European Financial Management, Vol. 13, No. 1, 2007, 49–70

Examining the Relationships between Capital, Risk and Efficiency in European Banking

Yener Altunbas*, Santiago Carbo†,
Edward P.M. Gardener* and Philip Molyneux*

*Bangor Business School, University of Wales, Bangor, LL57 2DG, UK †Department of Economics, Universidad de Granada, Campus Cartuja, s/n E-18071 Granada, Spain
e-mail: p.molyneux@bangor.ac.uk

Abstract

This paper analyses the relationship between capital, risk and efficiency for a large sample of European banks between 1992 and 2000. In contrast to the established US evidence we do not find a positive relationship between inefficiency and bank risk-taking. Inefficient European banks appear to hold more capital and take on less risk. Empirical evidence is found showing the positive relationship between risk on the level of capital (and liquidity), possibly indicating regulators' preference for capital as a mean of restricting risk-taking activities. We also find evidence that the financial strength of the corporate sector has a positive influence in reducing bank risk-taking and capital levels. There are no major differences in the relationships between capital, risk and efficiency for commercial and savings banks although there are for co-operative banks. In the case of co-operative banks we do find that capital levels are inversely related to risks and we find that inefficient banks hold lower levels of capital. Some of these relationships also vary depending on whether banks are among the most or least efficient operators.

Keywords: *bank capital*, *risk*, *efficiency*, *credit*, *European banks*.

JEL classification: *E*5, *E*52, *G*21

1. Introduction

In recent years European banking systems have become increasingly integrated and liberalised on the road to greater product and service deregulation. This progressive process

Thanks to Claudia Buch, Hans Degryse, Stephanie Stolz, Rudi Vander Vennet and other participants at the SUERF Kiel Workshop on Banking Risks in International Markets, February 2004 for helpful comments. Also thanks to the insightful comments of the anonymous referees. The usual disclaimer applies. The authors acknowledge the financial support of FUNCAS. Corresponding author: Philip Molyneux

of financial integration is enhancing competition and emphasising the importance of improved efficiency of financial institutions. However, several authors have argued that this increase in competition could lead – at least in the short term – to incentives for greater bank risk-taking (see e.g., Danthine *et al*., 1999; Hellman *et al*., 2000). Regulators have tried to counterbalance these incentives by giving capital adequacy a more prominent role in the banking regulatory process.[1] In this sense, due to both regulatory and market pressures, most European banks have been under pressure to boost their capitalisation.

The existing theoretical literature on the determinants of bank risk-taking, and more specifically, studies examining the relationship between a bank's capital and risk positions often yield conflicting predictions. The main reason for this is that most of the hypotheses are non-exclusive. For instance, agency cost and information asymmetry problems may have a significant impact on trade-offs between risk and bank capital (Jensen, 1986; Berger, 1995) and this explains why some institutions may react to the increased requirements of capital by taking on more risk, while others may reduce leverage.

Given that theory provides contradictory predictions the only way to determine the relationship between capital, risk and efficiency in European banking is to resort to empirical analysis. As indicated by Berger *et al*. (1995), and more recently by Jackson (1999), empirical research is scant on this topic, particularly in Europe. Hence, the aim of this paper is to examine the relationship between risk, leverage and efficiency in European banking.

2. Literature review

The recurrence of banking crises that has taken place over the last 20 years has increased concerns regarding the stability of the financial system.[2] Under this process, several authors have focused on the negative effects that a generous safety net may have in terms of incentives for bank risk-taking and hence, on the need for more stringent prudential regulation. Among the different tools used by regulators for prudential purposes, capital adequacy regulations have played an increasingly prominent role. Yet, the theoretical literature offers contradictory results as to the optimal design of capital adequacy regulation and to the effects of capital requirements on bank risk-taking incentives (see Berger *et al*., 1995; Freixas and Rochet, 1997; Santos, 1999; Boot *et al*., 1999; Rime, 2001b) so that the theoretical issue of how higher capital ratios reduces overall banking risk has largely been unresolved in the literature. On the other hand, there is almost a consensus that capital adequacy regulations should be set up in conjunction with other prudential regulatory and market instruments in order to create an optimal set of incentives (see e.g., Freixas and Gabillon, 1999). With regards to the latter various commentators (e.g., Flannery, 1998, 2001; Benink and Wihlborg, 2003; Sironi, 2003; Gropp *et al*., 2004) note the importance that market discipline can have on bank risk-taking and capital strength. The argument goes that holders of bank liabilities such as deposits or/and unsubordinated debt have an incentive to penalise banks by asking for higher returns if they take on more risk. Banks in turn will respond by holding

[1] For instance Vives (2000, p. 15) notes that 'the general trend is to introduce competition in banking and to check risk-taking with capital requirements and appropriate supervision'.

[2] Lindgren *et al*. (1998).

more capital to reduce insolvency risk. However, banks that take on more risk may not necessarily hold more capital if they believe all depositors are insured or if they underestimate the adverse systemic implications of bank failure. Nevertheless, bearing these factors in mind, the market discipline argument does suggest that holders of bank liabilities will restrict bank risk-taking by making such activity more costly.[3]

Turning to the empirical literature, there is an early line of US research that examines the effect of bank capital regulations on bank behaviour (see e.g., Peltzman, 1970; Mayne, 1972). The main concern of these early works was to analyse the effectiveness of financial regulation, and more specifically to test whether the existence of flat rate deposit insurance created incentives for excessive risk-taking by bankers at the expense of the Federal Deposit Insurance Corporation (FDIC). In order to avoid the transfer of value to the FDIC, financial regulation was expected to force financial institutions to hold an amount of capital adequate to the amount of risk that individual institutions were taking. Results from these earlier studies were sceptical about the effectiveness of banking capital regulation on affecting bank managers' target capital ratios and emphasised the need to control for other factors to limit risk-taking such as the influence of a deposit insurance flat fee rate or the effect of high nominal interest rates (Marcus, 1983).

The introduction of the 1988 Basle Accord on bank capital reignited interest on the effects of bank capital regulations (see e.g., Wall and Peterson, 1988, Shrieves and Dahl, 1990).[4] The results from these studies suggest that regulatory minimum capital constraints are important in influencing the financing decisions made by a significant subset of banks. More recent empirical studies analysing the effectiveness of capital adequacy regulations and the relationship between increases in banking capital and risk tend to find that capital regulation in banking has been effective in increasing capital ratios without substantially shifting their portfolio and OBS exposure towards riskier assets (see e.g., Shrieves and Dahl, 1992, Editz *et al*., 1997; Rime, 2001a). Interestingly, these studies express concerns as to whether these results would still hold in more recent years given that financial innovation has made the Basle 1988 risk weights less meaningful. Also, it could be argued that increased competition and more expensive cost of capital are likely to encourage risk-taking – in order to make up for the lost returns needed to increase capital ratios.

Kwan and Eisenbeis (1997) link the strand of empirical literature concerned with the effects of bank capital regulations and the numerous studies dealing with bank efficiency. Following Hughes and Moon (1995), these authors argue that it is necessary to recognise explicitly the concept of efficiency in the empirical models linking the relationship between bank capital and risk. In doing so, these studies link the aforementioned literature dealing with the effects of financial regulation on bank risk taking and the prolific strand of empirical work on bank efficiency.[5] Their results show that both efficiency and capital are relevant determinants of bank risk-taking and moral hazard incentives.

---

[3] Baumann and Nier (2003) use a sample of listed banks from 32 countries over 1993 to 2000 and find that government support and deposit insurance lowers capital buffers. Banks that have a higher proportion of interbank loans and/or are listed in the US hold higher capital buffers suggestive of market discipline.

[4] For non-US studies see for instance Altunbas *et al*. (2000) or Barrios and Blanco (2003).

[5] See Goddard *et al*. (2001) for an extensive review of the US and European bank efficiency literature.

Another important dimension relates to whether the relationship between capital, risk and efficiency varies for banks with different ownership structures. European banking is one of the few industries where private, public and mutual firms operate together in a competitive market (Goddard *et al*., 2001). However, there is little empirical guidance to suggest whether there are systematic differences in the relationship between risk-taking, capital strength and efficiency for banks with different ownership features. The seminal work by Jensen and Meckling (1976), Fama (1980) and Fama and Jensen (1983) suggests that a lack of capital market discipline for firms weakens owners' control over management, making management freer to pursue its own agenda, and thus providing it with fewer incentives to be efficient. Given that public and mutual banks have stated 'social' or/and economic development objectives one may expect them to have different performance and risk-taking features to their private sector competitors. Some theoretical studies have shown that mutual banks may have competitive/efficiency advantages even if they show expense preference behaviour (Purroy and Salas, 2000; Berenguer *et al*., 2003). As for empirical evidence, most studies have focused on efficiency comparisons between private and mutual banks in the USA. For instance O'Hara (1981) and Nicols (1967) indicate that mutual firms are likely to be more efficient than their private sector counterparts. Mester (1989, 1993) finds that mutual firms are more efficient while Cebenoyan *et al*. (1993) suggests there is no difference between the efficiency of mutual and joint stock Savings and Loans (S&L) banks. Other studies have found expense preference behaviour in mutual banks in the USA (Akella and Greenbaum, 1988; Krinsky and Thomas, 1995). In a more recent study on German banking Altunbas *et al*. (2001) find that public and mutual banks have slight cost and profit efficiency advantages over their private commercial banking counterparts and this they explain by their lower cost of funds'. The aforementioned literature, however, provides little guidance as to whether efficiency differences between various types of banks have any influence on their capital strength or risk profile. The following aims to address these issues.

3. The Methodological Framework

3.1. *Main hypotheses between capital and risk*

Foremost among the hypotheses underlined by the theoretical and empirical literature when trying to analyse the relationships between capital and risk would be the effect of moral hazard due to the existence of a safety net, agency problems as well as the intended/unintended effects of regulatory actions. In this section, we review these relationships and indicate how they explain the relationship between capital, risk and efficiency.

An important factor contributing to a positive relationship between capital and risk relates to the actions of regulators and supervisors (Shrieves and Dahl, 1992; Jacques and Nigro, 1997; Aggarwal and Jacques, 1998; Editz *et al*., 1998). According to this *regulatory hypothesis* regulators encourage banks to increase their capital commensurably with the amount of risk taken. This increase in capital, when the amount of risk rises, could also partly be due to efficient market monitoring[6] from markets

[6] This channel might be strengthened in the future if there is an increase of subordinated bank debt issuance.

when capital positions are deemed inadequate (Calomiris and Kahn, 1991; Berger, 1995).

An alternative hypothesis, however, suggests a negative relationship between capital and risk and argues that banks have incentives to exploit existing flat deposit insurance schemes. This 'moral hazard hypothesis' may become particularly relevant when the leverage and risk position of banks are already high, suggesting that banks would increase their risk positions as capital declines. The direction of causality that explains the moral hazard hypothesis could also flow from capital to risk and can be derived from the (unintended) consequences of regulatory actions. As indicated by Kahane (1977), Koehn and Santomero (1980) and Kim and Santomero (1988), banks could respond to regulatory actions forcing them to increase their capital by increasing asset risk.[7] A closely related extension to the moral hazard hypothesis could arise due to the existence of relevant *agency problems* between owners and stakeholders. According to Gorton and Rosen (1995), in an unhealthy banking industry (more prone to moral hazard), entrenched managers will tend to take on more risk rather than less risk. Under an environment in which increased competition is expected, managers who normally have better information on the quality of the portfolio might have a larger degree of manoeuvre from stakeholders to follow an expansionary strategy, which *ex post* could be shown to be excessively risky.[8]

In the framework of these two hypotheses, as suggested by Hughes and Moon (1995) and Hughes and Mester (1998), capital and risk are also likely to be influenced by the level of efficiency of the banking firm. From a regulatory perspective, and other things being equal, regulators may allow an efficient firm with better management probably more room for leverage. On the other hand, from a moral hazard point of view, a less efficient firm may be tempted to take on higher risk to compensate for the lost returns. Efficiency could, in turn, be also affected by the level of bank risk (Berger and De Young, 1997). For instance, managers who are not very efficient at assessing and monitoring loans are not likely to be very efficient in achieving a high level of operating efficiency. Finally, a bank may chose to maximise short-term profits by reducing the funds devoted to allocating and monitoring loans. This, other things being equal, would boost both efficiency and risk measures, producing (in the short-term) a positive relationship between risk and efficiency. Prior literature examining the determinants of banking risk takes into account the fact that capital and risk are both determined contemporaneously (Shrieves and Dahl, 1992; Jacques and Nigro, 1997; Rime, 2001a). Also capital and risk may also be simultaneously determined by the level of efficiency of the banking firm (Kwan and Eisenbeis, 1997; Hughes and Moon, 1995; Hughes and Mester, 1998).

Hence, capital, risk and efficiency are all related. This suggests that any empirical approach used to model the relationships between capital and risk also needs to take account of bank efficiency. In testing such relationships one also needs to take into account different bank ownership types as agency issues may have a differential impact on capital, risk and efficiency across private, mutual and public banks.

---

[7] See Freixas and Rochet (1997) for a criticism.

[8] Ownership characteristics might also be playing a role in the relative weight attributable to these hypotheses. Saunders *et al*. (1990) argue that managers of stockholder-controlled banking firms are more likely to take more risks than managerially-controlled firms as managers cannot diversify their human capital.

3.2. *Modelling Framework*

The modelling framework adopted to estimate the relationship between capital, risk and efficiency leads on from the various approaches suggested by Shrieves and Dahl (1992), Jacques and Nigro (1997), Kwan and Eisenbeis (1997), Hughes and Mester (1998) and Rime (2001a). We specify a system of equations and estimate these using Zellner's (1962) Seemingly Unrelated Regression (SUR) approach.[9] This allows for simultaneity between banks' risk, capital and efficiency while also controlling for important other bank and country-specific factors. The system of equations estimated is as follows:

$$\begin{aligned} LLRL_{ij} = {} & a + b\,ETA_{ij} + c\,INEFF_{ij} + d\,NLTA_{ij} + e\,LNTA_{ij} + f\,LAODEP_{ij} \\ & + g\,INSBOC_{j} + h\,SOLVENCY_{j} + i\,LAOAC_{j} + j\,LLPOAC_{j} \\ & + YEAR_{j} \end{aligned} \tag{1}$$

$$\begin{aligned} ETA_{ij} = {} & a + b\,INEFF_{ij} + c\,NLTA_{ij} + d\,LNTA_{ij} + e\,ROA_{ij} + f\,LAODEP_{ij} \\ & + g\,INSBOC_{j} + h\,SOLVENCY_{j} + i\,LAOAC_{j} + j\,ROCC_{j} + k\,COIRC_{j} \\ & + l\,OEPOAC_{j} + m\,LLPOAC_{j} + YEAR_{j}. \end{aligned} \tag{2}$$

$$\begin{aligned} INEFF_{ij} = {} & a + b\,ETA_{ij} + c\,LLRL_{ij} + d\,NLTA_{ij} + e\,LNTA_{ij} + f\,LAODEP_{ij} \\ & + g\,INSBOC_{j} + h\,SOLVENCY_{j} + i\,LAOAC_{j} + j\,COIRC_{j} \\ & + k\,OEPOAC_{j} + l\,LLPOAC_{j} + YEAR_{j} \end{aligned} \tag{3}$$

Where:

Bank-specific variables

$LLRL_{ij}$	Loan-loss reserves for bank i in country j
ETA_{ij}	Equity to assets ratio for bank i in country j
$INEFF_{ij}$	Cost inefficiency for bank i in country j (derived from stochastic cost frontier estimates)
$NLTA_{ij}$	Net loans to total assets for bank i in country j
$LNTA_{ij}$	Natural log of total assets for bank i in country j
ROA_{ij}	Return-on-assets for bank i in country j
$LAODEP_{ij}$	Liquid assets to customer and short-term deposits for bank i in country j

Country-specific variables

$INSBOC_{j}$	Interest rate spreads over 3-year government bonds in country j
$SOLVENCY_{j}$	Current assets to current liabilities (short-term shareholders funds) for non-financial companies in country j
$LAOAC_{j}$	Banking system liquid assets to total assets in country j
$ROCC_{j}$	Banking system return on capital in country j
$COIRC_{j}$	Banking system cost to income ratios in country j
$OEPOAC_{j}$	Banking system operating expenses to total assets in country j
$LLPOAC_{j}$	Banking system loan-loss provisions to total loans in country j
$YEAR_{j}$	Yearly dummy variables for 1992 to 2000

[9] SUR estimation, developed by Zellner (1962) is used when the set of equations are believed to have contemporaneous cross-equation error correlation.

The first model explains banking sector risk, the second bank capital levels and the final model examines the determinants of bank cost inefficiency. Models 1 uses loan-loss reserves levels as a proxy for banking risk as the dependent variable ($LLRL_{ij}$), Model 2 where capital is the dependent variable (ETA_{ij}) and finally the third model where bank cost inefficiency ($INEFF_{ij}$) is the dependent variable. A variety of bank-specific and country-specific variables are also included that are believed to also explain the variation in bank risk, capital and inefficiency across European banking markets.

Loan loss reserves as a fraction to total assets ($LLRL_{ij}$) is used as our measure of banking risk derived from accounting information. Higher levels of reserves are suggestive of greater banking risk. (This measure of risk is preferred to loan-loss provisions as there was substantial missing data for provisions in our sample. Also the variability of provisions data available indicated a much greater level of dispersion than for reserves, so we chose the latter as a more stable indicator of overall banking risk).[10] Of course, a limitation associated with using risk variables calculated from accounting data is that even assuming that they accurately reflect portfolio quality, managers are likely to have some timing discretion over these measures, and there is evidence that such discretion is exercised in a manner that minimises regulatory costs. In general, the measurement of banks' risk is quite problematic especially for those institutions that do not have frequently traded securities (Shrieves and Dahl, 1992; Rime, 2001a). As the majority of European banks do not have publicly traded securities, we resort to the use of accounting measures of banking risk.[11]

Capital is calculated simply as the ratio of equity to total assets (ETA_{ij}). Individual bank efficiency (INEFF) is obtained as the distance of a firm's observed operating costs to the minimum or 'best-practice' efficient cost frontier and are derived using the stochastic frontier approach.[12]

---

[10] Borio (2003) notes that banks provision in a counter cyclical fashion and they should build these up in good times and run them down when economic conditions and loan defaults increase. As such banks with higher levels of reserves could be interpreted as lower risk. We would argue that banks with higher levels of reserves have an expectation of higher future risk and are therefore more risky.

[11] We could not use data on individual bank loan-losses due to substantial missing data. We did estimate the model using a crude measure of bank risk, the loans to deposits ratio (higher ratios are suggestive of greater risk-taking) and the results were found to be very similar for those as reported where we use loan-loss reserves as our risk proxy. Accounting measures of bank risk are, of course, backward looking and therefore have various limitations.

[12] Cost inefficiencies are estimated using a two output (loans and securities) three input (wages, interest costs and other operating costs), translog cost function specification as follows:

$$\ln TC = \alpha_0 + \tau_1 t + \frac{1}{2}\tau_1 t^2 + \sum_{i=1}^{2}(\alpha_i + \varphi_i t)\ln Q_i + \sum_{h=1}^{3}(\beta_h + \theta_h t)\ln P_h + \frac{1}{2}\left[\sum_{i=1}^{2}\sum_{j=1}^{2}\delta_{ij}\ln Q_i \ln Q_j + \sum_{h=1}^{3}\sum_{m=1}^{3}\gamma_{hm}\ln P_h \ln P_m\right] + \sum_{i=1}^{2}\sum_{m=1}^{3}\rho_{im}\ln Q_i \ln P_m + \varepsilon$$

$\ln TC$ the natural logarithm of total costs (Operating and Financial cost);
$\ln Q_i$ the natural logarithm of bank outputs, total loans and total securities;

For the explanatory variables we use a range of bank-specific and country-specific variables that are believed to be important in explaining the performance and risk-taking propensity of banks. The bank-specific variables include net loans to total assets ($NLTA_{ij}$) as rapid loan growth may increase risk and impact adversely on capital and bank efficiency. Banks that are more liquid may be more efficient and need less capital so we account for this by using a liquid assets/deposits ratio ($LAODEP_{ij}$).[13] Bank size, through economies of scale, may influence the relationship between capital, risk and efficiency so we control for the assets size of banks ($LNTA_{ij}$). Big banks, typically hold less capital than smaller banks, they may also be more diversified and gain from other size advantages (Peltzman, 1984; Hughes *et al*., 2001) so it is important to control for this factor. In the capital model we also control for bank profits as capital levels are inextricably linked to bank performance. For instance, Scholtens (2000) in a study of international banks finds that profitability is strongly related to tier one capital, and earlier work by Berger (1995) also finds that profits and capital are positively related in US banking.

To control for country-specific factors we include a range of variables that relate to the interest rate environment and the solvency of the corporate sector. Differences in interest rate levels across countries may influence bank performance across countries as markets with higher rates can provide banks with potentially greater profits and therefore, improved opportunities to accumulate capital. However, a more variable interest rate environment is suggestive of a more volatile operating environment and this may be suggestive of greater pressure on bank capital and risks. As such we include a variable to account for the interest rate environment, namely, interest rate spreads over the 3-year German government bond yield ($INSBOC_j$). This indicates rate differences over the medium term. We also include a variable to account for the solvency of the European corporate sector, ($SOLVENCY_j$) which is simply the current assets to liabilities of firms. This variable is included to see if the financial strength of the corporate sector impacts on bank risk taking and capital strength. Finally, a range of country-specific

---

ln P_h the natural logarithm of *i*th input prices (*i.e.* wage rate, interest cost and physical capital price).

We estimate a global cost frontier for all banks in our sample and then identify the inefficiency levels for those of different ownership type. We cross checked the results with those derived from individual frontier estimates and the results were mainly the same, as such the results reported are from the global estimation. See Altunbas *et al*. (2001) for details on the use of the frontier approach for estimating cost inefficiency in European banking. The choice of the translog was partially motivated by the recently identified problems associated with using the Fourier functional form as identified by Altunbas and Chakravraty (2001), especially when dealing with heterogeneous data sets. We also estimated cost efficiencies including off-balance sheet estimates as a third output, as suggested by Stiroh (2000) but as the results from the SUR estimates remained very similar this paper includes results using the simplest model specification. The cost inefficiencies have a low correlation with bank cost-income ratios of around 0.1 and therefore are not expected to present multicollinearity problems in estimation of the model.

[13] Banks that are more liquid may be more efficient in the sense that, all other things being equal, an efficient bank can produce more output part of which includes liquid and other assets. It should also be noted that given that the liquidity costs of bank bailouts are substantial (Gorton and Huang, 2002), banks and banking systems that produce more liquidity than others perhaps can be viewed as both more 'liquidity efficient' and also less risky.

banking variables are included to take account of broad banking system differences. These include indicators of banking system liquidity ($LOAC_j$), efficiency ($COIRC_j$), return on capital ($ROCC_j$) and risk ($LLPOAC_j$). While these variables are similar to the bank-specific indicators they provide another dimension to the analysis in that they control for country differences in liquidity, efficiency and risk. In other words they help to show if country-specific financial differences impact on bank-specific risk, capital and efficiency.[14]

4. Data and Results

Bank-specific data were obtained from the Bankscope database that includes balance sheet and income statement information on European (and other) banks. We use data on banks operating in 15 European countries between 1992 and 2000. Appendix 1 shows the details on the number of banks and financial information for our sample of bank-specific variables. Information for the country-specific variables is obtained from EC (2002).[15]

Estimates from the risk equation (model 1) derived from the simultaneous estimation are reported in Table 1.[16] The columns show estimates for the full sample (all banks) and also for commercial, savings and co-operative banks. We focus on different bank ownership types because non-quoted (and/or private) firms may pursue different objectives than their joint-stock competitors. This means that commercial banks (privately listed and joint-stock firms) may perform differently to savings and co-operative banks (that have mutual/quasi public ownership in the case of savings banks and are mutual for co-operative banks). It could be the case that banks of different ownership characteristics differ in their attitudes to managing capital, costs as well as risks. The final two columns report estimates derived by using samples of the most and least cost efficient banks. The aim here is to see if the relationships differ if we look only at relatively cost efficient or inefficient banks.

Table 1 shows that for the full sample there is a positive relationship between capital levels and bank risks. Namely, banks with higher loan loss reserves also tend to have higher capital levels. This is the case for commercial and savings banks although it does appear that there is the opposite relationship for co-operative banks. Also the final columns show that for the most cost efficient banks an inverse relationship exists between capital and risk, possibly regulators/regulations allow more cost efficient banks to trade-off capital and risk-taking, compared with inefficient banks. It could be that capital restrictions are less binding for more efficient banks so they have greater flexibility in trading off capital and risk, and this option is less available to inefficient operators. The second row of the table again confirms that there is a preponderance of evidence

[14] A simple correlation of all the independent variables revealed relatively low levels and so is not suggestive of multicollinearity problems in our system estimation.

[15] The company solvency data were constructed from the AMADEUS dataset and the interest spread data from the European Central Bank.

[16] The SUR estimation was undertaken first using the whole sample, and repeated excluding German banks because of their large number relative to the total sample size. The results did not materially alter so we report the full estimates here. In addition, we also checked the robustness of the savings banks and co-operative banks estimates excluding the German banks and again the main findings are very similar so again the full sample estimates are reported.

Table 1

Bank risks ($LLRL_{ij}$ as the dependent variable)

Estimates from the risk equation (model 1) derived from the SUR simultaneous estimations are reported using loan-loss reserves to total assets (LLRLij) as the dependent bank-specific (risk) variable. The columns report the results obtained for six estimations of the system – for all banks, commercial banks, savings banks, cooperative banks, and for the most and least cost efficient banks in our sample. Independent variables include bank-specific indicators (denoted by subscripts ij) and country-specific variables (subscript j). The bank-specific indicators include: equity to assets ratios for bank i in country j (ETA_{ij}), cost inefficiency estimates derived for each bank from stochastic cost frontier estimation ($INEFF_{ij}$), the net loans to total assets ratio ($NLTA_{ij}$) for each bank, an indicator of the size of each bank measured by the natural log of total assets ($LNTA_{ij}$) and the the liquid assets to customer and short-term deposits ratio ($LAODEP_{ij}$) for each bank. The country specific indicators are: the interest rate spreads over 3-year government bonds in the respective country ($INSBOC_j$), non-financial firm solvency measured as current assets to current liabilities ($SOLVENCY_j$), a measure of banking system liquidity given by the liquid assets to total assets ratio ($LAOAC_j$), and overall banking system risk measured as the loan-loss provisions to total loans ($LLPOAC_{ij}$). Yearly dummy variables are included to control for time effects (D1992 to D1999) and the CONS is the constant (acting as a dummy variable for the year 2000).

Variables	All banks	Commercial banks	Savings banks	Cooperative banks	Most efficient banks[1]	Least efficient banks[2]
ETAij	0.085*	0.033*	0.091*	−0.066*	−0.059*	0.053*
	(0.0045)	(0.0078)	(0.0089)	(0.0117)	(0.0093)	(0.0093)
INEFFij	−0.008	−0.04*	−0.154*	−0.041*	−1.559*	0.056*
	(0.0042)	(0.0071)	(0.0089)	(0.0085)	(0.0486)	(0.0074)
NLTAij	−0.028*	−0.019*	−0.044*	−0.014*	−0.037*	−0.023*
	(0.0016)	(0.0030)	(0.0018)	(0.0023)	(0.0048)	(0.0028)
LNTAij	0.019	−0.223*	0.024	0.083*	−0.093^{+}	−0.215*
	(0.0173)	(0.0386)	(0.0176)	(0.0220)	(0.0404)	(0.0409)
LAODEPij	0.005*	0.006*	−0.002	0.018*	0.011*	−0.001
	(0.0012)	(0.0020)	(0.0014)	(0.0021)	(0.0024)	(0.0023)
INSBOCj	0.124*	−0.017	0.206*	0.022	0.906*	−0.303*
	(0.0271)	(0.0577)	(0.0283)	(0.0348)	(0.0691)	(0.0639)
SOLVENCYj	−0.025*	−0.012*	−0.018*	−0.05*	−0.006	−0.013*
	(0.0018)	(0.0033)	(0.0018)	(0.0031)	(0.0039)	(0.0037)
LAOACj	0.052*	0.043*	−0.034*	0.057*	0.078*	0.032*
	(0.0030)	(0.0055)	(0.0045)	(0.0048)	(0.0083)	(0.0055)
LLPOACj	1.519*	1.379*	0.708*	3.274*	1.354*	1.959*
	(0.0763)	(0.1478)	(0.0713)	(0.1326)	(0.1713)	(0.1863)
D1992	0.128	0.296	0.248	0.15	−0.854	0.047
	(0.2325)	(0.4522)	(0.2020)	(0.3469)	(0.5680)	(0.4730)
D1993	−0.288	−0.074	0.291	−0.432	−0.651	−0.469
	(0.2196)	(0.4325)	(0.1904)	(0.3347)	(0.5225)	(0.4578)
D1994	−0.702*	−0.558	0.032	−1.165*	−0.854	−1.225*
	(0.2205)	(0.4394)	(0.1904)	(0.3377)	(0.5202)	(0.4682)
D1995	−0.843*	−0.322	−0.007	−1.647*	−1.185^{+}	−0.846
	(0.2169)	(0.4313)	(0.1879)	(0.3338)	(0.5142)	(0.4547)
D1996	−0.597*	−0.084	0.079	−1.338*	−0.732	−0.736
	(0.2128)	(0.4229)	(0.1821)	(0.3254)	(0.5022)	(0.4487)
D1997	−0.324	0.21	0.147	−0.733^{+}	−0.535	−0.269
	(0.2109)	(0.4182)	(0.1793)	(0.3230)	(0.4947)	(0.4416)
D1998	−0.46^{+}	0.205	0.145	−1.229*	−0.321	−0.323
	(0.2097)	(0.4181)	(0.1778)	(0.3204)	(0.4919)	(0.4391)
D1999	−0.476^{+}	0.023	−0.094	−1.006*	−0.272	−0.314
	(0.2099)	(0.4224)	(0.1766)	(0.3191)	(0.4891)	(0.4447)

Table 1
Continued.

Variables	All banks	Commercial banks	Savings banks	Cooperative banks	Most efficient banks[1]	Least efficient banks[2]
CONS	3.786*	5.678*	8.408*	6.313*	28.199*	3.511*
	(0.3718)	(0.7074)	(0.3970)	(0.6233)	(1.0838)	(0.7971)
Observations	20,333	7,108	5,810	7,415	5093	5078
R sq	0.1483	0.0555	0.3688	0.3022	0.1778	0.0789

Notes: + significant at 5%; * significant at 1%
1. The top quartile of cost efficient banks are used as the sample.
2. The bottom quartile of cost efficient banks are used as the sample.

suggesting that risk and inefficiency are negatively related as indicated by the inverse sign on the $INEFF_{ij}$ variable for the full sample, different types of banks and the most efficient banks, although for the least efficient banks the relationship is positive. It could be that cost constraints inhibit the ability of inefficient banks to take on more risks. Possibly, inefficient banks are more reserve constrained and this may be bringing about this result. The table also shows that net lending ($NLTA_{ij}$) is inversely related to risk suggesting that loan growth is inextricably linked to loan loss reserve levels. Bank asset size also seems to be important as large commercial banks appear to be less risky than their smaller counterparts and bigger efficient and inefficient banks also seem to have lower loan loss reserve levels. This suggests that there are potential diversification benefits associated with size as noted by Hughes *et al*. (2001).[17]

There also appears to be a strong positive relationship between liquidity and risk as banks with higher liquidity levels have higher reserve levels. Taken together, the results from our risk equation suggest that overall banks with higher capital and liquidity levels take on more risks. Also, efficient banks take-on higher levels of risk. These findings generally confirm to the regulatory hypothesis whereby regulators encourage banks to hold more capital and liquidity to cover the risks being taken. We do not find any strong evidence that inefficient European banks are more risky, contrasting with the evidence from the USA (Hughes and Moon, 1995; Hughes and Mester, 1998).

The country-specific variables suggest that differences in short-term interest rates mainly positively impact on the level of loan-loss reserves. The variable that accounts for the solvency of the European corporate sector $SOLVENCY_j$ shows mainly a statistically significant inverse relationship with banking risks, as one would expect, given that the more financially sound the corporate sector then the less risky the banks. Finally, the country specific banking sector variables also suggest that the level of liquidity ($LAOAC_j$) and provisioning ($LLPOAC_j$) in the respective country's financial system are positively related to banking sector risks. In other words banking systems will take on more risks if they are more liquid and banks are provisioning at a higher level. There do not appear to be major differences in the aforementioned relationships across years apart for the co-operative bank sample as shown by the statistically significant yearly dummy variables.

[17] Beitel *et al*. (2004) find using an event study methodology that diversified bank mergers are more likely to destroy value than targeted mergers.

Table 2

Bank capital (ETA_{ij} as the dependent variable)

Estimates from the equity capital equation (model 2) derived from the SUR simultaneous estimations are reported using equity-to-assets (ETAij) as the dependent bank-specific (capital) variable. The columns report the results obtained for six estimations of the system – for all banks, commercial banks, savings banks, cooperative banks, and for the most and least cost efficient banks in our sample. Independent variables include bank-specific indicators (denoted by subscripts ij) and country-specific variables (subscript j). The bank-specific indicators include: cost inefficiency estimates derived for each bank from stochastic cost frontier estimation ($INEFF_{ij}$), the net loans to total assets ratio ($NLTA_{ij}$) for each bank, an indicator of the size of each bank measured by the natural log of total assets ($LNTA_{ij}$), return-on-assets (ROA_{ij}) and the liquid assets to customer and short-term deposits ratio ($LAODEP_{ij}$) for each bank. The country specific indicators are: the interest rate spreads over 3-year government bonds in the respective country ($INSBOC_j$), non-financial firm solvency measured as current assets to current liabilities ($SOLVENCY_j$), a measure of banking system liquidity given by the liquid assets to total assets ratio ($LAOAC_j$), the banking systems return-on-capital ($ROCC_j$), country specific cost-to-income ratios (COIRCj), operating expenses to total assets ($OEPOAC_j$) and overall banking system risk measured as the loan-loss provisions to total loans ($LLPOAC_{ij}$). Yearly dummy variables are included to control for time effects (D1992 to D1999) and the CONS is the constant (acting as a dummy variable for the year 2000).

Variables	All banks	Commercial banks	Savings banks	Cooperative banks	Most efficient banks[1]	Least efficient banks[2]
INEFFij	0.146*	0.02	0.085*	−0.14*	−2.652*	0.17*
	(0.0062)	(0.0104)	(0.0113)	(0.0072)	(0.0658)	(0.0107)
NLTAij	−0.01*	0.005	−0.014*	0.017*	−0.012	−0.001
	(0.0023)	(0.0044)	(0.0022)	(0.0019)	(0.0068)	(0.0041)
LNTAij	−1.199*	−1.898*	−0.531*	−0.261*	−1.061*	−1.588*
	(0.0247)	(0.0521)	(0.0205)	(0.0188)	(0.0555)	(0.0559)
ROAij	1.133*	1.016*	1.916*	1.594*	1.298*	0.903*
	(0.0307)	(0.0487)	(0.0699)	(0.0390)	(0.0688)	(0.0497)
LAODEPij	0.057*	0.065*	−0.011*	−0.002	0.072*	0.037*
	(0.0017)	(0.0029)	(0.0017)	(0.0019)	(0.0033)	(0.0033)
INSBOCj	0.596*	0.453*	0.273*	0.089*	1.517*	0.412*
	(0.0452)	(0.0986)	(0.0354)	(0.0348)	(0.1033)	(0.1142)
SOLVENCYj	−0.015*	0.007	0.005	−0.007	0.027*	−0.003
	(0.0028)	(0.0051)	(0.0024)	(0.0035)	(0.0061)	(0.0056)
LAOACj	0.108*	−0.025	−0.005	0.077*	0.095*	0
	(0.0075)	(0.0164)	(0.0066)	(0.0086)	(0.0167)	(0.0185)
ROCCj	5.961*	5.679*	1.813*	−2.447*	8.721*	4.436*
	(0.4355)	(0.8052)	(0.5513)	(0.8152)	(1.1215)	(0.9699)
COIRCj	0.241*	0.251*	0.017	−0.176*	0.291*	0.208*
	(0.0178)	(0.0329)	(0.0271)	(0.0321)	(0.0527)	(0.0372)
OEPOACj	1.091*	−2.138*	3.151*	8.196*	−1.466+	−1.161
	(0.2801)	(0.4964)	(0.3201)	(0.6324)	(0.6675)	(0.6144)
LLPOACj	0.073	−0.574+	0.712*	2.371*	−0.933*	0.071
	(0.1302)	(0.2588)	(0.0986)	(0.1400)	(0.2707)	(0.3388)
D1992	−4.218*	−2.19*	−3.676*	−4.874*	−4.424*	−3.161*
	(0.3505)	(0.6847)	(0.2495)	(0.3362)	(0.8127)	(0.7128)
D1993	−4.616*	−2.009*	−4.112*	−4.947*	−4.826*	−2.543*
	(0.3289)	(0.6527)	(0.2323)	(0.3136)	(0.7450)	(0.6843)
D1994	−4.188*	−1.726*	−3.803*	−4.911*	−3.979*	−3.006*
	(0.3277)	(0.6584)	(0.2292)	(0.3024)	(0.7381)	(0.6939)
D1995	−4.407*	−1.981*	−3.624*	−4.577*	−4.004*	−3.357*
	(0.3231)	(0.6481)	(0.2265)	(0.2915)	(0.7321)	(0.6752)

Table 2
Continued.

Variables	All banks	Commercial banks	Savings banks	Cooperative banks	Most efficient banks[1]	Least efficient banks[2]
D1996	−3.852*	−1.71*	−2.797*	−3.561*	−3.509*	−2.825*
	(0.3178)	(0.6339)	(0.2210)	(0.2821)	(0.7166)	(0.6658)
D1997	−3.108*	−1.466+	−2.243*	−2.546*	−2.748*	−2.604*
	(0.3154)	(0.6217)	(0.2198)	(0.2828)	(0.7108)	(0.6512)
D1998	−2.52*	−0.865	−2.235*	−2.783*	−2.345*	−2.277*
	(0.3099)	(0.6150)	(0.2161)	(0.2759)	(0.6952)	(0.6411)
D1999	−2.309*	−0.865	−1.639*	−1.766*	−1.689+	−2.505*
	(0.3162)	(0.6251)	(0.2228)	(0.2792)	(0.7050)	(0.6572)
CONS	−10.053*	2.743	1.708	9.656*	27.443*	0.292
	(1.4127)	(2.7406)	(1.9273)	(2.0333)	(4.0179)	(3.0039)
Observations	20,333	7,108	5,810	7,415	5093	5078
R sq	0.2942	0.3003	0.6149	0.7000	0.4195	0.2512

Notes: + significant at 5%; * significant at 1%
1. top quartile of cost efficient banks are used as the sample.
2. bottom quartile of cost efficient banks are used as the sample.

Table 2 presents the results for our capital equation derived from the simultaneous estimates. The results for the full sample suggest that inefficient banks hold more capital however results vary across types of ownership. There appears to be no relationship between capital and efficiency for commercial banks, a positive relationship for savings banks and an inverse relationship for co-operative banks. The results derived from the estimates for the most and least efficient banks also confirm overall that there is an inverse relationship between capital and efficiency. It seems that the different results obtained for various bank types are driven by the proportion of relatively efficient and inefficient banks of the respective ownership type.

Net lending appears to be positively related to bank capital levels for savings and co-operative banks but not for their commercial bank competitors, although for the full sample the results suggest a significant relationship. It is also clear from Table 2 that there is a strong inverse relationship between bank asset size and capital – bigger banks have lower capital levels than smaller banks irrespective of type and level of efficiency. In addition, we also confirm the findings of Berger (1995) and Scholtens (2000) that capital levels and profitability are strongly positively related. Liquidity levels also appear positively related to capital in most cases (although for savings banks there appears to be a trade-off).

The country-specific results also reveal some interesting findings. Bank capital levels appear to be strongly related to interest rate spreads (over 3-year government bonds in the respective countries) suggesting that yield curve effects influence bank capitalisation. Non-financial company solvency, ($SOLVENCY_j$) seems to be significantly inversely related to bank capital levels – the more solvent the corporate sector the lower levels of bank capital – but this is only found for the whole sample estimates and surprisingly we find the opposite relationship for efficient banks. The latter suggests that more efficient banks hold higher levels of capital the more financially sound the corporate sector. This can possibly be explained by the fact that when the corporate sector is more solvent it is more profitable and efficient banks can extract rent that they use to boost capital. The other country-specific variables are suggestive of system

Table 3

Bank cost inefficiency ($INEFF_{ij}$ as the dependent variable)

Estimates from the cost inefficiency equation (model 3) derived from the SUR simultaneous estimations are reported using cost inefficiency estimates derived for each bank from stochastic cost frontier estimation ($INEFF_{ij}$) as the dependent variable. The columns report the results obtained for six estimations of the system – for all banks, commercial banks, savings banks, cooperative banks, and for the most and least cost efficient banks in our sample. Independent variables include bank-specific indicators (denoted by subscripts ij) and country-specific variables (subscript j). The bank-specific indicators include: loan-loss reserves to total assets (LLRLij) as a measure of bank-specific risk, cost inefficiency estimates derived for each bank from stochastic cost frontier estimation ($INEFF_{ij}$), the equity-to-assets ratio (ETAij) as our bank-specific capital measure, the net loans to total assets ratio ($NLTA_{ij}$), an indicator of the size of each bank measured by the natural log of total assets ($LNTA_{ij}$) and the liquid assets to customer and short-term deposits ratio ($LAODEP_{ij}$) for each bank. The country specific indicators are: the interest rate spreads over 3-year government bonds in the respective country ($INSBOC_j$), non-financial firm solvency measured as current assets to current liabilities ($SOLVENCY_j$), a measure of banking system liquidity given by the liquid assets to total assets ratio ($LAOAC_j$), country specific cost-to-income ratios (COIRCj), operating expenses to total assets ($OEPOAC_j$) and overall banking system risk measured as the loan-loss provisions to total loans ($LLPOAC_{ij}$). Yearly dummy variables are included to control for time effects (D1992 to D1999) and the CONS is the constant (acting as a dummy variable for the year 2000).

Variables	All banks	Commercial banks	Savings banks	Cooperative banks	Most efficient banks[1]	Least efficient banks[2]
ETAij	0.176*	0.035*	0.079*	−0.356*	−0.094*	0.269*
	(0.0076)	(0.0131)	(0.0145)	(0.0165)	(0.0024)	(0.0173)
LLRLij	0.022	−0.102*	−0.309*	−0.102*	−0.107*	0.197*
	(0.0119)	(0.0204)	(0.0189)	(0.0160)	(0.0036)	(0.0268)
NLTAij	−0.023*	−0.008	−0.013*	−0.023*	0	−0.028*
	(0.0026)	(0.0050)	(0.0027)	(0.0031)	(0.0013)	(0.0053)
LNTAij	0.466*	0.161+	0.12*	0.318*	−0.087*	0.505*
	(0.0291)	(0.0645)	(0.0256)	(0.0302)	(0.0111)	(0.0775)
LAODEPij	−0.012*	−0.001	−0.023*	−0.026*	0.003*	0.002
	(0.0020)	(0.0034)	(0.0019)	(0.0029)	(0.0007)	(0.0044)
INSBOCj	0.436*	0.311*	0.538*	0.494*	0.328*	−0.028
	(0.0473)	(0.1052)	(0.0411)	(0.0480)	(0.0193)	(0.1380)
SOLVENCYj	−0.004	−0.001	0.003	0.021*	0.008*	−0.018+
	(0.0030)	(0.0056)	(0.0027)	(0.0055)	(0.0011)	(0.0071)
LAOACj	0.233*	0.143*	0.113*	0.206*	0	0.116*
	(0.0075)	(0.0156)	(0.0074)	(0.0138)	(0.0031)	(0.0196)
COIRCj	−0.076*	−0.04+	−0.04*	−0.04+	−0.004	−0.066*
	(0.0095)	(0.0186)	(0.0096)	(0.0160)	(0.0040)	(0.0232)
OEPOACj	1.726*	0.253	−0.454+	5.181*	−0.25*	1.805*
	(0.2213)	(0.4197)	(0.1989)	(0.5467)	(0.0810)	(0.5730)
LLPOACj	−1.508*	−1.276*	−0.011	0.156	0.048	−1.656*
	(0.1317)	(0.2510)	(0.1088)	(0.2277)	(0.0487)	(0.3639)
D1992	−1.564*	−0.745	−0.657+	−5.362*	−0.467*	0.272
	(0.3937)	(0.7728)	(0.2974)	(0.5331)	(0.1563)	(0.9176)
D1993	−2.105*	−1.156	−0.803*	−5.467*	−0.175	−0.249
	(0.3701)	(0.7385)	(0.2798)	(0.5005)	(0.1438)	(0.8836)
D1994	−1.21*	−0.464	−0.597+	−4.908*	−0.176	1.096
	(0.3702)	(0.7500)	(0.2771)	(0.4810)	(0.1428)	(0.8979)
D1995	−1.401*	−0.727	−0.582+	−4.592*	−0.18	0.665
	(0.3653)	(0.7368)	(0.2732)	(0.4643)	(0.1417)	(0.8761)
D1996	−1.471*	−0.619	−0.56+	−4.018*	−0.091	0.925
	(0.3588)	(0.7206)	(0.2646)	(0.4495)	(0.1385)	(0.8628)

Table 3
Continued

Variables	All banks	Commercial banks	Savings banks	Cooperative banks	Most efficient banks[1]	Least efficient banks[2]
D1997	−1.374*	−0.448	−0.401	−3.669*	−0.065	0.547
	(0.3555)	(0.7069)	(0.2617)	(0.4473)	(0.1372)	(0.8429)
D1998	−1.521*	−0.02	−0.507+	−3.566*	−0.096	0.251
	(0.3487)	(0.6991)	(0.2570)	(0.4379)	(0.1340)	(0.8292)
D1999	−1.008*	0.017	−0.004	−3.122*	−0.072	0.824
	(0.3559)	(0.7101)	(0.2623)	(0.4452)	(0.1359)	(0.8489)
CONS	16.499*	22.392*	18.883*	11.658*	17.114*	23.815*
	(0.8079)	(1.5508)	(0.7966)	(1.5612)	(0.3064)	(1.9492)
Observations	20,333	7,108	5,810	7,415	5093	5078
R sq	0.1275	0.0419	0.1310	0.2280	0.1939	0.0403

Notes: + significant at 5%; * significant at 1%
1. top quartile of cost efficient banks are used as the sample.
2. bottom quartile of cost efficient banks are used as the sample.

profitability positively influencing capital levels and cost efficiency being inversely related to capital.[18] However, there are mixed findings if one considers country indicators of loan loss provisioning ($LLPOAC_j$) and operating expenses ($OEPOAC_j$). In the case of the former, Table 2 shows that the level of loan-loss provisioning within a country has a negative influence on commercial bank and efficient banks' capital levels whereas for savings and cooperative banks there is a positive relationship. Of course, provisioning levels within banking systems may be dominated by commercial banks and this could explain this result but as we do not have sufficient bank-specific provisioning data it is difficult to know whether this is actually the case. Overall, country provisioning levels do not seem to matter as the full sample results do not suggest any statistically significant relationship. Higher levels of banking system operating expenses ($OEPOAC_j$) seem to positively relate to capital levels (again suggestive of inefficient systems having to hold more capital). However, relationships do differ across different bank ownership types.

Table 3 reports the results for our cost inefficiency equation obtained from various systems estimates. The results broadly confirm the findings reported earlier. For instance, in the majority of estimates bank inefficiency and capital are positively related. Inefficient banks hold higher levels of capital. The exceptions being for the most cost efficient banks and co-operative banks. This suggests that for the most efficient European banks when their efficiency falls they will hold less capital, in contrast, for the least efficient banks the same scenario is likely to encourage them to hold more capital. Risk (the level of loan loss reserves $LLRL_{ij}$) is found to be inversely related to inefficiency (so efficient banks take on more risk) and in most cases cost inefficiency is positively related to asset size (apart for the quartile of most cost efficient banks). Net bank lending appears to be inversely related to inefficiency suggesting that efficient banks are more successful in expanding their loans business. Evidence on the relationship between bank

[18] Note a positive sign on the country cost income ratio ($COIRC_j$) means that in banking systems with higher cost income ratios (ie less efficient banking systems) capital levels are higher.

Table 4

Changes in risk, capital and inefficiency

Estimates from the three equation system obtained from the SUR simultaneous estimations using changes in banking risk as measured by yearly change in the loan-loss reserves to total assets ratio ($DLLR_{ij}$), yearly changes in bank capital measured by the equity-to-assets ratio ($DETA_{ij}$) and annual changes in bank cost inefficiency ($DINEFF_{ij}$) derived from stochastic cost frontier estimates. The columns report the results obtained for the full sample of European banks for the three equation system. In addition to the dependent variables that are included as explanatory variables we also include other bank-specific indicators (denoted by subscripts ij) and country-specific variables (subscript j). The bank-specific indicators include: the net loans to total assets ratio ($NLTA_{ij}$), an indicator of the size of each bank measured by the natural log of total assets ($LNTA_{ij}$), return-on-assets as an indicator of bank profitability (ROA_{ij}) and the liquid assets to customer and short-term deposits ratio ($LAODEP_{ij}$) for each bank. The country specific indicators are: the interest rate spreads over 3-year government bonds in the respective country ($INSBOC_j$), non-financial firm solvency measured as current assets to current liabilities ($SOLVENCY_j$), a measure of banking system liquidity given by the liquid assets to total assets ratio ($LAOAC_j$),), the banking systems return-on-capital ($ROCC_j$), country specific cost-to-income ratios (COIRCj), operating expenses to total assets ($OEPOAC_j$) and overall banking system risk measured as the loan-loss provisions to total loans ($LLPOAC_{ij}$). Yearly dummy variables are included to control for time effects (D1992 to D1999) and the CONS is the constant (acting as a dummy variable for the year 2000).

Variables	Change in risk ($DLLR_{ij}$)	Change in capital ($DETA_{ij}$)	Change in inefficiency ($DINEFF_{ij}$)
DETAij	0.573*		0.064*
	(0.0063)		(0.0082)
DINEFFij	−0.094	0.047*	
	(0.0058)	(0.0069)	
DLLRLij			−0.159*
			(0.010)
NLTAij	0.002	−0.000	0.001
	(0.0011)	(0.0012)	(0.0014)
LNTAij	−0.042*	−0.056*	0.192
	(0.0116)	(0.0137)	(0.0151)
ROAij		0.416*	
		(0.0166)	
LAODEPij	0.004*	0.008*	−0.004*
	(0.0008)	(0.0009)	(0.0010)
INSBOCj	−0.048+	−0.029	0.094*
	(0.0201)	(0.0264)	(0.0274)
SOLVENCYj	−0.006*	0.001	0.005*
	(0.0013)	(0.0016)	(0.0018)
LAOACj	0.004	0.002	0.010*
	(0.0020)	(0.0042)	(0.0043)
ROCCj		0.092	
		(0.2741)	
ROCCj		0.092	
		(0.2741)	
COIRCj		0.027	−0.006
		(0.0107)	(0.0053)
OEPOACj		−0.385	0.084
		(0.1873)	(0.1294)

Table 4
Continued.

Variables	Change in risk ($DLLR_{ij}$)	Change in capital ($DETA_{ij}$)	Change in inefficiency ($DINEFF_{ij}$)
LLPOACj	0.306*	0.096	−0.361*
	(0.0618)	(0.0813)	(0.0862)
D1993	0.021	−0.140	−1.269*
	(0.1510)	(0.1810)	(0.1995)
D1994	−0.821	−0.261	−0.914*
	(0.1463)	(0.1736)	(0.1914)
D1995	−0.137	−0.287	−0.652*
	(0.1412)	(0.1684)	(0.1861)
D1996	−0.068	−0.299	−0.952*
	(0.1378)	(0.1644)	(0.1816)
D1997	−0.095	−0.365+	−0.828*
	(0.1366)	(0.1631)	(0.1801)
D1998	−0.124	−0.127	−0.692*
	(0.1352)	(0.1596)	(0.1761)
D1999	−0.199	−0.256	−0.898*
	(0.1352)	(0.1631)	(0.180)
CONS	0.646*	−0.881	0.625
	(0.2462)	(0.7993)	(0.469)
Observations	17,356	17,356	17,356
R sq	0.0142	0.0433	0.0098

Notes: + significant at 5%; * significant at 1%

liquidity and inefficiency is mixed. Viewing the country-specific indicators, overall it seems that banking system liquidity is positively linked to inefficiency, whereas system cost-income ratios appear to be inversely related to bank-specific cost inefficiency. The latter (counterintuitive) finding suggests that in countries with high cost to income ratios bank inefficiency will be lower. This can partially be explained by the fact that our cost inefficiency measure links costs to outputs without saying anything about income. (It could be that the risk-taking and capital allocation propensity of banks impact on income and outputs differently and this is why we get these results). Nevertheless, the main findings from Table 3 – that bank inefficiency and capital are positively related – broadly confirm the earlier reported findings.

So far the analysis examining the relationship between capital, risk and inefficiency has focused on levels rather than changes. In other words we have been examining whether the level of (say) risk is related to the level of efficiency or capital. It may, of course, may be more appropriate to look at changes, especially as some of the literature (e.g., Shrieves and Dahl, 1992) focus more on capital augmentation and risk changes. So as to corroborate our previous analysis we re-estimated the system of equations for the full sample using annual changes in risk ($DLLRL_{ij}$), capital ($DETA_{ij}$) and cost inefficiency ($DINEFF_{ij}$) and the results are reported in Table 4. For our full sample of European banks, changes in risk and capital, as well as changes in capital and inefficiency are positively related. Banks that are more risky and inefficient see to hold more capital. Changes in risk and inefficiency are negatively related suggesting that more efficient banks take on greater risk.

5. Conclusion

This paper analyses the relationship between capital, risk and efficiency for a large sample of European banks between 1992 and 2000. Inefficient European banks appear to hold more capital and take on less risk. Empirical evidence is found showing the positive relationship between risk on the level of capital (and liquidity), possibly indicating regulators' preference for capital as a means of restricting risk-taking activities. We also find evidence that the financial strength of the corporate sector has a positive influence in reducing bank risk-taking and capital levels. There are no major differences in the relationships between capital, risk and efficiency for commercial and savings banks although there are for co-operative banks. In the case of co-operative banks we do find that capital levels are inversely related to risks and we find that inefficient banks hold lower levels of capital. Some of these relationships also vary depending on whether banks are among the most or least efficient operators.

Unlike the previous literature that focuses on US banking, we do not find any strong relationship between inefficiency and bank risk-taking. This finding may be a consequence of the different methodologies adopted and time periods covered. For instance, Kwan and Eisenbeis (1997) examined capital, risk and efficiency relationships using a relatively small sample (174) of large US bank holding companies between 1986 and 1991. (The input and output specification of their stochastic cost frontier as well as the definition of risk and capital variables – while similar are not exactly the same.)[19] The work by Hughes and Moon (1995) focuses more on scale economies and risk factors rather than on cost efficiency and also studies banks in an earlier period. While methodological and data issues may explain the broadly different results for US and European banks, other factors may be important. It could be that US banks face greater shareholder maximisation pressure from their owners and this could force inefficient banks to take on more risk. The contrasting regulatory environments – especially the higher levels of deposit insurance in US banking in the 1980s compared to Europe – could explain differences in our findings. One needs to be cautious, however, in comparing the findings of US and European studies that examine capital, risk and efficiency issues as this literature is still in its infancy. Further areas of study should seek to investigate the consistency of our European bank findings applied to a more representative and contemporary sample of US banks. The approach could also be expanded to examine the consistency of findings by using alternative accounting and market-based indicators of banking risk, Basel capital strength factors and alternative bank cost and profit efficiency measures.

References

Aggarwal, R. and Jacques, K. T., 'Assessing the impact of prompt corrective action on bank capital and risk', *Federal Reserve Bank of New York Policy Review*, Vol. 4(3), 1998, pp. 23–31.

Akella, S. R. and Greenbaum, S. I., 'Savings and loan ownership structure and expense preference', *Journal of Banking and Finance*, Vol. 12 (3), 1988, pp. 419–37.

Altunbas, Y. Carbo, S. and Gardener, E. P. M., 'CAR 2: the impact of CAR on bank capital augmentation in Spain', *Applied Financial Economics*, Vol. 10 (5), 2000, pp. 507–18.

Altunbas, Y. and Chakravarty, S., 'Frontier cost functions and bank efficiency', *Economics Letters*, Vol. 72 (2), 2001, pp. 233–40.

[19] For instance they use a Translog stochastic cost frontier using a five output and three input specification, including contingent liabilities as one of the outputs.

Altunbas, Y., Evans, L. and Molyneux, P., 'Ownership and efficiency in banking', *Journal of Money, Credit and Banking*, Vol. 33 (4), 2001, pp. 926–54.

Baumann, U. and Nier, E., 'Market discipline and financial stability: some empirical evidence', *Bank of England Financial Stability Review*, Vol. 14 (June), 2003, pp. 134–41.

Barrios, V. and Blanco, J. M., 'The effectiveness of bank capital adequacy regulation: a theoretical and empirical approach', *Journal of Banking and Finance*, Vol. 27 (10), 2003, pp. 1935–58.

Beitel, P., Schiereck, D. and Wahrenburg, M., 'Explaining M&A success in European banks', *European Financial Management*, Vol. 10 (1), 2004, pp. 109–39.

Benink, H. and Wihlborg, C., (2002), The new Basel capital accord: making it effective with stronger market discipline', *European Financial Management*, Vol. 8(1), 2002, pp. 103–15.

Berenguer, M. I., Carbo, S. and Fortes, M. A., 'Can mutual banks outperform commercial banks in the loan market?' *Revista de Economia Financiera*, Vol. 1 (1), 2003, pp. 62–79.

Berger, A. N., 'The relationship between capital and earnings in banking', *Journal of Money, Credit, and Banking,* Vol. 27 (2), 1995, pp. 432–56.

Berger, A. N. and De Young, R., 'Problem loans and cost efficiency in commercial banking', *Journal of Banking and Finance,* Vol. 21 (6), 1997, pp. 849–70.

Berger, A. N., Herring, R. J. and Szego, P. G., 'The role of capital in financial institutions', *Journal of Banking and Finance*, Vol. 19 (3 and 4), 1995, pp. 393–430.

Boot, A. W. A., Dezelan, S. and Milbourn, T. T., 'Regulatory distortions in a competitive financial services industry', *Journal of Financial Services Research*, Vol. 16 (2 and 3), 1999, pp. 249–59.

Borio, C., 'Towards a macroprudential framework for financial supervision and regulation?' *BIS Working Papers*, No. 128, February, (Basel: Bank for International Settlements, 2003)

Calomiris, C. W. and Kahn, C. M., 'The role of demandable debt in structuring optimal banking arrangements', *American Economic Review*, Vol. 81 (3), 1991, pp. 497–513.

Cebenoyan, A. S., Cooperman, E. S., Register, C. A. and Hudgkins, S., 'The relative efficiency of stock versus mutual S & Ls: a stochastic frontier approach', *Journal of Financial Services Research,* Vol. 7 (2), 1993, pp. 151–70.

Danthine, J. P., Giavazzi, F., Vives, X. and Thaden, E. V., *The Future of European Banking*, Centre for Economic Policy Research, Monitoring European Integration Paper No 9, (London: CEPR, 1999).

Editz, T., Michael, I. and Perraudin, W., 'The impact of capital requirements on U.K. bank behaviour', *Reserve Bank of New York Policy Review*, Vol. 4 (3), 1998, pp. 15–22.

European Commission, *The Monitoring of Structural Changes and Trends in the Internal Market for Financial Services*, EC Study Contract ETD/2001/B5–3001/A/63, unpublished, 2002 (Brussels: EC.)

Fama, E., 'Agency problems and the theory of the firm', *Journal of Political Economy*', Vol. 88 (2), 1980, pp. 288–307.

Fama, E. and Jensen, M. C., 'Separation of ownership and control', *Journal of Law and Economics*, Vol. 26 (2), 1983, pp. 301–25.

Flannery, M. J., 'Using market information in prudential bank supervision: A review of the U.S. empirical evidence', *Journal of Money, Credit, and Banking,* Vol. 30 (3), 1998, pp. 273–305.

Flannery, M. J., 'The faces of "market discipline"', *Journal of Financial Services Research*, Vol. 20 (2–3), 2001, pp. 107–19.

Freixas, X. and Rochet, J., *Microeconomics of Banking* (Cambridge: MIT Press, 1997).

Freixas, X. and Gabillon, E., 'Optimal regulation of a fully insured deposit banking system', *Journal of Regulatory Economics*, Vol. 16 (2), 1999, pp. 111–34.

Goddard, J., Molyneux, P. and Wilson, J., *European Banking – Efficiency, Technology and Growth* (London: Wiley, 2001)

Gorton, G. and Rosen, R., 'Corporate control, portfolio choice and the decline of banking', *Journal of Finance,* Vol. 50 (5), 1995, pp. 1377–1420.

Gorton, G. and Huang, L., *Liquidity, Efficiency and Bank Bailouts*, NBER Working Paper No. w9158 (Washington DC: National Bureau of Economic Research, September, 2002).

Gropp, R., Vesala, J. and Vulpes, G., 'Market indicators, bank fragility, and indirect market discipline', *Federal Reserve Bank of New York Economic Policy Review*, Vol. 10 (2), 2004, pp. 53–62.

Hellmann, T. F., Murdock, K. C. and Stiglitz, J. E., 'Liberalization, moral hazard, in banking and prudential regulation: are capital requirements enough?' *American Economic Review*, Vol. 90 (1), 2000, pp. 147–65.

Hughes, J. P. and Mester, L., 'Bank capitalization and cost: evidence of scale economies in risk management and signalling, *Review of Economics and Statistics*, Vol. 80 (2), 1998, pp. 314–25.

Hughes, J. P., Mester, L. and Moon, C., 'Are scale economies in banking elusive or illusive. Evidence obtained by incorporating capital structure and risk-taking into models of bank production', *Journal of Banking and Finance*, Vol. 25 (12), 2001, pp. 2169–2208.

Hughes, J. P. and Moon, C., Measuring bank efficiency when managers trade return for reduced risk, *Department of Economics Rutgers University Working Paper*, No. 1995-20, 1995.

Jackson, P., *Capital Requirements and Bank Behaviour: The Impact of the Basle Accord*, Basle Committee on Banking Supervision, *Working Papers*, No. 1, April (Basel: Bank for International Settlements, 1999).

Jacques, K. and Nigro, P., 'Risk-based capital, portfolio risk, and bank capital: a simultaneous equations approach', *Journal of Economics and Business,* Vol. 49 (6), 1997, pp. 533–47.

Jensen, M. C., 'Agency costs of free cash flow, corporate finance and takeovers', *American Economic Review*, Vol. 76 (2), 1986, pp. 323–29.

Jensen, M. C. and Meckling, W. H., 'Theory of the firm: managerial behavior, agency costs and ownership structure', *Journal of Financial Economics*, Vol. 3 (October), 1976, pp. 305–60.

Kahane, Y., 'Capital adequacy and the regulation of financial intermediaries', *Journal of Banking and Finance*, Vol. 1 (2), 1977, pp. 207–18.

Kim, D. and Santomero, A. M., 'Risk in banking and capital regulation', *Journal of Finance*, 43 (5), 1988, pp. 1219–33.

Koehn, M. and Santomero, A., 'Regulation of bank capital and portfolio risk', *Journal of Finance*, Vol. 35 (5), 1980, pp. 1235–45.

Krinsky, I. and Thomas, H.,'Savings and loan ownership structure and expense-preference', *Journal of Banking and Finance*, Vol. 19 (1), 1995, pp. 165–70.

Kwan, S. and Eisenbeis, R., 'Bank risk, capitalization and operating efficiency', *Journal of Financial Services Research*, Vol. 12 (2 and 3), 1997, pp. 117–31.

Lindgren, C. J., Garcia, G. and Saal, M. I., *Bank Soundness and Macroeconomic Policy* (IMF: Washington DC, 1998).

Marcus, A. J., 'The bank capital decision: a time series-cross section analysis', *Journal of Finance*, Vol. 38 (4), 1983, pp. 1216–32.

Mayne, L. S., 'Supervisory influence on bank capital', *Journal of Finance*, Vol. 27 (3), 1972, pp. 637–51.

Mester, L. J., 'Testing for expense preference behaviour: mutual versus stock savings and loans', *The Rand Journal of Economics,* Vol. 20 (4), 1989 pp. 483–98.

Mester, L. J., 'Efficiency in the savings and loan industry', *Journal of Banking and Finance*, Vol. 17 (2 and 3), 1993, pp. 267–86.

Nicols, A., 'Property rights and behaviour: stock versus mutual savings and loan associations. Some evidence of differences in behaviour', *American Economic Review,* Vol. 57 (4), 1967, pp. 337–46.

O'Hara, M., 'Property rights and the financial firm', *Journal of Law and Economics,* Vol. 24 (2), 1981, pp. 313–33.

Peltzman, S., 'Capital investment in commercial banking and its relationship to portfolio regulation', *Journal of Political Economy*, Vol. 78 (1), 1970, pp. 1–26.

Peltzman, S., 'Bank market structure and competition. A survey – a comment', *Journal of Money, Credit and Banking*, Vol. 16 (4, Part 2), 1984, pp. 650–56.

Purroy, P. and Salas, V., 'Strategic competition in retail banking under expense preference behaviour', *Journal of Banking and Finance*, Vol. 24 (5), 2000, pp. 809–24.

Rime, B., 'Capital requirements and bank behaviour: empirical evidence for Switzerland', *Journal of Banking and Finance*, Vol. 25 (4), 2001a, pp. 789–805.

Rime, B.,An alternative view on regulatory distortions in a competitive financial services industry', *Journal of Financial Services Research*, Vol. 19 (1), 2001b, pp. 27–38.
Santos, J. A. C., 'Bank capital regulation: a review of the theoretical literature', *BIS Working Papers*, No. 90 (Basel: Bank for International Settlements, September, 1999).
Saunders, A., Strock, E. and Travlos, N., 'Ownership structure, de-regulation and bank risk taking', *Journal of Finance*, Vol. 15 (2), 1990, pp. 643–54.
Scholtens, B., 'Competition, growth and performance in the banking industry', *Working Paper* 2000-18 (Wharton Financial Institutions Center, February, 2000).
Shrieves, R. E. and Dahl, D., 'The impact of regulation on bank equity infusions', *Journal of Banking and Finance*, Vol. 14 (6), 1990, pp. 1209–28.
Shrieves, R. E. and Dahl, D., 'The relationship between risk and capital in commercial banks', *Journal of Banking and Finance*, Vol. 16 (2), 1992, pp. 439–57.
Sironi, A., 'Testing for market discipline in the European banking industry: evidence from subordinated debt issues', *Journal of Money, Credit, and Banking*, Vol. 35 (3), 2003, pp. 443–72.
Stiroh, K. J., 'How did bank holding companies prosper in the 1990s?' *Journal of Banking and Finance*, Vol. 24 (11), 2000, pp. 1703–45.
Wall, L. D. and Peterson, D. R., 'Capital changes at large affiliated banks', *Journal of Financial Services Research*, Vol. 1 (2), 1988, pp. 253–75.
Vives, X., 'Lessons from European banking liberalization and integration', in Claessens, S. and Jansen, M., eds, *The Internationalization of Financial Services: Issues and Lessons for Developing Countries* (Kluwer Law International: The Hague, 2000).
Zellner, A., 'An efficient method of estimating seemingly unrelated regression and tests for aggregation bias', *Journal of the American Statistical Association*, Vol. 57 (298), 1962, pp. 348–68.

Appendix

Table A1

Number of banks in sample

Bank data were obtained from the Bankscope database that includes balance sheet and income statement information on European (and other) banks. We use data on banks operating in 15 European countries between 1992 and 2000. The table shows the number of banks for each country between 1992 and 2000.

	Year								
Countries	1992	1993	1994	1995	1996	1997	1998	1999	2000
Austria	21	27	44	62	64	112	109	103	7
Belgium	29	47	56	59	59	55	45	39	4
Denmark	7	58	69	81	83	82	82	78	60
Finland	1	6	6	6	6	6	5	5	4
France	281	368	395	410	409	390	373	335	49
Germany	445	1,176	1,478	1,551	1,548	1,538	1,493	1,356	47
Greece	5	7	10	10	10	10	10	9	1
Ireland	4	9	11	13	13	12	12	10	3
Italy	103	207	224	271	303	296	285	272	35
Luxembourg	69	96	100	100	100	96	90	87	8
Netherlands	28	36	39	43	43	39	36	32	3
Portugal	29	33	36	39	39	39	36	30	5
Spain	16	84	90	97	114	114	112	105	94
Sweden	3	7	8	8	8	7	8	8	4
UK	60	90	93	95	98	97	91	79	28

Table A2

Number of banks by ownership type

This table uses shows the ownership breakdown of our bank sector across 15 European countries between 1992 and 2000. The table shows the number of commercial banks, co-operative banks and savings banks.

Countries	Commercial banks	Co-operative banks	Savings banks
Austria	217	79	253
Belgium	273	29	91
Denmark	361	10	229
Finland	38		7
France	1,704	980	326
Germany	1,267	5,293	4,072
Greece	72		
Ireland	87		
Italy	548	986	462
Luxembourg	725	14	7
Netherlands	275		24
Portugal	270		16
Spain	508	24	294
Sweden	47		14
UK	716		15