Capital ratios and banking crisis in the European Union*

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Abstract

We assess if capital ratios reduced the occurrence of banking crisis 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, Capital to assets ratio, Financial crises, Systemic risk.

JEL Classification: G21, E44

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1. Introduction

Banking crisis 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 crisis recessions are more costly than normal recessions in terms of lost output (Jordà et al., 2013). During the last two decades, the European Union (EU) experienced two major episodes of banking crisis (the so-called Great Recession and the Sovereign Debt Crisis). Relying on the work of Laeven and Valencia (2020)[1], output losses in the EU during the recent banking crisis are estimated around 40% of GDP and the public debt increased by more than 20% of GDP.

These episodes were followed by several modifications in the regulatory environment. While the macro-finance literature points out that rapid credit growth predicts banking crisis (Schularick and Taylor, 2012), macroprudential regulators are extensively using capital ratios to prevent them. In particular, the successive implementation of Basel 2 and Basel 3 Agreements lead to tighter capital requirements. More specifically, Basel 2 enforced an accurate risk assessment of bank assets (possibly through internal models) on which regulatory capital depends. This risk-weighted asset (RWA) calculation allowed a more refined estimate of the capital required. Basel 3 was even more exigent, enhancing the quality of the regulatory capital (increasing the percentage of equity and reducing the percentage of subordinate debt); increasing the level of the capital by the creation of a conservation buffer and establishing a leverage ratio (independent from the level of banks' risk). The EU adopted in a uniform way the Basel Agreement: Basel 2 was translated into the European laws through the Capital Requirements Directive (CRD) II (2008) and CRD III (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 gives 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. During banking crisis, non-performing loans rose sharply and deteriorate the health of the banking sector (see Table 1). As a consequence, monetary policy transmission channels are weakened so as the ability of central banks to fulfil their objectives. It is therefore crucial that the ECB promote effective regulations in that matter. Although the use of capital ratios has been extensively investigated in the empirical literature, to our knowledge, none have been focused on the EU.[2] Our paper aims at investigating the relationships between capital requirements and the probability of systemic banking crisis 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 crisis 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 prudent since they have more to lose. Actually, it is

[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.

argued that if bankers have "more skin in the game", they would be more careful 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 reduced the benefit 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 lead banks to be more cautious. A reduction of their risk-taking that reduces their RWA, makes possible either the decrease of the level of capital required, or simply an increase of the volume of business at a given level of capital (Martynova, 2015). In this line Repullo and Suarez (2013) show that Basel 2 make 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 requirement may not be sufficient to prevent banks from highly risky comportments and even lead them to take more risky portfolios in order 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. More specifically, they analyse the interaction between a RWA ratio and a leverage ratio and show that if cost of equity is high, banks that are bounded by the leverage ratio have incentive to increase their risk. 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 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 contribute 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 effects improve bank sector resilience. Berger and Bouwman (2013) show that higher levels of capital always reduce small banks' probability of default, while this benefice concerns medium and large banks only during banking crisis. Boissay et al. (2019) found through a meta-analysis that on average, a 1 percentage point increase in capital ratios is associated with a 1 percentage point decrease on 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., 2020). More broadly, this paper contributes to the literature on the determinants of banking crisis 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 crisis (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. (2020). 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 as to verify if their result is robust in the EU and specifically assess if two variables of capital ratios – the bank capital to total assets ratio that proxy the leverage and the bank regulatory capital to RWA - reduce the occurrence of banking crisis from 1998 to 2017. Banking crisis are identified by Laeven and Valencia (2020). We found that both measures affect negatively this probability 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.

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.

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). They consider that a systemic 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 (14.6%). According to this measure, 21 EU countries experienced a systemic crisis over the period, and 13 of them suffered from a crisis that last 5 years (See Figure 1). As expected, the events are concentrated between 2008 and 2012, but some countries also experienced banking crisis at the beginning of our sample (See Figure 2). In 2008 and 2009, 60% of the sample suffered from of systemic banking crisis, almost 40% during the period 2010-2012.

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 bank capital and reserves to total assets. Capital includes tier 1 capital and total regulatory capital, which includes several specified types of subordinated debt instruments (tier 2 and tier 3 capital). On average, Bank capital to total assets equals to 7.37% (see Table 2). Bank capital to total assets is a proxy of the leverage ratio so it's above the 3% required by the regulatory leverage ratio implemented by the Basel 3 Agreements. We also consider Bank regulatory capital to RWA that equals the ratio of total regulatory capital of banks to their assets held, weighted according to those assets' risk. On average, the ratio equals to 15.05%. This level complies with the 10.5% required by the Capital Adequacy Ratio under Basel 3 Agreements. 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 2 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. Starting in 2009 banks anticipated Basel 3: enhancement of the quality of the capital (with a higher share of core tier one) and a raising of the capital requirements (even if the transposition deadline of CRD IV was by the end of 2013). So, the observed increases may be explained by the necessity to fulfil the tighter level of capital requirements. The difference of dynamics can be explained 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

While assessing the effects of capital regulation on the probability of banking crisis, we include in our model some control variables that are likely to explain crises. First, we include credit to GDP, as it widely used in the literature as a robust predictor 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%.

We consider a set of variables in order to control for banks characteristics (Bank Controls thereafter). Bank net interest margin (on average equals to 2.39% of the interest-bearing assets) and Bank noninterest income to total income (on average equals to 40.45%) 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) and return on equity (RoE) as proxies of banks 'profitability, on average equal to 0.55% and 7.42%. More than 10% of the observations are negative. The banks' risk level is assessed by the Z-score and by Nonperforming loans, the ratio of defaulting loans (payments of interest and principal past due by 90 days or more) to total gross loans. On average, the Z-score equals to 11.84%, corresponding to a probability of default quite null. The minimal value (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 Nonperforming loans equals 6.28%. As expected, the maximum value and the last decile are high, respectively equals to 46.68% and 14.80%. 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: credits are also funded by financial markets or interbank market). Berger and Bouwman (2013) underlines 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 3 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 is a sign of fragility of the banking sector and can lead to a systemic crisis. Actually, this ratio equals to 37.41% on average, far from complying with the 100% required by the LCR rule and reflecting the liquidity crisis of the Great Recession. Liquid liabilities to GDP, the ratio between M3 aggregate and GDP, controls for global access to liquidity. Our sample show a great heterogeneity: from 3.69% to 938.72%, with a mean equal to 99%. At last, the concentration of the banking sector may play a role. Goetz (2018) recently shows that a low concentration (that is to say a high level of competition) pushes banks to achieve efficiency gains, thus increasing profits and asset quality and decreasing the likelihood of a systemic 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 equal to 80.40%.

We also 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 return 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 stick return (-74.62%) and its maximal value (125.05%).

At last, we control for macroeconomic conditions (Macro Controls thereafter). Central bank assets, the ratio of central bank assets to GDP, is a proxy of unconventional monetary policy. One can expect that a higher ratio is a sign that Central Banks act as a lender of last resort. We also control for the macroeconomic environment by using the GDP growth and the Inflation (equal to an average Consumer Price Index, base 100 in 2010). All variables are described in Table B in the Appendix and descriptive statistics are presented in Table 2.

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 precisely, we follow the literature (Barth and Miller, 2018; Jordà et. al., 2020) 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:

$$\Pr\left[\text{Crisis}_{i,t} = 1 \,\middle|\, \alpha_i, X_{i,t}\right] = \Phi(\alpha_i + \beta X_{i,t}) \quad (1)$$

$Crisis_{i,t}$ stands for the indicator of banking crisis for all years t and countries i in our sample. We begin by including in the vector $X_{i,t}$ the 5-year average annual growth rate of the ratio of credit to GDP (Δ_5 Credit/GDP). The literature has extensively documented that increases in the quantity of credit is a major predictor of banking crisis (Schularick and Taylor, 2012; Jordà et al., 2013; Mian et al., 2017; Jordà et al., 2020). We then introduce other explanatory 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.

We follow Jordà et al. (2020) and gauge the quality of classification compare to 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 the observations and tends to 1 otherwise. As a benchmark, we estimate a model with only the country-fixed effects and obtain an AUC = 0.55.

Table 3 presents our baseline estimates. First, we introduce the 5-year annual average credit growth rate (column 1) and found that this variable affects positively the probability of crisis as in Schularick and Taylor (2012) and Jordà et al. (2020). The AUC equals 0.68, indicating that the rate of accurate classifications is significantly higher than 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). The marginal effects are smaller than the average effect. Whereas Boissay et al. (2019) found that on average, a 1 percentage point increase in capital ratios is associated with a 1 percentage point decrease on crisis probability, we find that an increase of one point of bank capital to totals assets reduces the probability of crisis of 0.04 points. The marginal effect is even 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. Turning to columns 3 and 5, the coefficients associated with the evolution 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. These first results are robust to the use of a Logit model instead of a Probit model and to the exclusion of outliers (see Table C in the appendix).

However, our first 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 $X_{i,t}$. Table 4 presents the results when adding bank controls (columns 1, 2), financial controls (columns 3, 4), macro controls (column 5 and 6) and all the control variables (columns 7 and 8). Control variables improve the rate of classification provided by the model (The AUC ranges from 0.75 to 0.88). This is particularly true when we include additional banking variables.

Looking at the effects of bank capital ratios, the results are not statistically different than in the baseline.[3] 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 systemic crisis (see columns 1 and 7).

We study more thoroughly the role played by the level of bank capital in order to prevent banking crisis. 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 (above the median). Table 5 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. It suggests that only high values of this ratio are able to reduce the probability of crisis. This result is in line with theoretical results provided by Acosta-Smith et al. (2020): if cost of equity is high, banks that are bounded by the leverage ratio have incentive to increase their risk.

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 working. This approach is summarized in Table 6. We find that the capital to total assets ratio threshold at which its negative effect on banking crisis appears is roughly between the 85th and the 90th percentile following the specification. In another 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). Our result 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 be range between 5% and 12%. Our results confirm that the current temporal evolution of the average ratio (see figure 3), which is characterized by an increase to a level close to 9%, may allow for a stronger resilience of the banking system.

4. Conclusion

We investigate 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 found that capital ratios are associated with lower probabilities of banking crises. 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. It could suggest that the leverage ratio as implement by Basel 3 could have some adverse effects in some countries, especially when banks are bounded by the regulatory ratio,

[3] For completeness, Table D in the appendix presents the coefficients associated with each control.

counterbalancing the potential positive effects. Our results also show that the ratio of bank capital to RWA is effective to reduce the probability of a systemic 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 Basel 3 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.

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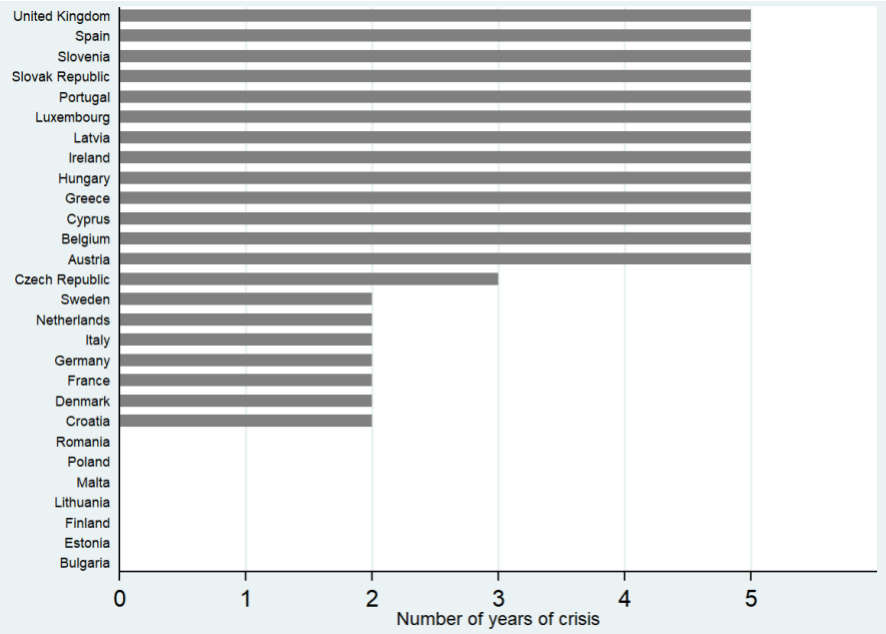
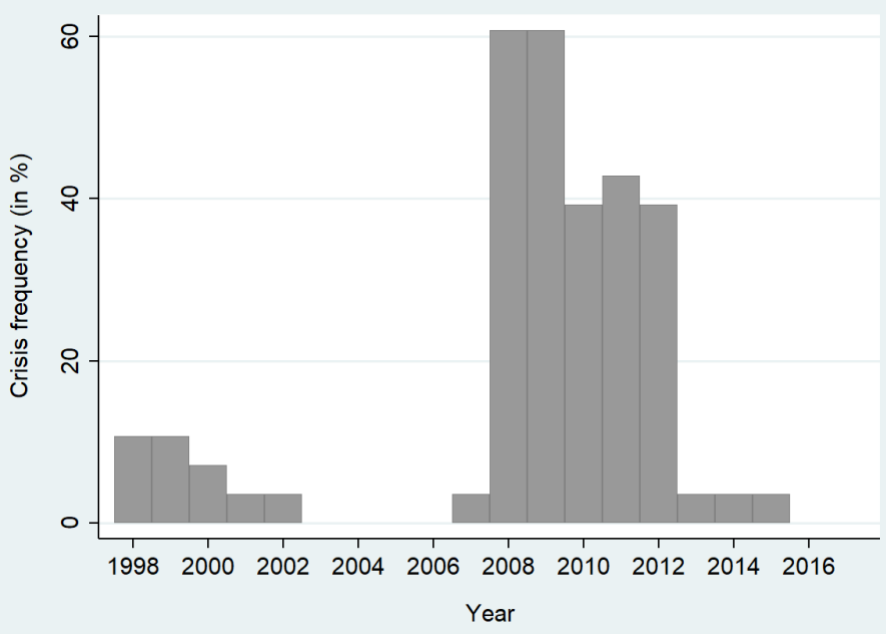
Figure 1. Occurrence of a systemic crisis by country



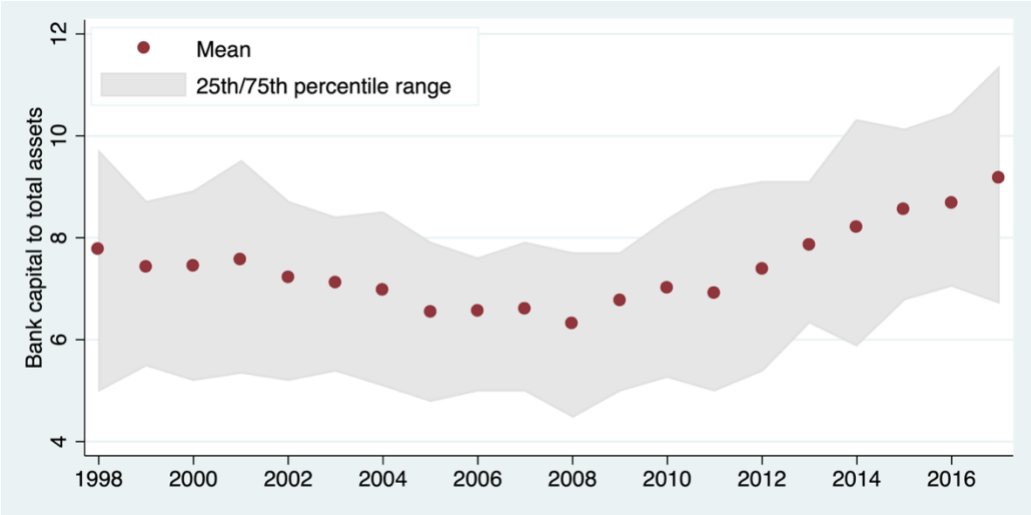
Source: GFDD

Figure 2: Occurrence of a systemic crisis by year



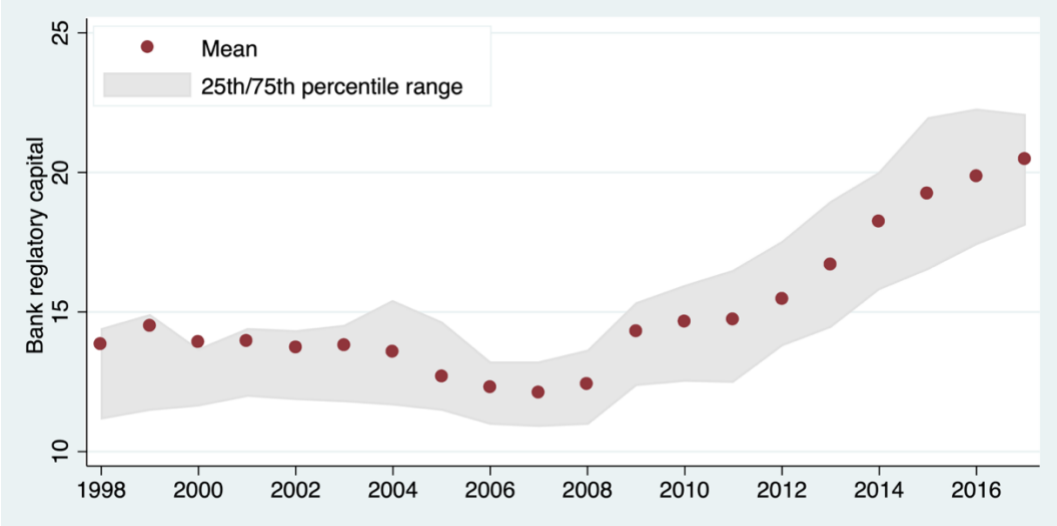
Source: GFDD

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



Source: GFDD

Figure 4. Bank regulatory capital to RWA



Source: GFDD

Table 1: Banking crisis 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 Rep	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: Laeven and Valencia (2020).

Table 2: 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: GFDD

Table 3: Baselines 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)

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 4: Controlling for bank characteristics, financial environment and macroeconomic dynamics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ_5 Credit/GDP	-1.13	-2.64	2.09	0.58	1.70	-0.19	-2.95	-5.02*
	[1.38]	[1.63]	[1.45]	[1.46]	[1.63]	[1.62]	[2.40]	[2.70]
Bank capital to total assets	-0.18***		-0.21***		-0.15***		-0.21***	
	[0.07]		[0.06]		[0.05]		[0.07]	
Bank regulatory capital to RWA		-0.15**		-0.11***		-0.15***		-0.21***
		[0.07]		[0.04]		[0.05]		[0.07]
Bank controls	Yes	Yes	No	No	No	No	Yes	Yes
Financial Controls	No	No	Yes	Yes	No	No	Yes	Yes
Macro Controls	No	No	No	No	Yes	Yes	Yes	Yes
N	371	386	403	417	410	426	336	349
AUC	0.85	0.86	0.75	0.75	0.78	0.80	0.87	0.88
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)

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, liquid liabilities, liquid assets to deposits, bank non-performing loans, bank credit to bank deposits, ROA, ROE, banking concentration, financial controls include stock market returns and stock market volatility and macro controls include GDP per capita growth rate, inflation and central banks assets. Clustered (by country) standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: 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***
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)

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 6: 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)

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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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 happen 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 (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. (2020)	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%

Table B: Data definitions and sources

Name	Description	Source
Banking crisis	Dummy variable equal to 1 when banking crisis occurs, 0 otherwise. Laeven and Valencia's database	GFDD
Bank capital to total assets	Ratio of bank capital and reserves to total assets (%)	GFDD
Bank regulatory capital to RWA	Total regulatory capital to RWA (%)	GFDD
Δ5 Credit/GDP	5-year average annual growth rate of the ratio of private credit to GDP (%)	GFDD
Bank net interest margin	Bank's net interest revenue to its interest-bearing assets (%)	GFDD
Bank noninterest income to total income	Bank's income generated by noninterest related activities as a percentage of total income (%)	GFDD
RoA	Return on Assets (%)	GFDD
RoE	Return on Equity (%)	GFDD
Z-score	(RoA+(equity/assets))/(Standard deviation of RoA)	GFDD
Nonperforming loans	Ratio of defaulting loans to total gross loans (%)	GFDD
Bank credit to bank deposits	Ratio of private credit provided by banks to their total deposits. (%)	GFDD
Liquid liabilities to GDP	Ratio of liquid liabilities (broad money, or M3) to GDP (%).	GFDD
Liquid assets to deposits and short-term funding	Ratio of banks' liquid assets to short-term funding plus total deposits (%)	GFDD
Concentration	Ratio of assets of five largest banks to total commercial banking assets	GFDD
Stock market return	Growth rate of annual average stock market index (%)	GFDD
Stock price volatility	Average of the 360-day volatility of the national stock market index	GFDD
Central bank assets	Ratio of central bank assets to GDP (%)	GFDD
GDP Growth	Annual variation of GDP per capita	GFDD
Inflation	Average Consumer Price Index (2010=100)	GFDD

Table C: Sensitivity estimations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Logit					Removing outliers			
Δ_5 Credit/GDP	4.69**	4.87**	21.01***	2.21	10.99**	2.61*	2.49		
	[2.16]	[2.45]	[5.14]	[2.41]	[4.54]	[1.36]	[1.53]		
Bank capital to total assets		-0.34***						-0.20***	
		[0.09]						[0.06]	
Bank regulatory capital to RWA				-0.19**					-0.09**
				[0.08]					[0.04]
Δ_5 Bank capital to total assets			2.66						
			[3.69]						
Δ_5 Bank regulatory capital RWA					-1.99				
					[5.37]				
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	472	428	308	444	325	392	398	392	406
AUC	0.68	0.72	0.80	0.71	0.75	0.70	0.69	0.75	0.72
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)

Note: The Table presents Logit (columns 1 to 5) and Probit models (columns 6 to 9) where the dependent variable is the banking crisis and the regressors are lagged by one period. "_rob" is associated to variables for which we discard the outliers (bottom 5% and top 95%). Country fixed effects are included. Clustered (by country) standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D: Controlling for bank characteristics, financial environment and macroeconomic dynamics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ_5 Credit/GDP	-1.13	-2.64	2.09	0.58	1.70	-0.19	-2.95	-5.02*
	[1.38]	[1.63]	[1.45]	[1.46]	[1.63]	[1.62]	[2.40]	[2.70]
Bank capital to total assets	-0.18***		-0.21***		-0.15***		-0.21***	
	[0.07]		[0.06]		[0.05]		[0.07]	
Bank regulatory capital to RWA		-0.15**		-0.11***		-0.15***		-0.21***
		[0.07]		[0.04]		[0.05]		[0.07]
Bank net interest margin (%)	0.01	0.05					0.32*	0.39***
	[0.15]	[0.12]					[0.17]	[0.15]
Bank noninterest income to total income (%)	-0.03**	-0.02					-0.02	-0.02
	[0.01]	[0.02]					[0.01]	[0.02]
ROA	0.12	0.08					-0.04	-0.01
	[0.18]	[0.18]					[0.14]	[0.19]
ROE	-0.03*	-0.04**					-0.01	-0.02
	[0.02]	[0.02]					[0.01]	[0.02]
Z-score	-0.05*	-0.04					-0.06**	-0.06**
	[0.03]	[0.03]					[0.03]	[0.03]
Nonperforming loans	-0.05	-0.06					-0.03	-0.03
	[0.04]	[0.04]					[0.04]	[0.04]
Bank credit to bank deposits (%)	0.01**	0.01**					0.00*	0.00
	[0.00]	[0.00]					[0.00]	[0.00]
Liquid liabilities to GDP (%)	0.00**	0.00***					0.00**	0.00***
	[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	-0.04***	-0.03***					-0.04***	-0.03**
	[0.01]	[0.01]					[0.01]	[0.01]
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]
Central Banks assets					-0.07*	-0.11**	-0.15**	-0.20**
					[0.04]	[0.04]	[0.07]	[0.08]
GDP Growth					-11.55***	-12.98***	-0.74	-2.95
					[2.89]	[2.67]	[4.58]	[4.37]
Inflation					-0.01	0.01	0.00	0.02
					[0.02]	[0.02]	[0.02]	[0.02]
N	371	386	403	417	410	426	336	349
AUC	0.85	0.86	0.75	0.75	0.78	0.80	0.87	0.88
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)

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, liquid liabilities, liquid assets to deposits, bank non-performing loans, bank credit to bank deposits, ROA, ROE, banking concentration, financial controls include stock market returns and stock market volatility and macro controls include GDP per capita growth rate, inflation and central banks assets. Clustered (by country) standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.