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The 'risk dividend' in banks' internal capital markets

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Abstract

We examine the impact of banks' internal capital markets (ICMs) before the 2008-09 financial crisis on bank risk-taking during the crisis in a panel of 8,068 banks across 16 countries. The size of ICMs was an important driver of risk during the crisis when banks with larger ICMs exhibited lower risk levels. Larger ICMs reduced risk further for well capitalized banks. Banks more likely to be in trouble in a crisis are likely to have smaller ICMs, be larger in size, less well capitalized, less efficient, less profitable, and more dependent on market funding.

JEL: G15, G21, G32

Keywords: Internal capital markets; bank risk; financial institution; subsidiaries; bank characteristics

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1. Introduction

Internal capital markets (ICMs) are an important mechanism by which firms allocate funds across business and geographic units. There are mixed views on how well ICMs carry out this function. Alchian (1969) and Williamson (1970) argue that ICMs are more efficient than external markets because corporate headquarters is likely to be better informed than external suppliers of capital about investment opportunities. By contrast, Meyer et al. (1992), Wulf (2009), Rajan et al. (2000), and Scharfstein and Stein (2000) argue that rent seeking by divisional managers can distort the functioning of internal capital markets, inducing corporate headquarters to allocate excessive capital to divisions with poor investment opportunities where rent-seeking incentives are strongest. Argawal et al. (2011) review much of the relevant empirical research for nonbank firms and argue that the majority provide evidence that resources often flow from efficient divisions to low-performing inefficient divisions. In banking, a growing empirical research analyzes whether ICMs impact on the transmission of monetary policy, in particular whether global banks can mitigate the effects of policy shocks by redistributing liquidity from subsidiaries and affiliates with excess liquidity to those in need of it. For example, Campello (2002) provides evidence that US banks that are part of a network are less affected by changes in monetary policy than stand-alone banks, as they absorb shocks through their ICM. Cetorelli and Goldberg (2012ab), Barba-Navaretti et al. (2010), De Haas and van Lelyveld (2010), and Schnabl (2012) report that ICMs are used by international banks to support their foreign affiliates during times of financial stress. At the same time, ICMs can transmit liquidity shocks in the home country to countries in which their subsidiaries and affiliates are located. For example, Giannetti and Laeven (2012ab) find that banks active in the syndicated loan market reallocated capital towards domestic markets in a "flight to

home effect", thereby transmitting negative shocks to the host country; and Acharya and Schnabl (2010), Chava and Purnandam (2011) and Cetorelli and Goldberg (2012a) report evidence that during the 'great recession' foreign subsidiaries of US banks reduced their lending compared to domestic banks when parent banks experienced liquidity problems. In this paper, we extend the research on the role of ICMs in banking by focusing on their role as a determinant of bank risk. In particular, we are interested in whether the additional flexibility in funds management offered by ICMs is reflected in a 'risk dividend' (i.e., lower levels of risk) for banks with larger ICMs. To this end, we analyze for parent banks headquartered in the US and the European Union (EU) how bank risk *during* the financial crisis of 2008-2009 was related to the size of banks' ICMs and to other key bank characteristics in the *pre-crisis* period of 2002-2007. This analytical approach is suggested by Altunbaş et al. (2017) and Shehzad and De Haan (2015) as a means of assessing the consistency of the results in the context of clustered signals of bank risk prior to the crisis and the variability in realized risk across individual banks after the crisis erupted. To anticipate our key result, we find that ICMs are a major driver of bank risk, with banks with larger ICMs before the crisis exhibiting lower levels of risk during the financial crisis.

Our paper makes two contributions to the banking literature. First, we contribute to the literature on the determinants of bank risk, which has shown banks to be susceptible to risks because of a variety of factors, including own characteristics such as size and efficiency (Berger and De Young, 1997), regulatory and supervisory frameworks (Laeven and Levine, 2009), market competition (Beck et al., 2013), funding diversification (Demirgüç-Kunt and Huizinga, 2010), and monetary and macro-prudential policy (Dell'Ariccia et al., 2017; Altunbaş et al., 2018). Noticeably absent in this literature is an examination of the links between the size of banks' ICMs and bank risk taking. Our finding that banks with larger ICMs exhibited lower levels of risk suggests—a 'risk

dividend'—suggest that these markets contribute importantly to financial stability. Second, we contribute to the literature on geographical diversification and bank risk, which posits that diversification reduces risk because banks enjoy cost-efficiencies (Diamond, 1984; Boyd and Prescott, 1986) or increase risk because bankers extract private benefits from managing a larger 'empire' (Jensen, 1986; Denis et al., 1997) or if distance hinders the ability to monitor subsidiaries (Brickley et al., 2003, Berger et al., 2005). As larger ICMs are associated with more geographically diversified banks, our results suggest that geographic diversification reduces risk in part because it gives banks access to a larger ICM.

2. Model, variables and data

2.1 Model

We employ the following baseline model to examine how bank risk for US and EU headquartered banks *during* the financial crisis of 2008-2009 was related to the size of their ICMs (and to other factors) in the *pre-crisis* period of 2002-2007:

$$r_{i,c} = \beta_0 + \beta_1 ICM_{i,b} + \delta X_{i,b} + \varepsilon_i \qquad (1)$$

In equation (1), the dependent variable $r_{i,c}$ measures the distress of bank *i* during the crisis period *c* (2007 to 2009), and $ICM_{i,b}$ is a measure of the size each bank's internal capital market and $X_{i,b}$ is a vector of bank characteristics with $ICM_{i,b}$ and $X_{i,b}$ computed as averages in the pre-crisis period *b* (2002 to 2007). The use of average information from the pre-crisis period to forecast

distress during the crisis serves to minimize endogeneity problems. A similar strategy has been adopted, for example, by Altunbaş et al. (2017), Bekaert et al. (2014), and Shehzad and De Haan (2015). From an econometric perspective, these variables can be considered predetermined, which guarantees consistent forecasts.

For robustness, we employ two measures of bank risk, $r_{i,c}$, and two measures of banks internal capital market, $ICM_{i,b}$. The first measure of risk is the z-score of each bank, which equals the return on assets plus the capital asset ratio divided by the standard deviation of asset returns, and where a higher z-score indicates that a bank is more stable. The z-score measures the distance from insolvency where insolvency is defined as a state in which losses surmount equity ($E < -\pi$) (where E is equity and π is profits).[1] Following the literature, we define the inverse of the probability of insolvency as the z-score. The second measure of bank risk captures the reaction of individual banks to *systemic* events. It measures tail dependence in the stock market returns of individual banks and equates the magnitude of tail dependence estimates as a measure of systemic risk. It is estimated via the marginal expected shortfall (MES) following the model by Acharya et al. (2017) at a standard risk level of 5% as follows:

$$MES_i^{5\%} = {}^{1}/_{days} \sum_t R_i \qquad (2)$$

where $MES_i^{5\%}$ is the marginal expected shortfall of bank i in 5% worst days; $days$ is the number of 5% worst days in the market; R_i is the average return of bank i in 5% worst days.

[1] The probability of insolvency, therefore, can be expressed as prob (-ROA<CAR), where ROA (= π/A) is the return on assets and CAR (= E/A) is the capital assets ratio. If profits are normally distributed, then the inverse of the probability of insolvency equals (ROA+CAR)/σ(ROA), where σ(ROA) is the standard deviation of ROA.

In the absence of publicly available data on intra-banking group transactions, we measure the size of a bank's ICM through the size of its subsidiary and affiliate network, which we represent alternately by the natural log of the total assets of each bank's subsidiaries and affiliates and by the natural log of the number of each bank's subsidiaries and affiliates. Our assumption is that the larger the total of these assets (or the larger the number of subsidiaries and affiliates), the larger is the bank's ICM and the greater the scope for mitigating the effects of liquidity shocks and other adverse developments in the bank's home or host country. This could be done, for example, by means of loans from within the banking group to the affected entity, or by capital injections from the parent. In this context, we would expect bank risk to be negatively related to the size a bank's ICM.

The vector $X_{i,b}$ comprises bank-specific variables drawn from previous empirical literature on the determinants of bank risk, though in some cases their impact on risk is ambiguous. The first variable included is bank size, which is measured as the natural logarithm of total assets. Large banks may have incentives to take more risk there is a high expectation of a government bailout in the event of failure to prevent systemic risk (Afonso et al., 2014). However, risk may also decline for large banks because they are better able to diversify their portfolio, whereas small banks tend to pursue traditional banking (Demirgüç-Kunt and Huizinga, 2010). The second variable is, bank capital, which is measured by the ratio of Tier 1 capital to total assets. The coefficient on capital is generally expected to be negative because well-capitalized banks can more effectively absorb the negative effects of shocks on bank lending (Bernanke and Lown, 1991; Gambacorta and Mistrulli, 2004). However, there is also some evidence of a non-linear relationship between capital and risk, whereby both very low and very high levels of capital induce banks to take on more risk.

For example, Calem and Rob (1999) model a U-shaped relationship between capital and risk-taking in which as bank's capital increases the bank first takes less risk and then more risk. The third variable is banks' asset structure, which is measured as the ratio of total loans to total assets. This variable provides a summary indication of the extent to which a bank is involved in traditional lending activities, which are generally viewed as less risky than banking strategies that rely prominently on generating non-interest income (De Jonghe, 2010; Demirgüç-Kunt and Huizinga, 2010). However, other studies have found that the diversification of income reduces bank risk-taking (Pennathur et al. 2012; Chiorazo, et al. 2008). The fourth variable is funding structure, which is measured by the ratio of customer deposits to total liabilities. The expected sign on this variable is negative because high switching costs and the presence of government insurance means that banks with a higher ratio of customer deposits will have a more stable source of funding, particularly during periods of crises (Shleifer and Vishny, 2010). The fifth variable is bank liquidity, which is measured as the ratio of liquid assets to total assets. The coefficient on this variable is generally expected to be negative since liquidity is traditionally viewed as a buffer against risks arising from financial and economic stresses. The sixth variable is bank efficiency, which is measured as the ratio of bank costs to total income. The coefficient on this ratio is expected to be positive as cost and revenue inefficiencies make it more difficult for banks to shore up capital levels and more prone to risk-taking (Berger and De Young, 1997). Our final bank-specific variable is the return on assets, which is measured as the ratio of net income to total assets. According to the "pecking order theory of finance," because increasing extra capital is costly, it may be easier to accumulate capital via higher retained earnings (Flannery and Rangan 2008). In contrast, greater profitability might also make capital requirements less binding so that banks are less averse to occasional losses through risk-taking (Calem and Rob, 1999; Perotti et al., 2011).

Our primary source of data is BankScope. This provides us with data to calculate the z-score and the size of the ICM for 8,068 public listed and privately held banks across 16 countries for the crisis period 2008-2009. We match the information on average bank risk with data on balance sheet characteristics of the banks from the pre-crisis period of 2002 to 2007. When we employ the systemic measure of risk, the number of banks in the sample drops sharply to 888 because this measure of risk restricts the sample to publicly listed banks. The numbers of parent banks and their subsidiaries and affiliates, and the value of the assets of subsidiaries and affiliates are listed by host country in Table 1. In our sample, the largest number of parent banks is located in Germany, the US, and Italy. Parent banks located in the US, the UK and Germany have the largest number of subsidiaries and affiliates (domestic and foreign), while parent banks located in the US, the UK and France have subsidiaries and affiliates with largest total assets. Summary statistics for the key variables are presented in Table 2. For each bank, the table illustrates the considerable diversity in risk across banks (e.g., the z-score ranges 3.87 to 46.82 in the sample of all banks), and in the number of subsidiaries and affiliates and the value of their assets. Variable definitions are given in Appendix Table 1.

3. Empirical results

Table 3 provides the estimates of equation 1 for the z-score and systemic measures of bank risk for the full sample of banks and separately for EU and US headquartered banks. All coefficients on the ICM variable are negative and statistically significant, suggesting strongly that banks with larger ICMs were significantly less risky during the 2008-2009 crisis. The economic size of the coefficients are consequential: on the z-score measure a one standard deviation change in the size

of the ICM is associated with a change of -0.16, -0.16, and -0.63 for all banks, EU banks and US banks, respectively (where the respective sample mean z-scores are 3.87, 3.85, and 3.93); on the systemic risk measure the change is -0.73, -0.26, and -0.96 (where the means for systemic risk are -4.08, -3.37, and -4.41). Accordingly, the 'risk dividend' ranges from 4-16% of the mean measure of risk in the case of the z-score and between 7.7-21.8% of mean measure of systemic risk. Moreover, risk reduction associated with ICMs is larger for US than for EU banks, which may reflect their somewhat larger networks of subsidiaries and affiliates in terms of the dollar value of assets. These results are consistent with banks using their ICMs for internal liquidity management to mitigate the adverse liquidity effects of the crisis and with ICMs providing a 'risk dividend' for those banks.

The coefficients on the bank-specific variables are all statistically significant in the z-score estimates but are more mixed in the systemic risk estimates, which may reflect the much reduced sample size in the latter case. In the z-score estimates: large banks were significantly riskier during the crisis, probably because they were considered as "too big to fail" (Afonso et al., 2014); banks that were focused on traditional lending activities were riskier, probably because of the lack of diversification in income sources (Pennathur et al. 2012; Chiorazo, et al. 2008); and inefficient banks were riskier because of the limited scope for strengthening capital levels (Berger and De Young, 1997). On the other hand, higher levels of capital and liquidity and more stable sources of funding provided buffers that reduced the probability of a bank distress during the crises (Bernanke and Lown, 1991; Gambacorta and Mistrulli, 2004; Shleifer and Vishny, 2010), and more profitable banks had less trouble maintaining capital ratios, which reduced risk. In the estimates of systemic risk, where the coefficients on the variables are significant their signs are consistent with the z-

score results. In particular, larger banks were associated with greater risk during the crisis, and banks that were better capitalized, had more stable funding, and were more profitable were negatively associated with risk taking.

For robustness, in Table 4, we report the impact of ICMs on the two measures of bank risk when the ICM is defined as the natural log of the total number of subsidiaries and affiliates of each bank. The results are very much in line with those reported in table 3. In particular, the coefficients on $ICM_{i,b}$ are all negative and statistical significant. The economic size of the coefficients is somewhat smaller in absolute terms and with respect to the sample means of the measures. For example, on the z-score measure, a one standard deviation change in the size of the ICM is associated with a change in risk of -0.06 to -0.21, and on the measure of systemic risk the change is between -0.08 to -1.12. Again, the reduction in risk is somewhat larger for the US banks. The coefficients on the bank-specific variables in the two sets of estimates also tell broadly the same story: riskier banks tend to be larger, focused on traditional lending, and less efficient, and less risky banks are better capitalized, more liquid, and have more stable funding sources. The difference in the estimates is with respect to impact on risk of profitability, which is associated with greater risk taking on the systemic risk measure (this variable not being statistically significant when our alternative measure of the internal capital market was employed).

We next examine whether ICMs allow banks to operate with lower capital ratios during the crisis without adversely impacting on bank risk—for example, because market participants view the bank as having sufficient alternative (internal) sources of funding available in the event of an adverse shock. To test for non-linear effects of bank capital on risk, we follow Calem and Rob (1999) and interact our measure of capital with a dummy indicator for banks with low capital ratios

(below 6 percent) and a dummy indicator for banks with high capital ratios (above 6%). We report the results employing both measures of bank risk and both measures of ICMs for all banks, and separately for EU and US banks in Tables 5-8. The results suggest strongly that ICMs do not mitigate the risk effects on banks of low capitalization, as indicated by the positive and statistically significant coefficient on the low-capital interaction term in all the estimates. Table 5 reports estimates including the interaction dummies for the z-score measure of risk for all banks and for European and US banks separately where the ICM is measured by the total value of assets of subsidiaries and affiliates. The interaction of the ICM term and the low capitalization dummy is positive and statistically significant in each estimate. That is, low bank capital ratios increased bank risk notwithstanding the presence of an ICM. In contrast the coefficient on the ICM-high capitalization dummy interaction is negative and statistically significant in each estimate, suggesting that well capitalized banks benefitted particularly from an ICM during the crisis. These conclusions hold in the estimates of the measure of systemic risk reported in Table 6 and when we employ our alternative measure of the ICM in Tables 7 and 8 (though the coefficients on the ICM-high capitalization dummy interaction terms are not always statistically significant). We conclude that the 'risk dividend' from a large ICM mainly accrues to banks that are relatively well capitalized.

4. Conclusions

We examined the impact of banks' access to internal capital markets before the 2008-09 financial crisis on bank risk-taking during the crisis employing a panel of 8,068 US and EU banks. We show that the relationship between ICMs and other bank characteristics on the one hand and bank risk on the other could be detected using measures of risk calculated prior to the financial crisis. More

specifically, our results show that the size of a bank's ICM is an important driver of bank risk as banks with ICMs exhibited lower levels of risk during the financial crisis, and that this 'risk dividend' mainly accrued to banks that were also well capitalized. Our results are robust to alternative measures of bank risk and of banks' internal capital market. For bank regulators, they suggest that the banks more likely to be in trouble in case of crisis are those with small internal capital markets as well being relatively large, poorly capitalized, more dependent on market funding, less efficient and less profitable.

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Table 1
Parent banks, subsidiaries and alliances by country, 2001-2010

Country	Number of HQ banks		Number of subsidiaries[1]		Number of affiliates[1]		Total assets of subsidiaries ($ billions)[2]		Total assets of affiliates ($ billions)[2]	
	All banks	Listed banks	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
Austria	330	13	975	694	1042	746	881.0	336.7	2864.8	2259.4
Belgium	134	9	517	2501	836	3807	1965.3	2086.3	9373.6	93832.5
Germany	2655	48	3323	952	4163	8276	2033.0	1763.5	34566.2	170390.3
Denmark	134	54	245	45	336	658	1722.1	116.0	403.8	13380.8
Finland	24	4	71	33	159	153	39.3	60.4	101.8	562.7
France	543	54	2679	1440	3190	8465	6663.5	1822.5	66635.2	220647.7
Greece	34	16	186	149	186	48	21.8	150.1	401.5	580.4
Ireland	70	7	264	91	63	224	528.4	228.8	391.4	8862.3
Italy	939	59	1108	169	2792	3411	8636.6	1810.7	32143.0	125567.2
Luxembourg	164	6	193	341	141	284	28.3	179.8	55.5	1363.4
Netherlands	105	11	658	387	256	5736	2139.3	988.3	8289.3	112336.6
Portugal	63	11	202	120	230	156	137.0	55.9	1255.8	776.6
Spain	260	19	1913	388	2060	765	3243.9	1245.9	17604.7	21214.5
Sweden	132	10	138	109	813	2970	326.0	564.9	7733.3	53703.6
UK	420	29	3786	834	7273	12444	12175.9	4136.8	98494.8	201742.9
USA	2061	538	7926	2027	38677	16694	16849.9	7586.9	505256.0	309072.8

Source:
[1] Ownership by parent greater than 49%
[2] Ownership by parent less than 49%.

Table 2
Summary statistics[1]

	Observations	Minimum	Maximum	Mean	Median	Standard deviation
A. Bank risk indicators, average 2008-2009						
Z-score, all banks	4162	0.01	46.82	3.87	2.96	4.02
EU banks	3309	0.01	46.82	3.85	2.83	4.21
US banks	850	0.01	33.08	3.98	3.79	2.62
MES all banks						
Systemic risk, all banks, average 2007Q4-2009Q4	510	-15.97	1.81	-4.08	-4.14	2.61
Systemic risk, European banks	305	-15.97	1.81	-3.47	-2.83	2.93
Systemic risk, US banks	205	-11.35	0.70	-4.41	-4.58	2.37
B. Internal capital market indicators, average 2002-2007						
Total assets of subsidiaries, all banks (log $million)	4162	0.00	9.86	0.74	0.07	1.47
Total assets of subsidiaries, European banks (log $million)	4162	0.00	7.73	0.78	0.19	1.30
Total assets of subsidiaries, US banks (log $millions)	4162	0.00	7.49	0.91	0.24	1.38
Total number of subsidiaries, all banks (log)	4162	0.00	9.04	1.87	1.39	1.33
Total number of subsidiaries, European banks (log)	3309	0.00	9.04	1.77	1.39	1.21
Total number of subsidiaries, US banks (log)	850	0.00	8.73	3.07	2.60	1.95
C. Bank specific variables, 2002-2007						
Size (log of total assets)	4162	7.40	21.62	14.01	13.78	2.03
Tier 1 capital-to-risk weighted asset ratio	4162	0.02	49.33	9.03	7.36	6.40
Funding structure ratio	4162	0.03	74.98	10.95	5.12	13.70
Asset structure ratio	4162	0.99	95.94	58.34	62.99	20.68
Liquidity ratio	4162	0.01	49.88	12.15	6.69	12.34
Efficiency ratio	4162	0.99	168.40	66.16	67.07	16.17
Profitability ratio	4162	-9.99	8.99	0.71	0.53	1.22
Undercapitalization dummy	4162	0.00	1.00	0.33	0.00	0.47
High capitalization dummy	4162	0.00	1.00	0.67	1.00	0.47

[1] Definitions of variables are provided in the appendix table.

Table 3
Bank risk and internal capital markets (ICM): ICM measured as the log of total assets of subsidiaries and affiliates

F	Risk measure: Z-score			Risk measure: Systemic risk		
	All banks	EU banks	US banks	All banks	EU banks	US banks
ICM	-0.1101**	-0.1235***	-0.4599***	-0.5011**	-0.1969***	-0.6963***
	(0.0467)	(0.0265)	(0.1326)	(0.1172)	(0.0667)	(0.0249)
Size	0.1687***	0.1629***	-0.0150	0.5566***	0.6182***	1.3037***
	(0.0236)	(0.0123)	(0.0326)	(0.0792)	(0.0546)	(0.0529)
Capital	-0.3153***	-0.2114***	-0.2431***	-0.0943**	-0.1496***	-0.0236***
	(0.0043)	(0.0036)	(0.0045)	(0.0425)	(0.0351)	(0.0037)
Asset structure	0.0068***	0.0033***	0.0192***	0.0119	0.0159	0.0185***
	(0.0022)	(0.0012)	(0.0027)	(0.0114)	(0.0110)	(0.0026)
Funding structure	-0.0130***	-0.0070***	-0.0116***	-0.0414***	-0.0557***	-0.0038***
	(0.0034)	(0.0022)	(0.0024)	(0.0133)	(0.0152)	(0.0013)
Liquidity	-0.0038*	-0.0048***	-0.0089**	0.0029	-0.0035	-0.0013
	(0.0023)	(0.0014)	(0.0035)	(0.0092)	(0.0091)	(0.0071)
Efficiency	0.0181***	0.0276***	0.0104***	-0.0181	-0.0023	-0.0012
	(0.0027)	(0.0017)	(0.0032)	(0.0163)	(0.0226)	(0.0020)
Profitability	-0.0557***	-0.0168***	-0.0791***	-0.5256	0.4125	0.8446
	(0.0065)	(0.0043)	(0.0031)	(0.3410)	(0.3174)	(0.7264)
Intercept	-3.9349***	-5.5228***	-0.7552	-4.2295*	-3.4818	-6.6264***
	(0.5157)	(0.2542)	(0.8406)	(2.3250)	(2.3948)	(0.3887)
R^2	0.649	0.543	0.540	0.312	0.581	0.398
Observations	4160	3309	850	510	305	205

OLS estimations with robust standard errors in parenthesis clustered at the country level for EU banks and at the bank level for US banks. The internal capital market (ICM) is the log of total assets of each bank's subsidiaries. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively

Table 4
Bank risk and internal capital markets (ICM): ICM measured as the log of the number of subsidiaries and affiliates

	Risk measure: Z-score			Risk measure: Systemic risk		
	All banks	EU banks	US banks	All banks	EU banks	US banks
ICM	-0.0630***	-0.0500**	-0.1083*	-0.6323***	-0.0704	-0.5968***
	(0.0216)	(0.0226)	(0.0564)	(0.0967)	(0.2030)	(0.0619)
Size	0.1644***	0.2144***	-0.0731	1.3093***	0.7683***	1.6809***
	(0.0200)	(0.0163)	(0.0673)	(0.1288)	(0.2577)	(0.1614)
Capital	-0.2877***	-0.1626***	-0.0320**	-0.0757**	-0.1047***	-0.0558*
	(0.0070)	(0.0034)	(0.0163)	(0.0372)	(0.0141)	(0.0333)
Asset structure	0.0084***	-0.0022*	-0.0055	0.0131	-0.0035	0.0303***
	(0.0010)	(0.0014)	(0.0058)	(0.0111)	(0.0031)	(0.0114)
Funding structure	-0.0067***	-0.0036***	0.0162***	-0.0403***	-0.0417***	-0.0059
	(0.0013)	(0.0064)	(0.0045)	(0.0126)	(0.0157)	(0.0253)
Liquidity	-0.0053***	-0.0040***	-0.0096*	-0.0002	0.0145*	0.0041
	(0.0014)	(0.0012)	(0.0056)	(0.0107)	(0.0079)	(0.0038)
Efficiency	-0.0084***	0.0107***	0.0029	0.0101	0.0046	-0.0034
	(0.0028)	(0.0016)	(0.0059)	(0.0147)	(0.0216)	(0.0158)
Profitability	-0.5751***	-0.4208***	-0.1162	0.8148***	0.6245*	0.5648
	(0.0575)	(0.0268)	(0.1757)	(0.2877)	(0.3750)	(0.5880)
Intercept	-3.7521***	-5.0081***	-1.4185	-6.3408**	-8.5733*	-9.2413**
	(0.4763)	(0.2843)	(1.4032)	(2.9709)	(4.8492)	(3.6460)
R^2	0.665	0.568	0.092	0.365	0.534	0.393
Observations	4160	3309	850	510	305	305

OLS estimations with robust standard errors in parenthesis clustered at the country level for EU banks and at the bank level for US banks. The internal capital market (ICM) is the log of total assets of each bank's subsidiaries. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively

Table 5
Bank risk and internal capital markets with bank capital interactions. ICM measured as the log of total assets of subsidiaries and affiliates

	Bank risk measure: Z-score					
	All banks		EU banks		US banks	
ICM	-0.1277**	-0.0290	-0.0643**	-0.0694**	-0.5188***	-0.4618***
	(0.0474)	(0.0636)	(0.0315)	(0.0302)	(0.1349)	(0.1401)
Size	0.1664***	0.1671***	0.1613***	0.1774***	-0.0147	0.0306***
	(0.0236)	(0.0236)	(0.0177)	(0.0128)	(0.0325)	(0.0448)
Capital	-0.3147***	-0.3143***	-0.2171***	-0.1972***	-0.2429***	-0.2383***
	(0.0043)	(0.0043)	(0.0040)	(0.0044)	(0.0043)	(0.0023)
Asset structure	0.0070***	0.0067***	0.0027*	0.0035***	0.0191***	0.0182***
	(0.0022)	(0.0022)	(0.0016)	(0.0012)	(0.0026)	(0.0030)
Funding structure	-0.0132***	-0.0132***	-0.0119***	-0.0096***	-0.0115***	-0.0180
	(0.0034)	(0.0034)	(0.0031)	(0.0025)	(0.0025)	(0.0115)
Liquidity	-0.0039*	-0.0037	-0.0045***	-0.0055***	-0.0091***	-0.0103***
	(0.0023)	(0.0022)	(0.0016)	(0.0014)	(0.0032)	(0.0036)
Efficiency	0.0178***	0.0178***	0.0228***	0.0277***	0.0104***	0.0091*
	(0.0027)	(0.0027)	(0.0022)	(0.0018)	(0.0033)	(0.0049)
Profitability	-0.0564***	-0.0564***	-0.0304***	-0.0167***	-0.0790***	-0.0770***
	(0.0066)	(0.0065)	(0.0052)	(0.0045)	(0.0032)	(0.0018)
ICM*low capital	0.4941*		0.0722***		0.2184***	
	(0.2489)		(0.0192)		(0.0106)	
ICM *high capital		-0.1410*		-0.0271***		-0.0291***
		(0.0755)		(0.0052)		(0.0084)
Intercept	-3.8920***	-3.8889***	-5.0733***	-5.8057***	-0.7534	-0.5476
	(0.5214)	(0.5152)	(0.3460)	(0.2602)	(0.8335)	(1.1035)
R^2	0.649	0.648	0.595	0.539	0.540	0.538
Observations	4160	4160	3309	3309	850	850

OLS estimations with robust standard errors in parenthesis clustered at the country level for EU banks and at the bank level for US banks. The internal capital market (ICM) is the log of total assets of each bank's subsidiaries. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 6
Bank risk and Internal capital markets with bank capital interactions. ICM measured as the log of total assets of subsidiaries and affiliates

	Bank risk measure: Systemic risk					
	All banks		EU banks		US banks	
ICM	-0.5414**	-0.1352**	-0.1699**	-0.2566**	-0.6849***	-0.6865***
	(0.1510)	(0.0625)	(0.0669)	(0.1230)	(0.0180)	(0.0301)
Size	0.6962***	0.5518***	0.6201***	0.7212***	1.2845***	1.3470***
	(0.0924)	(0.0400)	(0.1045)	(0.0732)	(0.0411)	(0.0685)
Capital	-0.0080	-0.0865***	-0.1674***	-0.1011***	-0.0030	-0.0096***
	(0.0486)	(0.0182)	(0.0495)	(0.0357)	(0.0028)	(0.0034)
Asset structure	0.0200	0.0107	-0.0048	-0.0068	-0.0139***	-0.0222*
	(0.0134)	(0.0154)	(0.0147)	(0.0142)	(0.0018)	(0.0130)
Funding structure	-0.0712***	-0.0401**	-0.0458***	-0.0556***	-0.0219***	-0.0098***
	(0.0145)	(0.0174)	(0.0179)	(0.0131)	(0.0012)	(0.0014)
Liquidity	0.0018	0.0028	0.0149	-0.0158	-0.0018	-0.0025
	(0.0105)	(0.0071)	(0.0131)	(0.0134)	(0.0075)	(0.0123)
Efficiency	-0.0264	-0.0038	0.0015	-0.0061	-0.0054	0.0040
	(0.0163)	(0.0065)	(0.0230)	(0.0249)	(0.0950)	(0.0079)
Profitability	-0.0828	0.5472***	0.6016	0.4469	0.6917	0.9083
	(0.3826)	(0.1023)	(0.3800)	(0.3415)	(0.5575)	(0.6198)
ICM*low capital	0.8769**		0.1050		1.0728***	
	(0.3545)		(0.1435)		(0.0054)	
ICM *high capital		-0.4159***		-0.0736***		-0.1350***
		(0.0795)		(0.0217)		(0.0114)
Intercept	-5.3102*	-4.2097**	-5.2722*	-6.2055*	-5.5965***	-7.9343***
	(2.7203)	(1.7783)	(2.9600)	(3.1800)	(0.2805)	(0.5943)
R^2	0.314	0.649	0.574	0.514	0.442	0.514
Observations	510	510	305	305	205	205

OLS estimations with robust standard errors in parenthesis clustered at the country level for EU banks and at the bank level for US banks. The internal capital market (ICM) is the log of total assets of each bank's subsidiaries. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 7
Bank risk and internal capital markets with bank capital interactions. ICM measured as the log of the number of subsidiaries and affiliates

	Bank risk measure: Z-score					
	All banks		EU banks		US banks	
ICM	-0.0655***	-0.0643***	-0.0532**	-0.0492*	-0.1182**	-0.1145**
	(0.0220)	(0.0375)	(0.0226)	(0.0289)	(0.0562)	(0.0553)
Size	0.1640***	0.1658***	0.2141***	0.2070***	-0.0710	-0.0699
	(0.0199)	(0.0262)	(0.0163)	(0.0299)	(0.0675)	(0.0670)
Capital	-0.2874***	-0.2878***	-0.1618***	-0.1650***	-0.0305*	-0.0356**
	(0.0069)	(0.0043)	(0.0034)	(0.0258)	(0.0157)	(0.0171)
Asset structure	-0.0085***	-0.0083***	-0.0020*	0.0011	-0.0056	-0.0082
	(0.0009)	(0.0021)	(0.0011)	(0.0027)	(0.0057)	(0.0054)
Funding structure	-0.0068***	-0.0068**	-0.0037***	0.0011	0.0160***	0.0164***
	(0.0013)	(0.0029)	(0.0014)	(0.0027)	(0.0046)	(0.0040)
Liquidity	-0.0054***	-0.0053**	-0.0041***	0.0059***	-0.0098*	-0.0103*
	(0.0014)	(0.0021)	(0.0012)	(0.0021)	(0.0055)	(0.0054)
Efficiency	-0.0084***	0.0085***	0.0105***	-0.0030	0.0025	0.0023
	(0.0028)	(0.0027)	(0.0016)	(0.0029)	(0.0058)	(0.0052)
Profitability	-0.5754***	-0.5753***	-0.4220***	0.0161***	-0.1137	-0.1414
	(0.0576)	(0.0362)	(0.0268)	(0.0047)	(0.1747)	(0.1171)
ICM*low capital	0.2635***		0.3539***		0.9247***	
	(0.0615)		(0.1281)		(0.2368)	
ICM *high capital		-0.0117		-0.1977***		-0.0039
		(0.0514)		(0.0327)		(0.0699)
Intercept	-3.7552***	-3.7715***	-5.0141***	-5.5732***	-1.4358	-1.1708
	(0.4699)	(0.4734)	(0.2840)	(0.5008)	(1.3728)	(1.4242)
R^2	0.665	0.665	0.569	0.574	0.095	0.102
Observations	4160	4160	3309	3309	850	850

OLS estimations with robust standard errors in parenthesis clustered at the country level for EU banks and at the bank level for US banks. The internal capital market (ICM) is the log of total assets of each bank's subsidiaries. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 8
Bank risk and Internal capital markets with bank capital interactions. ICM measured as the log the number of subsidiaries and affiliates

	Bank risk measure: Systemic risk					
	All banks		EU banks		US banks	
ICM	-0.6296***	-0.6132***	-0.2524**	-0.2257***	-0.6131***	-0.6184***
	(0.0849)	(0.0975)	(0.1244)	(0.0664)	(0.1470)	(0.0636)
Size	1.2819***	1.2259***	0.9787***	0.6219***	1.7052***	1.7951***
	(0.1089)	(0.1309)	(0.1154)	(0.1073)	(0.2259)	(0.1314)
Capital	-0.0842***	-0.0889**	-0.0670***	-0.0780*	-0.0287***	-0.0341***
	(0.0400)	(0.0418)	(0.0249)	(0.0410)	(0.0069)	(0.0022)
Asset structure	0.0199***	-0.0191*	-0.0079	0.0074	0.0306***	0.0338***
	(0.0099)	(0.0100)	(0.0081)	(0.0087)	(0.0014)	(0.0041)
Funding structure	-0.0488***	-0.0424***	-0.0482***	-0.0393***	-0.0156***	-0.0066
	(0.0118)	(0.0121)	(0.0177)	(0.0083)	(0.0045)	(0.0153)
Liquidity	0.0001	-0.0004	0.0197**	0.0232***	0.0038	0.0034
	(0.0090)	(0.0092)	(0.0084)	(0.0022)	(0.0065)	(0.0047)
Efficiency	0.0042	0.0049	-0.0125	-0.0043	-0.0025	0.0019
	(0.0144)	(0.0143)	(0.0134)	(0.0194)	(0.0241)	(0.0192)
Profitability	-0.5258*	0.5787*	0.0456	0.4340*	0.5317	0.6853
	(0.2997)	(0.3015)	(0.0796)	(0.1863)	(0.9129)	(0.7244)
ICM*low capital	0.5455***		0.1610*		0.4177***	
	(0.2071)		(0.0934)		(0.1212)	
ICM *high capital		-0.0720		-0.4385***		-0.2572***
		(0.1215)		(0.1152)		(0.0731)
Intercept	-5.6221**	-4.8094*	-11.1604***	-6.1527*	-12.7983**	-14.7741***
	(2.6957)	(2.8693)	(2.2066)	(3.5769)	(5.5576)	(3.4985)
R^2	0.388	0.373	0.566	0.608	0.405	0.389
Observations	510	510	305	305	205	205

OLS estimations with robust standard errors in parenthesis clustered at the country level for EU banks and at the bank level for US banks. The internal capital market (ICM) is the log of total assets of each bank's subsidiaries. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Appendix Table 1
Variable definitions and data sources.

Variable	Description	Source
A. Bank risk indicators		
Z-score	Average of yearly Z-scores constructed for each bank i for the crisis (2008-2009) period. The Z-score is calculated as Z=(k+ROA)/σROA, where k is equity capital as percent of assets, ROA is the average after-tax return as a percent of assets, and σROA is the standard deviation of the after-tax return on assets, as a proxy for return volatility.	Bankscope and authors' calculation
Systemic risk	Marginal expected shortfall (MES) as in Acharya et al. (2017), using a risk level of a=5% calculated for the crisis (2007Q4-2009Q4) using individual banks' and countries' daily logarithmic stock market returns.	Datastream and authors' calculation following Acharya et al. (2017).
B. Internal capital market indicators		
Internal capital market, all banks	Log of average annual value of total assets of subsidiaries and affiliates of each bank, 2002 to 2007; or log of the number of subsidiaries and affiliates of each bank, 2002 to 2007.	Bankscope and Authors' calculation
Internal capital market, EU banks	Log of average annual value of total assets of subsidiaries and associates of European Union banks, 2002 to 2007; or log of the number of subsidiaries and affiliates of each bank, 2002 to 2007.	Bankscope and Authors' calculation
Internal capital market, US banks	Log of average annual value of total assets of subsidiaries and associates of USD banks, 2002 to 2007; or log of the number of subsidiaries and affiliates of each bank, 2002 to 2007.	Bankscope and Authors' calculation
C. Bank specific variables		
Size	Log of banks' total assets for the pre-crisis period, 2002 to 2007	Bankscope
Capital	Ratio of bank tier 1 capital to total assets, 2002 to 2007	Bankscope
Asset structure	Ratio of bank loans to total assets, 2002 to 2007	Bankscope
Funding structure	Ratio of time deposits to total deposits, 2002 to 2007	Bankscope
Liquidity	Ratio of liquid assets to total assets, 2002 to 2007	Bankscope
Efficiency	Ratio of bank costs to bank income, 2002 to 2007	Bankscope
Profitability	Ratio of net income to total assets, 2002 to 2007	Bankscope
Undercapitalization dummy	Equal to 1 if a bank has a Tier I ratio below 6% for the pre-crisis period 2002 to 2007 and 0 otherwise.	Bankscope and Authors' calculation
High capitalization dummy	Equal to 1 if a bank has a Tier I ratio above 6% for the pre-crisis period 2002 to 2007 and 0 otherwise.	Bankscope and Authors' calculation