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What drives the risk of European banks during crises? New evidence and insights

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Abstract

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Keywords: European banking, bank risk, financial crisis, Z-score.

JEL: G21

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What drives the risk of European banks during crises? New evidence and insights

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Abstract:

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1. Introduction

All crises highlight the weaknesses of financial institutions and last financial crisis is not an exception. The bank internal deficiencies as well macroeconomic environment lead to waves of banking crises in 1990s in Emerging European countries and in 2008-2009 in entire Europe. Given the huge impact of banking crises on the stability of banking firms, on the financing of the economy and on the costs in terms of resolution and output losses[1], it is very important to unveil the factors that caused them.

The existing literature on banking crises has explored more or less the same bank and macroeconomic and regulatory factors. However, the results diverge depending on the measures of bank risk, sample of banks and studied period. The bank risk can be measured with accounting- and market-based indicators. The latter were largely developed after the last financial crisis and rely exclusively on market data (option prices, CDS spreads or banks' stocks prices). One approach focuses on the estimation of the individual risk of banks without wondering about their role in the stability of the banking system. The Value-at-Risk *VaR*, measuring the maximum loss with a certain probability of default, the Expected Shortfall *ES*, estimating the expected loss for probabilities of default higher than that of *VaR's*, and the Distance to Default, issued from the option model of Merton (1974) and showing how far a bank is from a default event, are based all on the concept of the probability of failure of banks. Another approach extends this reasoning and aims at identifying the Systemically Important Financial Institutions. *CoVaR* and Δ*CoVaR* of Adrian and Brunnermeier (2009), measuring the *VaR* of financial institutions conditional on other institutions being in distress and its difference with the financial system's *VaR*, the Marginal Expected Shortfall *MES* of Acharya et al. (2010), reflecting the sensitivity of the financial system's risk to the change of a financial institution's risk, the systemic risk *SRISK* of Brownlees and Engle (2012), measuring the capital shortfall of a financial institution in the a whole financial system, the *tail beta* of De

[1] See Honohan and Klingebiel (2000).

Jonghe (2010), assessing the probability of a substantial decline in a bank's stock price conditional on the drop of the value of a banking index, and other market-based measures of the systemic risk[2] are also mostly based on the probability of default. This huge advantage of market-based risk measures is offset by the reduced sample of banks since they can be applied only for banks that are listed. Because the listed banks are very few, especially in Eastern European countries, it is worth to use accounting-based risk measures, but only Z-score is based on the concept of the probability of default. Being linked to the probability that a bank's losses cover entirely its capital, this risk measure can be applied for all banks and for a larger time sample. However, the main shortcoming of the traditional formula is the implicit hypothesis of the same distribution function for the returns-on-assets *ROA* random variable both across banks and over time, which makes the results incomparable.

Hence, this paper aims at providing new evidences on main driving factors of European banks' risk-taking but with an adjusted Z-score computed with an individual distribution function for each bank and each time point. This allows firstly to keep the link between the probability of default and the Z-score, and secondly to consider the most of banks of all European countries. In this way, one obtains a complete and detailed picture on factors that drive the risk-taking behaviour of European banks, which is necessary, especially for regulators, to hamper the propensity of banks to be involved in riskier activities especially during periods propitious for risk-taking, as when interest rates are too low for too long (Rajan, 2005; Dell'Ariccia and Marquez, 2006; Borio and Zhu, 2012; Borio et al., 2017).

While previous papers have been focused only on one (Louizis et al., 2012) or very few European countries (Baselga-Pascual et al., 2015; Lapteacru, 2019) and conclude on the experience of very few banks, our study comprises all Central and Western European countries and most of Eastern European economies, which comprises 28 countries, a very large panel of 1,156 European banks and covers almost 90% of all national banking markets. The time

[2] see VanHoose (2011) for a good survey of the systemic risk.

sample spanning from 1995 to 2015 is also large and includes all crises that hit Western and Eastern European banks during nineties and the last global financial crisis of 2008-2009.

The inclusion of both waves of banking crisis allows considering the most important aspects of determinants of European banks' riskiness related either to inefficient and risk-orientated activities of Central and Eastern banking institutions during the transition period (Bonin et al., 2015) or to the collapse of the "modern banking" during the last financial crisis. The main theoretical and empirical factors we study are related to both balance-sheet structure of banks and their management policies. Capitalisation, liquidity, management performances, income and funding diversification, and the size were found, theoretically and empirically, to be important determinants of banks' riskiness.

Capital regulation has the role to mitigate the well-known moral hazard problem related to both deposit insurance and bailout with public funds (Furlong and Keeley, 1989; Keeley and Furlong, 1990; Santos, 2001), improve the quality of loans (Kopecky and Van Hoose, 2006) and to strengthen the banks' soundness (Gennotte and Pyle, 1991; Santos, 1999). However, if, within more stringent capital requirements, raising equity is excessively costly, the only possibility for banks to increase their capital tomorrow is to increase their risk today (Blum, 1999) and this effect may be amplified during crisis periods when banks are seeking to increase their capital (Demirgüc-Kunt et al., 2013).

All crises also pinpoint the vulnerability of banks that heavily rely on very liquid sources of funding, as the deposits are, highlighting the role of liquid liabilities for banks' soundness (Bryant, 1980; Diamond and Dybvig, 1983), especially during crisis periods (Hong et al., 2014). The reliance of banking firms on deposits makes them vulnerable not only because the deposits may be easily withdrawn but also because of the moral hazard problem that they can engender being insured. Hence, the deposits do not more play a disciplinary role (Demirgüç-Kunt and Huizinga, 2004; Ioannidou and Penas, 2010) and do not more prevent banks from taking on more risk (Keeley, 1990; Demirgüç-Kunt and Detragiache, 2002), leading to banking crises (Demirgüç-Kunt and Detragiache, 2002; Demirgüç-Kunt and Kane, 2002; Barth et al., 2004). Although Anginer et al. (2014) point out that this "moral hazard effect" dominates only in good times and that during the recent global financial crisis bank risk is lower and systemic stability is greater in countries with deposit insurance coverage, the overall effect remains however negative since the destabilizing effect during normal times is higher in magnitude. This side of liquidity risk is considered through the reliance of bank lending on deposits.

Another side linked to the creation of asset liquidity is taken into account by the share of liquid assets. The banking crises in the U.S., for instance, have been often preceded by abnormal liquidity creation (Berger and Bouwman, 2008, 2009) and it is also explained theoretically that high levels of asset liquidity can increase the risk of banks, threatening hence the stability of banking system (Wagner 2007; Acharya and Naqvi, 2012). According to Acharya and Naqvi (2012), bank managers behave in an overly aggressive manner by mispricing downside risk when bank liquidity is sufficiently high and asset price bubbles are formed for high enough bank liquidity, which is related to the results of Adrian and Shin (2009). Berger and Bouwman (2010) also point out that high liquidity creation is accompanied by a high likelihood of the occurrence of a crisis.

Many authors have also highlighted the importance of managerial quality and skills of bank managers to face the shocks that hit the banks. The cost-to-income ratio is widely applied as a simple measure of cost inefficiency of banks' activities and most of studies on the subject confirm the bad management hypothesis highlighted by Berger and DeYoung (1997). The authors find for U.S. banks that cost inefficiency precedes the problems related to non-performing loans and their result is supported by many studies on the practices of European banks too (Williams, 2004; Podpiera and Weill, 2008; Männasoo and Mayes, 2009; Louzis et al., 2012). The profitability is another signal of managerial qualities since lower profitability may be related to higher amount of non-performing loans (Louzis et al., 2012). Poghosyan and Čihak (2011) provide solid evidence on European banks finding that banks with higher earnings have less risk to be in financial distress. The impact of the profitability may pass also through the franchise value of banks, since more profitable banks may have higher franchise value, which may hamper them from risk-taking (Demsetz et al., 1996).

Banks' diversification strategies may also be related to their risk-taking behaviour. According to portfolio theory based on Diamond (1984), the diversification should reduce the risk of banks and enhance the stability of banking system (Berger et al., 1999; Campa and Kedia, 2002). However, some authors explain that diversification gains are more than offset by the costs related to exposure to volatile non-interest-generating activities (Stiroh and Rumble, 2006; among others), supporting the idea that diversification worsens the risk profile of banks. De Jonghe (2010) finds that the shift to non-traditional activities increases the systemic risk, whereas Demirgüç-Kunt and Huizinga (2010) find a non-linear relationship between income diversification and risk of banks. At low levels of non-interest income, there are some diversification benefits of being involved in non-traditional activities. However, at higher levels of non-interest income share, higher increases worsen the risk profile of banking firms.

Funding diversification may also play a role. The non-deposit financiers may provide market discipline (Calomiris, 1999) by their capacity to monitor banks (Calomiris and Kahn, 1991) and, in this way, may enhance *ex ante* the stability of banks. However, when a crisis occurs, they can withdraw their funds immediately and precipitately based on the least noisy public signal on bank solvency (Huang and Ratnovski, 2011), which makes banks more vulnerable. Finally, the banks' riskiness depends also on their size. On the one hand, due to more diversification opportunities, more risk management skills, and more information gathering, greater economies of scale and scope large banks are less risky (Banz, 1981; Boyd and Prescott, 1986; Boyd and Runkle, 1993; Demsetz and Strahan, 1997; Salas and Saurina, 2002). On the other hand, due to moral hazard problem related to too-big-to-fail behaviour large banks may be encouraged to carry out riskier activities (Uhde and Heimeshoff, 2009; De Jonghe, 2010; Demirgüç-Kunt and Huizinga, 2013).

Although some of these factors have already been studied, this paper provides however new evidences issued from an adjusted and more consistent Z-score measure, larger sample of countries, larger sample of banks and a complete set of main banks' risk drivers. Moreover, all our results are obtained with different methodological approaches. As in other papers on the subject, we apply fixed effects panel model and a crisis dummy variable to emphasize the effects during 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). Consequently, besides this benchmark methodological setting, we apply a panel threshold econometric methodology, which allows the determination of the crisis period endogenously and, to deal with endogeneity, we also run dynamic panel and 2SLS models. Other tests are also made, like regressions with country fixed effects and country clustering, in order to measure the stability of our findings. Finally, we split the impact of main risk factors between Western European and Central and Eastern European banks since the Central and Eastern European banking institutions have had a riskier profile (Lapteacru, 2019), which would have impacted their behaviour.

Our results are consistent with the existing literature. Moreover, some new insights regarding the determinants of European banks' risk-taking and their effects during crisis periods are provided. Higher capital, lower ratios of loans to deposits and of liquid assets to total assets and lower share of non-deposit and short-term funding in total funding are associated with lower bank risk and this relationship is stronger during the crises. As expected, having lower costs compared to their revenues reduces the risk of European banks in normal times and has the same impact during the crises, while being involved in non-interest-generating activities makes banks riskier during trouble events. Finally, being large and having higher net interest margin make banks more stable, but this positive effect is diminished for the size and vanished for the profitability during crisis times.

In order to determine the main factors of European banks' risk-taking and their effects during the crisis periods, 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 in section 3 and our main results as well complementary findings in section 4. Finally, we conclude in section 5.

2. Asymmetric Z-score as measure of bank risk

As measure of bank risk, we adjust the Z-score estimating an individual distribution of ROA variable for each bank and each time point. We firstly present our methodology and explain its advantages compared to the traditional formula. We then provide empirical divergences between our Z-score measure and its traditional counterpart.

2.1 Method of computation

The Z-score has the advantage of being based on concept of default and is exempt from being addressed only to listed banks. A bank is in default when its current losses exceed its capital and the probability of default is, in consequence, $\Pr[-\Pi > C]$, where Π is the bank's profit and C its capital (Boyd and Graham, 1986; Hannan and Hanweck, 1988; Boyd and Runkle, 1993; Boyd et al., 1993), or $\Pr[\Pi \leq -C] = \Pr[ROA \leq -COA]$, where $ROA = \Pi/A$ is the returns-on-assets ratio and $COA = C/A$ is the capital-on-assets ratio. The bank's performance, *i.e.* its returns on assets, is a random event and is reflected by its distribution. The link between the Z-score and the probability of default is obtained through the formula $\Pr[ROA \leq -COA] = \Pr\left[\frac{ROA - E(ROA)}{\sigma(ROA)} \leq -Zscore\right]$, where $Zscore = \frac{COA + E(ROA)}{\sigma(ROA)}$ with $E(ROA)$ for the expected value of ROA and $\sigma(ROA)$ for its standard deviation. That is, the probability of default is $\mathrm{Pd} = \mathrm{F}(-Zscore)$, where $\mathrm{F}(.)$ is the cumulative distribution function of ROA variable. Considering the empirical mean and empirical standard deviation, the traditional formula of the Z-score, which is widely applied in the banking literature, is

$$\text{Zscore}_{trad} = \frac{\text{mean}(ROA) + COA}{\text{std}(ROA)}. \tag{1}$$

However, this formula supposes three important constraints. First, in order to ensure the comparability of Z-score results across banks and over time, the distribution function $\text{F}(.)$ which they are based on should be the same. If the probability distribution function changes, for instance, from $\text{F}_1(.)$ to $\text{F}_2(.)$, the insolvency of a bank may rise instead of decreasing with the increase in its Z-score, as depicted in Figure 1. It should be the case when the new distribution function is left-skewed and has an excess of kurtosis compared to the previous one. Although the type of distribution function does not matter, in the banking literature the normal distribution $N(.)$ is considered as reference distribution. The probability of default becomes therefore $\Pr[ROA \leq -COA] = N(-Zscore)$ and the Z-score is computed as

$$\text{Zscore} = N^{-1}\big(\text{F}(-COA)\big). \tag{2}$$

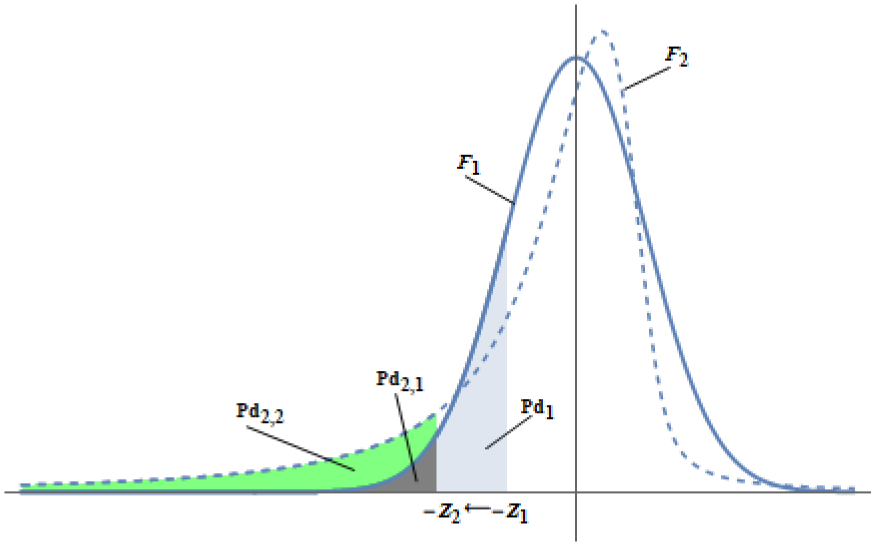
Second, as highlighted by the authors of the Z-score themselves (Boyd and Graham, 1986; Hannan and Hanweck, 1988; Boyd and Runkle, 1993; Boyd et al., 1993), one assumes implicitly that the ROA variable follows itself a normal distribution. With $\text{F}(.) = N(.)$ and with empirical mean and standard deviation, from equation (2) one obtains the result for the traditional Z-score. But this variable is generally left-skewed during downturns and right-skewed during upturns, and often has a kurtosis different from three[3], which implies that its distribution function changes over time and across banks.

Third, as mentioned above, the computation of the traditional Z-score uses the empirical mean instead of the expected value of ROA and the empirical standard deviation instead of the theoretical value. The empirical values become closer to their theoretical ones only for very large samples. Considering an estimation rolling-window with few time points (ten years in our

[3] The authors of the Z-score have warned against this important constraint (for instance, Boyd and Graham, 1986 p. 5; Boyd and Runkle, 1993 p. 53) and have proposed to apply the convergence properties of the ROA random variable through the Bienaymé-Tchebycheff inequality. However, in this case it is related to the maximum probability of default and the results are incomparable.

papers, but three or five years in banking literature) makes them very different.

Figure 1. Probability of default with different distribution functions of ROA.



Note: This figure depicts the probability of default with two different probability distribution functions F_1 and F_2 of ROA variable. The first is presented by a continuous line and the second by a dashed line. Z_1 is the Z-score at time t_1 and Z_2 is the Z-score at time t_2, with $t_2 > t_1$. The probability of default related to the first Z-score is the shaded area between the distribution function F_1 and x-axis till the point $-Z_1$, *i.e.* Pd_1. The probability of default related to Z_2 can take two values. If the distribution function does not change, it is the shaded area between the distribution function F_1 and x-axis till the point $-Z_2$, *i.e.* $\mathrm{Pd}_{2,1}$. Otherwise, if the distribution function of ROA is henceforth described by F_2, the probability of default related to Z_2 becomes the shaded area between this function and x-axis till the point $-Z_2$, *i.e.* $\mathrm{Pd}_{2,2}$. As is depicted on this figure, with the increase in Z-score the probability of default may increase ($\mathrm{Pd}_{2,2} > \mathrm{Pd}_{2,1}$) instead of decreasing. Hence, the insolvency of banks may rise with the increase of the Z-score when one does not refer on the same distribution function.

In order to deal with last two unrealistic constraints, one should consider the real distribution of this variable or, at least, its closest distribution for each bank and each year and apply its parameters instead of empirical mean and standard deviations. We therefore propose a very flexible distribution function that allows a good fit of banks' ROA data which is the stable cumulative distribution function, $\mathrm{F}(.) = \mathrm{F}_{\mathrm{st}}(.)$. The probability of default becomes

$$\Pr(ROA \leq COA) = \mathrm{F}_{\mathrm{st}}(-COA; \beta, \alpha, \mu, \sigma), \quad (2)$$

where $0 < \beta \leq 2, -1 \leq \alpha \leq 1, \mu \in \mathbb{R}$ and $\sigma > 0$ are stability, skew, location and scale parameters, respectively. With four parameters, instead of two as for the normal distribution, the stable distribution has a quasi-general form and accounts for skewness and kurtosis of the ROA variable, and it becomes a normal distribution for $\beta = 2$ that allows considering the traditional case too. Applying the same approach as for the computation of the traditional Z-score and equation (2), our asymmetric Z-score is computed as

$$AsZscore = -N^{-1}\big(\mathrm{F}_{\mathrm{st}}(-COA; \beta, \alpha, \mu, \sigma)\big). \quad (3)$$

The flip side of its large flexibility is the lack of 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 $\Phi = \tan\left(\frac{\pi\beta}{2}\right)$ if $\beta \neq 1$ or $\Phi = -\frac{2}{\pi}\log|t|$ if $\beta = 1$. We therefore apply an empirical approach in the determination of these parameters for each bank and each year, which consists to find the parameters that draw the probability distribution function the closest to the smooth kernel distribution.[4] The minimisation of the distance between the estimated stable distribution and smooth kernel distribution is made on one thousand equidistant points. The parameters are thereby estimated for each bank within a ten-year-estimation rolling window.

2.2 How the asymmetric Z-score is related to its traditional counterpart?

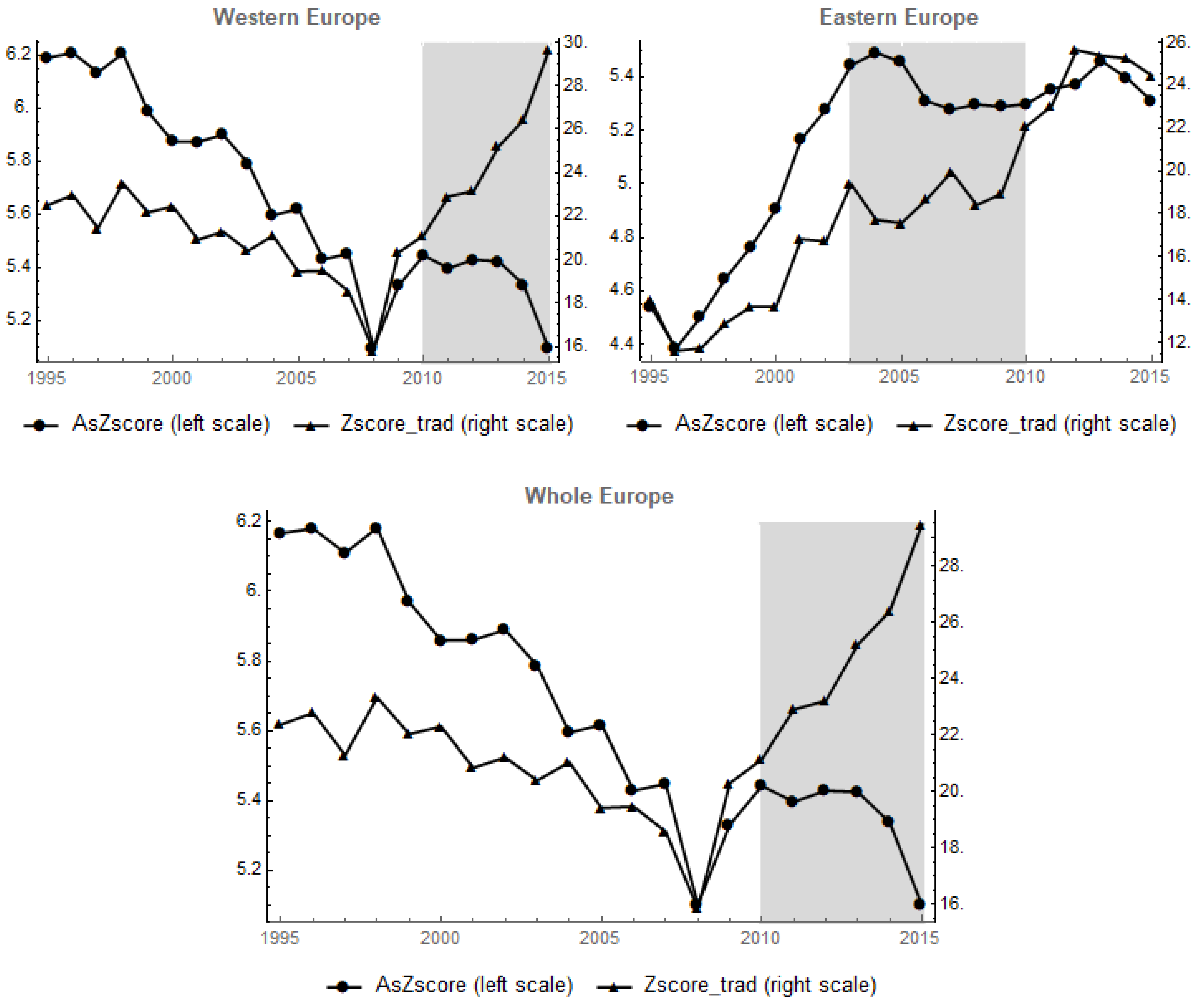
The previous thoughts on the difference between our asymmetric Z-score and the traditional formula are depicted in Figure 2 which shows that the two accounting-risk measures are different in scale and, for some periods, have different patterns. For both Western and Eastern European regions, it seems that the asymmetric Z-score describes more accurately the occurrence of crisis events. Hence, one may highlight the following advantages of this risk measure compared to traditional Z-score.

First, the evolution of the asymmetric and traditional Z-scores does not follow the same pattern, especially after 2010, for Western European banks, and between 2003 and 2010, for

[4] We consider a Gaussian kernel specification, whose the bandwidth selection method is Silverman's (1998) rule.

Eastern European banking institutions (shaded areas in Figure 2). Although both measures

Figure 2. Evolution of the asymmetric and traditional measures of the Z-score.



Note: This figure depicts the evolution of the traditional measure, computed with equation (1), and asymmetric measure, computed with equation (3), of the Z-score. Beyond different scale of their values, they follow different path during the 2010-2015 period for Western European banks and entire European banking system, and during the 2003-2010 period for Eastern European banks, which is marked by shaded areas. The yearly data are averages weighted by banks' assets.

indicate an increase in risk of Western European banks till 2008 with an important fall of their soundness in the year of the beginning of crisis, the traditional Z-score reflects a sharp increase of banks' soundness after 2010, as if the European debt crisis had never existed and/or Western European banks had never been impacted, while this European crisis episode is well-caught by our asymmetric Z-score. After 2010, it decreases sharply highlighting the augmentation of banks' fragility, *i.e.* their capacity to cover their losses according to the distribution of their returns. A similar difference is illustrated for Eastern European banking institutions. The two risk measures evolve in opposing directions between 2003 and 2007. According to the traditional Z-score, these banks become more risky during 2003-2005 period and less risky during 2005-2007 period. According to our asymmetric Z-score, their vulnerability increases continuously before being stabilised in 2007. Hence, the asymmetric Z-score accounts better for capitalisation but also for non-performing loans problems faced by some important Central and Eastern European banks during the beginning of 2000s.

Second, there is a large difference between these two accounting-based risk measures, as the Spearman rank correlation coefficient varies across countries and across years from very negative values to very positive ones (Table 1), highlighting for some countries and some years opposing results. Finally, making a quartile analysis, among 10 per cent of most fragile banks classified according to both Z-score measures only 57 per cent of banking firms are the same and among 10 per cent of safest banks only 4 per cent are the same. Hence, both theoretical and empirical divergences lead us to use the asymmetric Z-score instead of the traditional formula.

3. Data and empirical methodology

To determine the factors of European banks' risk during the crisis periods, we employ an extensive dataset on 1,314 European banks from 28 European countries. Our bank sample consists of commercial, savings and specific governmental banking institutions of all sizes and covers the European banking markets almost entirely. We winsorized data at 1% level and, to have a balanced panel necessary for panel threshold model used for robustness checks, 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

Table 1. Spearman rank correlation coefficient between the asymmetric Z-score and the traditional Z-score.

Country	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Austria	0.16	0.12	0.15	0.13	-0.04	-0.20	0.10	-0.01	-0.01	0.10	0.10	0.13	0.28	0.32	0.33	0.33	0.46	0.55	0.47	0.51	0.56
Belgium	-0.08	-0.16	-0.01	-0.02	0.21	0.12	0.59	0.40	0.71	0.50	0.66	0.67	0.72	0.22	0.63	0.66	0.45	0.73	0.51	0.79	0.75
Bulgaria	0.64	0.53	0.32	0.07	0.20	-0.24	-0.13	-0.38	-0.56	-0.41	-0.12	0.12	0.10	-0.16	0.05	0.06	0.05	0.61	0.39	0.65	0.79
Croatia	0.84	0.87	0.71	0.83	0.41	0.70	0.73	0.40	0.62	0.72	0.72	0.40	0.49	0.41	0.27	0.43	0.52	0.47	0.38	0.50	0.54
Cyprus	0.21	0.64	0.82	0.46	0.93	0.89	0.82	0.43	0.89	0.78	-0.07	0.78	0.03	0.46	0.64	0.32	0.53	0.68	0.28	0.10	0.21
Czech Rep.	0.43	0.75	0.76	0.86	0.65	0.83	0.71	0.86	0.63	0.35	0.60	0.26	0.01	-0.11	0.48	0.33	0.25	0.13	0.16	0.05	0.40
Denmark	0.89	0.65	0.10	0.10	-0.01	0.12	0.02	0.04	0.18	-0.05	0.26	0.43	0.35	0.53	0.58	0.41	0.56	0.53	0.51	0.61	0.60
Estonia	0.40	0.40	0.80	0.40	0.40	0.40	0.40	0.60	0.80	0.60	0.60	-0.80	-1.00	0.20	1.00	0.80	1.00	0.40	0.40	0.80	0.80
Finland	0.60	-0.57	0.18	0.43	0.50	0.61	0.53	0.50	0.71	0.07	0.39	0.03	0.43	0.82	0.53	0.57	0.18	0.36	0.39	0.21	0.39
France	0.44	0.55	0.54	0.38	0.35	0.32	0.31	0.27	0.30	0.46	0.42	0.37	0.29	0.34	0.36	0.33	0.24	0.33	0.38	0.36	0.35
Germany	-0.07	-0.12	-0.09	-0.12	-0.11	-0.03	-0.01	-0.05	-0.00	0.04	0.11	0.09	0.09	0.16	0.17	0.18	0.25	0.32	0.30	0.25	0.31
Greece	0.28	0.43	0.75	0.36	0.32	0.68	0.53	0.75	0.75	0.71	0.75	0.82	0.64	0.75	0.82	0.75	1.00	0.96	0.50	0.86	0.68
Hungary	0.56	0.71	0.63	0.85	0.71	0.49	0.55	0.55	0.67	0.61	0.68	0.68	0.56	0.62	0.64	0.78	0.66	0.78	0.64	0.90	0.92
Italy	0.08	0.12	0.02	0.09	0.06	0.06	0.03	0.03	0.03	0.06	0.09	0.18	0.16	0.16	0.22	0.24	0.48	0.52	0.58	0.66	0.65
Latvia	0.90	0.94	0.91	0.94	0.95	0.86	0.68	0.83	0.51	0.78	0.70	0.90	0.89	0.91	0.95	0.93	0.82	0.90	0.27	0.85	0.88
Lithuania	0.88	0.93	0.81	-0.09	0.64	0.16	0.59	0.90	0.90	0.26	0.83	0.95	0.83	0.76	0.78	0.69	0.74	0.74	0.76	0.64	0.66
Luxembourg	0.39	0.36	0.34	0.39	0.25	0.34	0.23	0.26	0.19	0.28	0.36	0.33	0.45	0.47	0.39	0.40	0.48	0.34	0.33	0.30	0.24
Malta	0.40	0.80	-0.20	-0.80	-0.80	-0.80	-0.40	-0.80	-0.80	-0.20	-0.40	0.40	0.40	0.40	0.40	-0.20	-0.40	0.40	0.40	0.80	0.00
Netherlands	0.47	0.72	0.86	0.67	0.53	0.70	0.38	0.16	0.31	0.49	0.43	0.33	0.44	0.47	0.52	0.75	0.74	0.76	0.74	0.77	0.76
Poland	0.25	0.43	0.62	0.48	0.60	0.46	0.54	0.54	0.33	0.40	0.55	0.46	0.42	0.57	0.50	0.39	0.34	0.29	0.09	0.03	0.01
Portugal	0.00	0.05	0.12	0.22	-0.02	-0.26	-0.08	0.24	0.21	0.08	0.11	0.14	0.34	0.38	0.29	0.51	0.46	0.68	0.79	0.91	0.90
Romania	0.87	0.87	0.86	0.78	0.69	0.55	0.62	0.57	0.54	0.54	0.69	0.66	0.81	0.60	0.67	0.65	0.64	0.71	0.77	0.68	0.75
Slovakia	0.71	0.72	0.71	0.84	0.80	0.70	0.62	0.60	0.70	0.68	0.73	0.76	0.76	0.79	0.87	0.70	0.88	0.90	0.85	0.83	0.83
Slovenia	0.20	0.16	0.04	0.02	-0.17	-0.18	0.05	-0.27	-0.18	-0.09	0.33	0.32	0.35	0.20	0.24	0.62	0.74	0.82	0.96	0.92	0.90
Spain	0.33	0.30	0.34	0.28	0.35	0.10	0.22	0.15	0.15	0.38	0.27	0.30	0.23	0.38	0.39	0.51	0.59	0.62	0.66	0.73	0.66
Sweden	0.13	0.23	0.03	-0.18	0.10	0.21	0.15	-0.15	-0.11	0.15	0.08	0.00	0.08	0.16	0.21	0.33	0.26	0.25	0.36	0.30	0.33
UK	0.25	0.37	0.40	0.42	0.35	0.29	0.24	0.17	0.01	0.21	0.35	0.33	0.49	0.46	0.60	0.53	0.46	0.46	0.45	0.47	0.52
Western Europe	0.04	0.04	0.07	0.07	0.05	0.08	0.13	0.12	0.14	0.22	0.28	0.27	0.26	0.32	0.33	0.32	0.37	0.42	0.42	0.42	0.44
Eastern Europe	0.63	0.68	0.66	0.62	0.56	0.59	0.61	0.52	0.55	0.53	0.62	0.58	0.58	0.58	0.65	0.65	0.67	0.72	0.66	0.73	0.71
All countries	0.16	0.18	0.20	0.17	0.15	0.19	0.24	0.21	0.23	0.29	0.35	0.34	0.33	0.37	0.38	0.37	0.42	0.47	0.46	0.48	0.50

Note: This table presents Spearman rank correlation coefficient between the traditional measure, computed with equation (1), and asymmetric measure, computed with equation (3), of the Z-score. In Western European region are included Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Spain, Sweden, and the UK, and Eastern European region the other countries, i.e. Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

presented in Table 3 and our variables are defined and explained in Table 2. Our data cover banks of all sizes, from very small to very large, and from different periods, from high economic growth to financial crisis.

3.1 Explanation of variables

Our risk measure is the $AsZscore$ variable computed with equation (3). Table 3 indicates that it is, on average, lowest for Baltic countries' banking institutions and highest for banks from Malta, Italy and Poland. The very high risk for some Baltic banks is explained by an important worsening of financial conditions of some banks during Russian financial crisis of nineties and also during the recent financial crisis, more than for banks of other Eastern European economies.

3.1.1 Bank risk factors

As determinants of European banks' risk, we examine capitalisation level (Capital), bank liquidity factors (Coverage liquidity and Assets liquidity), bank Inefficiency and Profitability factors, bank diversification policies expressed by Income diversification and Funding diversification, and the size of banking institutions.

The capital ratio is undoubtedly one of the most important determinants of banks' stability, being a sign of a better quality of loans (Kopecky and Van Hoose, 2006) and of lower risk for banks (Furlong and Keeley, 1989; Keeley and Furlong, 1990). However, if the rise in banks' capital is excessively costly and encourages banks to take on more risk, we may obtain an opposite effect (Blum, 1999). Although the COA ratio is included in the Z-score formula, it is not directly related to this risk measure, which allows to analyse it as a factor of European banks' risk-taking.

Liquidity is another characteristic that may influence the risk-taking behaviour of European banks and two of its aspects are emphasized. The first point of view refers to the

Table 2. Definition, 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 (3). 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		
Capital	Equity to total assets ratio	Bankscope and authors' computations
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
Inefficiency	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
Bank, regulatory and macroeconomic controls		
Regulation index	The index is constructed as explained in Appendix B. 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
Monetary policy	Shadow interest rate computed according to the method of Krippner (2014, 2016) for each country separately.	Datastream, internet web site of national banks and authors' computations
Crisis	A dummy variable equal to 1 for crisis periods, defined when GDP growth is lower than 0.4%, and 0, otherwise.	Authors' computations
Stock exchange return	The return of stock exchange indexes of all 28 European countries of our sample.	Datastream and authors' computations
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 3. Sample of countries and banks. Descriptive statistics for the period 1995-2015.

Country	**Nr. of banks**	**AsZscore**	**Capital**	**Coverage liquidity**	**Assets liquidity**	**Inefficiency**	**Profitability**	**Income diversification**	**Funding diversification**	**Size**	**Regulation index**	**Monetary policy**	**Stock exchange return**	**GDP growth**
Austria	74	6.223	0.073	0.695	0.386	0.621	0.022	0.349	0.250	6.800	0.495	0.023	0.072	0.018
Belgium	19	5.254	0.062	0.527	0.506	0.495	0.020	0.311	0.304	9.305	0.509	0.023	0.067	0.028
Bulgaria	15	5.984	0.154	0.706	0.318	0.603	0.044	0.385	0.186	6.205	0.510	0.192	0.164	0.033
Croatia	15	4.871	0.139	0.908	0.307	0.611	0.040	0.381	0.157	6.708	0.487	0.064	0.070	0.037
Cyprus	7	4.690	0.094	0.784	0.354	0.555	0.029	0.390	0.198	7.725	0.446	0.071	-0.002	0.025
Czech Rep.	9	4.606	0.107	0.635	0.443	0.723	0.033	0.388	0.266	8.215	0.727	0.036	0.061	0.027
Denmark	57	5.861	0.128	0.744	0.387	0.612	0.039	0.334	0.161	6.541	0.429	0.027	0.125	0.015
Estonia	4	2.803	0.125	0.680	0.289	0.556	0.036	0.430	0.219	6.349	0.408	0.044	0.160	0.044
Finland	7	6.321	0.064	0.927	0.304	0.547	0.017	0.437	0.396	9.136	0.323	0.024	0.153	0.022
France	90	5.904	0.086	0.677	0.412	0.629	0.025	0.433	0.363	8.055	0.446	0.024	0.056	0.016
Germany	504	6.967	0.063	0.663	0.395	0.593	0.024	0.264	0.258	7.537	0.383	0.023	0.103	0.014
Greece	7	4.001	0.070	0.756	0.353	0.516	0.028	0.330	0.262	9.676	0.479	0.042	0.081	0.009
Hungary	13	4.840	0.104	0.692	0392	0.585	0.038	0.437	0.406	7.755	0.655	0.108	0.207	0.022
Ireland	2	5.646	0.162	1.047	0.418	0.341	0.013	0.398	0.566	9.669	0.443	0.028	0.091	0.060
Italy	100	6.455	0.095	1.030	0.332	0.608	0.029	0.580	0.290	8.019	0.429	0.031	0.038	0.006
Latvia	10	3.989	0.105	0.518	0.376	0.571	0.034	0.512	0.176	5.897	0.438	0.029	0.104	0.040
Lithuania	8	2.844	0.124	0.743	0.286	0.697	0.034	0.452	0.278	6.268	0.478	0.027	0.135	0.063
Luxembourg	47	6.302	0.068	0.331	0.682	0.459	0.009	0.500	0.452	8.258	0.487	0.024	0.014	0.045
Malta	4	7.269	0.074	0.553	0.432	0.510	0.024	0.261	0.057	7.379	0.545	0.033	0.113	0.047
Netherlands	11	5.888	0.077	1.238	0.319	0.456	0.016	0.333	0.360	9.171	0.319	0.023	0.069	0.020
Poland	23	6.413	0.129	0.719	0.395	0.615	0.036	0.413	0.334	7.791	0.487	0.096	0.117	0.042
Portugal	13	5.184	0.090	0.833	0.331	0.512	0.019	0.479	0.453	8.739	0.492	0.031	0.041	0.013
Romania	20	4.707	0.168	0.688	0.264	0.800	0.076	0.387	0.262	6.444	0.538	0.246	0.200	0.030
Slovakia	13	4.294	0.130	0.743	0.450	0.652	0.032	0.371	0.242	7.327	0.590	0.062	0.081	0.042
Slovenia	11	5.130	0.100	0.849	0.326	0.446	0.031	0.409	0.223	7.354	0.600	0.054	0.003	0.028
Spain	31	5.968	0.093	0.713	0.411	0.637	0.021	0.374	0.360	8.887	0.522	0.029	0.078	0.022
Sweden	9	5.554	0.096	0.938	0.269	0.575	0.028	0.382	0.248	9.591	0.338	0.029	0.117	0.026
UK	33	5.613	0.104	0.547	0.504	0.568	0.018	0.383	0.447	8.978	0.319	0.031	0.044	0.022
All countries														
Mean	1,156	6.290	0.081	0.704	0.398	0.594	0.026	0.354	0.284	7.665	0.430	0.035	0.087	0.019
Std:		2.340	0.241	0.379	0.232	0.325	0.018	0.281	0.239	1.796	0.083	0.091	0.262	0.030

Note: This table details our sample of 28 European countries and provides several descriptive statistics. AsZscore is our benchmark asymmetric Z-score computed with the methodology explained in Section 2, Capital is the ratio of Equity on total assets, 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, Inefficiency 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 B, Monetary policy reflects the shadow interest rate computed with the method of fixed interest rate lower bound of Krippner (2014, 2016), Stock exchange return is the return of stock exchange index and GDP growth is the real growth of Gross Domestic Product.

coverage of banks' loans by their deposits, since more loans than deposits may make banks riskier because their ability to cover their loan losses by their depositors is threatened. Because of the existence of deposit insurance and high switching costs for retail deposits (Kim et al., 2003), the "sluggishness" of deposits plays a stabilising role and contributes to cover unexpected loan losses. Hence, a higher ratio of total loans to total deposits, called coverage liquidity, would worsen the riskiness of these institutions, which should be even more the case during financial crises. The second aspect of liquidity is related to the role of liquid assets held by banks as safety cushion and/or buffer for monetary shocks (Cornett et al., 2011). Indeed, it is very likely that banks store more liquid assets when they expect to face some return shocks (Alger and Alger, 1999) and one may expect that a higher ratio of liquid assets to total assets, called assets liquidity, to be the characteristic of riskier banks.

The fourth factor that may impact the risk-taking behaviour of European banks, especially during crisis periods, is banks' operational or cost inefficiency, proxied by the ratio of banks' overhead cost to net interest revenue and non-interest income. Many studies use the cost-to-income ratio as a proxy for inefficiency or managerial quality (Berger and DeYoung, 1997; Chen et al., 2017; Fiordelisi et al., 2011; Louzis et al., 2012; Männasoo and Mayes, 2009; Poghosyan and Čihak, 2011; Williams, 2004; among others). Higher value of this ratio suggests lower efficiency in banks' management and should increase their riskiness. When the current costs cannot be covered by current revenues, the banks' capital is eroded and their financial stability is threatened and this negative relationship is expected to be enhanced during financial turmoil. Louzis et al. (2012), for instance, state that high cost inefficiency is positively associated with increases in future non-performing loans, as long as bad management leads to poor skills in credit scoring, appraisal of pledged collaterals and monitoring of borrowers.

The profitability of banks, measured as ratio of net interest margin to earning assets, is considered as another determinant of banks' risk. Obviously, the profitability should reduce the riskiness of banks and this widespread consensus is also confirmed on the experience of European banks by Poghosyan and Čihak (2011). Worse performance may lead to more non-performing loans because of lower quality skills with respect to lending (Louzis et al., 2012) and may, in addition, reduce the franchise value with negative effect on risk-taking behaviour of banks (Behr et al., 2010). However, during financial turmoil the behaviour of banks is not so obvious. The riskiest institutions may be incentivised to increase their interest rates to cover the decline of their revenues and the erosion of their capital. If they succeed, *i.e.* their interest margin increases and the relationship between banks' profitability and risk becomes positive; otherwise, *i.e.* when banks fail in their self-rescue operation and, on the contrary, register a decrease in their interest margin, this relationship remains negative.

The sixth factor we consider is the income diversification, computed as the share of non-interest income in operating income. As non-interest income, we consider non-interest gains, net insurance income, commissions and fees, and other operating income. There are many studies about the effect of income diversification on bank risk, and the conclusions differ. Income diversification may ensure income stability (Berger et al., 1999; Campa and Kedia, 2002) or instead may make bank revenue less stable and banks riskier (Stiroh and Rumble, 2006). A non-linear relationship has also been found (Demirgüç-Kunt and Huizinga, 2010; Lapteacru, 2019). Because of increase in volatility and in losses of non-lending activities during the crisis periods, one may expect a negative relationship between income diversification and riskiness of banks.

When a bank relies on non-deposit funding to support long-term illiquid assets, as explained above, it becomes vulnerable to failure of its debtors and also to runs of its creditors. The seventh important factor is thus the funding diversification that is expressed by the share of non-deposit, short-term funding in total deposits and short-term funding. As for previous factor, the effect may be ambiguous. Because it is not covered by any insurance scheme, non-deposit funding can have a disciplinary effect (Calomiris and Kahn, 1991), encouraging bankers to monitor the projects they finance and to improve their return-risk trade-off. On the other hand, non-deposit funding comprises short-term uninsured funds that are immediately withdrawn when trouble events occur, which may make a solvent bank to fail (Huang and Ratnovski, 2011).

The last factor we study is the size of banks, computed as natural logarithm of total assets. The role of the size is really very ambiguous and hence there is no consensus in the banking literature. Large banks may behave risky due to a moral hazard problem (Uhde and Heimeshoff, 2009; De Jonghe, 2010) or, on the contrary, may have less risky profile due to their managerial capacity and efficiency to diversify loan portfolio risks more efficiently. This efficiency is based on greater economies of scale and scope (Boyd and Prescott, 1986; Salas and Saurina, 2002) and on more information about banks' projects (Banz, 1981).

3.1.2 Regulatory and macroeconomic controls

Since bank risk-taking behaviour is strongly linked to economic, financial and regulatory environments we also control for these country-specific factors. Many studies have assessed the impact of banking regulatory requirements on the risk-taking. Keeley (1990), for instance, argues that financial liberalisation is more likely to raise the riskiness of banks. Most of papers focused on the role of the deposits insurance and a part of them argue that it may be a source of moral hazard encouraging banks to invest in riskier assets (Demirgüç-Kunt and Detragiache, 2002). Hence, we control for the banking regulatory environment and construct a banking regulation index, as explained in Appendix B. This index 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.

A lot of studies argued that the monetary policy stance impacts the risk of banking institutions, especially through the risk-taking channel during the period of low interest rate environment (e.g., Rajan, 2006, Borio and Zhu, 2012). A monetary expansion may increase bank leverage and risk, which, in turn, may raise asset price volatility and reduce economic product (Angeloni et al., 2015). Indeed, in periods of monetary policy easing, banks may search for riskier investments to compensate the erosion of their margins (Rajan, 2005) and such search-for-yield mechanism is strengthened when interest rates are low for too long. Banks may easily grant new loans to riskier borrowers (Jiménez et al., 2009) and with lower loan spreads (Paligorova and Santos, 2017). Hence, many studies find a negative relationship between central banks' interest rates and bank risk during pre-crisis period (Maddaloni and Peydro, 2011; Delis et al., 2012; Dell'Ariccia et al., 2017). Our period sample comprises both crisis and post-crisis periods, when monetary authorities set up unconventional monetary tools and the central banks' interest rates do not more allow to correctly accounts for monetary policy stance because of the (zero) lower bound (LB) constraint. Hence, we apply a shadow interest rate to take into account both conventional and unconventional stances of monetary policy, computed according to the methodology of Krippner (2014, 2016). We rely on two-factor model and use a continuous-time Gaussian affine term structure with both fixed and estimated lower bounds of interest rates. The former lower bound is fixed by central banks and the latter is estimated by the model. Since the effect of ECB's monetary policy may be different on national banking markets and on sovereign debts, we compute the shadow interest rate for each country of the euro-zone as we did for countries outside euro-area. For this, we use the short term yield curve that comprises both interest rates from interbank market and of sovereign bonds with maturities no more than 12 months (see Appendix A, Table A.1.). However, since the results of fixed and estimated lower bounds are very close, we apply the former in all our regressions.[5]

Even though very few banks from our sample are listed, financial market may play an important role in risk-taking behaviour of all banks. Thus, we use the yearly average of daily

[5] We also run all our regressions with shadow interest rate computed with estimated lower bound and the results are the same.

stock returns of national stock exchange markets to control for financial environment of banking firms. Since the bank risk-taking exhibits a cyclical behaviour (Demirgüç-Kunt and Detragiache, 1998; Marcucci and Quagliariello, 2009; Poghosyan and Čihak, 2011; Iannotta et al., 2013; Lapteacru, 2019), the last control variable is the yearly real GDP growth rate.

3.2 Econometric methodology

Our baseline econometric model is the following fixed effect (FE) panel model, with bank fixed effects ν_i and time fixed effects π_t:

$$AsZscore_{i,j,t} = \alpha_0 + \sum_{k=1}^{n} \alpha_k X_{k,i,j,t} + \sum_{l=n+1}^{m} \alpha_l Y_{l,j,t} + \nu_i + \pi_t + \varepsilon_{i,j,t}, \tag{4}$$

where *n* is the number of bank-specific variables (*n*=8), *m*-*n* is the number of country-specific variables (*m*=12), $X_{k,i,j,t}$ 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 in panel threshold model, used as an alternative econometric approach, where the GDP growth is the regime-shift, threshold variable, the economic cycle reflects the occurrence of crises. We apply therefore 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 and when the last financial crisis occurred firstly, and grabs also the banking crises of 1990s underwent by emerging European countries. All FE models are chosen based on the Hausman test that shows that the regressors are correlated with time-invariant bank-specific effects. We use heteroscedasticity and within-panel correlation robust standard errors in our FE estimations.

4. Baseline and complementary results

To check whether the chosen bank characteristics drive the risk-taking behaviour of European banks, especially during the crisis times, we run our baseline FE model and make some further investigations.

4.1 Baseline results with FE model

The estimation results for our baseline model, reported in Table 4, show that the main determinants of European banks' risk during the crisis periods are Capital, Coverage liquidity, Assets liquidity, Inefficiency, Income diversification and Funding diversification variables, and the size of banking institutions (Panel "Crisis effect: Wald test"). Banks with higher capital, lower ratios of loans to deposits and of liquid assets to total assets and with lower share of no-deposit funding in total funding are less risky and they are even more so during trouble times. Indeed, the tightening of capital reduces the riskiness of banks, which is related to findings of Furlong and Keeley (1989), Keeley and Furlong (1990), Gennotte and Pyle (1991) and Santos (1999). This result supports the bank regulator policies of tightening capital requirements, especially because of the amplified effects of capital loosening during the crisis periods, and is statistically and economically very important. For instance, for banks with a 10% probability of default (from Eq. 3, $AsZscore_{mean} = 1.28$), an increase of one standard deviation in the capital-on-assets ratio is associated with an increase of 0.067 points (0.280×0.241, Tables 3 and 4), on average, in the asymmetric Z-score, which decreases by 1.1% their probability of default ($\Delta Pd = N\big(-(AsZscore_{mean} + \Delta AsZscore)\big) - N(-AsZscore_{mean}) = 0.011$). But during crisis periods, if the same banks succeed to increase by one standard deviation their capitalisation, then their probability of default decreases by 3.7%.

As the last financial crisis unveiled, the liquidity is another important factor that plays a crucial role, with two different aspects. The reliance of bank lending on deposits brings some

Table 4. Determinants of European banks' risk.

Variables	Capital	Coverage liquidity	Assets liquidity	Inefficiency	Profitability	Income diversification	Funding diversification	Size
Bank factors								
Capital	**0.280*****	0.286***	0.285***	0.285***	0.283***	0.284***	0.284***	0.286***
	(0.062)	(0.062)	(0.062)	(0.062)	(0.062)	(0.062)	(0.061)	(0.060)
Crisis×Capital	**0.741*****							
	(0.296)							
Coverage liquidity	-0.234***	**-0.203*****	-0.226***	-0.229***	-0.229***	-0.229***	-0.236***	-0.224***
	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)
Crisis×Coverage liquidity		**-0.192*****						
		(0.043)						
Assets liquidity	-0.260***	-0.255***	**-0.168****	-0.249***	-0.247***	-0.250***	-0.247***	-0.252***
	(0.064)	(0.064)	(0.069)	(0.064)	(0.064)	(0.064)	(0.064)	(0.064)
Crisis×Assets liquidity			**-0.328*****					
			(0.077)					
Inefficiency	-0.085**	-0.084**	-0.086**	**-0.083****	-0.084**	-0.085**	-0.089**	-0.086**
	(0.040)	(0.040)	(0.040)	(0.042)	(0.040)	(0.040)	(0.040)	(0.040)
Crisis×Inefficiency				**-0.006**				
				(0.052)				
Profitability	1.321	1.483	1.681*	1.488	**1.852***	1.572	1.666*	1.689*
	(0.997)	(0.995)	(0.995)	(0.997)	(1.028)	(1.009)	(0.995)	(0.993)
Crisis×Profitability					**-1.146**			
					(1.073)			
Income diversification	-0.007**	-0.006**	-0.006**	-0.006**	-0.006**	**0.028**	-0.006**	-0.006**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.060)	(0.003)	(0.003)
Crisis×Income diversification						**-0.034**		
						(0.052)		
Funding diversification	-0.855***	-0.828***	-0.833***	-0.848***	-0.844***	-0.845***	**-0.735*****	-0.806***
	(0.092)	(0.092)	(0.092)	(0.092)	(0.092)	(0.092)	(0.094)	(0.092)
Crisis×Funding Diversification							**-0.530*****	
							(0.094)	
Size	0.135***	0.134***	0.131***	0.131***	0.132***	0.133***	0.135***	**0.142*****
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
Crisis×Size								**-0.035*****
								(0.005)

Variables	Capital	Coverage liquidity	Assets liquidity	Inefficiency	Profitability	Income diversification	Funding diversification	Size
Regulatory and macroeconomic controls								
Regulation index	2.153***	2.220***	2.276***	2.182***	2.191***	2.186***	2.269***	2.323***
	(0.254)	(0.254)	(0.255)	(0.254)	(0.254)	(0.254)	(0.254)	(0.255)
Monetary policy	-0.864***	-0.811***	-0.808***	-0.833***	-0.813***	-0.833***	-0.799***	-0.796***
	(0.154)	(0.154)	(0.153)	(0.154)	(0.155)	(0.154)	(0.154)	(0.153)
Stock exchange return	0.201***	0.130*	0.135**	0.176***	0.162**	0.174***	0.130*	0.092
	(0.070)	(0.071)	(0.070)	(0.071)	(0.071)	(0.070)	(0.070)	(0.071)
GDP growth	1.386***	0.522	0.574	1.042**	0.896*	1.002**	0.422	0.039
	(0.520)	(0.516)	(0.515)	(0.517)	(0.522)	(0.510)	(0.514)	(0.519)
Constant	5.196***	5.130***	5.102***	5.188***	5.164***	5.168***	5.065***	5.033***
	(0.432)	(0.430)	(0.431)	(0.432)	(0.432)	(0.433)	(0.427)	(0.430)
Some statistics								
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.564	0.564	0.564	0.564	0.564	0.564	0.564	0.564
Number of banks	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
Crisis effect: Wald test								
Capital	1.021***							
Coverage liquidity		-0.395***						
Assets liquidity			-0.495***					
Inefficiency				-0.089*				
Profitability					0.706			
Income diversification						-0.007**		
Funding diversification							-1.266***	
Size								0.107***

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.

troubles for European banks, which are intensified during crisis periods. Vulnerable banks, *i.e.* banking firms with 10% probability of default, can reduce their probability of default by 1.4% in normal times and by 2.9% in crisis periods, if they can reduce the loan-to-deposits ratio by one standard deviation. The negative effect of assets liquidity ratio is consistent with theory prediction and empirical findings. Alger and Alger (1999) refer to the need of riskier banks to store more liquid assets. Our result, also related to Wagner (2007), Berger and Bouwman (2008, 2009, 2010) and Acharya and Naqvi (2012), is amplified during the crisis periods. Higher assets liquidity ratios of one standard deviation raise the risk of default of vulnerable banks by 0.7% in normal times and by 2.2% in trouble times.

The Funding diversification ratio is another factor that has a negative impact on European banks' risk-taking that amplifies during crisis periods. Our results refer to "the dark side" of bank funding effect, explained by Huang and Ratnovski (2011). Instead of having a disciplinary effect (Calomiris, 1999; Calomiris and Kahn, 1991) or of refinancing unexpected retail withdrawals (Goodfriend and King, 1998), non-interest funding makes banks riskier because the non-deposit financiers may have lower incentives to conduct costly monitoring of banks and may withdraw based on negative public signals (Huang and Ratnovski, 2011). This result complements the previous finding on the stabilising role of deposits. The probability of default of vulnerable banks increases by 3.4% during normal times and by 6.4% during the crises if their non-interest funding ratio rises by one standard deviation.

Inefficiency, profitability, income diversification and size variables also have a differential effect, but not so homogeneously as previous ones. As for management quality factors, only reducing the cost-to-income ratio allows banks to improve their risk profile during the crises, with the same impact during the normal period. However, the economic impact is very weak because the decrease of the probability of default of vulnerable banks is only of 0.5%, due to one standard deviation decrease of their cost-to-income ratio, even though the result is consistent with Berger and DeYoung (1997) for U.S. banks, Podpiera and Weill (2008) for

Czech banks, Männasoo and Mayes (2009) for Eastern European banks and with Williams (2004) for European banking firms.

The beneficial effect of having high net-interest margin during the normal period, which is consistent with Poghosyan and Čihak (2011), disappears during crisis times. Our result may be related to the self-rescue operation of banks. During turmoil period, the riskiest banking firms may be encouraged to increase their interest rates and therefore their net interest margin to cover loan losses and the erosion of their capital. Quantitatively, both positive and negative impacts are not so important. During normal times, vulnerable banking firms will decrease their probability of default with 0.57% for one standard deviation increase of their profitability ratio and this rise is lowered by 0.36% during crisis times; in other words, it vanishes.

The diversification of bank activities can either reduce (Diamond, 1984; Berger et al., 1999; Campa and Kedia, 2002) or increase the risk of banks (Stiroh and Rumble, 2006; De Jonghe, 2010). A non-linear relationship has been also found (Demirgüç-Kunt and Huizinga 2010; Lapteacru 2019). Therefore, both effects may compensate each other leading to the obtained result during normal times, *i.e.* no statistical effect of income diversification on risk-taking of European banks. Nevertheless, the negative impact predominates during crisis periods, but with weak economic impact. Finally, as in Stiroh and Rumble (2006), Sanya and Wolfe (2011) and Lapteacru (2019), the size ensures stability for large banks. Even though the positive effect of the size is diminished during financial turmoil, it however remains significant statistically and economically.

As for regulatory and macroeconomic controls, our results rely on theoretical and empirical literature. Financial stability of banks tends to improve where and when banking regulation is tighter, which is consistent with prior works by Keely (1990), Martínez Pería and Schmukler (2001), Barth et al. (2004), Laeven and Levine (2009) and Chen et al. (2017). A monetary expansion reduces the risk of European banks and the stock exchange return is positively associated with their asymmetric Z-score, implying an overall beneficial effect of the high return stock exchange markets on risk-reducing behaviour of European banks. Finally, this behaviour seems to follow the economic cycle as found by Demirgüç-Kunt and Detragiache (1998), Marcucci and Quagliariello (2009), Poghosyan and Čihak (2011) and Iannotta et al. (2013).

4.2 Checking for the sample-oriented results

Our sample is composed of approximately of all banks of 28 European countries and the German banks occupy the most part: more precisely, 504 banks and 10,584 bank-year observations. We hence may wonder whether our results are driven by German banks. We thus decided to run regressions without these institutions and check whether the results always hold. The regressions with panel FE model (Table 5) show that, with few exceptions, the results remain qualitatively unchanged. However, it seems that the decrease in cost-to-income ratio and the increase in size are more beneficial to German banks, since they have no effect on banks of other European countries.

4.3 Is there a difference between regions?

Another important point is the difference in risk-taking behaviour between Western and Eastern European banks. 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 (Bonin et al., 2015). This is why we decided to split the sample between Western Europe and Eastern Europe. The countries belonging to the first sample are Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Spain, Sweden and the UK, and those included in the second sample are Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

Table 5. Determinants of European banks' risk, without Germany.

Variables	**Capital**	**Coverage liquidity**	**Assets liquidity**	**Inefficiency**	**Profitability**	**Income diversification**	**Funding diversification**	**Size**
Bank factors								
Capital	**0.287*****	0.296***	0.296***	0.295***	0.295***	0.293***	0.294***	0.297***
	(0.064)	(0.064)	(0.064)	(0.064)	(0.064)	(0.064)	(0.064)	(0.063)
Crisis×Capital	**1.138*****							
	(0.336)							
Coverage liquidity	-0.313***	**-0.286*****	-0.307***	-0.308***	-0.308***	-0.307***	-0.323***	-0.309***
	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)
Crisis×Coverage liquidity		**-0.181*****						
		(0.049)						
Assets liquidity	-0.241***	-0.224***	**-0.115**	-0.219***	-0.219***	-0.221***	-0.212***	-0.219***
	(0.070)	(0.070)	(0.078)	(0.070)	(0.070)	(0.070)	(0.071)	(0.070)
Crisis×Assets liquidity			**-0.364*****					
			(0.092)					
Inefficiency	-0.058	-0.060	-0.063	**-0.078**	-0.059	-0.059	-0.066	-0.065
	(0.044)	(0.044)	(0.044)	(0.049)	(0.044)	(0.044)	(0.044)	(0.044)
Crisis×Inefficiency				**0.047**				
				(0.062)				
Profitability	1.207	1.489	1.724*	1.419	**1.551**	1.580	1.754*	1.771*
	(1.049)	(1.046)	(1.047)	(1.050)	(1.088)	(1.061)	(1.048)	(1.045)
Crisis×Profitability					**-0.228**			
					(1.187)			
Income diversification	-0.006**	-0.006**	-0.006**	-0.006**	-0.006**	**0.035**	-0.006**	-0.006**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.056)	(0.003)	(0.003)
Crisis×Income diversification						**-0.041**		
						(0.056)		
Funding diversification	-0.745***	-0.722***	-0.724***	-0.739***	-0.735***	-0.732***	**-0.596*****	-0.699***
	(0.106)	(0.105)	(0.105)	(0.105)	(0.105)	(0.105)	(0.107)	(0.105)
Crisis×Funding Diversification							**-0.671*****	
							(0.112)	
Size	0.035	0.023	0.020	0.024	0.025	0.026	0.023	**0.027**
	(0.032)	(0.032)	(0.077)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
Crisis×Size								**-0.041**
								(0.006)

Variables	Capital	Coverage liquidity	Assets liquidity	Inefficiency	Profitability	Income diversification	Funding diversification	Size
Regulatory and macroeconomic controls								
Regulation index	2.512***	2.440***	2.497***	2.505***	2.499***	2.498***	2.473***	2.424***
	(0.273)	(0.274)	(0.273)	(0.273)	(0.273)	(0.273)	(0.273)	(0.273)
Monetary policy	-0.845***	-0.764***	-0.755***	-0.804***	-0.789***	-0.791***	-0.736***	-0.726***
	(0.159)	(0.158)	(0.157)	(0.159)	(0.159)	(0.158)	(0.158)	(0.156)
Stock exchange return	0.067	0.029	0.029	0.049	0.043	0.044	0.029	0.017
	(0.077)	(0.077)	(0.077)	(0.077)	(0.078)	(0.077)	(0.077)	(0.077)
GDP growth	2.295***	1.401***	1.397***	1.910***	1.796***	1.767***	1.154**	0.825
	(0.559)	(0.555)	(0.553)	(0.557)	(0.562)	(0.510)	(0.553)	(0.559)
Constant	5.162***	5.229***	5.189***	5.217***	5.202***	5.186***	5.149***	5.212***
	(0.437)	(0.434)	(0.435)	(0.436)	(0.436)	(0.436)	(0.429)	(0.433)
Some statistics								
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.554	0.554	0.554	0.554	0.554	0.554	0.554	0.554
Number of banks	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
Crisis effect: Wald test								
Capital	1.426***							
Coverage liquidity		-0.466***						
Assets liquidity			-0.479***					
Inefficiency				-0.031				
Profitability					1.323			
Income diversification						-0.007**		
Funding diversification							-1.266***	
Size								-0.015

Note: This table provides the regression results of determinants of European banks' risk using a panel fixed effects model for the panel without German banks. 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.

As it is presented in Table 6, the Western European banks reduce their risk during trouble periods if they have higher capital, lower coverage and assets liquidity ratios, and lower income and funding diversifications. Hence, the cost-to-income ratio and the size do not matter for these banking firms during crisis times. On the other hand, the Eastern European banks are much more receptive on these factors but also on all others. Being large and having lower cost-to-income ratio is associated with lower risk for these banks. As for whole bank sample, the profitability has no effect for both Western and Eastern institutions.

4.4 Alternative econometric methodologies

Finally, we estimate our model by employing alternative econometric methodologies and report the estimation results in Table 7. We first use 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 the thresholds endogenously, instead of imposing a regime change 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:

$$AsZscore_{i,j,t} = \delta_1 \mathbf{I}\left(GDPgrowth_{j,t} \leq \gamma\right) + \lambda_1 X^*_{i,j,t} \mathbf{I}\left(GDPgrowth_{j,t} \leq \gamma\right) + \lambda_2 X^*_{i,j,t} \mathbf{I}\left(GDPgrowth_{j,t} > \gamma\right) + \sum_{k=1}^{n-1} \alpha_k X_{k,i,j,t} + \sum_{l=n+1}^{m} \alpha_l Y_{l,j,t} + \nu_i + \pi_t + \varepsilon_{i,j,t}, \quad (5)$$

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 crisis period, while λ_2 denotes its effect when the GDP growth exceeds the threshold γ, *i.e.* during the normal period. The regime-dependent variable is, in turns, capital,

Table 6. Determinants of European banks' risk for two European regions.

Variables	Capital	Coverage liquidity	Assets liquidity	Inefficiency	Profitability	Income diversification	Funding diversification	Size
Panel A: Western Europe								
Bank factor	0.210***	-0.306***	-0.366***	-0.028	2.310	0.002	-0.666***	0.059*
Crisis×Bank factor	0.993***	-0.129***	-0.207**	0.096	0.914	-0.008	-0.295***	-0.026***
Crisis effect	1.203***	-0.435***	-0.573***	0.068	3.224	-0.006**	-1.061***	0.033
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of banks	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
Panel B: Eastern Europe								
Bank factor	5.222***	-0.099	-0.009	-0.128**	-0.175	-0.380**	-0.846***	0.479***
Crisis×Bank factor	-0.764	-0.218*	-0.296*	-0.015	-1.318	-0.287	-0.603**	-0.036**
Crisis effect	4.458***	-0.317**	-0.305**	-0.143**	-1.493	-0.667**	-1.449***	0.443***
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of banks	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

Note: This table provides the regression results of determinants of European banks' risk using a panel fixed effects model, distinguishing between Western and Eastern Europe. In Western European region are included Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Spain, Sweden, the UK, and Eastern European region the other countries, i.e. Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. Bank and time fixed effects are considered but not reported. Bank controls, macro controls, bank and time fixed effects are considered but not reported. ***, ** and * represent statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

coverage liquidity, assets liquidity, inefficiency, profitability, income diversification, funding diversification and size variables.

The results, presented in Panel A, show that not all variables follow a regime-switching evolution. The estimated thresholds of the GDP growth, which indicate the change in the evolution of the regime-dependent variable, are significant for all variables but correspond to the beginning of the recent financial crisis only for capital, coverage liquidity, assets liquidity, funding diversification and size (see Figure 3, Panel A). All these factors are associated to the risk-taking of European banks in the same way as our baseline results suggest. Banks with higher capital, lower loans-to-deposits and liquid assets-to-total assets ratios, lower share of non-deposit funding in their total funding and which are larger are also less risky during both normal (the coefficient λ_2) and crisis (the coefficient λ_1) periods. The results are bit different for unchanging-regime variables (see Figure 3, Panel B). Very high thresholds for inefficiency and income diversification variables suggest that, first, there is no regime switching because these thresholds exceed the crisis level, and, second, only below-threshold coefficient must be considered. In this case, the coefficient λ_1 indicates whole period sample without distinguishing between normal and crisis periods. Hence, according to our baseline results, higher cost-to-income ratio and higher share of non-interest income in total income increase are associated with higher risk for European banks. Although the threshold for profitability is lower, it however exceeds the GDP growth during crisis periods. Therefore, we consider only the coefficient λ_1 and conclude that higher net interest margin reduces the risk of European banks.

We also consider the dynamic process for our risk measure by adding its one-year lagged values as a covariate and then use the system GMM estimator. We assume bank characteristics to be endogenous that are instrumentalised with their own lags and with macroeconomic and regulatory controls. We also make AR(1)/AR(2) test of autocorrelation and Sargan/Hansen test of overidentification restrictions. Our results remain qualitatively unchanged (Table 7 Panel B).

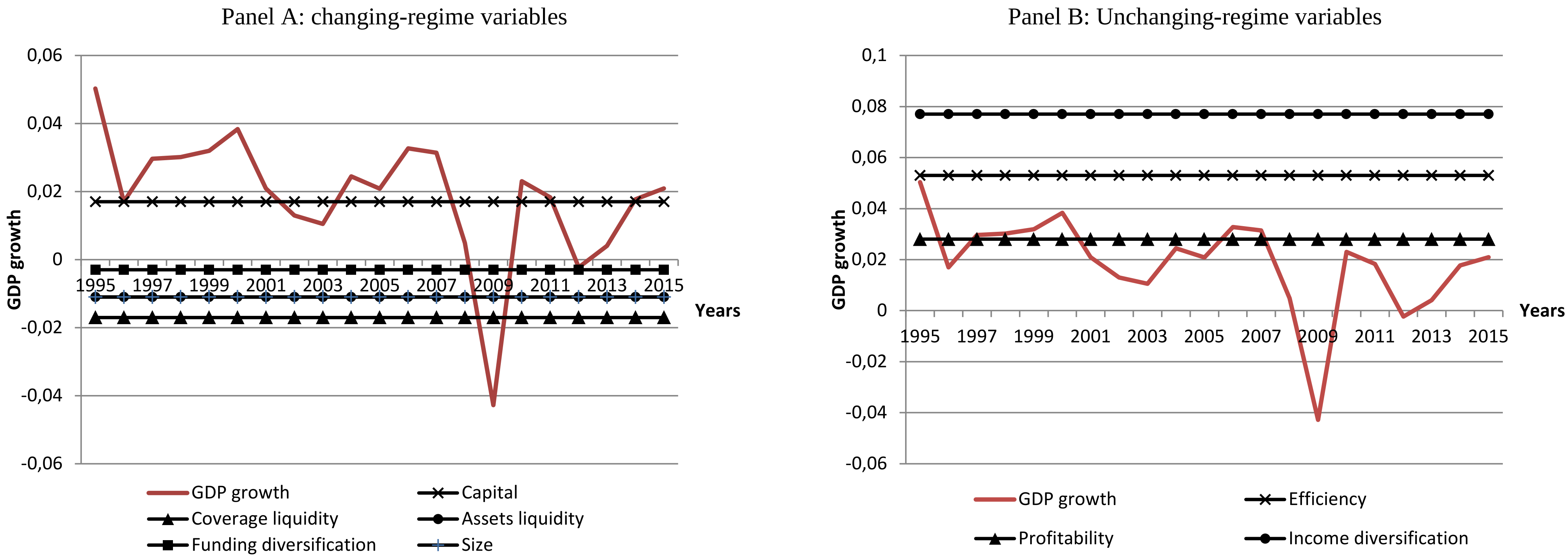
Table 7. Determinants of European banks' risk, with alternative econometric methodologies.

Variables	Capital	Coverage liquidity	Assets liquidity	Inefficiency	Profitability	Income diversification	Funding diversification	Size
Panel A: Panel threshold model								
γ, threshold estimate	0.017**	-0.017***	-0.011***	0.053**	0.028***	0.077*	-0.003***	-0.011***
λ_1, below the threshold	0.794***	-0.617***	-0.756***	-0.073**	3.212***	-0.006*	-1.446***	0.072***
λ_2, above the threshold	0.201***	-0.202***	-0.209***	-0.356***	-1.112	-0.599***	-0.748***	0.141***
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	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
Observations	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276
Panel B: Dynamic panel estimation								
Bank factor	0.131*	-0.128*	0.337**	-0.061	4.946*	0.035	-0.016	0.082*
Crisis×Bank factor	0.551**	-0.268***	-0.200	-0.046	-2.131	-0.055	-0.391*	-0.032***
Crisis effect	0.682***	-0.396***	0.137	-0.107	2.815	-0.020	-0.407*	0.050
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(1)/AR(2)	0.001/0.155	0.000/0.180	0.000/0.236	0.000/0.206	0.000/0.305	0.000/0.260	0.000/0.219	0.000/0.253
Sargan/Hansen	0.000/0.166	0.093/0.344	0.003/0.067	0.895/0.133	0.069/0.409	0.374/0.279	0.046/0.237	0.083/0.293
GMM: Hansen/Difference tests	0.255/0.152	0.770/0.090	0.119/0.122	0.223/0.081	0.688/0.172	0.375/0.116	0.804/0.042	0.783/0.063
IV: Hansen/Difference tests	0.317/0.149	n.a./0.863	n.a./n.a.	0.294/0.072	n.a./0.884	0.432/0.119	n.a./0.748	n.a./0.868
Number of banks	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156
Observations	21,964	21,964	21,964	21,964	21,964	21,964	21,964	21,964
Panel C: Addressing endogeneity with one-year lag of bank factors								
Bank factor	0.516***	-0.201***	-0.069	-0.063	2.584***	0.075	-0.649***	0.131***
Crisis×Bank factor	-0.321	-0.268***	-0.406***	-0.069	-1.960**	-0.081	-0.581***	-0.039***
Crisis effect	0.195	-0.469***	-0.475***	-0.122**	0.624	-0.006**	-1.230***	0.092***
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	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
Observations	23,120	23,120	23,120	23,120	23,120	23,120	23,120	23,120

Panel D: Addressing endogeneity with 2SLS estimation								
Bank factor	0.264**	-0.354***	-0.338*	-0.445*	2.886	-0.002	-1.029***	0.147***
Crisis×Bank factor	1.118***	-0.132***	-0.197**	0.252*	-0.902	-0.004	-0.401***	-0.028***
Crisis effect	1.382***	-0.486***	-0.535***	-0.193	1.984	-0.006***	-1.430***	0.119***
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Under- / weak-identification tests	0.000/8.798	0.000/8.985	0.000/8.762	0.000/13.439	0.000/8.614	0.000/8.389	0.000/8.939	0.000/8.800
Hansen J / endogeneity tests	0.249/0.002	0.250/0.005	0.248/0.004	0.245/0.003	0.248/0.003	0.248/0.003	0.248/0.003	0.251/0.005
Number of banks	1,156	1,156	1,156	1,156	1,156	1,156	1,156	1,156
Observations	23,120	23,120	23,120	23,120	23,120	23,120	23,120	23,120
Panel E: FE model with country fixed effects								
Bank factor	0.278***	-0.193***	-0.426***	-0.612***	-0.497	-0.295***	-0.565***	0.003
Crisis×Bank factor	0.905**	-0.193***	-0.354***	0.121	-0.510	0.285***	-0.466***	-0.033***
Crisis effect	1.183***	-0.386***	-0.780***	-0.491***	-1.007	-0.010**	-1.031***	-0.030***
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	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
Observations	24,276	24,276	24,276	24,276	24,276	24,276	24,276	24,276
Panel F: FE model with country clustered standard errors								
Bank factor	0.280***	-0.203*	-0.168	-0.083	1.852	0.028	-0.735***	0.142
Crisis×Bank factor	0.741*	-0.192**	-0.328***	-0.006	-1.146	-0.034	-0.530***	-0.035***
Crisis effect	1.021**	-0.395**	-0.495***	-0.089	0.706	-0.007***	-1.266***	0.107
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	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
Observations	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 alternative econometric methodologies. For the panel threshold model, GDP growth is 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 crises and those related to λ_2 correspond to the effects during the normal period. Bank controls, macro controls, bank and time fixed effects are considered but not reported.. ***, ** and * represent statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

Figure 3. Evolution of the country 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 financial crises.

The next and last four econometric models provide also the same conclusions about the effect of eight selected bank factors on European banks' risk-taking. The dynamic panel model addresses the endogeneity of bank factors but imposes a dynamic process for the dependent variable. However, running regressions with one-year lagged covariates (Table 7 Panel C) allows accounting for the endogeneity of explanatory variables caused by an eventually mutual effect between dependent and explanatory variables without considering a dynamic process. Another way to deal with endogeneity is to instrument the explanatory variables supposed to be endogenous. The fifth econometric method we apply is the 2SLS instrumental variable estimation where the bank specific factors are instrumented with their one-lagged values. All tests to check the goodness of our regressions are applied and all of them reject the hypotheses of under- and weak identification of instruments, of exogeneity of regressors and cannot reject the hypothesis of overidentification test of all instruments (Table 7 Panel D). In the last two models, we substitute the bank specific effects by country specific effects and considered country clustered standard errors (Table 7 Panels E and F). Our results do not change qualitatively too.

5. Summary and conclusion

Successive waves of banking crises of 1990s and 2000s in both Eastern and Western European countries lead us to wonder about the key drivers of European banks' vulnerability. Even though this issue has been somewhat explored, we provide new evidence and insights issued from a new measure of Z-score, a larger sample of banks and countries and new methodological approaches. We find that higher capital, lower ratios of loans to deposits and of liquid assets to total assets and lower share of non-deposit and short-term funding in total funding are associated with lower bank risk and this effect is much stronger during the crisis times. These basic results, obtained from a large sample of 1,156 banks from 28 European countries, support the efforts of European banking regulators, from both Western and Eastern regions, in tightening of bank capital requirements. The European banking firms should also ensures that their illiquid long-term assets are mostly based on stable source of funding, which are customer deposits. Both indicators, *i.e.* loans-to-deposits and non-deposit ratios, confirm the stabilisation role of deposits for European banks. As for assets liquidity ratio, it is a good marker of banks in distress, since the banks may proceed to abnormal liquidity creation when their stability is threatened. Both liquidity ratios have effects on banks of both European regions during crisis periods and only on Western European banks during normal times. On the other hand, when banks base more their financing on non-deposit financiers, they are riskier in both European regions with amplified effect during crisis periods.

Other four factors are heterogeneously associated with riskiness of European banks. The managerial performances are associated as expected to the solvability of European banks during normal periods but a bit different during crisis times. The cost-to-income ratio does still increase the bank risk and the net interest margin ratio loses its positive effect. Finally, the European banks involved in non-interest-generating activities do not globally change their risk profile during normal times. However, there is a difference between Western and Eastern banking institutions. The overall result concerns the former, whereas the latter are riskier when they increase the share of non-interest income and their risk is higher during crisis periods. The banks from both regions are less risky during normal times if they are larger and the role of the size is diminished for the Eastern banking firms and is cancelled for Western banking institutions. Our results remain mostly qualitatively unchanged after different robustness tests and provide useful insights for bank regulators and professionals.

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Appendix A:

Table A.1. Data applied to compute the shadow rate and the estimated lower bound of monetary policy rate.

Country	Interest rates employed for shadow rate computations	r_{lb} fixed by CB, %	r_{lb} estimated, %
Austria	Interbank market: 1, 3, 6 and 12 months	0.00	-0.05
Belgium	Interbank market: 1, 2, 3, 6 and 12 months Sovereign bonds: 1, 2, 3, 6 and 12 months	0.00	-0.21
Bulgaria	Interbank market: 1 and 3 months	0.01	0.35
Croatia	Interbank market: 1, 3 and 6 months	0.50	0.63
Cyprus	Interbank market: 3 months Sovereign bonds: 12 and 24 months	0.00	0.37
Czech Rep.	Interbank market: 1, 3, 6, 9 and 12 months	0.05	0.17
Denmark	Interbank market: 1, 2, 3, 6 and 12 months Sovereign bonds: 3 and 6 months	0.00	-0.30
Estonia	Interbank market: 3 months	0.00	
Finland	Interbank market: 1, 3, 6 and 12 months	0.00	-0.03
France	Interbank market: 1, 2, 3, 6 and 12 months Sovereign bonds: 1, 3, 6, 9 and 12 months	0.00	-0.04
Germany	Interbank market: 1, 2, 3, 6, 9 and 12 months Sovereign bonds: 1, 2, 3, 6, 9 and 12 months	0.00	-0.06
Greece	Interbank market: 1, 2, 3 and 6 months Sovereign bonds: 3 and 6 months	0.00	-0.01
Hungary	Interbank market: 1, 2, 3 and 6 months Sovereign bonds: 3, 6 and 12 months	1.35	0.10
Ireland	Interbank market: 1, 3, 6 and 12 months	0.00	-0.17
Italy	Interbank market: 1, 2, 3, 6, 9 and 12 months Sovereign bonds: 3, 6 and 12 months	0.00	-0.02
Latvia	Interbank market: 1, 3, 6 and 12 months Sovereign bonds: 6 and 12 months	0.00	0.27
Lithuania	Interbank market: 1 and 7 days and 1 and 3 months	0.00	0.21
Luxembourg	Interbank market: 3 months	0.00	
Malta	Sovereign bonds: 1, 3 and 6 months	0.00	-0.12
Netherlands	Interbank market: 1, 2, 3, 6 and 12 months	0.00	-0.07
Poland	Interbank market: 1, 3, 6, 9 and 12 months Sovereign bonds: 12 months	1.50	0.11
Portugal	Interbank market: 1, 2, 3, 6 and 12 months	0.00	0.09
Romania	Interbank market: 1, 6, 9 and 12 months	1.75	0.35
Slovakia	Interbank market: 1, 3, 6 and 12 months	0.00	-0.05
Slovenia	Interbank market: 1, 2, 3, 6, 9 and 12 months	0.00	-0.07
Spain	Interbank market: 1, 2, 3, 6 and 12 months Sovereign bonds: 6 and 12 months	0.00	-0.04
Sweden	Interbank market: 1, 2, 3 and 6 months Sovereign bonds: 1, 3, 4, 5, 6 and 7	-0.35	-0.41
UK	Interbank market: 1, 2, 3, 6 and 12 months Sovereign bonds: 1, 3 and 12 months	0.50	0.46

Note: This table provides data applied to compute the shadow interest rate with fixed and estimated lower bound constraint of monetary policy, according to the methodology of Krippner (2014, 2016).

Appendix B. 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 (2019), 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.

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