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The Future of Financial Regulation – is there a link from bank size to risk?

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Abstract: In the wake of the subprime crisis there has been widespread discussion of the risks posed to the financial system by large banks that may be "too big to fail". Large banks may have incentives to take greater risks than smaller institutions, raising their contribution to systemic risk further. We present results of GMM estimation for a large sample of OECD banks which show that larger banks take on more risk, as measured by the level and the standard deviation of charge-offs (losses). In addition, we show that increases in equity lead to less risk taking in all banks, but banks with large proportions of Tier 2 capital are particularly vulnerable to adverse incentives. There are important implications for bank regulation.

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1 Introduction

There has been increasing concern over the evolution of the industrial organisation of banking systems which has allowed increases in both the size and complexity of individual banks[6]. Banks that are "too-big-to-fail" may face incentives which induce them to take excessive risks. In addition the failure of large and highly interconnected institutions would generate a disproportionate contribution to systemic risk. Linking these two problems, Haldane (2010) discusses the too-big-to-fail aspect of banks in the context of financial system architecture, where interconnectivity between banks crucially influences systemic risk, and these links may have been increasing. Under such structures, damage to a large or highly connected bank becomes systemically disastrous and bailouts are needed to prevent systemic risk. Aware of this, banks have an incentive to become bigger and more complex, since by adopting risky strategies they increase shareholder wealth if outturns are good whilst ensuring future public support guarantees when they are poor. In contrast hedge funds that have unlimited liability and do not enjoy public safety nets adopt a different organisational structure: less concentration and less complexity in business activity. Clearly, Haldane's argument implies that large banks not only pose systemic risks from a structural point of view but may have incentives to boost their own levels of risk relative to those taken by smaller institutions.

There have been many regulatory responses to these problems, with the most important coming from the Basel Committee which has suggested higher capital adequacy requirements for systemically important institutions (as proposed by the Basel Committee (Bank for International Settlements, 2010). There have also been suggestions that they should face higher taxation (Cottarelli, 2010) or better supervision, both conducted nationally, as well as internationally (Financial Stability Board, 2010).

Evidence to support a direct link from bank size to risk taking is, however, weak. Studies of individual bank performance, generally at national level, have tended to look at the determination of risk taking in relation to macroeconomic variables, such as real house price growth and the rate of growth of real GDP as well as micro economic variables such as bank capital, the loan/asset ratio and net interest margins, none of which are necessarily associated directly to bank size. Bank failure is the most obvious indicator of risk, but a lack of observations and a lack of clarity in micro data sources over the meaning of failure makes analysis at an international level problematic. Most studies investigate performance indicators which include loan growth and the return on assets, but these only indirectly impinge on the possibility of failure. In contrast charge offs, which we use here, do relate directly to the possibility of failure, because excessive charge offs indicate a materialisation of risk and may lead to insolvency.

The objective of this paper is to assess the influence of bank size on bank risk taking, as measured by the standard deviation of charge offs, and on mean losses, as measured by bank charge offs in an international panel. We also look at the impact of

[6] For an extensive review of institutional changes that have permitted this, such as withdrawal of the Glass-Steagall Act, see Kay (2009).

the composition of regulatory capital held by banks on the mean and standard deviation of charge offs when size is allowed for. We carry out a microeconomic analysis of performance using a data set that contains 713 banks over 16 years from 1993 in 14 countries: Belgium, Canada, Denmark, Finland, France, Germany, Japan, Netherlands, Norway, Spain, Sweden, UK and US[7]. Before reporting on our results we briefly discuss the theoretical and empirical issues concerning bank size and risk.

2 Background literature

2.1 Banks' balance sheets, risk and incentives

Abstracting initially from regulation, banks act as intermediaries that allocate surplus funds on behalf of their creditors and they generate income from the spread between loan rates and deposit rates (Goodhart 2010). All their potential loans[8] attract some risk, and they have to hold enough capital to absorb this risk and hence the value of claims issued by the bank, and these assets may be described as loans for simplicity, outweighs the value of its liabilities, which may be described as deposits for simplicity. In addition, banks' assets and liabilities suffer from mismatches of characteristics; bank loans are typically long-term, indivisible, illiquid and risky whereas deposits are cashable on demand, highly divisible, liquid and less risky, and hence banks need to hold low yielding liquid assets to cover any potential mismatches in flows. Insolvency may happen because of depositor bank runs, as discussed in Diamond and Dyvbig (1983), or because sufficient borrowers default for the bank to become insolvent. These are separate problems, reflecting the two sides of a bank's balance sheet. A simplified model of banks balance sheets helps us understand the dynamics of bank risk taking and the rationale for regulation.

Banks take in deposits (D) in some form, on which they pay interest at a rate $r_{d,}$ and make loans (L) or enter into other credit provision arrangements on which they charge interest r_l. Depositors may randomly demand cash and hence some low-risk liquid assets (LA with a rate of return $r_{ra},$) have to be held, with r_d- r_{ra} the cost of liquidity. The appropriate (on-book) liquid asset ratios will depend on the variance of deposits (var(D)), their maturity composition and on the availability of off-book, or wholesale market, liquidity. We may write the asset side of the bank's balance sheet (AS) as

$$AS = L + LA \text{ where } LA/D = f(var(D), wholesale) \quad (1)$$

When banks make loans they take risks, and the loan book will face a default rate that will vary over time with economic conditions. The expected default rate (b) is included in the spread between borrowing and lending rates, which will also include administrative costs (ad) and payment for risk taking (rp):

$$r_l = r_d + b + ad + rp \quad (2)$$

We may re-write this as an expression for the Net Interest Margin (NIM) which is the lending rate r_l less the deposit rate r_d

$$NIM = b + ad + rp \quad (3)$$

[7] This is the same country group as that used in Barrell et al (2010) for banking crisis prediction.
[8] We abstract from lending via non liquid securities without loss of generality.

Given that banks may make larger-than-anticipated losses on their loan portfolio in some periods, they have to carry both contingency reserves (provisions) and finance some of their loan book with equity capital in some form.[9]. In the absence of regulation, the amount of capital held by a bank will depend on the variance of loan losses (var(BL)) and on the cost of generating capital. The larger the quantity of capital (K) relative to loans (K/L), the lower the probability of bankruptcy for a given var(BL) and hence the lower the cost of capital to the bank. A bank may be concerned with the probability of default, and for a given var(BL) it may choose its level of capital to ensure that there is a reasonable distance to default (dtd) in terms of the number of standard deviations the equity base will cover. The classic form of capital is equity. Additional loss-absorbing capacity can be provided by subordinated debt, although since it is an obligation it does not protect against bankruptcy in the way that equity does. If the composition of the capital base between pure equity (EQ with return r_{eq}) and subordinated debt (SD with return r_{sd}) does not change the behaviour of the bank, then the Modigliani-Miller theorem suggests that the providers of bank equity will be indifferent between debt and equity finance. However, as Levonian (2001) suggests, increasing subordinated debt raises risk in banks, and hence the cost of capital will change with the mix of equity and subordinated debt[10]. The liabilities of the bank may be written as

$$LS = EQ + SD + D \qquad (4)$$

The gross profits (Π_g) of the bank after allowing for current charge-offs (BL) may be written as

$$\Pi_g = r_l\, L + r_{ra}\, LA - r_{sd}\, SD - r_d\, D - BL - ad\, L \qquad (5)$$

If bad loan provisions (bL) exceed charge offs (BL) then the bank can build its provisions P with (bL – BL) or pay out some proportion (β) of the gain (or claw back a loss) in current profit. Profits (Π) may then be written as

$$\Pi = \Pi_g + \beta\, (bL - BL) - (bL - BL) \qquad (6)$$

The pure capital of the bank (K), all else equal, is its capital base plus its provisions, and abstracting from new issues of equity or of subordinated debt, capital evolves in relation to profit retentions (γΠ) and excess provisioning (1- β) (bL – BL), with (-1) indicating previous period values.

$$K = EQ + SD + P \;= EQ(-1) + \gamma\Pi + SD(-1) + P(-1) + (1-\beta)\,(bL - BL) \qquad (7)$$

In this context, a failure might emerge either because a bank does not have enough on-book liquidity to meet the needs of depositors, and cannot access the wholesale market, or because loan losses have built up to the point where capital is expected to be exhausted. The higher is LA/D for a given var(D) the less likely is a liquidity

[9] Loss absorbing equity is not the same as the equity value of a bank on the market, as the latter may include goodwill and other intangibles that cannot be used to offset losses on the loan book. In its simplest form, the loss absorbing equity in a bank is the difference between its current assets and its other liabilities.
[10] See also Evanoff and Wall (2000)

crisis, and the higher K/L or (EQ+SD)/L for a given var(BL) the less likely a solvency crisis will emerge. Other factors may affect the decision to hold capital, and these will include the regulatory and legal environment within which the bank operates. Banks' risk appetites may entail negative externalities for society since bank failures harm depositors directly, and, by impairing the payments system and subsequent credit allocation, harm the economy as a whole. Moreover if these externalities are systemically large, taxpayers may be forced to bail out imprudent banks. As failure may involve external social costs, regulators may require banks to hold more capital to absorb losses than the banks themselves may choose.

Banks, perhaps to a greater extent than other companies, face principal-agent problems between managers and the providers of finance. The managers have asymmetric incentives, with a large positive stimulus to raise profitability and take risks owing to the use of bonuses, while the downside outcome of losses is a low risk of losing employment. There is an interaction between managers and funders which determines the level of risk taking, and this is policed by monitoring by the providers of finance. It is reasonable to assume the degree of monitoring from a given source of finance depends on the volume of finance provided and on the funding provider's perceptions of potential losses. The larger the potential losses, the more intensive will be the level of the monitoring. More subordinated debt (Tier 2 capital) implies more bondholder monitoring and more equity (Tier 1 capital), more shareholder monitoring for a given distribution of perceptions of losses. Bondholders may be more active monitors than index tracking funds holding equities, but this may not be the case. If bondholders perceive that they would not take many losses, for instance because they expect the government to step in to recapitalise the bank, their intensity of monitoring might drop below that of shareholders. It is an empirical question which is more effective. It is also possible that the intensity of all monitoring might decline with the size of banks because all providers of funds recognise the possibility of government support may well rise with size, and we turn to that issue next.

2,2 Optimal bank size and possible links to risk

The size of banks and the industrial structure of the banking industry depend on a number of factors, including the degree of macro-economic or cyclical uncertainty, as well as the regulatory framework and the effective guarantee offered by the state to the banking industry in times of crisis. Krasa and Villamil (1992) look at the factors affecting bank size, focusing on the gains from size as compared to the costs of monitoring the quality of a bank's book. They show that these two factors ensure that optimal bank size (from the perspective of the equity owner) is determinate, and depends upon the environment that determines expected loan losses, and hence loan loss provisions (or more generally expected losses on all assets).

A simple model of bank size can be constructed using Krasa and Villamil's results. Banks take in deposits, and as Goodhart (2010) discusses, they are price takers, in that they accumulate them at a fixed price or interest rate to ensure they have enough to cover their loans. They have an equity base to cover expected losses, and the return on equity is in excess of normal operating costs. If each loan has an expected loss rate of c then the loss on the portfolio is this expected loss plus a function of the covariance of the loan loses. Banks operate on the basis that the covariance between loan losses, $cov(BL)$, is negative, and hence the larger the bank the lower the expected loss rate on the loan book as a whole (denoted b above) and hence the lower their expected operating costs in excess of the rate paid on deposits. We may write total operating costs *TC* as

$$TC = ad*L+f(cL,cov(BL)) \qquad (8)$$

This might suggest that banks may become infinitely large as costs fall with scale. However, Krasa and Villamil (1992) argue that the monitoring costs, *MC*, borne by equity holders rise more than linearly with the size of the portfolio, and hence as the bank increases in size the marginal cost of raising equity capital rises. We may write monitoring costs and hence the cost of raising equity capital as depending positively on the size of the bank and negatively on the perceived threshold for lender of last resort (*llr*) action

$$MC = g(L, llr) \qquad (9)$$

Hence the optimal size of a bank is determined by the increase in monitoring costs, dMC/dL matching the marginal decline in expected operating costs from increasing portfolio size, $dTC/L = ad+df/dL_1 * c+df/dL_2 d(cov(BL))/dL$ where $d(cov(BL))/dL<0$. This implies that when the second derivative of TC with respect to size is equal to the second derivate of monitoring costs the bank has reached its optimal size from the viewpoint of the shareholders. Krasa and Villamil (1992) show that a more volatile macro economic environment raises the common component of the covariance of losses, and this will in turn reduce optimal bank size. Lender of last resort guarantees reduce monitoring costs, as the losses shareholders would face in a crisis are potentially borne by somebody else, and hence increase optimal size. This may also lower the cost of deposits and give large banks a further competitive advantage. For both these reasons, the stronger the belief that the state will step in and bail out large banks, the larger banks will become. This model suggests that larger banks should have lower loan losses as a percent of their portfolio of loans, but that loan losses for all banks should rise with macroeconomic volatility. A similar conclusion can be drawn on the role of internal monitoring, and Cerasi and Daltung (2000) suggest the optimal size of a bank is linked to a balance between diversification benefits from size and the overload costs that bankers face from monitoring more projects.

In an Arrow Debreu world, where risks faced by lenders are exogenous, we would expect that we should clearly observe lower loss rates in large banks. However, if risks are endogenous in that there are a range of possible projects to lend on or assets to purchase, with some being more risky than others, then declining loss rates with size may be in part mitigated by an increased appetite for risk if it is associated with increased expected profit. It may then be optimal for a bank to raise its mean loss on the asset book until the gain is matched by the increased cost of risk. Larger banks may therefore have charge off rates that do not decline with size, and they may even increase. As long as they are aware of these risks and charge for them by increasing the NIM, their actions would pose no systemic risks. This would require that the NIM increased with size. Estimates of the determinants of the NIM reported in Barrell, FitzGerald, Fic, Karim, Orazgani and Whitworth (2011) suggest that this is not the case, and hence banks may be relying on lender of last resort implicit insurance as they increase in size and take on more risk, mitigating the effects of size on the NIM.

If there is an extreme cost involved in bankruptcy then the bank will plan to keep expected losses below a threshold. Risk may be taken on until the distance to default, measured by $K/sd(BL) = z_f$ reaches a ceiling, where sd(BL) is the standard deviation of loan losses. This is the acceptable risk of catastrophic failure. Let us assume that risks are normal and that the acceptable probability is 0.001, much as is discussed in Zhu (2008). Then the bank may take on additional more risky loans and assets until its (maximum) expected loss is no higher than $X_m = z_f^* * SD$ where z_f^* is approximately 3.3 for a 0.001 probability. We may describe expected losses X as

$$X = h(\text{size, capital, bank specific factors, macro factors}) \qquad (10)$$

where the derivative with respect to size may be negative because of the covariance of risks in the portfolio, but it may also be positive if there is lender of last resort support expected. The set of other factors affecting expected losses will depend in part on decision making by the bank. This will include both its level of capital and the structure of that capital in terms of Tier 1 and Tier 2. Expected loses will also depend on the factors affecting the macro economic environment the bank faces.

We would expect that in a world of exogenous risk sd(BL) would decline with size, and hence larger banks could have a lower level of capital for a given distance to default (dtd or z_f^*). It is of course possible that sd(BL) could change as a result of the change in the nature of loans and assets taken on for other reasons. If there is implicit lender of last resort insurance then as size increases banks may increase the riskiness of their portfolios, for instance. We may describe sd(BL) as being determined by size and by the bank portfolio decision making indicators, J, including the size and structure of capital, as well as by other factors outside the control of the bank, W:

$$sd(BL) = k(\text{size}, J, W) \qquad (11)$$

If sd(BL) increases with a change in the structure of the portfolio induced by an increase in size then in order to keep distance to default z_f^* constant more capital would have to be held. If sd(BL) falls with increasing size then it is possible that there will be fall in capital, with the distance to default z_f^* remaining constant or declining. We test this proposition below.

2.3 The safety net and moral hazard for large banks

There is an extensive literature based on Merton (1977) on moral hazard for large banks, where size might generate an implicit 'too big to fail' guarantee. As noted in Beck et. al. (2007) the implicit insurance from 'too big to fail' means that large banks have an incentive to lower capital adequacy. Demsetz and Strahan (1997) in a study of US banks found that, though larger bank holding companies are better diversified than smaller ones, they do not translate this advantage into less total risk. Rather, larger banks use their diversification advantage to operate with lower capital ratios and pursue riskier strategies, with greater concentrations of consumer and industry loans and exposure to systematic risk.[11].

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[11] Osborne and Lee (2001) found some attenuation of this relationship in the wake of the enactment of the Federal Deposit Insurance Corporation Improvement Act (FDICIA) in 1991 which reduced forbearance and introduced some element of risk related deposit insurance. But their sample ended before the LTCM rescue in 1998 that reinforced the too-big-to-fail perception in the US.

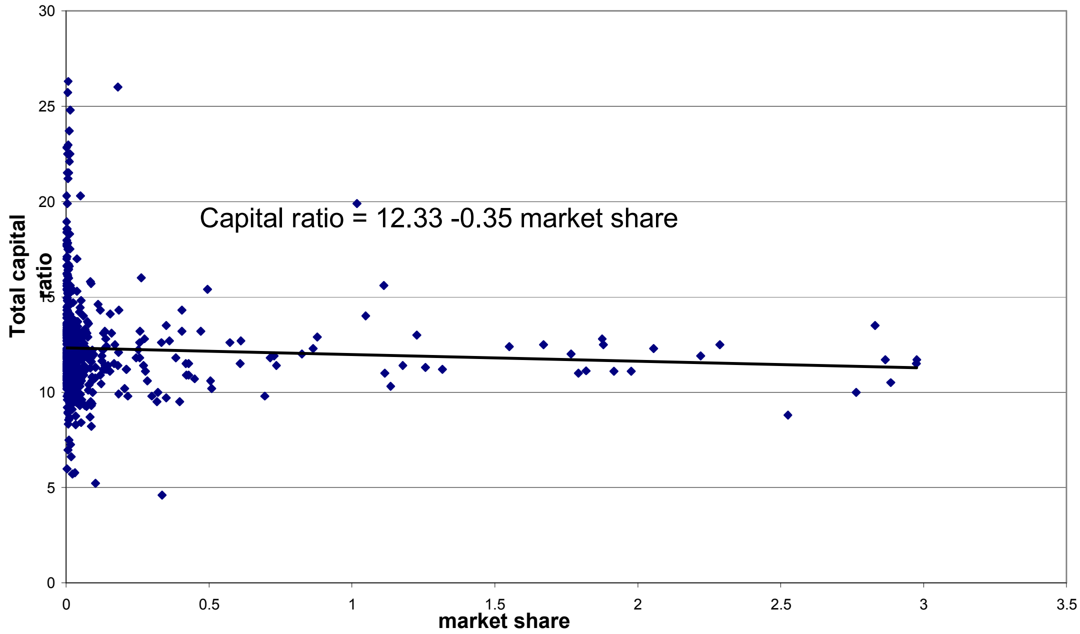
Other studies of risk taking have tended to abstract from size. Salas and Saurina (2002) modelled the problem loans of Spanish banks, controlling for macro factors, the level of indebtedness in the non-financial sector and numerous bank-specific variables, as is feasible in a study of a national market as opposed to an international study where only standardised variables can be used. Recessions, for example, reduce the ability of borrowers to repay loans, as well as a tightening of credit by banks, the effects of which on bad loans are aggravated by high indebtedness. Nevertheless, individual bank level variables also have high explanatory power for credit risk. For example, loan losses arise following aggressive growth policies, as shown by credit expansion and market penetration. In one of the few international studies of bad loans, Davis and Zhu (2009) found both macro variables, including property prices, and bank specific variables, including capital adequacy and loan growth, were significant in determining non performing loan ratios.

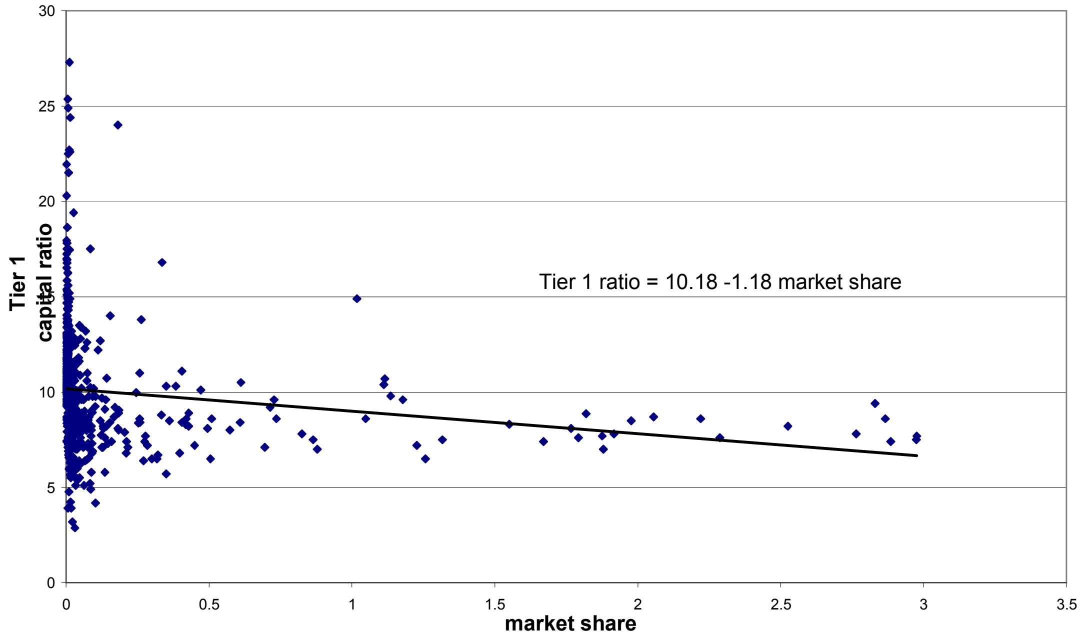
Despite the regulatory interest in the quality of capital (such as Basel Committee (BIS, 2010)), the theoretical literature on bank capital has not tended to comment on the distinction between total and equity capital adequacy (see Van den Heuvel (2002) and references therein). There remains a literature which asserts that Tier 2 capital in the form of subordinated debt may have positive benefits in terms of market discipline (such as Chami and Cosimano, 2003). It is argued that unlike for equity, there may be alignment of the interests of subordinated debt holders with deposit insurers, incentives created for bankers to disclose information to the market and visibility of financial distress signals provided by subordinated debt spreads over the risk free rate. There is little empirical work on capital composition. Francis and Osborne (2009, 2010) using UK bank data from 1998 to 2006/7 for 168 banks found a positive association between capital ratios and capital quality (i.e. better capitalised banks have proportionally less Tier 2), although they did not probe the impact of capital quality on behaviour. We attempt to redress this imbalance in the literature in this study.

3 The nature of the bank data set

In this study, bank-specific data are derived from the Bankscope database over 1993-2008. We utilise the balance sheet variables: total assets and loans, net charge-offs, the ratios total capital to risk adjusted assets and Tier 1 to risk adjusted assets. The difference between these is obviously the risk adjusted Tier 2 ratio. Details of the dataset are set out in an appendix. We exclude the central bank, government and multilateral institutions but include all other types of bank and bank-like financial institutions. We use the definition “large banks” as set out by Bankscope, as well as consolidated balance sheet data only. Consolidated data gives a greater role for banks in the US and Japan (which have long used consolidated data) compared with European countries, although since 2000 more and more European banks have also provided consolidated accounts. We also excluded banks with less than four years’ continuous observations. Charge-offs are reported for all banks, and they are recorded as a percent of total assets, and we take these as our dependent variable and use the discussion of the determinants of expected loses set out above to inform us about the driving variables.

Figure 1 Global size as a per cent of total market and capital ratios (2006)





Source Bankscope

Figure 1 plots the distribution of all banks in our sample against the Tier 1 equity ratio for 2006, as well as against total risk weighted capital. Both figures contain a trend line, and it is clear that both total capital and Tier 1 capital ratios decline with size but the total capital ratio declines by less. Over our whole sample the correlation between the size indicator and total capital is -0.11 whilst the correlation between size and Tier One is -0.20. It is clear that the Tier 2 ratio rises with size, and the correlation is 0.25. Tier 1 can be taken as the main loss absorbing assets of the equity holders in banks, and hence an indicator of monitoring effectiveness. As we can see from the figure, most banks are small, and many small banks have ratios well above the minimum level of capital. The number of banks in our sample rises over time, and hence it is possible that there is a downward trend in average share, and our measure of size, which we use in estimation, is designed to remove this problem associated with an unbalanced panel. We calculated the mean and the standard deviation of the bank assets across all countries in each year, and we then scaled each bank by the number of standard deviations it was from the mean.

Krasa and Villamil (1992) suggest that size may be a relative matter, with share of market being important. In addition it is the capacity of the lender of last resort that affects the scale of the backstop to losses. Hence we also use an indicator of size that is country specific, but not related to the mean and standard deviation of bank size with in the period. As the number of banks in each country increases generally over time, we estimate the country specific regressions with time dummies to remove the impacts of the unbalanced panel on our results.

4 Results

We are interested in the behaviour of individual banks and we first look at the impacts of factors on the level of charge offs, and we then turn to the determinants of the standard deviation of charge offs. The impacts of size on charge offs is investigated in a panel context, whilst the impacts of size on the standard deviation of charge offs is investigated in a cross section analysis.

4.1 Size and charge offs

In the analysis of charge offs we apply Generalised Method of Moments (GMM) dynamic panel techniques. The literature uses various estimation methods to estimate panel models (e.g. 2SLS, OLS), but the GMM estimator allows for the possible endogeneity between the dependent and the explanatory variables and enables us to include a lagged dependent variable and account for possible autocorrelation. The two econometric arguments behind using the GMM are complemented by economic reasoning. The latter suggests that bank behaviour displays inertia and this effect will be captured by the lagged dependent variable. Moreover, the regulatory policy variables – the capital ratio and the tier 2 proportion, as well as other control variables, and charge-offs are simultaneously determined (although the lag on the bank-specific variables reduces the importance of this issue). The use of the lagged dependent variable may also be interpreted in terms of modelling a slow process driving losses, with decisions made in the past affecting losses now, and hence with the factors affecting those decisions influencing charge offs now. In addition, banks have some discretion over when they declare losses, and they may delay doing so, and this may be indicated by the coefficient on the lagged dependent variable.

The combination of the use of lags and instruments in GMM for current variables as well as the lagged dependent variable eliminate some of our short time series for individual banks, and our sample is reduced from 713 to 427 banks across 14 countries and 12 years.[12] Our regression period is 1996-2007. By not including 2008 in the regressions, we avoid the risk that the results are generated by the abnormal period of financial instability in the latter years. In each regression, we use charge-offs as a per cent of total assets as the dependent variable, and we expect to find a role for macro economic variables, such as real GDP growth and real house price growth.

[12] In each regression we had to dummy extreme outliers around 2000 for 2 Japanese banks

Their impacts on charge-offs should be negative as in a strongly growing economy fewer people will be forced to default, and if real property prices are growing, housing and commercial property loan defaults are less likely. In all regressions we use contemporaneous growth rates for GDP and for real house prices, with the consumer expenditure deflator scaling nominal house prices. We also include the micro variables loan growth (which may boost charge-offs if it indicates adverse selection), the total capital ratio and Tier 2 proportion. As we do not presume that the effects of size are constant we include a squared term to see if larger banks behaved differently from smaller ones.

Cross country size indicator

Table 1 presents the results of our GMM estimations of net charge-offs to total assets which depend upon GDP growth, real house price growth, real loan growth, overall and tier one capital and a pair of terms to give a quadratic in our normalised size indicator. We instrument the level of lagged charge-offs, the change in real lending and house prices, as well as the regulatory variables[13]. There is a good deal of inertia in the equation, with a lagged dependent variable of 0.7, but it is very significantly different from one, suggesting the long run relationship is not spurious. The macro factors are significant, in that more rapid current GDP growth in the economy in question reduces charge-offs, and more rapid current real house price growth also reduces them. However, if loan growth has been rising then charge-offs rise, perhaps because more risky loans are taken on to the bank's book, owing in part to adverse selection.

Table 1. Bank size and performance

	Coeff	t-Statistic
Lagged dependent	0.6968	40.36
Real GDP Growth(0)	-0.0389	-9.48
Real house price growth (0)	-0.0143	-8.76
Real loan growth (-1)	0.0014	3.45
Capital adequacy (-1)	-0.0161	-3.57
Tier 2 proportion (-1)	0.3144	7.32
SIZE (normalised) (-1)	0.8494	11.64
SIZE squared	-0.0003	-2.98
Sargan J	106.8	
Significance	**P value = 0.0864**	
Instrument rank	**96**	

Observations 2531, banks, 427, 1996-2007
Dependent variable net charge off/assets
Size variable: number of standard deviations away from mean size

These results provide clear evidence that the two types of capital differ in terms of their quality. The overall capital ratio is negatively related to write-offs, consistent with Salas and Saurina (2002) and Davis and Zhu (2009). The Tier 2 proportion has a positive effect – the more Tier 2, the higher the losses. These results imply that banks with a high share of Tier 2 may be subject to poor risk management, but this can only

[13] The instruments were the second lag of the difference of the net charge- off rate and its second lagged level, and the second lagged values of real loan growth, real house price growth, total capital, tier 2 proportion. The Sargan test result indicates that the over identifying restrictions are valid.

be confirmed by looking at the impact of capital structure on the standard deviation of charge offs. The results suggest that there is scope for more moral hazard by banks that limit their exposure to monitoring by shareholders. The global market share indicator is significant, and the initial effect of size is noticeably smaller than its long run effect[14], but as the squared term is significant the impact of size is not linear. If a small bank increases its share of the global market by one tenth of a per cent then its charge-off ratio will initially increase by 0.0056 percentage points of its total assets, but as banks get bigger the effects of an increase in size decline[15]. The average bank in the sample has no more than a quarter of one per cent share in the overall market, and the sample average charge off rate is 0.38 per cent. In other words, after allowing for the amount and quality of capital, the macroeconomic environment and its impact on charge-offs, larger banks take on more risk as reflected in having a higher ratio of charge-offs to assets.

Regulators should be less concerned with the impact on size on charge offs if the greater risk provided greater profit and was charged for in the spread between borrowing and lending rates. However, the increase in expected losses with increases in size is not reflected in increases in the net interest margin (NIM), as Barrell, Fic, FitzGerald, Karim, Orazgani and Whitworth (2011) show. Using the same data set they show that the NIM declines slightly with size until a bank has around 2 per cent or more of the global market, and hence losses, at least those incurred on the loan book, are not necessarily covered by increases in risk premia on loans. They show that increases in loan growth and increases in GDP growth are associated with a higher NIM, and increases in capital also increase it. The relationship between size and charge off rates in this paper, which appears not to be absorbed into the NIM, may be present because banks lose managerial control over their lending behaviour, or it could be because they come to depend on lender of last resort support because they know they are too big to fail and hence equity holders exert less leverage on risk taking. However, lender of last resort is at least in part a country specific role, and we turn to country specific size indicators.

Country specific size indicators

Size within a country is perhaps a better indicator of too big to fail as compared to size within the whole set of banks we study, although the two measures are clearly related to each other. We do not calculate country and time specific means and standard deviations and hence there might be an unbalanced panel problem with our estimate, and in order to overcome this we have included a time specific size indicator by dummying the country specific size variable by the year, giving us 12 size dummies, denoted SIZE (country-specific) (-1)*d96 in 1996 and similarly for each year. This allows us to abstract from the effects on the size dummy of the increasing density of banks over time in our sample.

Table 2 sets out our GMM results using a country specific size indicator, and the three variables that take up cyclical and bank specific factors, GDP growth, real house price growth and real loan growth. The last three variables remain significant with similar coefficients as in Table 1. Capital adequacy has a larger and more significant

[14] We should scale them up by approximately 3, or more exactly by 1/(1-ldv) where ldv is the coefficient on the lagged dependent variable.

[15] These calculations require we unscramble the coefficients and the standard deviation. The decline in the effects of size continue well above the maximum size bank we observe.

coefficient when we use a country specific size indicator, although Tier 2 effects remain the same. As bank market share increases within a country, its charge-off rate rises as a percent of assets, despite the fact that we would expect loan loss rates on a neutral portfolio to fall or perhaps stay constant as market share increased. This would indicate that larger banks are taking on more risk as they are aware that their regulator knows they are too big to fail. We can say that in 1998 a bank with a one tenth of one per cent greater market share than another would have a charge off rate that was initially 0.00244 percentage points higher than its comparator. By 2006 this had risen to 0.00296 percentage points increase in the charge-off rate for every one tenth of a percentage point higher market share. In general as time moves forward the impact of the country specific size indicator (market share) increases, suggesting that risk taking rose over time with the average dummied coefficient being 0.268 over 1996-2001 and 0.294 over 2002-2007.

Table 2 Bank size within country and performance (net charge off/assets)
Time dummies included

	Net charge-offs/assets	
	Coeff	t-Statistic
Lagged dependent	0.750	42.5
Real GDP Growth(0)	-0.0434	-6.0
Real house price growth (0)	-0.009	-4.4
Real loan growth (-1)	0.003	4.5
Capital adequacy (-1)	-0.030	-3.5
Tier 2 proportion (-1)	0.396	2.5
SIZE (country-specific) (-1)*d96	0.251	7.3
SIZE (country-specific) (-1)*d97	0.278	9.8
SIZE (country-specific) (-1)*d98	0.244	10.4
SIZE (country-specific) (-1)*d99	0.260	10.4
SIZE (country-specific) (-1)*d00	0.289	11.3
SIZE (country-specific) (-1)*d01	0.287	10.6
SIZE (country-specific) (-1)*d02	0.292	10.5
SIZE (country-specific) (-1)*d03	0.314	11.4
SIZE (country-specific) (-1)*d04	0.290	10.6
SIZE (country-specific) (-1)*d05	0.287	9.9
SIZE (country-specific) (-1)*d06	0.296	9.9
SIZE (country-specific) (-1)*d07	0.283	9.4
Sargan J	90.3	
Significance	**P value =0.161**	
Instrument rank	**96**	

Observations 2531, banks, 427, 1996-2007
Dependent variable net charge off/assets

5 Losses, volatility and size

The impact of size on the volatility of charge offs is important in assessing bank risk taking, but it is an empirical issue, and we can address it within our data set by calculating the standard deviation of charge offs for each individual bank and regressing this variable on size as well as on other variables that may influence it. As we are collapsing the time domain and undertaking a cross sectional analysis, we cannot use the macro-economic variables we have included elsewhere, or the real loan growth indicator, but we can use other bank specific variables.

If size affects the standard deviation of charge offs then we can calculate the potential effect it has on distance to default. Table 3 reports on a regression of the bank specific standard deviation of charge offs against a constant, capital adequacy, the structure of capital and size (squared size was not significant) where we use normalised global size and country size measures. We use data on bank specific capital variables averaged up to 2007 and measures of global and national size in 2007. We also include a regression of the capital ratio against size. As distance to default is the ratio of the capital of the bank to the standard deviation of its losses the impact of size on distance to default can be gauged from the ratio of the two size coefficients[16].

Table 3 Bank size, capital and the standard deviation of charge offs
Dependent variable – standard deviation of charge offs

	Global Indicator		Country Indicator		Capital	
			Country specific size		Whole sample	
	Coeff	t-Stat	Coeff	t-Stat	Coeff	t stat
Constant	0.520	6.69	0.55	7.05	12.52	270
Capital	-0.030	5.89	-0.031	-6.14		
Tier 2 ratio	0.582	4.25	0.532	4.04		
Size	-0.112	3.45	-0.012	-3.84	-.344	8.32

Observations – 427 banks

In all cases the effects of size is negative, as we might expect, but the impact of size is larger in the capital equation than in the standard deviation equation, suggesting distance to default falls with bank size. A bank one tenth of a percent larger than another will have a distance to default 0.023 standard deviations less, and there is no evidence that the decline in distance to default is not linear as squared size is not significant. The only possible explanation of this result is that large banks are relying on the existence of implicit lender of last resort implicit insurance, and hence economise on capital to increase profits (and perhaps bonuses).

There are other important implications we can draw from these results. The higher the capital ratio, the lower the standard deviation of charge offs, suggesting that better capitalised banks adopt more conservative portfolio strategies, and have a larger distance to default that a bank with less capital. The increased monitoring that goes hand in hand with increased capital appears to ensure that risk taking is held in check. However, the higher the Tier 2 ratio the higher the standard deviation of charge offs, contrary to the 'market discipline' literature on subordinated debt. It appears that the distance to default is smaller when more Tier 2 is held and that the intensity of monitoring declines when subordinated debt is increased,

6 Policy implications

After the financial crises in 2007 to 2009, regulators began to discuss many changes in the potential structure of bank regulation, including restrictions on size, the initial focus of this paper. There a number of potential policy issues that can be addressed with our results, including the impact of size on charge offs and distance to default and an increase in capital requirements or capital structure on charge offs and distance

[16] We should of course be cautious as bank capital is risk weighted, and distance to default is not.

to default. Given our results in Table 1, we can see from Table 4 that a one percentage point increase in overall capital with a constant Tier 2 ratio will reduce net charge offs by 0.016 percentage points in the short run and by 0.053 percentage points in the long run. The sample mean of charge offs is 0.38 percentage points. A swap of one percentage point of Tier 2 for Tier 1 capital with a constant overall level of capital will reduce charge offs by 0.026 percentage points in the short run and by 0.085 percentage points in the long run. Increases in global market share will increase charge offs, but the rate at which they do so depends on the initial size. The marginal impact of an increase in size declines with size in our result, but in Table 4 we report the effects of an increase of 0.1 percentage points in global size at an initial share of 0.2 percent. Clearly regulators could use capital requirements, capital structure and limits on size to reduce average charge offs in the global banking system.

Table 4 Impacts size and capital on charge offs and distance to default

Impact on	1/10th percent increase in global size indicator	1 percentage point increase in capital	Swap of 1% capital from Tier 2 for Tier 1
Charge offs impact	0.0056	-0.016	-0.026
Charge offs long run	0.0186	-0.053	-0.085
Time to 90%	5 years	5 years	5 years
Distance to default[17]	-0.023	0.11	0.058

Perhaps more interestingly we can also look at the effects of the same changes on distance to default, which we take as 3.3 standard deviations. A one percentage point increase in overall capital will reduce the standard deviation and also increase the capital stock in the distance to default calculation, and hence a one percentage point increase in capital will increase the distance to default by 0.05[18]. A swap of Tier 1 for Tier 2 will also reduce the standard deviation, and will increase distance to default by 0.026. An increase in size of 0.1 percent of global markets will raise the standard deviation of charge offs and reduce the distance to default by 0.012. Regulators can respond to the problem of size, and in order to keep distance to default constant for every 0.001 increase in global share they could increase required capital by half a percentage point[19].

Table 5: Basel III capital requirements

Calibration of the Capital Framework Capital requirements and buffers (all numbers in per cent)			
	Common equity (after deductions)	Tier 1 capital	Total capital
Minimum	4.5	6.0	8.0
Conservation buffer	2.5		
Minimum + conservation buffer	7.0	8.5	10.5
Countercyclical buffer range	0-2.5		

Source: BIS

[17] Calculated on the risk weighted capital to assets ratio
[18] On average in the UK the risk weighted capital ratio is about half the unweighted ratio, and we use this ratio in these rough calculations. However, this ratio varies between countries.
[19] Again given that the ratio of risk weighted to unweighted assets is 0.5

We can use these figures in our analysis of proposed regulatory policy changes. The Basel Committee (2010) has introduced a new set of rules oriented at enhancing the stability of the banking system after recognising the risks which result from the inadequate capital (and liquidity) framework of Basel II. Basel III increases the required minimum level of Tier 1 capital to 6 per cent of risk weighted total assets, maintaining the minimum requirement for total capital at 8 per cent. At the same a common equity capital conservation buffer of 2.5 per cent to be held by all banks will increase the required level of equity capital to 7 per cent, Tier 1 capital to 8.5 per cent and the ratio of total capital to assets to 10.5 per cent. On top of that banks are required to hold a countercyclical capital buffer of 0 to 2.5 per cent monitored nationally with the aim of cushioning exuberance of risk taking should it materialise during boom periods of the business cycle or early phases of a build up of a house price bubble. We might expect banks to on average hold around 1.5 percentage points extra capital over the cycle as a result. Banks normally hold a buffer of operational capital above the regulatory floor, and this will vary with market conditions. However, changes in the regulatory minimum are likely to have a minimal impact of the scale of the buffer, and we would expect it to remain around the 4.5 percentage points observed between 1998 and 2007.

Basel III raises total capital requirements on average over the cycle by around 4 percentage points (2.5 base and 1.5 cycle), and requires a reduction in Tier 2 capital to below 2 percent of risk weighted assets (as compared to 2.5 percent or more held on average by banks in our sample in 2007). We can see this as an increase in Tier 1 of 5 per cent and a reduction in Tier 2 of one per cent, and this will have a significant impact on average risk taking. Overall we might expect net charge offs would fall by around 0.23 percentage points as compared to their sample average of 0.38 percent. Around half of this change would be due to the conservation buffer, whilst the rest is the result of the underlying increase in capital and the conversion of some Tier 2 into Tier 1 capital. In addition we might expect the distance to default on average to increase by 0.3 (given that the ratio of risk weighted to unweighted assets is 0.5) as compared to a presumed target of 3.3 standard deviations. Naturally, effects in individual banks would differ from this summary measure.

6 Conclusion

We have found a strong relationship between bank size and risk as measured by charge-offs and by the standard deviation of the portfolio and hence on the distance to default. We also find that real loan growth in the past raises bank charge offs as do real house price declines in the recent past. Larger banks make larger charge-offs as a proportion of their assets. The level of capital and the standard deviation of losses decline with size, but capital declines more, and hence distance to default declines with size. The relationship between size and risk taking is consistent with the existence of implicit too big to fail insurance which induces moral hazard.

Our results also show that increases in Tier 2 capital (or subordinated debt issuance) increase charge-offs and the standard deviation of charge offs whilst increases in Tier 1 (or risk absorbing capital that is a shareholder asset) reduce them. It would appear that share holder monitoring remains more effective than that undertaken by subordinated debt holders.

Our discussion of our data set suggests that larger banks hold less total capital and more Tier 2 capital, and both of these will raise charge-offs rates. It is perhaps the case that large banks hold more poor quality capital to ensure bailouts as Alessandri and Haldane (2009) and Kay (2009) suggest. Our results imply that regulators who increase Tier 1 ratios, reduce Tier 2 ratios and reduce the scale of large banks will produce industries less prone to system wide failure.

References

Alessandri, Piergiorgio and Haldane, Andrew, G. (2009). "Banking on the State". Bank of England.

Barrell, R., Davis, E P., Karim, D., Liadze, I., (2010), "Bank regulation, property prices and early warning systems for banking crises in OECD countries", *Journal of Banking and Finance*, 34, 2455-64

Barrell R, Davis E P, Fic T and Karim D (2011), "Tier 2 capital and bank performance", Discussion Paper No. 375, NIESR

Barrell R, Fic, T., FitzGerald, J., Karim. D., Orazgani, A and Whitworth R., (2011) 'The Banking Sector and Recovery in the EU Economies' *National Institute Economic Review* April 2010 no 216 pages R41-52

Cottarelli C., (2010) Fair and substantial – taxing the financial sector, in: Taxing the financial sector, The IMF's report to the G20 and background material, IMF, 2010

Basel Committee (2010), "Basel III, a global regulatory framework for more resilient banks and banking systems", Basel Committee on Banking Supervision, Basel

Cerasi V and Daltung S (2000), "The optimal size of a bank, costs and benefits of diversification", *European Economic Review*, 44, 1701-26

Chami R and Cosimano T (2003), "The nature of capital adequacy constraints under the Basel accord", mimeo, IMF Institute

Davis E P and Zhu H (2009), "Commercial property prices and bank performance", *Quarterly Review of Economics and Finance* 49, 1341–1359

Demsetz, R.S. and P.E. Strahan (1997), `Diversification, Size, and Risk at Bank Holding Companies', Journal of Money, Credit, and Banking, 29, 300-13.

Diamond, D. W., and Dybvig, P. H, (1983). "Bank Runs, Deposit Insurance, and Liquidity," *Journal of Political Economy*, University of Chicago Press, vol. 91(3), pages 401-19, June.

Evanoff D and Wall L D (2000), "Subordinated debt and bank capital reform", Federal Reserve Bank of Chicago, Economic Perspective, 24, 40-53

Francis W and Osborne M (2009), "Regulation, capital and credit supply in the UK banking industry: Measuring the Impact of Prudential Standards", Financial Services Authority Occasional Paper no. 36

Francis W and Osborne M (2010), "On the behaviour and determinants of risk-based capital ratios: Revisiting the evidence from UK banking institutions, *International Review of Finance*, Vol. 10, No. 4, pp. 485-518, 2010

Financial Stability Board (2010), "Macroprudential instruments and frameworks: report published by the Committee on the Global Financial System" 21 May 2010, Basel

Goodhart, C.A.E., (2010) 'Money, Credit and bank behaviour, the need for a new approach' *National Institute Economic Review* no 214 October pp F73-82

Haldane, Andrew, G. (2010). "Rethinking the Financial Network". Bank of England.

672-701

Kay, John (2009). "Narrow Banking: The Reform of Banking Regulation". Centre for the Study of Financial Innovation.

Krasa, S., and Villamil, A., (1992) 'A Theory of Optimal Bank Size' *Oxford Economic Papers*, vol 44 no 4 pp725-749

Levonian M (2001), "Subordinated debt and the quality of Market discipline in banking", Federal Reserve of San Francisco, mimeo

Merton, R. (1977), "An Analytical Derivation of the Cost of Deposit Insurance and Loan Guarantees", *Journal of Banking and Finance* 1, 3-11.

Osborne D K and Lee S (2001), "Effects of Deposit Insurance Reform on Moral Hazard in US Banking", *Journal of Business Finance and Accounting* 28, 979–992

Salas, V., and Saurina, J. (2002), "Credit risk in two institutional regimes: Spanish commercial and savings banks", *Journal of Financial Services Research*, 22, 203–224.

Van den Heuvel S (2002), "Does bank capital matter for monetary transmission?", *FRBNY Economic Policy Review*, May 2002, 259-265

Vickers J (2011), "How to Regulate the Capital and Corporate Structures Of Banks?", Speech at LBS, 22 January 2011

Zhu, Haibin (2008). "Capital regulation and banks' financial decisions". *International Journal of Central Banking*, March 2008.

Appendix: Data and Bank Coverage

In order to avoid outliers we trimmed the data according to the following rules:

Return on average assets not exceeding 10%
Loan growth not exceeding 50% in absolute terms
Asset growth not exceeding 50% in absolute terms
A ratio of bank loans to bank assets larger than 10% and smaller than 90%;

The resultant dataset has 713 banks and the country distribution is shown in Table A1 below, with around half of banks being from the US and Japan, the rest distributed across EU countries and Canada.

Table A1: Country distribution of banks

Country	Banks	Percent of sample			
Belgium	4	0.6	**Japan**	132	18.5
Canada	27	3.8	**Netherlands**	20	2.8
Denmark	12	1.7	**Norway**	9	1.3
Finland	6	0.8	**Spain**	48	6.7
France	53	7.4	**Sweden**	5	0.7
Germany	36	5.0	**UK**	51	7.2
Italy	35	4.9	**US**	275	38.6
Total	**713**				

Variable	Source	Notes	Coverage
Net Charge Offs	Bankscope*	Extracted from banks' annual statements	1993 - 2008
Total Assets	Bankscope*	Extracted from banks' annual statements	1993 - 2008
Real Loan Growth	Bankscope*	Calculated from loan levels which are extracted from banks' annual statements	1993 - 2008
Capital Adequacy	Bankscope*	Extracted from banks' annual statements	1993 - 2008
Tier 2 Proportion	Calculated based on Bankscope data for Tier 1and Capital Adequacy	Tier 1 data extracted from banks' annual statements	1993 - 2008
GDP growth	National Accounts	Extracted from the NIESR NiGEM database	1993 - 2008
Property Price Growth	European Central Bank and Bank for International Settlements	Extracted from the NIESR NiGEM database	1993 - 2008
* Bankscope is the proprietary database of Bureau van Dijk Electronic Publishing			