.05	-0.01					0.32*	0.38**
	[0.15]	[0.13]					[0.18]	[0.15]
Bank noninterest income to total income (%)	-0.02	-0.02					-0.02	-0.02
	[0.01]	[0.02]					[0.01]	[0.01]
RoA	-0.17*	-0.27***					-0.16	-0.21**
	[0.10]	[0.09]					[0.11]	[0.10]
Z-score	-0.05*	-0.04					-0.06**	-0.06**
	[0.03]	[0.03]					[0.03]	[0.03]
Nonperforming loans	-0.04	-0.04					-0.02	-0.03
	[0.03]	[0.03]					[0.04]	[0.04]
Bank credit to bank deposits (%)	0.00**	0.00*					0.00*	0.00
	[0.00]	[0.00]					[0.00]	[0.00]
Liquid liabilities to GDP (%)	0.00**	0.00***					0.00**	0.01***
	[0.00]	[0.00]					[0.00]	[0.00]
Liquid assets to deposits and short term funding (%)	-0.02**	-0.01					-0.02**	-0.01
	[0.01]	[0.01]					[0.01]	[0.01]
Concentration	-0.03***	-0.03***					-0.04***	-0.03**
	[0.01]	[0.01]					[0.01]	[0.01]
Financial Controls								
Stock market return			-0.01***	-0.01***			-0.01**	-0.01*
			[0.00]	[0.00]			[0.00]	[0.00]
Stock price volatility			0.01	0.00			0.02	0.02
			[0.01]	[0.01]			[0.02]	[0.02]
Macro Controls								
Central Banks assets					-0.07*	-0.11**	-0.15**	-0.19**
					[0.04]	[0.04]	[0.07]	[0.08]
GDP Growth					-11.55***	-12.98***	-0.80	-3.10
					[2.89]	[2.67]	[4.52]	[4.29]
Inflation					-0.01	0.01	0.01	0.02
					[0.02]	[0.02]	[0.02]	[0.02]
N	371	386	403	417	410	426	336	349
AUC	0.84	0.84	0.75	0.75	0.78	0.80	0.87	0.88
se	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02
AUC-PR	0.51	0.52	0.35	0.36	0.33	0.40	0.54	0.55

Note: The Table presents Probit models where the dependent variable is the banking crisis and the regressors are lagged by one period. Country fixed effects are included. Bank controls include bank interest margin, bank non-interest income, RoA, Z-score, bank non-performing loans, bank credit to bank deposits, liquid liabilities, liquid assets to deposits, banking concentration. Financial controls include stock market returns and stock market volatility and macro controls include central banks assets, GDP per capita growth rate and inflation. Clustered (by country) standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4. Distribution of capital ratios

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Below median Bank capital to total assets		Above median Bank capital to total assets		Below median Bank regulatory capital to RWA		Above median Bank regulatory capital to RWA	
Δ_5 Credit/GDP	2.58	-1.99	2.09	-5.67*	0.49	-4.40	3.48	-31.76***
	[2.36]	[3.16]	[1.40]	[3.32]	[1.48]	[3.22]	[3.13]	[11.64]
Bank capital to total assets	-0.07	0.05	-0.21***	-0.68***				
	[0.10]	[0.16]	[0.06]	[0.14]				
Bank regulatory capital to RWA					-0.25***	-0.38***	-0.11***	-0.29***
					[0.06]	[0.15]	[0.04]	[0.10]
Bank controls	No	Yes	No	Yes	No	Yes	No	Yes
Financial Controls	No	Yes	No	Yes	No	Yes	No	Yes
Macro Controls	No	Yes	No	Yes	No	Yes	No	Yes
N	195	156	233	180	206	164	238	185
AUC	0.72	0.76	0.70	0.82	0.69	0.82	0.71	0.74
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)
AUC-PR	0.27	0.27	0.25	0.41	0.26	0.49	0.27	0.28

Note: The Table presents Probit models where the dependent variable is the banking crisis and the regressors are lagged by one period. Country fixed effects are included. Bank controls include bank interest margin, bank non-interest income, RoA, Z-score, bank non-performing loans, bank credit to bank deposits, liquid liabilities, liquid assets to deposits, banking concentration. Financial controls include stock market returns and stock market volatility and macro controls include central banks assets, GDP per capita growth rate and inflation. Clustered (by country) standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

APPENDIXES

Table A. Link between capital ratio and banking crisis. Summary of results from the empirical literature

	Type of capital ratio	Dependent variable	Coverage	Period	Econometric model	Results
Almenberg et al. (2017)	Ratio Tier 1 capital to total assets	Probability of a banking crisis, which happens when at least one of the four large Swedish bank is defaulting	Major Swedish banks	NA	Standard structural and reduced probability of default models (Merton, 1974)	Increasing the ratio of capital decreases the probability of a crisis, and the appropriate capital Tier 1 ratio lies between 10 and 24%
Barth and Miller (2018)	Ratio Tier 1 capital to total assets	Probability of a banking crisis, using data from multiple studies	US banks	1892-2014	Probit, Logit	Increasing the ratio of Tier 1 capital from 4 to 15 percent decreases the probability of a crisis from 25% to around 7-8% for a given year. The optimal leverage ratio equals 19%
Berger and Bouwman (2013)	Ratio Core Tier 1 Capital to total assets	Banks'survival	U.S. banks	1984-2010	Logit	Increasing the ratio of Core tier 1 to gross total assets by on standard deviation increases banks' survival probabilities by about 50%
Basel Committee on Banking Supervision (2010)	Ratio Core Tier 1 Capital to RWA	Probability of a banking crisis, using data from Reinhart and Rogoff (2008) and Laeven and Valencia (2008)	BCBS members	1980-2008	Reduced-form models, calibrated portfolio models, calibrated stress test models	The optimal ratio lies between 10 and 15%. Increasing the capital ratio from 7 to 8% reduces the probability of a crisis by one third
Boissay et al. (2019)	Actual capital ratios and regulatory capital ratios	Probability of a crisis (definition varies between studies)	83 studies from the FRAME[10] (13 assess the impact of regulatory ratios on the probability of crisis/banks' default)	NA	Meta-analysis	A one percentage point increase in the capital ratio decreases crisis risk by 1.07 percentage points. Results are quite similar between studies
Brooke et al. (2015)	Ratio Core Tier 1 capital to total assets	Probability of a banking crisis, which happened when system-wide recapitalization costs exceed 3% of GDP, as in Laeven and Valencia (2012)	UK banks	NA	Bottom-up approach and top-down approach with a Logit	An increase in capital ratios decrease the probability of a crisis. The optimal Tier 1 capital ratio lies between 10% and 14% in United Kingdom
Dagher et al. (2016)	Capital to RWA	Nonperforming loans/total banks assets, using the indicator from Laeven and Valencia (2013)	Countries that experienced a banking crisis since 1970	1970-2011	Bottom-up approach	Banks' risk-weighted capital ratios between 15% and 23% would have been enough to absorb losses in advanced economies during 80% of the banking crises
Firestone et al. (2019)	Ratio Tier 1 capital to total assets	Probability of a crisis, using the indicator from Laeven and Valencia (2012)	US banks	1988-2014	Bottom-up approach and top-down approach with a Logit	The optimal capital ratio lies between 13% and 26% in the US. An increase in capital ratios decrease the probability of a crisis
Jordà et al. (2021)	Ratio Core Tier 1 capital to total assets	Probability of a banking crisis, using narrative identification	17 advanced economies	1870 -2015	Probit	A 2-percentage point rise in the capital ratio leads to a 0.34 percentage point increase in the likelihood of a banking crisis
Mikkelsen and Pedersen (2017)	Ratio Tier 1 capital to total assets	Probability of a financial crisis, using the indicator from Jordà et al. (2017)	OECD	1980-2013	Logit	A 1 percentage point rise in the capital ratio lead to a 1.2 percentage points decrease in the likelihood of a financial crisis
Miles et al. (2013)	Ratio Tier 1 capital to RWA	Probability of system banking crisis, which happens when asset values decrease by more than the level of bank equity	UK banks	Nearly 200 years	Bottom-up and top-down approaches	Higher capital requirements reduce the probability of systemic banking crises. The optimal capital ratio lies between 16% and 20%

[10] The Financial Regulation Assessment: Meta Exercise (FRAME) is an online repository which contains studies that focus on the economic impact of numerous types of financial regulations.

Table B. Data definitions and sources

Name	Description
Banking crisis	Dummy variable equal to 1 when banking crisis occurs,
Bank capital to total assets	Ratio of bank capital and reserves to total assets (%)
Bank regulatory capital to RWA	Total regulatory capital to RWA (%)
Δ5 Credit/GDP	5-year average annual growth rate of the ratio of private credit to GDP (%)
Bank net interest margin	Bank's net interest revenue to its interest-bearing assets (%)
Bank noninterest income to total income	Bank's income generated by noninterest related activities as a percentage of total income (%)
RoA	Return on Assets (%)
RoE	Return on Equity (%)
Z-score	(RoA+(equity/assets))/(Standard deviation of RoA)
Nonperforming loans	Ratio of defaulting loans to total gross loans (%)
Bank credit to bank deposits	Ratio of private credit provided by banks to their total deposits (%)
Liquid liabilities to GDP	Ratio of liquid liabilities (broad money or M3) to GDP (%)
Liquid assets to deposits and short-term funding	Ratio of banks' liquid assets to short-term funding plus total deposits (%)
Concentration	Ratio of assets of five largest banks to total commercial banking assets
Stock market return	Growth rate of annual average stock market index (%)
Stock price volatility	Average of the 360-day volatility of the national stock market index
Central bank assets	Ratio of central bank assets to GDP (%)
GDP Growth	Annual variation of GDP per capita
Inflation	Average Consumer Price Index (2010=100)

Note: the source of the data is the World Bank Global Financial Development Database (GFDD)

Table C. Descriptive Statistics

	Obs	Mean	Std. Dev.	Min	Max	1st decile	9th decile
Bank capital to total assets (%)	505	7.37	2.69	2.00	18.30	4.50	11.26
Bank regulatory capital to RWA	522	15.05	4.31	6.60	41.80	10.90	20.47
Δ_5 Credit/GDP	499	0.03	0.08	-0.42	0.31	-0.06	0.13
Bank net interest margin (%)	560	2.39	1.67	0.13	20.47	0.85	4.23
Bank noninterest income to total income (%)	559	40.45	11.30	14.64	81.25	26.80	55.62
RoA (%)	560	0.55	1.30	-10.47	4.24	-0.32	1.66
RoE (%)	560	7.42	14.81	-117.67	55.18	-4.74	18.80
Z-Score (%)	559	11.84	7.40	0.02	47.57	4.33	21.65
Nonperforming loans	507	6.28	7.30	0.10	48.68	0.70	14.80
Bank credit to bank deposits (%)	528	118.88	55.49	17.79	367.08	63.48	178.82
Liquid liabilities to GDP (%)	543	99.08	126.81	3.69	938.72	38.30	145.49
Liquid assets to deposits and short-term funding (%)	560	37.41	16.81	5.26	130.63	18.11	59.79
Concentration	549	81.40	13.72	41.40	100.00	66.23	98.14
Stock market return	511	7.29	26.87	-74.62	125.05	-25.27	37.48
Stock price volatility	508	21.60	9.07	6.34	61.33	12.00	33.20
Central banks assets	525	2.19	3.81	0.00	28.41	0.01	7.31
GDP Growth	560	0.02	0.04	-0.16	0.21	-0.01	0.06
Inflation	560	92.61	15.08	15.06	115.46	73.72	108.63

Source: World Bank Global Financial Development Database

Table D. Sensitivity estimations

Panel A: Logit						
	(1)	(2)	(3)	(4)	(5)	
Δ_5 Credit/GDP	4.69**	4.87**	21.01***	2.21	10.99**	
	[2.16]	[2.45]	[5.14]	[2.41]	[4.54]	
Bank capital to total assets		-0.34***				
		[0.09]				
Bank regulatory capital to RWA				-0.19**		
				[0.08]		
Δ_5 Bank capital to total assets			2.66			
			[3.69]			
Δ_5 Bank regulatory capital RWA					-1.99	
					[5.37]	
N	472	428	308	444	325	
AUC	0.68	0.72	0.80	0.71	0.75	
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	
AUC-PR	0.25	0.27	0.52	0.26	0.38	
Panel B: Subsamples						
		Removing outliers			*2008-2010*	
	(1)	(2)	(3)	(4)	(5)	(6)
Δ_5 Credit/GDP	2.61*	2.49			4.81	3.27
	[1.36]	[1.53]			[3.87]	[3.98]
Bank capital to total assets			-0.20***		-0.20	
			[0.06]		[0.13]	
Bank regulatory capital to RWA				-0.09**		-0.24**
				[0.04]		[0.09]
Bank capital to total assets _rob	-0.18***					
	[0.07]					
Bank regulatory capital _rob		-0.09*				
		[0.04]				
Δ_5 Credit/GDP_rob			6.17***	3.82*		
			[2.16]	[2.21]		
N	392	398	392	406	75	76
AUC	0.70	0.69	0.75	0.72	0.72	0.71
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
AUC-PR	0.24	0.26	0.33	0.31	0.28	0.26
Panel C: Credit/GDP						
	(1)	(2)	(3)	(4)	(5)	(6)
Credit/GDP		0.01***			0.01***	
		[0.00]			[0.00]	
Δ_1 Credit/GDP			0.55			-0.95
			[0.75]			[0.94]
Bank capital to total assets	-0.10**	-0.11**	-0.11**			
	[0.04]	[0.05]	[0.05]			
Bank regulatory capital to RWA				-0.11***	-0.11***	-0.13***
				[0.03]	[0.04]	[0.04]
N	485	464	457	500	480	473
AUC	0.62	0.74	0.65	0.67	0.76	0.69
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
AUC-PR	0.20	0.35	0.23	0.27	0.46	0.24

Note: The Table presents Logit (Panel A) and Probit (Panel B and C) models where the dependent variable is the banking crisis and the regressors are lagged by one period. In panel B "_rob" is associated to variables for which we discard the outliers (bottom 5% and top 95%). In panel C, Credit/GDP stances for the level of credit to GDP and Δ1 Credit/GDP is one-year annual growth rate of credit to GDP ratio. Country fixed effects are included. Clustered (by country) standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table E. Threshold

	(1)	(2)	(3)	(4)	(5)	(6)
	Below 80th percentile		Below 85th percentile		Below 90th percentile	
Δ_5 Credit/GDP	2.44*	-2.75	2.54*	-2.99	2.60*	-3.32
	[1.44]	[2.61]	[1.44]	[2.62]	[1.42]	[2.51]
Bank capital to total assets	-0.10	-0.09	-0.13*	-0.11	-0.16***	-0.17**
	[0.08]	[0.08]	[0.07]	[0.08]	[0.06]	[0.08]
Bank controls	No	Yes	No	Yes	No	Yes
Financial Controls	No	Yes	No	Yes	No	Yes
Macro Controls	No	Yes	No	Yes	No	Yes
N	336	269	354	281	374	296
AUC	0.72	0.86	0.72	0.86	0.72	0.87
	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.02)
AUC-PR	0.28	0.51	0.27	0.53	0.27	0.54

Note: The Table presents Probit models where the dependent variable is the banking crisis and the regressors are lagged by one period. Country fixed effects are included. Bank controls include bank interest margin, bank non-interest income, RoA, Z-score, bank non-performing loans, bank credit to bank deposits, liquid liabilities, liquid assets to deposits, banking concentration. Financial controls include stock market returns and stock market volatility and macro controls include central banks assets, GDP per capita growth rate and inflation. Clustered (by country) standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.