What drives the risk of European banks during the crisis?

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Abstract:

Based on an extensive dataset of 1,156 European banks over the 1995-2015 period, we aim to provide new insights on the determinants of bank risk during crisis events, employing a novel asymmetric Z-score and a methodology which allows the determination of the crisis period endogenously. The results of FE panel model and panel threshold model suggest that coverage liquidity, assets liquidity, funding diversification, efficiency and profitability ratios are the main drivers of European banks' risk. The banks with higher values of these ratios during the crisis period have a lower capitalisation with respect to the distribution of their returns. Moreover, during the crisis as for normal times larger banks are less risky because they are better capitalised with respect to the distribution of their returns.

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1. Introduction

The recent global financial crisis and the subsequent debt crisis (GFC) threatened the solvency of many European banks, some of them having even been liquidated. According to the European Commission, the cost of European bank resolution is very high, amounting to 13.2% of EU GDP during 2008-2015 (Millaruelo and del Río, 2017). But beyond its financial cost, the failure and the vulnerability of banks caused important economic and social impacts.

A better understanding of the determinants of bank risk is therefore needed, especially for policy makers, due to their large involvement on state policy support during the GFC (Gerhardt and Vander Vennet, 2017). A close attention should be given to large banks that, due to implicit state support, are encouraged to take on more risk (Demirgüç-Kunt and Huizinga, 2013), to banks' liquidity, which was at the heart of heightening of the GFC, and to non-interest-generating activities and management quality features, which weakened banks that were highly involved in such activities.

An important contribution to the exiting banking literature is the use of a large dataset on 1,156 European banks over the 1995-2015 period. We therefore provide new insights on determinants of European banks' risk during the recent financial crisis that can be generalised without hindrance, since our database covers nearly entirely all European banking markets.

The only way to consider the risk of such a large database is to apply an accounting-based risk measure. Therefore, our second major contribution to the banking literature is the use of an asymmetric Z-score. Indeed, contrary to most of studies that apply a traditional formula of the Z-score, which is based on the very unrealistic hypothesis of the normal distribution of returns-on-assets random variable, we compute an asymmetric Z-score that accounts for skewness and excess of kurtosis of this random variable. Moreover, we keep the original concept of risk that compute the probability of default of the event when a bank's losses cover entirely its capital. Thus, contrary to the traditional Z-score, we maintain the link between our asymmetric Z-score and the probability of default. This measure, computed according to Lapteacru (2018), also

ensures the comparability of risk data across banks and over time.

Most of the studies on this subject construct a crisis dummy variable to emphasize the crisis period. However, an endogenous framework is more adequate to determine the crisis period, since it describes better the financial instability (Hauben et al., 2004). Our third major contribution is to apply a panel threshold econometric methodology, which allows the determination of the crisis period endogenously. This framework permits to identify any regime shift due to the evolution of the GDP growth and determines thresholds endogenously across countries, instead of imposing a regime changing as in the fixed effects (FE) panel model.

In order to determine the main factors of European banks' risk-taking, we construct an asymmetric Z-score that measures the level of banks' capitalisation with respect to the distribution of their returns, whose methodology is explained in section 2. We then present our database and econometric methodology section 3 and our main results in section 4. Finally, we conclude in section 5.

2. Individual risk of banks

Unlike ratios of loan loss provisions and of impaired loans to total loans and some other asset quality indicators, Z-score is the only accounting-based risk measure that is founded on the risk concept. But, its main shortcoming is the unrealistic assumption of normal distribution of ROA. We therefore apply the novel methodology of Lapteacru (2018) and compute an asymmetric Z-score with the stable distribution instead of the normal one, which allows for better consideration of ROA distributions. Therefore, from the definition of the probability of default and concept of the Z-score:

$$\Pr(ROA \leq COA) = \mathrm{F}_{\mathrm{st}}(-COA; \beta, \alpha, \mu, \sigma), \quad (1)$$

where $\mathrm{F}_{\mathrm{st}}(.)$ denotes the stable cumulative distribution function, β, α, μ and σ are its stability,

skew, location and scale parameters, respectively, and COA is capital-on-assets ratio. With four parameters, instead of two as for the normal distribution, the stable distribution has a quasi-general form and accounts for skewness and excess of kurtosis of the ROA variable, and it becomes a normal distribution for $\beta = 0$. The asymmetric Z-score is therefore computed as:

$$AsZscore = -N^{-1}\left(\mathrm{F}_{\mathrm{st}}(-COA; \beta, \alpha, \mu, \sigma)\right), \quad (2)$$

where $N(.)$ stands for the normal cumulative distribution function.

The main advantage of the stable distribution function is its great flexibility that allows the consideration of most of distribution cases. The difficulty is that it hasn't a general analytical expression for probability distribution and cumulative distribution functions. A random variable is called stable if its characteristic function can be written as $\varphi(t; \beta, \alpha, \mu, \sigma) = \exp\left[it\mu - |\sigma t|^{\beta}(1 - i\alpha \mathrm{sgn}(t)\Phi)\right]$, where

$$\Phi = \begin{cases} \tan\left(\frac{\pi\beta}{2}\right), & if\ \beta \neq 1 \\ -\frac{2}{\pi}\log|t|, & if\ \beta = 1, \end{cases}$$

and $0 < \beta \leq 2$ represents the stability index, $-1 \leq \alpha \leq 1$ the skewness parameter, $\mu \in \mathbb{R}$ the location parameter and $\sigma > 0$ is the scale parameter. The huge advantage of the stable distribution is its quasi-general form that comprises some well-known distributions. For $\beta = 2$, it is transformed into a normal distribution with variance $2\sigma^2$ and expectation μ, and therefore the skewness parameter α has no effect. For $\beta = 1$ and $\alpha = 0$, one obtains Cauchy distribution and for $\beta = 1/2$ and $\alpha = 1$ Lévy distribution, both distributions with scale parameter σ and location parameter μ.

The parameters of this distribution function are estimated for each bank within a ten-year-estimation rolling window. Hence, the estimated distribution functions are different both across banks and across years, which makes our asymmetric Z-score different as well. Because the stable distribution has not an analytical form, we apply an empirical approach in the determination of its parameters for each banks and each year. It consists to find the parameters

that draw the probability distribution function the nearest to the smooth kernel distribution. The latter has a probability density function for a value x that is given by a linearly interpolated version of $\frac{1}{nh}\sum_{i=1}^{n} k\left(\frac{x-x_i}{h}\right)$ for a smoothing kernel $k(x)$ and bandwidth parameter h, where n is the number of observations of the sample composed by x_i values. We consider a Gaussian kernel specification, whose the bandwidth selection method is Silverman's (1998) rule. The optimal choice provided by this rule is $h = (4\hat{\sigma}^5/3n)^{\frac{1}{5}}$, where $\hat{\sigma}$ is the standard deviation of the sample.

3. Data and empirical methodology

To determine the factors of European banks' risk during the recent financial crisis, we employ an extensive dataset on 1,314 European banks from 28 European countries. We winsorized data at 1% level and, to have a balanced panel necessary for panel threshold model and we excluded banks with missing data over the period 1995-2015. The final sample of 1,156 banks and 24,276 bank-year data, breakdowned across countries, and some descriptive statistics are presented in Table 2 and our variables are defined and explained in Table 1.

For robustness, we employ two different methodologies. In the first stage, we run a fixed effect (FE) panel model, with bank fixed effects ν_i and time fixed effects π_t:

$$AsZscore_{i,j,t} = \alpha_0 + \sum_{k=1}^{n} \alpha_k X_{k,i,j,t} + \sum_{l=n+1}^{m} \alpha_l Y_{l,j,t} + \nu_i + \pi_t + \varepsilon_{i,j,t}, \quad (3)$$

where n is the number of bank-specific variables (n=7), m-n is the number of country-specific variables (m=10), $X_{k,i,j,t}$ is the k-th bank-specific factor, which is checked to be a determinant of a bank i's risk at year t in country j, and $Y_{l,j,t}$ is the l-th country-specific factor of country j at year t. Standard errors $\varepsilon_{i,j,t}$ are robust to heteroscedasticity.

As determinants of European banks' risk, we examine bank liquidity factors (Coverage liquidity and Assets liquidity, bank Efficiency and Profitability factors and bank diversification

policies expressed by Income diversification and Funding diversification. The risk can also vary with size, expressed by the natural logarithm of banks' assets. To control for macroeconomic and regulatory environment, we consider a banking regulation index, constructed according to Lapteacru (2018), the stock exchange return, and the real GDP growth.

Table 1. Definition and sources of risk measures and explanatory variables.

Variable	Definition	Data source
Dependent variable		
AsZscore	Asymmetric Z-score measure estimated according to the methodology explained in section 2 and with equation (2). It indicates the level of a bank's capitalisation with respect to the distributions of its returns. Higher AsZscore means lower risk.	Bankscope and authors' computations
Bank risk factors		
Coverage liquidity	Total loans to total deposits ratio	Bankscope and authors' computations
Assets liquidity	Liquid assets to total assets ratio. As liquid assets we considered loans and advances to banks and other securities.	Bankscope and authors' computations
Efficiency	Cost to income ratio.	Bankscope and authors' computations
Profitability	Net interest margin to earning assets ratio.	Bankscope and authors' computations
Income diversification	The share of non-interest income in operating income.	Bankscope and authors' computations
Funding diversification	The share of non-deposit, short-term funding in total deposits and short-term funding.	Bankscope and authors' computations
Size	Natural logarithm of total assets.	Bankscope and authors' computations
Macroeconomic and regulatory environment		
Regulation index	The index is constructed as explained in Appendix A. It takes values between zero and one, and environments in which laws are enforced to a greater extent and are closer to Basel requirements correspond to values that are closer to one.	Barth, Caprio and Levine's database and authors' computations
Stock exchange return	The return of stock exchange indexes of all 28 European countries of our sample.	Datastream
GDP growth	The annual growth rate of the real gross domestic product.	Datastream

Note: This table defines our variables and provides sources of data.

Table 2. Sample of countries and banks. Descriptive statistics for the period 1995-2015.

Country	Nr. of banks	AsZscore	Coverage liquidity	Assets liquidity	Efficiency	Profitability	Income diversification	Funding diversification	Size	Regulation index	Stock exchange return	GDP growth
Austria	74	6.223	0.695	0.386	0.621	0.022	0.349	0.250	6.800	0.495	0.072	0.018
Belgium	19	5.254	0.527	0.506	0.495	0.020	0.311	0.304	9.305	0.509	0.067	0.028
Bulgaria	15	5.984	0.706	0.318	0.603	0.044	0.385	0.186	6.205	0.510	0.164	0.033
Croatia	15	4.871	0.908	0.307	0.611	0.040	0.381	0.157	6.708	0.487	0.070	0.037
Cyprus	7	4.690	0.784	0.354	0.555	0.029	0.390	0.198	7.725	0.446	-0.002	0.025
Czech Rep.	9	4.606	0.635	0.443	0.723	0.033	0.388	0.266	8.215	0.727	0.061	0.027
Denmark	57	5.861	0.744	0.387	0.612	0.039	0.334	0.161	6.541	0.429	0.125	0.015
Estonia	4	2.803	0.680	0.289	0.556	0.036	0.430	0.219	6.349	0.408	0.160	0.044
Finland	7	6.321	0.927	0.304	0.547	0.017	0.437	0.396	9.136	0.323	0.153	0.022
France	90	5.904	0.677	0.412	0.629	0.025	0.433	0.363	8.055	0.446	0.056	0.016
Germany	504	6.967	0.663	0.395	0.593	0.024	0.264	0.258	7.537	0.383	0.103	0.014
Greece	7	4.001	0.756	0.353	0.516	0.028	0.330	0.262	9.676	0.479	0.081	0.009
Hungary	13	4.840	0.692	0392	0.585	0.038	0.437	0.406	7.755	0.655	0.207	0.022
Ireland	2	5.646	1.047	0.418	0.341	0.013	0.398	0.566	9.669	0.443	0.091	0.060
Italy	100	6.455	1.030	0.332	0.608	0.029	0.580	0.290	8.019	0.429	0.038	0.006
Latvia	10	3.989	0.518	0.376	0.571	0.034	0.512	0.176	5.897	0.438	0.104	0.040
Lithuania	8	2.844	0.743	0.286	0.697	0.034	0.452	0.278	6.268	0.478	0.135	0.063
Luxembourg	47	6.302	0.331	0.682	0.459	0.009	0.500	0.452	8.258	0.487	0.014	0.045
Malta	4	7.269	0.553	0.432	0.510	0.024	0.261	0.057	7.379	0.545	0.113	0.047
Netherlands	11	5.888	1.238	0.319	0.456	0.016	0.333	0.360	9.171	0.319	0.069	0.020
Poland	23	6.413	0.719	0.395	0.615	0.036	0.413	0.334	7.791	0.487	0.117	0.042
Portugal	13	5.184	0.833	0.331	0.512	0.019	0.479	0.453	8.739	0.492	0.041	0.013
Romania	20	4.707	0.688	0.264	0.800	0.076	0.387	0.262	6.444	0.538	0.200	0.030
Slovakia	13	4.294	0.743	0.450	0.652	0.032	0.371	0.242	7.327	0.590	0.081	0.042
Slovenia	11	5.130	0.849	0.326	0.446	0.031	0.409	0.223	7.354	0.600	0.003	0.028
Spain	31	5.968	0.713	0.411	0.637	0.021	0.374	0.360	8.887	0.522	0.078	0.022
Sweden	9	5.554	0.938	0.269	0.575	0.028	0.382	0.248	9.591	0.338	0.117	0.026
UK	33	5.613	0.547	0.504	0.568	0.018	0.383	0.447	8.978	0.319	0.044	0.022
All countries												
Mean	1,156	6.290	0.704	0.398	0.594	0.026	0.354	0.284	7.665	0.430	0.087	0.019
Std:		2.340	0.379	0.232	0.325	0.018	0.281	0.239	1.796	0.083	0.262	0.030

Note: This table details our sample of 28 European countries and provides several descriptive statistics. AsZscore is our asymmetric Z-score computed with the methodology explained in Section 2, Coverage liquidity is the ratio of gross loans to deposits and short-term funding, Assets liquidity is the ratio of Loans and advances to banks and other securities to Total assets, Efficiency is the ratio of Total cost to Total income, Profitability is the ratio of Net interest revenues on Total earning assets, Income diversification is the ratio of Non-interest income to Total operating income, Funding diversification is the ratio of non-deposit, short-term funding to total deposits and short-term funding, Size is the natural logarithm of total assets, Regulation index is the regulation index of the banking industry constructed according to the methodology explained in Appendix A, Stock exchange return is the return of stock exchange index, GDP growth is the real growth of Gross Domestic Product.

To determine the risk factors during the crisis, we construct a Crisis dummy variable that takes the value of 1 if GDP growth is lower than 0.4% and 0, otherwise. This threshold corresponds to the average GDP growth in 2008 across advanced European countries, where the GFC occurred firstly.

We apply then a panel threshold model that permits to identify any regime shift due to the evolution of the GDP growth. It identifies changes in coefficients of the main regressors and determines thresholds endogenously, instead of imposing a regime changing as in the FE panel model. Following the methodology of Hansen (1999), our model is based on one threshold, *i.e.* two identified regimes (normal and crisis periods), taking the following form:

$$AsZscore_{i,j,t} = \delta_1 \mathbf{I}\left(GDPgrowth_{j,t} \leq \gamma\right) + \lambda_1 X^*_{i,j,t} \mathbf{I}\left(GDPgrowth_{j,t} \leq \gamma\right)$$
$$+\lambda_2 X^*_{i,j,t} \mathbf{I}\left(GDPgrowth_{j,t} > \gamma\right) + \sum_{k=1}^{n-1} \alpha_k X_{k,i,j,t} + \sum_{l=n+1}^{m} \alpha_l Y_{l,j,t}$$
$$+\nu_i + \pi_t + \varepsilon_{i,j,t}, \qquad (4)$$

where $\mathbf{I}(.)$ stands for the indicator function suggesting the regime specified by the threshold variable $GDPgrowth_{j,t}$ and γ is its threshold. $X^*_{i,j,t}$ is the regime-dependent variable and the coefficient λ_1 denotes its effect when the GDP growth is below the regime-changing threshold γ, *i.e.* during the GFC, while λ_2 denotes its effect when the GDP growth exceeds the threshold γ, *i.e.* during the normal period.

4. Results

4.1. Basic results with FE model

We apply a panel fixed effects model (Table 3) and a panel threshold model (Table 4) and run two different regressions. For each regression and each model, we find that all bank specific factors have a differential effect on European banks' riskiness in normal and crisis periods.

All results show that the main determinants of European banks' risk during the GFC are Coverage liquidity, Assets liquidity, Efficiency, Profitability, Income diversification and Funding diversification variables. Banks that have higher Coverage liquidity ratio, assets liquidity and Funding diversification ratios are riskier in normal times, corresponding to the results of López-Espinosa et al. (2013). The first result (coefficient -0.184, with FE panel model, and -0.184, with panel threshold model) refers to lending coverage effect. The negative effect of Assets liquidity ratio (coefficient -0.209, with FE model, Table 3, and -0.206, with threshold model, coefficient λ_2 in Table 4) may be explained by a higher involvement of riskier banks into the money market. The effect of Funding diversification ratio refers to "the dark side" of bank funding effect, explained by Huang and Ratnovski (2011). Being not covered by any insurance scheme, interbank funding can have a disciplinary effect (Calomiris, 1999; Calomiris and Kahn, 1991) and refinance unexpected retail withdrawals (Goodfriend and King, 1998), which would reduce the risk of banks. However, in an environment with a costless but noisy public signal on bank project quality, banks may have lower incentives to conduct costly monitoring of other banks and may withdraw based on negative public signals, amplifying the risk of borrowed banks (Huang and Ratnovski, 2011), which can explain the negative relationship between non-interest funding and riskiness of European banks (coefficient -0.750, with FE model, and -0.764, with threshold model).

During the GFC, these effects are amplified. The Wald test for the FE panel model shows that the crisis effect coefficient becomes -0.386 for Coverage liquidity ratio, -0.514 for Assets liquidity ratio and -1.308 for Funding diversification ratio (Table 3), and it is -0.636, -8.19 and -1.496, respectively, with the panel threshold model (coefficient λ_1 in Table 4). The amplification is important in terms of European banks' (in)solvency. For instance, for banks with a 10% probability of default (from Eq.2, $AsZscore_{mean} = 1.28$), an increase of one standard deviation in the Coverage liquidity ratio is associated with a decrease of 0.07 (-0.198×0.379, Table 3) points ($\Delta AsZscore = -0.07$), on average, in the asymmetric Z-score,

Table 3. Determinants of European banks' risk, using a FE panel model.

Variables	Coverage liquidity		Assets liquidity		Efficiency		Profitability		Income diversification		Funding diversification		Size	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Bank factors														
Coverage liquidity	**-0.198*** **	**-0.184*** **	-0.227***	-0.209***	-0.228***	-0.211***	-0.228***	-0.211***	-0.228***	-0.211***	-0.238***	-0.220***	-0.224***	-0.207***
	(0.052)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)
Crisis×Coverage liquidity	**-0.229*** **	**-0.201*** **												
	(0.041)	(0.043)												
Assets liquidity	-0.272***	-0.258***	**-0.175*** **	**-0.164** **	-0.265***	-0.251***	-0.258***	-0.247***	-0.267***	-0.253***	-0.263***	-0.249***	-0.269***	-0.254***
	(0.064)	(0.064)	(0.069)	(0.069)	(0.064)	(0.064)	(0.064)	(0.065)	(0.064)	(0.064)	(0.064)	(0.065)	(0.064)	(0.064)
Crisis×Assets liquidity			**-0.361*** **	**-0.350*** **										
			(0.073)	(0.077)										
Efficiency	-0.060	-0.071*	-0.062	-0.074*	**-0.036**	**-0.060**	-0.060	-0.071*	-0.062	-0.072*	-0.064*	-0.076*	-0.060	-0.073*
	(0.040)	(0.040)	(0.040)	(0.040)	(0.043)	(0.042)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
Crisis×Efficiency					**-0.077**	**-0.035**								
					(0.050)	(0.053)								
Profitability	1.817*	1.713*	2.026**	1.925**	1.810*	1.735*	**2.851*** **	**2.444** **	1.941**	1.838*	2.024**	1.908**	2.105**	1.934**
	(0.998)	(1.004)	(1.000)	(1.005)	(1.003)	(1.007)	(1.033)	(1.039)	(1.015)	(1.018)	(0.999)	(1.004)	(0.996)	(1.002)
Crisis×Profitability							**-3.257** **	**-2.263** **						
							(0.995)	(1.073)						
Income diversification	-0.006**	-0.006**	-0.006**	-0.006**	-0.006**	-0.006**	-0.006**	-0.006**	**0.081**	**0.049**	-0.006**	-0.006**	-0.006**	-0.006**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.052)	(0.053)	(0.003)	(0.003)	(0.003)	(0.003)
Crisis×Income diversification									**-0.088***	**-0.055**				
									(0.052)	(0.053)				
Funding diversification	-0.891***	-0.848***	-0.900***	-0.853***	-0.909***	-0.867***	-0.900***	-0.859***	-0.910***	-0.866***	**-0.793*** **	**-0.750*** **	-0.872***	-0.825***
	(0.093)	(0.093)	(0.093)	(0.093)	(0.093)	(0.092)	(0.093)	(0.093)	(0.093)	(0.093)	(0.094)	(0.094)	(0.093)	(0.093)
Crisis×Funding Diversification											**-0.576*** **	**-0.558*** **		
											(0.090)	(0.094)		
Size	0.176***	0.158***	0.173***	0.155***	0.171***	0.156***	0.174***	0.156***	0.174***	0.158***	0.177***	0.158***	**0.187*** **	**0.165*** **
	(0.026)	(0.027)	(0.026)	(0.027)	(0.026)	(0.027)	(0.026)	(0.027)	(0.027)	(0.027)	(0.026)	(0.027)	(0.026)	(0.027)
Crisis×Size													**-0.035*** **	**-0.036*** **
													(0.005)	(0.005)
Macroeconomic and regulatory environment														
Regulation index		2.131***		2.192***		2.095***		2.113***		2.095***		2.184***		2.238***
		(0.254)		(0.255)		(0.255)		(0.254)		(0.255)		(0.254)		(0.255)
Stock exchange return		0.159**		0.164**		0.202***		0.179***		0.204***		0.158**		0.120*
		(0.071)		(0.070)		(0.071)		(0.072)		(0.071)		(0.071)		(0.071)
GDP growth		0.930*		0.972**		1.424***		1.165**		1.413***		0.815*		0.428
		(0.517)		(0.515)		(0.518)		(0.005)		(0.511)		(0.514)		(0.520)
Constant	6.008***	5.008***	6.017***	4.977***	6.067***	5.051***	6.017***	5.021***	6.046***	5.032***	5.962***	4.941***	5.930***	4.911***
	(0.415)	(0.429)	(0.416)	(0.431)	(0.417)	(0.431)	(0.417)	(0.431)	(0.419)	(0.433)	(0.411)	(0.426)	(0.413)	(0.428)

Variables	**Coverage liquidity**		**Assets liquidity**		**Efficiency**		**Profitability**		**Income diversification**		**Funding diversification**		**Size**	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Some statistics														
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.561	0.563	0.561	0.563	0.561	0.562	0.561	0.563	0.561	0.562	0.561	0.563	0.562	0.563
Number of banks	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156
Observations	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276
Crisis effect: Wald test														
Coverage liquidity	**-0.426*** **	**-0.386*** **												
Assets liquidity			**-0.536*** **	**-0.514*** **										
Efficiency					**-0.112** **	**-0.095***								
Profitability							**-0.406**	**0.182**						
Income diversification									**-0.007** **	**-0.007** **				
Funding diversification											**-1.370*** **	**-1.308*** **		
Size													**0.151*** **	**0.129*** **

Note: This table provides the regression results of determinants of European banks' risk using a panel fixed effects model. Bank and time fixed effects are considered but not reported. Heteroscedastic robust standard errors are in parentheses. ***, ** and * represent statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

which increases by only 1.3% their probability of default ($\Delta Pd = N\big(-(AsZscore_{mean} + \Delta AsZscore)\big) - N(-AsZscore_{mean}) = 0.013$). But during the GFC, the same banks undergoes a decrease by 0.15 (-0.426×0.379) in their Z-score, which means an increase by 2.9% of their probability of default. As consequences of their involvement in interbank and money market, the impact is even more important: the increase of their probability passes from 3.6 to 6.5%, due to one standard deviation increase of their funding diversification ratio, and from 0.8 to 2.4%, due to one standard deviation increase of assets liquidity ratio.

4.2. The results with panel threshold model

The results do not change when taking into account macroeconomic and regulatory variables (model (2)) and when using the panel threshold model (Table 4). For the latter regressions, all thresholds of GDP growth, which indicate the change in the evolution of the regime-dependent variable, correspond to the beginning of the GFC (Figure 1). Even the average level of 0.03 and 0.028 (model (2) with Efficiency and Profitability ratios, respectively, as regime-dependent variable) lies between the level of 2007, with average GDP growth of 3.65%, and the level of 2008, with average GDP growth of 0.94%.

Income diversification, Efficiency and Profitability variables also have a differential effect. The diversification of bank activities can reduce the risk of banks in two ways. First, combining different types of activities enables the collection of more information about banks' customers and thus the reduction of their default risk (Diamond, 1991; Rajan, 1992). Second, the income diversification may lead to risk diversification and therefore to bank stability (Berger et al., 1999; Campa and Kedia, 2002). On the other hand, if diversification causes co-movements of the risky incomes with more volatile non-interest income, it leads to riskier, more volatile activities (Demirgüç-Kunt and Huizinga, 2010; Stiroh and Rumble, 2006). This opposite effect neutralizes the global impact during the normal period. However, our results

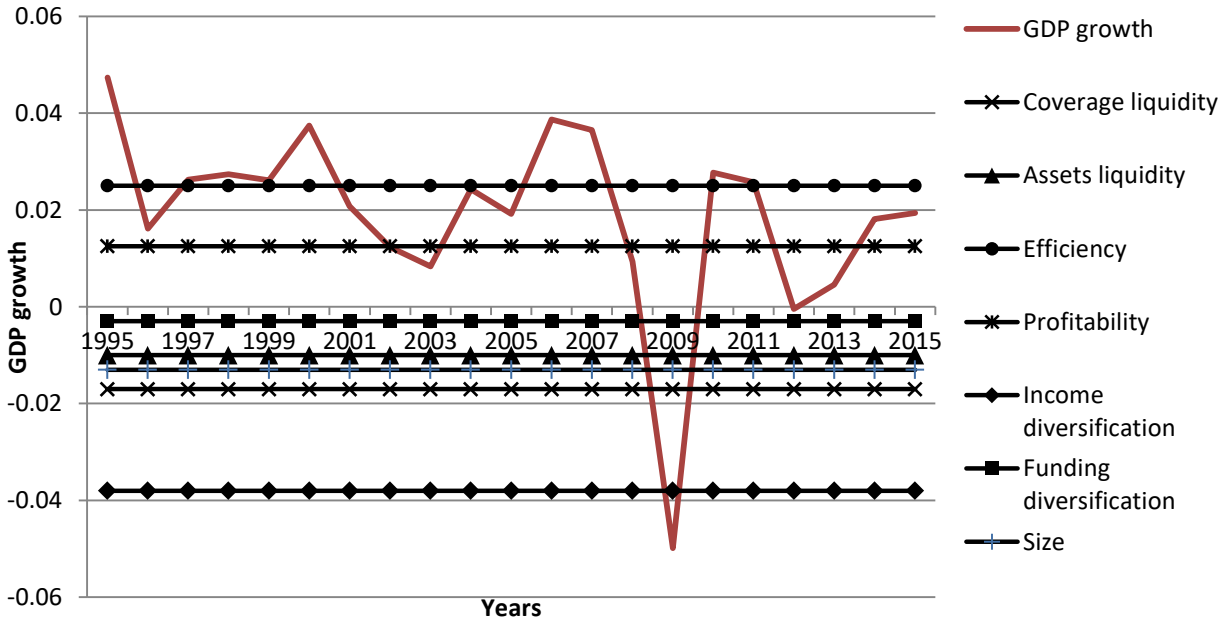
Table 4. Determinants of European banks' risk, using a panel threshold model.

Variables	**Coverage liquidity**		**Assets liquidity**		**Efficiency**		**Profitability**		**Income diversification**		**Funding diversification**		**Size**	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
γ, threshold estimate	-0.017***	-0.017***	-0.010***	-0.010***	-0.003	0.030**	-0.003***	0.028***	-0.038***	-0.038***	-0.003***	-0.003***	-0.009***	-0.017***
95% confidence interval	[-0.023 ; -0.013]	[-0.023 ; -0.013]	[-0.013 ; -0.009]	[-0.013 ; -0.009]	[-0.006 ; 0.000]	[0.051 ; 0.054]	[-0.008 ; 0.000]	[0.027 ; 0.029]	[-0.043 ; -0.035]	[-0.043 ; -0.035]	[-0.004 ; 0.000]	[-0.004 ; 0.000]	[-0.012 ; -0.007]	[-0.029 ; -0.013]
Regime-dependent coefficients														
λ_1, below the threshold	**-0.702*** (0.088)**	**-0.636*** (0.089)**	**-0.867*** (0.138)**	**-0.819*** (0.140)**	**-0.186*** (0.068)**	**-0.354*** (0.090)**	**-1.733 (1.230)**	**-0.866 (1.075)**	**-0.878*** (0.188)**	**-0.734*** (0.192)**	**-1.584*** (0.130)**	**-1.496*** (0.133)**	**0.111*** (0.024)**	**0.072*** (0.025)**
λ_2, above the threshold	**-0.198*** (0.049)**	**-0.184*** (0.049)**	**-0.216*** (0.069)**	**-0.206*** (0.069)**	**-0.046 (0.038)**	**0.004** (0.041)	**2.999*** (0.984)**	**3.367*** (0.998)**	**-0.006* (0.004)**	**-0.006* (0.003)**	**-0.803*** (0.093)**	**-0.764*** (0.093)**	**0.184*** (0.023)**	**0.161*** (0.023)**
Regime-independent coefficients														
Bank risk factors														
Coverage liquidity			-0.236*** (0.049)	-0.218*** (0.049)	-0.229*** (0.049)	-0.215*** (0.049)	-0.230*** (0.049)	-0.226*** (0.049)	-0.234*** (0.049)	-0.209*** (0.049)	-0.235*** (0.049)	-0.217*** (0.049)	-0.217*** (0.049)	-0.208*** (0.049)
Assets liquidity	-0.272*** (0.068)	-0.258*** (0.068)			-0.266*** (0.068)	-0.258*** (0.068)	-0.264*** (0.068)	-0.255*** (0.068)	-0.264*** (0.068)	-0.252*** (0.068)	-0.269*** (0.068)	-0.255*** (0.068)	-0.261*** (0.068)	-0.255*** (0.068)
Efficiency	-0.063* (0.037)	-0.073** (0.037)	-0.066* (0.037)	-0.075** (0.037)			-0.062* (0.037)	-0.079** (0.037)	-0.063* (0.037)	-0.074** (0.037)	-0.067* (0.037)	-0.077** (0.037)	-0.069* (0.037)	-0.079** (0.037)
Profitability	1.652* (0.935)	1.622* (0.936)	1.864** (0.936)	1.819** (0.937)	1.780** (0.937)	1.655* (0.937)			1.657* (0.935)	1.556* (0.937)	1.936** (0.935)	1.817** (0.936)	2.050** (0.934)	1.902** (0.936)
Income diversification	-0.007* (0.004)	-0.006* (0.004)	-0.007* (0.004)	-0.007* (0.004)	-0.007* (0.004)	-0.007* (0.004)	-0.006* (0.004)	-0.006* (0.004)			-0.007* (0.004)	-0.007* (0.004)	-0.007* (0.003)	-0.007* (0.004)
Funding diversification	-0.900*** (0.091)	-0.855*** (0.091)	-0.909*** (0.092)	-0.861*** (0.092)	-0.912*** (0.091)	-0.863*** (0.092)	-0.900*** (0.091)	-0.866*** (0.091)	-0.911*** (0.091)	-0.865*** (0.091)			-0.875*** (0.091)	-0.827*** (0.091)
Size	0.173*** (0.023)	0.156*** (0.024)	0.170*** (0.023)	0.154*** (0.023)	0.169*** (0.023)	0.151*** (0.023)	0.172*** (0.023)	0.142*** (0.024)	0.165*** (0.023)	0.159*** (0.023)	0.175*** (0.023)	0.156*** (0.024)		
Macroeconomic and regulatory environment														
Regulation index		2.043*** (0.252)		2.107*** (0.252)		2.096*** (0.252)		2.093*** (0.252)		2.075*** (0.252)		2.134*** (0.252)		2.052*** (0.251)
Stock exchange return		0.208*** (0.068)		0.211*** (0.068)		0.225*** (0.068)		0.230*** (0.068)		0.195*** (0.068)		0.158** (0.068)		0.211*** (0.068)
GDP growth		0.929* (0.525)		0.995** (0.527)		2.307*** (0.567)		2.590*** (0.563)		2.467*** (0.577)		0.762 (0.528)		0.383 (0.533)
Constant	5.790*** (0.193)	5.014*** (0.216)	5.808*** (0.193)	5.000*** (0.216)	5.821*** (0.193)	5.008*** (0.216)	5.763*** (0.194)	5.056*** (0.217)	5.865*** (0.193)	4.956*** (0.217)	5.762*** (0.193)	4.974*** (0.216)	5.697*** (0.193)	5.002*** (0.216)
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of banks	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156
Observations	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276

Note: This table provides the regression results of determinants of European banks' risk using a panel threshold model. GDP growth is also the threshold variable and bank specific factors are successively the regime-dependent variable. γ is the threshold level of the GDP growth variable estimated endogenously by the model. The coefficients related to λ_1 correspond to effects during the GFC and those related to λ_2 to the effects during the normal period. Bank and time fixed effects are considered but not reported. Heteroscedastic robust standard errors are in parentheses. ***, ** and * represent statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

with the panel threshold model suggest a high negative effect during the GFC (coefficient λ_1 in Table 4). The involvement of European banks in non-interest-income-generating activities is associated with weaker capitalisation with respect to the distribution of their returns. In terms of (in)solvency impact, banks with a 10% probability of default undergo an increase by 5.2% of their insolvency if they raise their non-interest income-to-operating income ratio by one standard deviation.

Figure 1. Evolution of the average GDP growth over time and threshold levels of GDP growth in estimations with bank factors as regime-dependent variables.



Note: This figure shows the evolution of the GDP growth variable over the period 1995-2015 and its threshold levels in estimations with panel threshold model where the regime-dependent variable is one of the driving factors of European banks' risk during the GFC.

As for management quality factors, only reducing the cost-to-income ratio allows banks to improve their risk profile during the crisis and hence to need less government support (Gerhardt and Vander Vennet, 2017). Both methodologies and models suggest this risk-reducing effect and no impact during the normal period. The beneficial effect of having high net-interest margin during the normal period disappears during the crisis and the Profitability ratio is not more a risk-reducing factor. As in Lapteacru (2018), Sanya and Wolfe (2011) and

Stiroh and Rumble (2006), we find that large banks are less risky, likely because of more opportunities and more information on their projects and because of 'too-big-to-fail' guarantees.

Controlling for macroeconomic and regulatory environment keeps our results unchanged, in terms of both economic and statistical significances. In countries and periods with tighter banking regulation and higher stock exchange returns and economic growth banks are better capitalised with respect to the distribution of their returns.

4.3. Checking for the sample-oriented results

Our sample is composed of approximately of all banks of 28 EU member states and, consequently, the German banks have the most part; more precisely, 504 banks and 10,584 bank-year observations. We hence may wonder about the fact that our result may be sample-oriented. We thus decided to run regressions without German banks and check whether the results always hold. The regressions with panel threshold model (Table 5) show that the results remain unchanged with only one exception regarding the size as risk factor of EU banks. Without German banks, the size of banks of other European countries has no more role during the GFC, the coefficient λ_1 becoming nonsignificant, and its role is diminished during normal times, the coefficient λ_2 becoming lower (Table 5).

4.4. Is there a difference between regions?

Another important point is the difference in risk-taking behaviour between Western European banks and Eastern European banks and their risk profile. One may suppose that the former have, in general, a better risk profile since they own better risk valuation and management techniques. Moreover, the Eastern European banks were urged to carry out risky activities without being really ready to hedge their risk. This is why we decided to analyse the found effects splitting the sample between Advanced Europe and Emerging Europe.

Table 5. Determinants of European banks' risk, using a panel threshold model: without Germany.

Variables	**Coverage liquidity**		**Assets liquidity**		**Efficiency**		**Profitability**		**Income diversification**		**Funding diversification**		**Size**	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
γ, threshold estimate	-0.001***	-0.017***	-0.010***	-0.010***	-0.003	0.030**	-0.001***	0.028***	-0.031***	-0.038***	-0.001***	-0.001***	-0.001***	-0.029***
95% confidence interval	[-0.004 ; 0.000]	[-0.024 ; -0.016]	[-0.013 ; -0.009]	[-0.013 ; -0.009]	[-0.018 ; -0.001]	[0.051 ; 0.055]	[-0.004 ; 0.000]	[0.027 ; 0.029]	[-0.039 ; -0.029]	[-0.043 ; -0.035]	[-0.004 ; 0.000]	[-0.004 ; 0.000]	[-0.004 ; 0.000]	[-0.031 ; -0.023]
Regime-dependent coefficients														
λ_1, below the threshold	**-0.681*** (0.075)**	**-0.715*** (0.097)**	**-0.922*** (0.153)**	**-0.812*** (0.155)**	**-0.153* (0.081)**	**-0.395*** (0.095)**	**-1.635 (1.292)**	**-2.319* (1.411)**	**-1.052*** (0.205)**	**-0.783*** (0.190)**	**-1.743*** (0.150)**	**-1.555*** (0.153)**	**-0.012 (0.029)**	**-0.019 (0.031)**
λ_2, above the threshold	**-0.273*** (0.054)**	**-0.267*** (0.263)**	**-0.170** (0.078)**	**-0.169*** (0.078)**	**-0.023 (0.043)**	-0.028 (0.042)	**3.636*** (1.067)**	**3.013*** (1.039)**	**-0.006* (0.004)**	-0.006* (0.004)	**-0.637*** (0.107)**	**-0.601*** (0.107)**	**0.057** (0.028)**	**0.053* (0.028)**
Regime-independent coefficients														
Bank risk factors														
Coverage liquidity			-0.324*** (0.053)	-0.302*** (0.053)	-0.315*** (0.053)	-0.302*** (0.053)	-0.315*** (0.053)	-0.295*** (0.053)	-0.318*** (0.053)	-0.296*** (0.053)	-0.330*** (0.053)	0.307*** (0.053)	-0.314*** (0.053)	-0.291*** (0.053)
Assets liquidity	-0.239*** (0.077)	-0.229*** (0.077)			-0.234*** (0.077)	-0.232*** (0.077)	-0.218*** (0.077)	-0.237*** (0.077)	-0.233*** (0.077)	-0.222*** (0.077)	-0.217*** (0.077)	-0.211*** (0.076)	-0.226*** (0.077)	-0.227*** (0.077)
Efficiency	-0.040 (0.042)	-0.047 (0.041)	-0.045 (0.042)	-0.049 (0.042)			-0.039 (0.042)	-0.047 (0.041)	-0.038 (0.042)	-0.049 (0.041)	-0.048 (0.042)	-0.051 (0.042)	-0.047 (0.042)	-0.049 (0.041)
Profitability	2.137** (0.998)	1.758* (0.998)	2.182** (0.999)	1.955** (0.999)	2.036** (1.000)	1.759* (0.999)			1.943** (0.998)	1.645* (0.999)	2.443*** (0.998)	2.143** (0.998)	2.582*** (0.998)	1.868* (0.998)
Income diversification	-0.007* (0.004)	-0.007* (0.004)	-0.007* (0.004)	-0.007* (0.004)	-0.007* (0.004)	-0.007* (0.004)	-0.007* (0.004)	-0.006* (0.004)			-0.007* (0.004)	-0.007* (0.004)	-0.007* (0.003)	-0.007* (0.004)
Funding diversification	-0.786*** (0.105)	-0.735*** (0.105)	-0.804*** (0.105)	-0.741*** (0.105)	-0.813*** (0.105)	-0.739*** (0.105)	-0.793*** (0.106)	-0.731*** (0.105)	-0.807*** (0.105)	-0.742*** (0.105)			-0.752*** (0.105)	-0.739*** (0.105)
Size	0.051* (0.028)	0.049* (0.028)	0.053* (0.028)	0.046* (0.028)	0.054* (0.028)	0.040 (0.028)	0.056** (0.028)	0.039 (0.028)	0.052* (0.028)	0.052* (0.028)	0.050* (0.028)	0.043 (0.028)		
Macroeconomic and regulatory environment														
Regulation index		2.306*** (0.277)		2.365*** (0.277)		2.378*** (0.277)		2.364*** (0.277)		2.356*** (0.277)		2.259*** (0.277)		2.324*** (0.277)
Stock exchange return		0.083 (0.076)		0.084 (0.076)		0.101 (0.077)		0.108 (0.076)		0.067 (0.076)		0.061 (0.076)		0.064 (0.076)
GDP growth		1.790*** (0.583)		1.853*** (0.585)		3.446*** (0.630)		3.303*** (0.615)		3.558*** (0.642)		1.367** (0.589)		1.615*** (0.589)
Constant	5.898*** (0.232)	4.761*** (0.263)	5.888*** (0.232)	4.744*** (0.264)	5.897*** (0.232)	4.752*** (0.263)	5.828*** (0.233)	4.740*** (0.263)	5.925*** (0.232)	4.670*** (0.263)	5.873*** (0.232)	4.815*** (0.263)	5.857*** (0.231)	4.746*** (0.263)
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of banks	652	652	652	652	652	652	652	652	652	652	652	652	652	652
Observations	13,692	13,692	13,692	13,692	13,692	13,692	13,692	13,692	13,692	13,692	13,692	13,692	13,692	13,692

Note: This table provides the regression results of determinants of European banks' risk using a panel threshold model. GDP growth is also the threshold variable and bank specific factors are successively the regime-dependent variable. γ is the threshold level of the GDP growth variable estimated endogenously by the model. The coefficients related to λ_1 correspond to effects during the GFC and those related to λ_2 to the effects during the normal period. Bank and time fixed effects are considered but not reported. Heteroscedastic robust standard errors are in parentheses. ***, ** and * represent statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

The results presented in Table 6 clearly show that our findings are mostly driven by the behaviour of Western European banks. The thresholds and the impact of our bank risk factors are almost the same. As for Eastern banks, many thresholds and effects are not more significant.

5. Conclusions

Applying an extensive dataset on European banks, we find that the main determinants of their risk during the GFC are Coverage liquidity, Assets liquidity, Efficiency, Profitability, Income diversification and Funding diversification ratios. Even though banks with these higher ratios are also less capitalised with respect to the distribution of their returns, this risk-enhancing effect is amplified during the GFC and these effects are mostly driven by Western European banks.

Table 6. Determinants of European banks' risk with a panel threshold model: Estimations on two European regions.

Variables	Coverage liquidity		Assets liquidity		Efficiency		Profitability		Income diversification		Funding diversification		Size	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Panel A: Advanced Europe														
γ, threshold estimate	-0.017***	-0.017***	-0.011***	-0.011***	0.020	0.020**	0.027**	0.028***	-0.036**	-0.036	-0.010***	-0.010**	-0.029***	-0.029***
λ_1, below the threshold	-0.818***	-0.755***	-0.983***	-0.904***	0.092*	0.109**	5.491***	6.115***	-0.769***	-0.566***	-1.460***	-1.365***	-0.047	-0.036
	(0.097)	(0.098)	(0.155)	(0.157)	(0.055)	(0.055)	(1.492)	(1.501)	(0.229)	(0.232)	(0.164)	(0.166)	(0.030)	(0.031)
λ_2, above the threshold	-0.317***	-0.304***	-0.357***	-0.358***	-0.074	-0.137**	-0.103	-1.445	-0.006*	-0.006*	-0.670***	-0.660***	0.048*	0.048*
	(0.057)	(0.057)	(0.085)	(0.085)	(0.059)	(0.060)	(1.637)	(1.651)	(0.004)	(0.004)	(0.102)	(0.102)	(0.028)	(0.028)
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Number of banks	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015
Observations	21,315	21,315	21,315	21,315	21,315	21,315	21,315	21,315	21,315	21,315	21,315	21,315	21,315	21,315
Panel B: Emerging Europe														
γ, threshold estimate	0.012	0.108	0.012	0.108	-0.054	0.108	-0.059	-0.059	0.026*	-0.003*	0.013***	0.016*	0.012**	0.108*
λ_1, below the threshold	-0.279*	0.173	-0.249	0.040	-0.919***	-0.126**	-4.722	-3.950	-0.712***	-0.998***	-1.723***	-1.498***	0.255***	0.270***
	(0.167)	(0.121)	(0.190)	(0.128)	(0.324)	(0.058)	(3.185)	(3.202)	(0.211)	(0.292)	(0.292)	(0.291)	(0.065)	(0.063)
λ_2, above the threshold	0.030	-0.235	0.134	-1.491**	-0.128**	-0.864**	3.486**	2.842*	-0.087	-0.219	-0.697***	-0.627***	0.298***	0.171**
	(0.108)	(0.174)	(0.141)	(0.670)	(0.058)	(0.379)	(1.509)	(1.511)	(0.195)	(0.188)	(0.239)	(0.240)	(0.063)	(0.074)
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Number of banks	141	141	141	141	141	141	141	141	141	141	141	141	141	141
Observations	2,961	2,961	2,961	2,961	2,961	2,961	2,961	2,961	2,961	2,961	2,961	2,961	2,961	2,961

Note: This table provides the regression results of determinants of European banks' risk using a panel threshold model. GDP growth is also the threshold variable and bank specific factors are successively the regime-dependent variable. γ is the threshold level of the GDP growth variable estimated endogenously by the model. The coefficients related to λ_1 correspond to effects during the GFC and those related to λ_2 to the effects during the normal period. Bank and time fixed effects are considered but not reported. Heteroscedastic robust standard errors are in parentheses. ***, ** and * represent statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

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Appendix A. Construction of Banking regulation index

This Appendix provides details about the construction of the banking regulation index, which is based on four Bank Regulation and Supervision databases of the World Bank, elaborated by Barth, Caprio and Levine for the years 2000, 2003, 2007 and 2012. These databases consist of approximately 300 questions divided into 12 sub-groups, each of which corresponds to specific aspects of banking regulation, including requirements related to entry into banking market, ownership structure, capital adequacy, bank activities, external auditing, internal management and organisational structure, liquidity and diversification aspects, depositor protection, provisioning obligations, accounting and information disclosure obligations, discipline and problematic institutions exit, and requirements related to supervisory structure.

Some of the questions in the surveys require yes/no answers. Following Lapteacru (2018), we assigned a value of 1 to those that involve the tightening of different aspects of the banking regulation, and 0 otherwise. For indicators expressed in domestic currency we converted into USD with exchange rates extracted from DataStream.

We then aggregated the results relative to each of our 13 indicators IND_i (i=1,...,13). Two correspond to the Barriers to Entry index (BEI): overall entry index (0.6) and permission activity index (0.4). The others correspond to the Stability Regulation Index (SRI): capital adequacy (0.2), activity diversification (0.1), liquidity (0.175), provisioning (0.175), deposit insurance (0.05), accounting standards (0.05), auditing requirements (0.05), internal management (0.05), ownership (0.05), discipline and enforcement (0.05) and supervisory structure (0.05). To make each of these 13 indicators comparable across countries and years, they are normalised using the formula $\overline{IND}_{i,t} = \left(IND_{i,t} - \min_{i,t} IND_{i,t}\right) / \left(\max_{i,t} IND_{i,t} - \min_{i,t} IND_{i,t}\right)$. The weights of these indicators in the composition of the Barriers to Entry Index and Stability Regulation Index are

presented in parentheses, and the BEI and SRI are equally weighted in the composition of the Banking regulation index.