Brunel University London
Department of
Economics and Finance

Economics and Finance Working Paper Series

Working Paper No. 19-02

E Philip Davis, Dilruba Karim and Dennison Noel

Bank Leverage Ratios, Risk And Competition – An Investigation Using Individual Bank Data

January 2019

http://www.brunel.ac.uk/economics

31st January 2018

BANK LEVERAGE RATIOS, RISK AND COMPETITION – AN INVESTIGATION USING INDIVIDUAL BANK DATA

E Philip Davis, Dilruba Karim and Dennison Noel[1]
Brunel University and NIESR
London

Brunel Economics and Finance Working Paper No. 19-02

Abstract: Following experience in the global financial crisis (GFC), when banks with low leverage ratios were often in severe difficulty, despite high-risk-adjusted capital measures, a leverage ratio was introduced in Basel III to complement the risk-adjusted capital ratio (RAR). Empirical testing of the leverage ratio, individually and relative to regulatory capital is, however, sparse. More generally, the capital/risk/competition nexus has been neglected by regulators and researchers. In this paper, we undertake empirical research that sheds light on leverage as a regulatory tool controlling for competition. We assess the effectiveness of a leverage ratio relative to the risk-adjusted capital ratio (RAR) in predicting bank risk given competition for up to 8216 banks in the EU and 1270 in the US, using the Fitch-Connect database of banks' financial statements. The results cast light inter alia on the relevance of the "skin in the game hypothesis" versus the "regulatory hypothesis" in explaining the relation of capital to risk separately for the US and Europe, as well as indicating the importance of allowing for banking competition as an indicator for macro- and microprudential policies.

Keywords: Macroprudential policy, capital adequacy, leverage ratio, bank competition, bank risks, panel estimation, quantile regressions.
JEL Classification: E58, G28

[1] E Philip Davis, Professor of Banking and Finance, Brunel University, Uxbridge, Middlesex, UB8 3PH, UK, and Fellow, NIESR, 2 Dean Trench Street, Smith Square, London SW1P 3HE, emails philip.davis@brunel.ac.uk and e_philip_davis@msn.com, Dilruba Karim, Senior Lecturer, Brunel University email dilruba.karim@brunel.ac.uk, Dennison Noel, Brunel University, email dennison.noel@brunel.ac.uk. We thank Corrado Macchiarelli, Michael Straughan and those present at an internal seminar at Brunel University, participants at the Brunel conference on "Bank regulation, competition and risk" on July 11th 2018 and participants in a seminar at the Bank of England for helpful comments. This paper is part of a project supported financially by the Bank of England entitled "Bank leverage ratios, competition and risk. Does Basel III go far enough?" under Research Grant number RDC201614

1 Introduction

Leverage of banks – as measured by the simple capital to assets ratio – was widely ignored prior to the financial crisis. Whereas leverage ratios were often very low (i.e. leverage itself was high), banks appeared to have sound capital adequacy according to risk-adjusted capital ratios (RAR). The predictive power of low leverage ratios was shown during the crisis, when banks with low leverage ratios were often in severe difficulty despite high-risk-adjusted capital measures. This pattern related, for example, to the excessively optimistic ratings given to structured products, and also to excessive optimism built into credit risk models, that were allowed to determine capital adequacy under the IRB/Basel II system of risk weights.

As a response, Basel III introduced a leverage ratio of 3% to complement the risk-adjusted capital ratio (RAR) (Basel Committee 2014, revisions proposed 2016). Among suggested benefits, it can prevent excessive leverage building up both for individual institutions and for the system as a whole (D'Hulster 2009). It can be argued that it acts against procyclicality and against regulatory arbitrage and model risk that was prevalent prior to the crisis and has the benefit of simplicity. However it also has limitations – it may have difficulty capturing "embedded leverage"[2] and may give wrong incentives, encouraging banks to take risks, given the lack of risk weighting (Kellermann and Schlag 2013). Questions arise whether and when it should be a binding constraint on bank lending as opposed to RAR, or whether it could lead to a "race to the bottom" if it is set lower than average bank ratios. A more general point is that the capital/risk/competition nexus has been neglected by regulators. Competition may give a signal for higher risk that regulators should not neglect in their capital regulation.

In this context, we undertake empirical research that sheds light on leverage as a regulatory tool, while allowing for competition. We assess the effectiveness of a leverage ratio (which is distinct from that of Basel III as it includes all equity capital in the numerator and on-balance-sheet assets in the denominator) relative to two measures of the RAR (total regulatory capital ratio and Tier 1 regulatory capital ratio) in predicting bank risk, given competition. This is undertaken across a large sample of EU and US banks over the period 1998-2016, drawn from the Fitch-Connect database of banks' financial statements. The comparison is of particular interest given US banks have long been subject to a leverage ratio constraint, as well as risk-adjusted measures and related "prompt corrective action" (Stackhouse 2008), whereas for Europe, leverage only came to the fore as a regulatory tool from roughly 2010 onwards. The results cast light, inter alia, on the relevance of the "skin in the game" view versus the "regulatory hypothesis", as explained further below, in interpreting the estimated relation of capital to risk.

The paper is structured as follows: in Section 2 we provide an overview of the existing literature, Section 3 introduces the data and methodology, Section 4 provides the main estimation results. Section 5 shows robustness checks, Section 6 provides complementary Quantile estimates and Section 7 concludes.

A separate paper looks at issues raised for financial stability analysis within the competition/risk/capital nexus using global macroeconomic data (Davis et al 2019).

2 Existing literature

[2] This term relates to the use of options contracts or exchange-traded funds where leverage is built into the product thus altering leverage without having to increase borrowing and actual balance sheet leverage. See paper by Frazzini and Pederson (2012). Note however that Basel Committee (2014) states that for regulatory reporting purposes in measuring bank leverage, "in order to adequately capture embedded leverage, the framework incorporates both on- and off-balance sheet exposures".

Whereas the interest of economists in bank leverage ratios dates back at least to Minsky (1982) and also theoretical work such as Holmstrom and Tirole (1997) and Diamond and Rajan (2000), these contributions did not focus on incorporating leverage into regulation. However, the role of leverage and the fact that risk-adjusted capital was often misleading prior to the subprime crisis has been widely acknowledged. This related, for example, to the excessively optimistic ratings given to certain securitisation products (Barrell and Davis 2008). Indeed, Dermine (2015) contends leverage ratios are helpful in preventing bank runs when there is imperfect information on the value of a bank's assets, as it gives a floor under the RAR that may itself be distorted by arbitrage and incentives to underplay risk. On the other hand, theoretical and empirical work on leverage ratios as a regulatory instrument in the Basel context is quite recent and sparse.

Recent theoretical work has nonetheless highlighted the appropriate level and variability of leverage. For example Kiema and Jokivuolle (2014), suggest regulation of the leverage ratio would induce banks to hold similar diversified portfolios which may accordingly be vulnerable to common shocks. The convergence of portfolios occurs because banks with low-risk portfolios may require more capital based on leverage than on a risk-adjusted approach. Accordingly, banks with such low-risk lending strategies will seek to diversify into high-risk loans till the leverage ratio is no longer a constraint. This may in turn further increase the overall balance of risk in the banking sector, because of the greater effect of model risk on each loan category. Accordingly, they suggest the actual leverage ratio should be higher than current proposals. Barth et al (2018) add an alternative mechanism, namely that when a leverage ratio constraint binds, and capital is costly, then banks skilled in credit assessment may be unable to absorb the supply of deposits; instead, there will be new entry of less capable banks. They suggest this would not occur with a risk-weighted approach.

Grill et al (2015), using a theoretical micro model backed by empirical work, show a leverage ratio requirement incentivises banks bound by the constraint to slightly increase risk-taking, but this is more than outweighed by the increase in loss-absorbing capacity from higher capital, thus increasing bank stability. Bruno et al (2014) propose a theoretical model in which an optimal level of leverage exists which minimises financial fragility and which varies with the business cycle, (consistent with empirical observation by Adrian and Shin (2010)), leading them to recommend an adjustable leverage ratio over the cycle.

In a similar vein, Pfeifer et al (2015) show the constraining effect of the leverage ratio on exposures is diminished unless it rises in line with the RAR when the latter is increased for macroprudential purposes. As a measure of policy, they employ the critical average risk weight (CARW), dividing the total leverage ratio by the regulatory risk-adjusted capital ratio. The CARW is the average risk weight at which the bank is equally constrained by the two capital regulation tools, or at which the bank must maintain the same capital requirement to comply with both tools. They argue that a variable leverage ratio could have a positive effect on macroprudential policy effectiveness in terms of mitigating cyclical and structural risks, especially if systemic risk arises at a time when risk weights are below the CARW for a large number of institutions with large market shares. To set the macroprudential leverage ratio, it may be appropriate to apply a fixed rule that keeps the CARW constant, although this might lead to the issue identified by Kiema and Jokivuolle (2014), that regulation of the leverage ratio should induce banks to hold similar diversified portfolios which would then be more vulnerable to common shocks.

Turning to empirical work using macro data, papers on prediction of banking crises such as Barrell et al (2010) indicates the aggregate leverage ratio is a key predictor of banking crises and Karim et al (2013) show the additional importance of off balance sheet (OBS) exposures to financial instability. Ondo-Ndong and Rigot (2011) test for the effectiveness of a global aggregated leverage ratio (including investment banks) and find it a helpful empirical indicator of overall financial stress. Brei and Gambacorta (2014) tested for procyclicality of capital ratios and found the Basel III leverage ratio is significantly more countercyclical than the RAR (as well as Tier 1/total assets); it is a tighter constraint for banks in booms and a looser constraint in recessions. This result is driven by the inclusion of guarantees and other off-balance sheet items (credit lines, acceptances and other off-balance sheet items connected with securitization activity) in the "exposure measure" definition (the denominator of the leverage ratio). Recent work such as Barrell et al (2009) looking at optimal capital show how the dynamics of bank capital buffers can lead to effects on lending and pricing of loans. Such research helps justify inclusion of leverage in the Basel III proposals as well as risk-adjusted capital ratios.

Looking at work on micro data, Yang (2016) tested leverage and risk-weighted capital as predictors in 417 US bank failures between 2008 and 2012 using logit, finding leverage was important for both large and small banks but that risk-adjusted capital was not significant for large banks. This is in line with Haldane and Madouros (2012) who also found the leverage ratio a superior failure predictor to the RAR. Hambusch and Shaffer (2012) sought to forecast bank leverage as an alternative tool for assessing the likelihood of failure, albeit not against the RAR. Results support the use of leverage as an indicator for such likelihood.

Meanwhile, Davis and Karim (2018) and many others show empirically that bank competition has a clear link to risk that has been widely disregarded among policymakers (notably, they found a short term change in competition indicates higher risk taking). Note though that their work also found that competition had a link to lower risk in the longer term with one indicator (the H statistic). The wider literature on competition and risk is divided between those supporting "competition-fragility" (more competition leads to higher risk) and "competition-stability" which suggests more competition leads to lower risk (see the summaries in Zigraiova and Havranek (2016) and Davis and Karim (2018)).

In this context, Schaeck and Čihák (2012) look at the inverse effect of competition on capital for 2,600 banks from 10 European countries and find higher competition gives rise to higher capital ratios. This may offer an offset to higher risks taken in highly competitive banking systems. On the other hand, de-Ramon et al (2018) find that higher competition in the UK leads to lower leverage ratios although the effect on stability may be offset by higher profitability. Berger et al (2009) found that banks with market power tend to have higher capitalisation, although the relation with the level of the Lerner index is not significant. These are some of the few analyses of capital ratios that take into account competition, which is a paradox give the sizeable literature on bank competition and risk (as summarised in Zigraiova and Havranek (2016) and Davis and Karim (2018)).

There remains quite a sizeable literature on the capital-risk relation. Diverse results of empirical studies of the relation of capital and risk justify differing hypotheses on the relation of capital to risk. According to "skin in the game", it would be expected that a higher capital ratio would be consistent with lower risk, as bank managers become prudent and wiser in their investment choices (Bitar et al 2018). Banks hold higher capital to resist earnings shocks and to be able to repay deposits as requested. Hence, obliging banks to hold more capital via regulation improves screening and monitoring and reduces the risk of bailouts (Demirgüç Kunt et al 2013). In a recent study of Asian banks, Lee and Hseih (2013) did find a negative relation between capital and risk, allowing for the influence of profitability on both, as did Tan and Floros (2013) studying Chinese banks, and Anginer and Demirgüç Kunt (2014) looking at banks in 48 countries, with the risk measure being systemic risk. A corollary of "skin in the game" is that a low capital ratio may give incentives to take risks and "gamble for resurrection" as for the US Savings and Loans in the 1980s (Davis 1995), especially when as in that case there is generous and mispriced deposit insurance. "Skin in the game" may apply strongly to large banks that may consider themselves too big to fail.

As a response, regulators may require banks to hold more capital to reduce moral hazard and ensure capital is commensurate with risks. Hence the “regulatory hypothesis” would suggest that regulators require higher capital in response to higher risk, and so a positive relation of capital to risk would be expected. Blum (1999) suggests further that raising capital may lead to increased risk since capital is seen as costly; it may lead the bank to raise the riskiness of its portfolio. This is, for example, found by Iannotta et al (2007) who detected a significant positive relation of capital to loan loss provisions in European banks over 1999-2004. Bitar et al (2018) found a similar positive relation for leverage ratios to loan loss reserves/assets but not for risk-adjusted measures. Alternatively, such a positive relation could be explained by agency issues in banks with high capital, such that there may be an “outsider equity effect” with managers taking risks or being less active in screening at the expense of shareholders.

Some studies find no relation of capital to risk. For example Cathcart et al (2015) found banks had Tier 1 ratios that were double the regulatory minimum at the onset of the crisis but these had no benefit to risk absorption or systemic risk. Bitar et al (2018) found risk-based capital measures are unrelated to bank risk, whereas unadjusted measures such as the leverage ratio are, as noted, significantly positively related to risk as shown by loan loss reserves/assets, in line with the “regulatory hypothesis”. They suggest that the ineffectiveness of risk-adjusted measures may relate to untruthful assessment of bank real risk exposure. We comment that leverage ratios are intrinsically related to risk, since they show the overall debt/equity ratio of the bank; on the other hand, if risk adjustment is done properly, then risk-adjusted measures will have a weaker relation to risk, depending on whether the authorities choose to enforce higher risk-adjusted ratios for risky banks (or managers choose such higher ratios independently).

Empirical studies of bank capital ratios and the link to risk do not usually take into account the contribution that competition may make to risk. We consider our inclusion of competition as a control variable to be a major contribution that adds to the relevance of our study. In this we follow Freixas and Ma (2015) who look at the relation of bank competition to financial stability with a theoretical model and find the effect depends crucially on a bank’s type of funding (retail versus wholesale) and whether leverage is exogenous or endogenous. They suggest that “this opens the road for new empirical analysis on the competition-stability link that should depend upon the type of banks and the state of the economy”.

3 Data and Methodology

In the light of the above, we now go on to undertake an econometric investigation of the relationship of the leverage ratio to risk given competition relative to two risk-adjusted measures of capital adequacy. This is undertaken with standard control variables from 1998-2016, using micro data for Europe and US from the Fitch-Connect database of bank financial statements.

In our sample, we include universal commercial banks, retail and consumer banks and banks per se, but not investment banks (with a different balance sheet and income structure) or bank holding companies (to avoid double counting). We have up to 1270 banks in the US sample and over 8000 in Europe. This approach is in line with the work of Schaeck and Čihák (2012), who tested commercial banks versus a wider sample in their study of the link of competition to capital adequacy and concluded that ‘constraining the sample to profit maximising institutions, although justified on theoretical grounds, is not necessary for the empirical tests’ (2012: 838).

Four dependent variables of macroprudential relevance are used:

First, the *loan loss provisions/loans ratio* is a measure of loan quality, being an indicator of a precautionary reserves policy and also an anticipation of high non performing revenue (although with the introduction of

IFRS in Europe the latter should have been less evident for European banks over the period since 2005). It takes the past and future performance of the loan portfolio into account (Lee and Hseih 2013).

Second, we use the *non-performing loans (NPL)/loans ratio*. This is often used as a proxy for asset quality and may show problems with asset quality in the loan portfolio across the banking sector as a whole. It is defined as the ratio of defaulting loans (payments of interest and principal past due by 90 days or more) to total gross loans (total value of loan portfolio). The loan amount recorded as nonperforming includes the gross value of the loan as recorded on the balance sheet, not just the amount that is overdue.[3] Note however, that impaired loans are in some senses a lagging indicator of bank risk, as the measure rises when loans actually become delinquent.

Third, we employ the *growth rate of loans* as measured by the log-difference of loans. This measure aims to capture the risk that banks seeking to grow their loan books rapidly will take on poor quality loans in a form of adverse selection, as identified by Stiglitz and Weiss (1981) and others. In contrast to the impaired loan ratio it can be seen as an advance indicator of potential risk.

Finally we use the *bank Z-Score* which captures the distance from insolvency of a bank. Z-score compares the buffer of a bank (capitalization and return on assets (ROA)) with the volatility (standard deviation (SD)) of those returns. Hence Z-Score = (ROA+(Capital/Assets))/SD(ROA)).[4] It captures the number of standard deviations by which returns would have to fall from the mean to wipe out all the equity of the bank (Boyd and Runkle 1993). It has been used extensively in recent studies such as IJtsma et al (2017), Davis and Karim (2018) and de-Ramon et al (2018). As noted by Lui et al (2013) it is appropriate to log the Z-score as the level is highly skewed, while the log is normally distributed. Hence we use log Z-score as the dependent variable. However, a difficulty for the current exercise is that the Z-Score includes leverage (capital/assets) in its measurement so its correlation with leverage may be arithmetic rather than causal. Accordingly, we consider the Z-score to be less relevant than the other measures, but include it for completeness and comparability with other studies. We also lag the capital measure to reduce potential correlation.

Then, we use the lagged leverage ratio (equity/assets), the lagged regulatory capital/risk-adjusted assets and the corresponding lagged Tier 1 ratio measures to test for the link of capital ratios to risk, controlling for competition. We note that the leverage measure used is not that of Basel III owing to the denominator excluding off balance sheet items and the numerator including all equity capital. The regulatory capital, Tier 1 capital and risk adjustment of the other measures is as reported in the financial statements of the banks and not sourced from regulators.

In measuring competition, we use two approaches, the Lerner index of Iwata (Bikker 2004) and as a robustness check, the Panzar-Rosse H statistic (Bikker et al 2012). We note that recent work suggests no significant link from the alternative competition measure, banking sector concentration, to risk as measured by the log Z-score, either at bank or country level (IJtsma et al 2017). This is unsurprising in some ways, since concentrated markets may still be subject to competition from potential competitors (i.e. they may remain “contestable” in the sense of Baumol et al (1982)).

---

[3] What NPL data typically do not record is whether the loans are recoverable and have been collateralized. Hence the impact on banks’ balance sheet may vary. This implies write offs and uncollateralized NPL may be measures to look at as well.

[4] Note that this is quite distinct from the standard statistical definition of Z-Score which indicates how many standard deviations an element is from the mean. We measure ROA using pre-tax profits rather than net income, implying it is the operating ROA we utilise.

The Lerner index is a measure of the price-cost margin; it can be seen as a proxy for current and future profits stemming from pricing power, and it varies at the level of the individual bank. Under perfect competition the index is zero as the output price (marginal revenue) equals marginal cost, and "normal" economic profits are zero. The Lerner index is positive as a firm's market power increase and price rises above marginal cost in a quantity-setting oligopoly model,[5] with the limiting case being monopoly. We derived the Lerner Index for banks in Europe as a whole and the US, following Anginer et al. (2014), Beck et al. (2013) and Weill (2013). To obtain the Lerner index, we first estimate the following translog cost function:

$$\log(C_{it}) = \alpha + \beta_1\log(TA_{it}) + \beta_2(\log(TA_{it}))_2 + \beta_3\log(W_{1,it}) + \beta_4\log(W_{2,it}) + \beta_5\log(W_{3,it})$$

$$+\beta_6\log(TA_{it})\log(W_{1,it}) + \beta_7\log(TA_{it})\log(W_{2,it}) + \beta_8\log(TA_{it})\log(W_{3,it})$$

$$+ \beta_9(\log(W_{1,it}))_2 + \beta_{10}(\log(W_{2,it}))_2 + \beta_{11}(\log(W_{3,it}))_2 + \beta_{12}\log(W_{1,it})\log(W_{2,it})$$

$$+ \beta_{13}\log(W_{1,it})\log(W_{3,it}) + \beta_{14}\log(W_{2,it})\log(W_{3,it}) + \Theta\text{Year Dummies} + \varepsilon_{it} \quad (1)$$

where C_{it} is total costs and TA_{it} is the quantity of output and is measured as total assets. Our input prices are $W_{1,it}$, which is the ratio of interest expenses to the sum of total deposits and money market funding (IES); $W_{2,it}$, is measured as personnel expenses divided by total assets (PTA); and $W_{3,it}$ is the ratio of other operating expenses to fixed assets (OCF). We include time fixed effects, in line with the existing literature. Having estimated this equation, we impose the following restrictions, again in line with earlier authors, to ensure homogeneity of degree one in input prices:

$$\beta_3 + \beta_4 + \beta_5 = 1;\ \beta_6 + \beta_7 + \beta_8 = 0;\ \beta_9 + \beta_{12} + \beta_{13} = 0;\ \beta_{10} + \beta_{12} + \beta_{14} = 0;\ \beta_{11} + \beta_{13} + \beta_{14} = 0 \quad (2)$$

We then use the coefficient estimates from the previous regression to estimate the marginal costs for bank i in calendar year t:

$$MC_{it} = \delta C_{it}/\delta TA_{it} = Cit/TA_{it} * [\beta_1 + 2\beta_2\log(TA_{it}) + \beta_6\log(W_{1,it}) + \beta_7\log(W_{2,it}) + \beta_8\log(W_{3,it})] \ (3)$$

The Lerner index for each bank–year is

$$Lerner_{it} = (P_{it} – MC_{it})/P_{it} \quad (4)$$

where P_{it} is the price of assets and is equal to the ratio of total revenue to total assets.

Our second competition measure is the Panzar-Rosse H Statistic, which has been used extensively in banking studies (such as Schaeck and Čihák (2012) and Davis and Karim (2018)). According to this approach, market power is measured by the extent to which changes in factor prices are reflected in revenues.[6] Accordingly, authors such as Claessens and Laeven (2004) argue it to be a superior measure of the degree of competition because it is derived from profit-maximising equilibrium conditions.

---

[5] As noted by Shaffer and Spierdijk (2015), a positive Lerner applies in a variety of theoretical oligopoly pricing situations.

[6] With perfect competition and when banks operate within their long-run equilibrium and with constant demand elasticity and Cobb Douglas production technology, a proportional increase in factor prices (including the interest rate on liabilities) induces an equiproportional change in gross revenues. The output does not change in volume terms, while the output price rises to the same extent as the input price (i.e. demand is perfectly elastic). On the other hand, under monopolistic competition or where potential entry leads to a contestable market equilibrium, revenues will increase less than proportionally, since the demand for banking products facing individual banks is inelastic (Tirole,

However, we note that recent articles have noted some shortcomings of the measure. In particular, Shaffer and Spierdijk (2015) show that under a variety of conditions, an H Statistic exceeding zero may still be consistent with substantial market power in banking; a value over zero can arise in a variety of oligopoly settings, all consistent with a positive Lerner Index.[7] These are independent of the timing of banks' actions, relative costs, choice of strategic variable, degree of product differentiation, strategy (static or dynamic), and degree of heterogeneity in banks' conduct (collusive versus fringe). Hence, a case of market power with H above zero may be common. Meanwhile, use of H for a diverse national banking market such as the US may be problematic as there are distinct regional patterns to bank activity, inter alia due to historic restrictions on interstate banking. Also, our results for the market equilibrium test[8] are weaker than for European banks over 1998-2012 in Davis and Karim (2013). Following these points, we have used H as a robustness check and suggest that most weight should be given to results with the Lerner Index.

To derive H, we initially estimated revenue functions for each European country and the US. Following Bikker et al. (2012) and in line with Panzar and Rosse (1987), we use an unscaled revenue function.[9] Accordingly, our estimating equation for the H-statistic is as follows:

$$\text{Log}R_{it} = \Sigma J_{(j=1)}\ \alpha_j \text{Log}\ w_{jit} + \Sigma N_{(n=1)} \gamma n \text{Log}\ X_{nit} + \varepsilon_{it} \qquad (5)$$

for bank i at time t, where t = 1,…. ,T, with T the number of periods observed; i = 1,…., I, with I the total number of banks; and R_{it} is unscaled gross interest revenues. In our case, we have J = 3 inputs, so that w_{jit} for each bank is a three-dimensional vector of factor prices (the logarithm of the ratio of interest expense to total debt funding (IED); the logarithm of the ratio of personnel expenses to total assets (PTA); and the logarithm of the ratio of other costs as a proportion of fixed assets (OCF), consistent with the intermediation approach to banking output measurement, where bank liabilities are inputs to produce loans and other earning assets. The term X_{it} is a vector of exogenous and bank-specific variables that may shift the cost and revenue schedule (business mix). In this context, we have N = 4, the logarithm of loans as a proportion of assets (LAR), showing credit risk (with an expected positive sign, since banks compensate for risk); the logarithm of the ratio of other non-earning assets to total assets (OTA), reflecting asset composition; the logarithm of customer deposits as a proportion of deposits plus money market liabilities (CDT), showing liquidity risk (but whose sign is ambiguous); and the logarithm of equity to total assets (LEVERAGE), showing leverage and hence risk preferences (expected to have a negative sign).

We estimate the H-statistic by country and in sub periods, using the within estimator and both bank and year fixed effects in line with the results of De Bandt and Davis (2000). For the current exercise, we then estimate the H-statistic as an annual time series for each individual country. We apply the restriction of at least 12 banks per year.

1988). In the limiting case of a monopoly, there may be no response or even a negative response of gross revenues to changes in input costs.

[7] The scenarios are respectively Stackelberg duopoly with linear costs, homogeneous Cournot duopoly with asymmetric costs and linear demand, differentiated Bertrand duopoly, dynamic open-loop duopoly equilibrium with sticky prices and stable cartel with a Cournot fringe and linear costs and demand.

[8] The test for market equilibrium uses the log of ROA on the left hand side and tests whether the H-ROA sum of elasticities on inputs is zero. This seeks to verify that input prices are not correlated with industry returns.

[9] Bikker et al. (2012) have shown that forms of scaling (e.g. including assets or equity on the right-hand side) or the use of a price and not a revenue variable on the left (e.g. revenue scaled by assets) upward-biases the H-statistic (i.e. imperfect competition is rejected too frequently). After extensive testing using 100,000 observations on 17,000 banks in 63 countries over 1994–2004, the authors found that price and scaled revenue functions cannot identify imperfect competition in the same way unscaled revenue functions can and that 'this conclusion disqualifies a number of studies since they apply a Panzar–Rosse test based on a price function or scaled revenue function' (Bikker et al, 2012: 1016).

We then use these annual competition variables as key control variables in equations relating capital adequacy to indicators of bank and systemic risk, controlling for relevant variables. Our results link capital ratios but also competition each year to the four measures of risk outlined above. We enter the Lerner index and H-Statistic as measures of competition in terms of both levels and differences, to distinguish between levels of competition and change in competition, as in the unique approach of Davis and Karim (2018). The current difference of the Lerner index and H-statistic is complemented by the second and third lags of their levels, thus avoiding any overlap between levels and differences and possible false conclusions. Since the H-statistic is a countrywide variable, we did not consider it to be correlated with bank-level risk and, accordingly, do not instrument the current difference, whereas we do so for the Lerner index as detailed below.

Other control variables (lagged one year to avoid potential issues of endogeneity) were similar to Beck et al (2013), Davis and Karim (2018) and de-Ramon et al (2018), namely:

- NIR (share of noninterest income in the total)[10]; this is often seen as a beneficial form of diversification that enables wider information to be collected on clients reducing asymmetric information, although empirical work often shows it to actually increase risk (such as Demirgüç Kunt and Huizinga (2010), Davis and Karim (2018))
- LAR (ratio of bank loans to assets); is commonly seen to raise risk (as in Davis and Karim (2018)) but others argue that loans could be less risky than derivatives or structured products as an alternative to loans on the balance sheet, as well as in some cases being less costly to monitor (Bitar et al 2018).
- CDT (ratio of customer deposits to total short term funding), where it would be expected that more wholesale funding would entail greater risk (as found by Davis and Karim 2018).
- PII (loan loss provisions to income ratio) which as argued above is an indicator of loan quality and hence likely to be positively related to risk. We omit this control in the estimates of the loan loss provisions to loans ratio below.
- Log of total assets and its first difference. Large banks may benefit from economies of scale and portfolio diversification that should reduce risk exposure, including attracting quality staff and having better systems for credit risk assessment (Tan and Floros 2013). However, Bhagat et al (2015) found that larger banks were riskier up to and during the crisis, notably due to higher leverage, although too-big-to-fail may also have been important. Meanwhile, rapid growth may again lead to adverse selection of assets with a negative effect, in a similar argument to that made above for loan growth.

We use panel OLS, estimated using the within estimator and pooled FGLS, with year fixed effects and White (1980) cross-sectional standard errors and covariance (corrected for degrees of freedom) as in Davis and Karim (2018). All variables are entered, as noted, as 1-year lags to assess indicator properties and reduce the risk of simultaneity, except for competition where, as noted, LERNER and H are entered as a first difference, second and third lag to enable short and long run effects to be distinguished. The first difference of LERNER is instrumented by first and second lags of itself to reduce simultaneity (a particular concern for Z-Score as since the margin is related to the return on assets that enters the Z-score). Time dummies are included to allow for the effects of potentially omitted variables in the time dimension.

[10] The noninterest income share is bank's income that has been generated by noninterest related activities as a percentage of total income (net-interest income plus noninterest income). Noninterest related income includes net gains on trading and derivatives, net gains on other securities, net fees and commissions and other operating income.

We show in Appendix 1 the statistical properties of the variables. All variables are winsorised at 99% to avoid an impact of outliers, except for H in Europe which is winsorised at 95%. The exceptions in the table are the price and marginal cost measures that are intermediate to calculating the Lerner index. On balance, we see these are reasonable and comparable between the US and Europe.

Particular comment is appropriate for the capital adequacy measures, as shown in Table 1 below. It can be seen that the mean levels of each ratio is well above the regulatory minima, with leverage ratios (LEV) being 11.7% in the US and 12% in Europe compared with the minimum of 3% in the US and in Europe since 2010. Similarly, the total regulatory risk-adjusted capital ratio (TOT) is 17.2% in the US and 18.0% in Europe, compared to the Basel 8% minimum. Tier 1 (TIER) where the denominator is also risk-adjusted, is intermediate.

This is consistent with earlier observations such as Barth et al (2006) who showed capital ratios are on average 75% above regulatory requirements; Flannery and Rangan (2008) showed similar outcomes for the US. As noted by Ashcraft (2001) this may suggest other factors than regulation help determine capital ratios, such as market discipline leading banks to hold excessive capital so as to attract high quality borrowers in a competitive credit market (Allen et al 2011). That said, an alternative that does give influence to regulation is that banks seek to maintain a buffer over the regulatory minimum to avoid penalties imposed by regulators when minima are breached (consistent with this, Barrell et al (2009) find that such "headroom" over mimima and also inverse headroom impact on bank loan spreads). Note that for Europe there are fewer observations for the risk-weighted measures, partly because only in 2007 did reporting become mandatory, as Basel II was adopted.

Table 1: Statistical properties of capital ratios (winsorised at 99%)

	US			Europe		
	Leverage	Total	Tier 1	Leverage	Total	Tier 1
Mean	0.117	0.172	0.159	0.12	0.186	0.164
Median	0.0959	0.137	0.123	0.0797	0.162	0.140
Maximum	0.777	1.067	1.071	0.901	0.773	0.706
Minimum	0.0217	0.081	0.066	0.00619	0.0762	0.054
Std. Dev.	0.0958	0.128	0.13	0.147	0.101	0.0978
Observations	14704	13585	13487	86080	39431	30518

Notes, Leverage is the leverage ratio, Total is the total regulatory capital ratio risk-adjusted, and Tier 1 is the corresponding Tier 1 ratio.

Figures 1-3 below show the simple average capital adequacy ratios for US and European banks. According to Figure 1, the leverage ratio has shown a steady upward trend since the crisis, in line with Basel III, having been flat up to that point apart from a rise from 1998 to 2001. We note in this context that accounting for derivatives as well as securitisation of loans means that the assets figure for the US may underestimate risk, and the underlying leverage ratio may be lower than shown. Figure 2 shows that the European banks' average regulatory capital ratio fell from 1998 till 2008, as did that in the US from 2002 to 2007, a similar pattern prevailed for the Tier 1 ratio. The pattern is more marked for Europe however. For both the US and Europe, the regulatory capital ratios rose from 2008 onwards, in line with Basel III, although in the US it appears to have peaked in 2012.

Figure 1: Leverage ratios for US and European banks

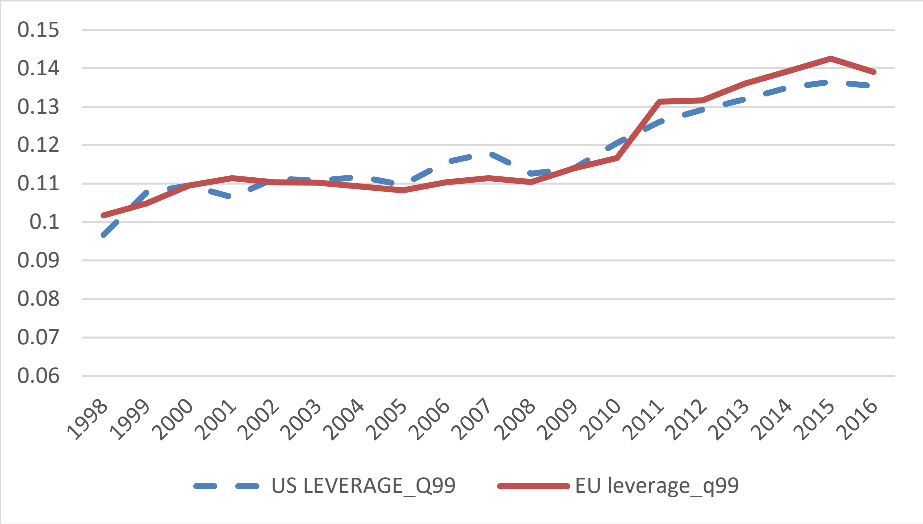


Figure 2: Regulatory capital ratios for US and European banks

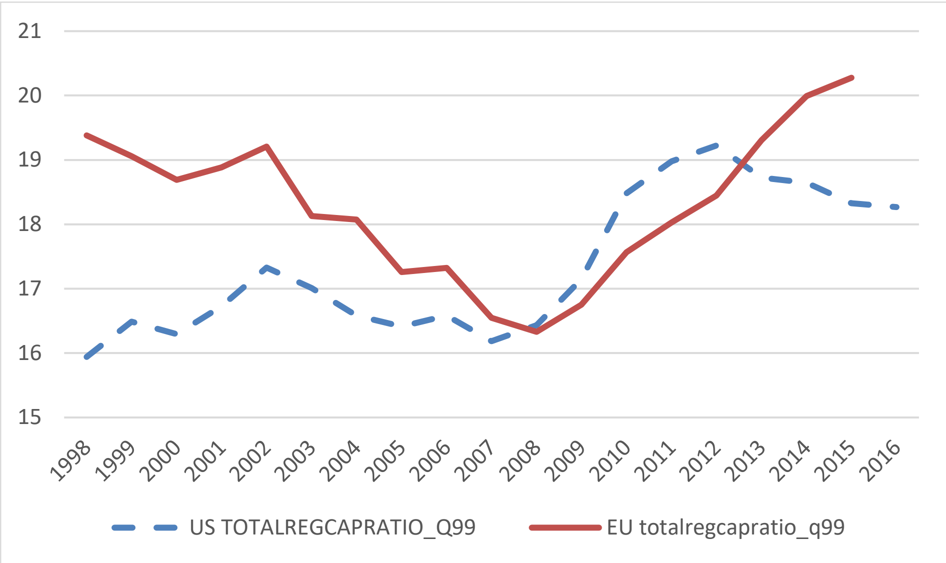
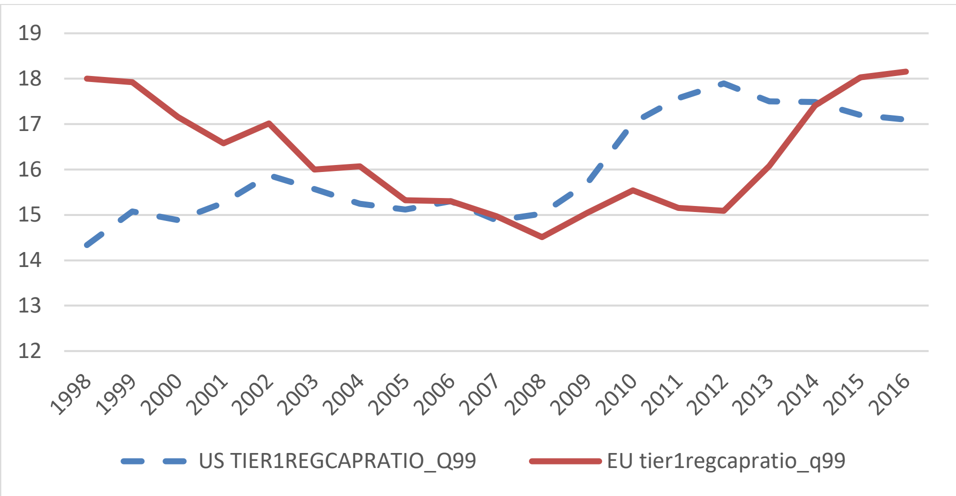


Figure 3: Tier 1 ratios for US and European banks



The econometric estimates of the competition measures for the Lerner Index, and for the full data sample for H are shown in Appendix 2. It can be seen that the results for the restricted cost function needed to derive the Lerner Index are highly comparable between the US and Europe, suggesting use of similar banking technology. The B(4) coefficient differs but is insignificant for both areas. Results for H are more diverse. The estimated value of H for Europe is 0.12 while for the US it is 0.32, suggesting a more competitive market in the US.

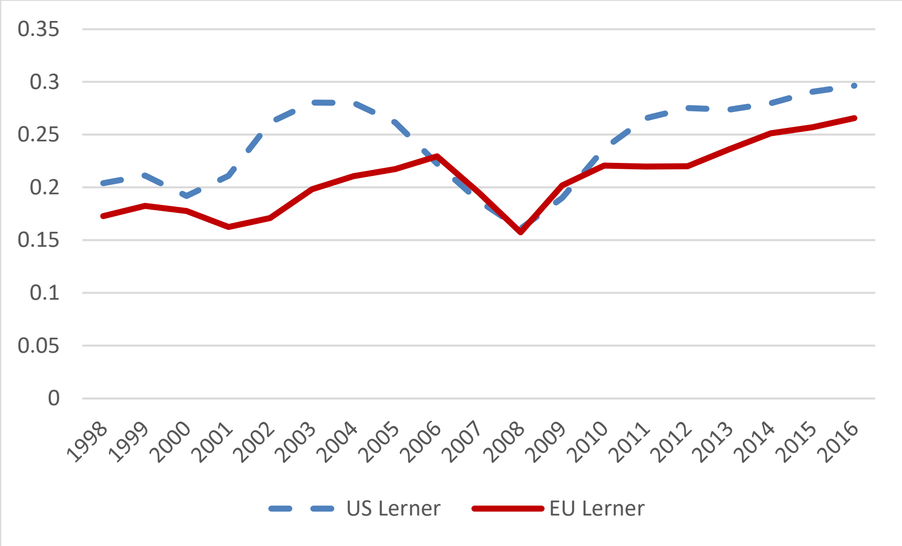
Note that whereas the Lerner Indices are derived directly from the estimates in Table A3 (as outlined above), the measures of H used in the regressions are derived using separate regressions year-by-year and country-by-country. The statistical properties of the resulting competition measures used in the regressions for risk are shown in Table 2 below. The competition indicators are similar in the US and Europe for the Lerner Index, but surprisingly the H Statistic is much lower in the US than in Europe, contrary to the average results in Appendix 2 mentioned above. The European mean, in contrast, is very close to the average over 1998-2016 from the full sample estimate.

Table 2: Statistical properties of competition measures (winsorised at 99% except H in Europe winsorised at 95%)

	Lerner Index		H Statistic	
	US	Europe	US	Europe
Mean	0.239	0.211	-0.25	0.121
Median	0.246	0.214	-0.465	0.313
Maximum	0.551	0.567	0.758	1.47
Minimum	-0.376	-0.397	-1.188	-2.169
Std. Dev.	0.141	0.135	0.549	0.973
Observations	13491	72381	24130	149354

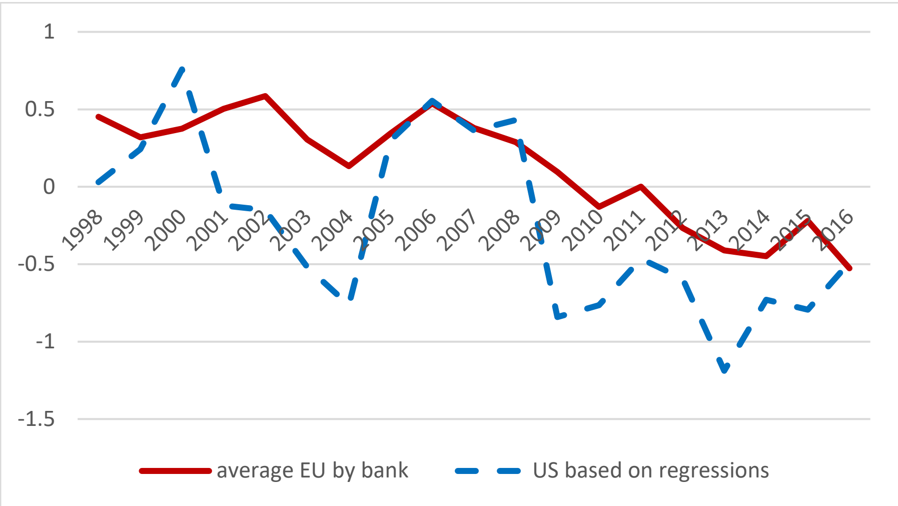
We show below the time patterns for the Lerner index in Europe and the US (Figure 3). The patterns have strong parallels, with a decline in competition (rise in margins) after the Russia/LTCM, Asian and Dotcom crises of the late 1990s/early 2000s, followed by a rise in competition in the run-up to the subprime crisis. This was sharply reversed after 2008 and margins continued to rise up to 2016. We note that margins in the US are somewhat more volatile and higher on average than in Europe, consistent with Table 2 above. We note that de-Ramon et al (2018) have a similar pattern to Europe for the UK Lerner index, with a trough in 2008 and a rise up to the end of their data in 2013.

Figure 4: Average Lerner indices for the US and EU



Similar patterns are apparent for Lerner indices in many individual European countries shown in Appendix 3, Figures A1-A8. Finally, in Figure 5 we show the patterns for the H statistic. For Europe, the ratio was flat before rising prior to the subprime crisis over 2004-7, after which competition declined according to this measure. A much more volatile pattern is apparent in the US, with rises prior to the dotcom boom and also the subprime, with again a low level of competition from 2008 onwards. We reiterate the concerns over the H statistic that are to some degree underlined by these patterns, and put greater emphasis on the Lerner index as shown above.

Figure 5: H Statistics for the US (single series) and Europe (weighted by the number of banks in each country)



4 Results

The bank-level estimates of Lerner and the country level estimates of H are then fed into equations for risk as noted above. The basic Provisions/Loans results for H and Lerner, omitting capital ratios, are shown in Table 3 as an example. Note that Q99 implies winsorised variable at 99%, and Q95 at 95%. Variables are as defined in Section 3 above.

Table 3: Regression results for Provisions/Loans using Lerner index and H Statistic (2001-2016)

Dependent variable: Provisions/loans	**Competition measure: Lerner Index**		**Competition measure: H Statistic**	
Variable	US	Europe	US	Europe
C	0.2 (1.1)	1.5*** (5.7)	-0.57 (0.9)	2.12*** (11.5)
Δ LERNERINST_Q99	-0.4** (2.6)	0.34** (2.3)		
LERNER_Q99(-2)	-0.22 (0.7)	0.34 (1.4)		
LERNER_Q99(-3)	0.47* (1.8)	0.69** (2.4)		
Δ H_Q95 (Europe) Q99 (US)			-0.22 (1.0)	0.017 (0.3)
H99_ Q95 (-2) (Europe) Q99 (US)			0.2 (1.1)	-0.11** (2.2)
H99_ Q95 (-3) (Europe) Q99 (US)			0.36* (1.8)	-0.08 (1.4)
CDT_Q99(-1)	-1.64*** (8.4)	-0.81*** (6.7)	-0.95*** (5.3)	-0.72*** (6.5)
LAR_Q99(-1)	0.8*** (5.1)	-0.3* (1.9)	0.74*** (4.0)	-0.35*** (3.1)
NIR_Q99(-1)	0.84*** (4.2)	0.52*** (3.0)	0.81*** (4.2)	0.47*** (3.8)
PII_Q99(-1)	Na	Na	Na	Na
LOG(TOTALASSETS_Q99(-1))	0.04* (1.8)	-0.02** (2.3)	0.07*** (2.8)	-0.04*** (5.5)
Δ (LOG(TOTALASSETS_Q99(-1)))	-0.12 (1.6)	-0.007 (0.1)	-0.15 (1.6)	0.02 (0.4)
Periods included	16	16	16	16
Banks included	944	5359	969	5812
Observations	9903	47824	10797	53604
R-squared	0.298	0.054	0.164	0.055
Adjusted R-squared	0.297	0.054	0.163	0.055
S.E. of regression	0.923	1.31	1.03	1.35
Fixed effects	Period	Period	None	Period

Notes: t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%. Δ LERNERINST is the first difference of the Lerner Index, instrumented by the first and second lags of itself, LERNER is the Lerner Index, Δ H is the first difference of the H statistic, H is the H statistic, CDT is the ratio of customer deposits to total short term funding, LAR is the ratio of bank loans to assets, NIR is the share of noninterest income in the total, PII is the loan loss provisions to income ratio, LOG(TOTALASSETS) is the log of total assets and Δ (LOG(TOTALASSETS)) is its first difference. Q99 shows a variable winsorised at 99% and Q95 a variable winsorised at 95%.

Bear in mind when reading the table that a higher provisioning ratio implies higher risk in the balance sheet, consistent with the use of the comparable loan loss reserves/assets measure as a risk indicator in Bitar et al (2018).

As shown also by De Jonghe (2010), higher noninterest revenue (NII) relate to increases in banks' risk exposure. In all cases, a higher share of retail (customer) deposits in the total (CDT) reduces risk, consistent with experience during the crisis when banks dependent on wholesale funding were most vulnerable. In the US, a higher loan-asset ratio (LAR) increases risk, whereas this is not the case for Europe, where it either reduces risk or is insignificant. We omit the provisions/income ratio (PII) in this equation (given it is close to being a lagged dependent variable) but include it for the other risk indicators. Larger banks (LOG(TOTALASSETS)) are shown to be higher risk in the US (as in Bhagat et al 2015) but lower risk in Europe; the log-difference of assets is not significant in either case.

We find that an increase in competition raises risk according to this measure in the US according to Lerner in the short run and H in the long run (as is found for example in Beck et al 2013). On the other hand, for short run Lerner in Europe and for the long run with Lerner for both the US and Europe, competition lowers risk. Also for H in Europe in the long run, in line with results of Davis and Karim (2018), we find a long run favourable effect of competition on risk.[11] Note that we could not include period fixed effects for the US with H as they are correlated with H (which is the same for all banks).

We now go on to include capital in the equations for risk, along with the variables shown above. We note that most studies look at the relation of capital to risk or competition to risk but rarely include competition as a control in assessing capital's relation to risk (Beck and De Jonghe (2013) mention this as a robustness check to their work on competition and risk, but do not mention the coefficients on capital). We consider this an important aspect of our own work. Note that we repeated the exercise with country dummies for Europe (see Section 5) as well as other robustness checks, and found very similar results. Table 4 shows significant capital measures at 90% and above. Recall that Z-score is negatively related to risk, while the other measures are positively related. To aid interpretation, cells shown in grey show a negative relation of capital ratios to risk, cells shown in white show a positive relation of capital ratios to risk.

[11] In a separate test, we found that as per Beck and De Jonghe (2013), higher competition also increases the volatility of profits (the denominator of the Z-score – results not shown), thus showing the link is not spuriously due to the relation of a mark-up (such as Lerner) and a risk measure that includes profitability. The exception is again H in Europe which as shown in Davis and Karim (2018) appears to derive its negative relation to risk to a negative relation to the volatility of profits.

Table 4: Regression results for capital measures: risk measures

		US			Europe		
Risk measure	**Competition Measure**	Leverage	Total	Tier 1	Leverage	Total	Tier 1
Provisions/ loans ratio	Lerner index	1.14*** (2.7)			1.32** (2.2)	-1.0*** (4.7)	
Impaired loans ratio	Lerner index	-0.016** (2.4)			0.18*** (7.1)		0.04*** (4.4)
Loan growth	Lerner index		-0.09** (2.1)	-0.086** (2.0)	0.081** (2.2)		
Z-Score	Lerner index	0.74*** (2.8)				0.46*** (2.9)	0.51*** (3.5)
		US			**Europe**		
Risk measure	**Competition Measure**	Leverage	Total	Tier 1	Leverage	Total	Tier 1
Provisions/ loans ratio	H Statistic	1.1*** (3.0)	0.4*** (2.7)	0.31* (1.9)	0.99*** (2.7)	-0.52*** (2.7)	
Impaired loans ratio	H Statistic	-0.016** (2.2)			0.11*** (6.0)		0.04*** (3.8)
Loan growth	H Statistic		-0.12*** (3.1)	-0.11*** (3.0)	0.046* (1.7)		
Z-Score	H Statistic	1.04*** (3.6)			0.84*** (5.1)	0.6*** (3.7)	0.53*** (3.0)

Note: Results are shown for capital ratios only, each regression includes all the additional control variables shown in Table 3, except for PII for the provisions ratio. Cells shown in grey show a significant negative relation of capital ratios to risk, cells shown in white show a positive relation of capital ratios to risk. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.

The most important point is that capital ratios are consistently significant as predictors of risk, with competition as one of the controls. Inclusion of competition does not make capital ratios insignificant – but equally competition remains important when capital ratios are included (see competition coefficients in Table 11 below). Accordingly, regulators may need to pay greater heed to competitive conditions in considering bank and banking sector risks than is the case at present, while naturally not disregarding capital ratios. Leverage is clearly as or more relevant than the risk-adjusted measures, being more commonly significant for each competition measure and region.

As regards the relation of capital ratios to the individual risk indicators, regarding the provisions ratio, higher leverage ratios predict higher provisions in US and Europe (as also in Altunbas et al (2007) and Iannotta et al (2007)), so there is in each case a positive relation to risk, consistent with the "regulatory hypothesis". However, results for the risk-weighted measures are more diverse. In the US, the risk-adjusted measures are significant for the H equations, and show again a positive relation of capital ratios to risk, consistent with the leverage ratio and the "regulatory hypothesis". On the other hand, the risk-adjusted measures for the European countries have a negative sign, showing support for "skin in the game". This is not consistent with the results of Bitar et al (2018), who found only unadjusted measures to be significantly (and positively) related to risk as measured by provisions/total assets. They argued (following Dermine 2015) that the failure of risk-adjusted measures was consistent with manipulation of risk-weighted assets in a way that did not reflect risk exposures; our results are more favourable to the indicator properties of risk-adjusted ratios. The difference in their results may relate to a sample ending in 2013 in Bitar et al (2018) as opposed to 2016 in our case, as well as in their case covering a wider range of OECD countries.

Concerning impaired loans, a higher leverage ratio predicts lower impaired loans in US but the opposite in Europe, so for the US there is a negative relation of the leverage ratio to risk and a positive one in Europe. Hence whereas the US follows the "skin in the game" the European pattern is more consistent with the "regulatory hypothesis". Note that in no case does the total risk-adjusted measure predict impaired loans, the Tier 1 ratio is significant for European banks with the same positive sign as the leverage ratio.

Regarding loan growth, higher risk-adjusted capital ratios predict decelerating loan growth in the US, suggesting again a role for "skin in the game". The corollary, that lower capital ratios imply higher risk is arguably consistent with moral hazard and the danger of low-capitalised banks "gambling for resurrection". The leverage ratios are positive for Europe suggestive of the "regulatory hypothesis". Note that the measure we use, the log-difference of loans, gives a percentage growth rate that is consistent across small and large banks.

As noted, the log of Z-score is likely to be correlated with leverage but we include results for completeness and comparability with extant work. Z-score results for the US for leverage suggest rising leverage ratios predict a rising Z and hence safer banks, while the risk-adjusted measures are not significant. Meanwhile in Europe the same result is consistent across capital ratios. All these results suggest a negative relation of capital ratios to risk, consistent with the "skin in the game" hypothesis.

Overall, we contend that the results for the US are largely consistent with the "skin in the game" hypothesis, as in each case except for provisions, higher capital gives rise to less risk. In contrast, the European results for leverage are partly consistent with the "regulatory hypothesis", in the sense that higher capital tends to accompany higher risk, except for the Z-score (which as noted has technical difficulties) and total capital ratios for provisions. The leverage ratio is more often significant as a risk indicator than are the risk-adjusted measures for both the US and Europe.

We contend that these contrasting patterns are a major finding that warrants further investigation. Accordingly, we now go on to test for two breakdowns of the data (low and high leverage ratio and pre and post-crisis) so as to assess the cross sectional and time series heterogeneity of the sample, as in Anginer and Demirgüç Kunt (2014) and Bitar et al (2018). We consider the division between banks above and below median leverage as a most important breakdown. To aid interpretation, again cells shown in grey show a negative relation of capital ratios to risk ("skin in the game"), cells shown in white show a positive relation of capital ratios to risk ("regulatory hypothesis").

Table 5: Regression results for capital measures in subsamples: Provisions ratio for low and high leverage and pre and post-crisis

Competition measure: Lerner Index	US			Europe		
	Leverage	Total	Tier 1	Leverage	Total	Tier 1
Full sample (Table 4)	1.14*** (2.7)			1.32** (2.2)	-1.0*** (4.7)	
Low leverage ratio			-1.7*** (2.7)	5.6*** (4.0)	-2.3*** (4.9)	-1.2*** (3.1)
High leverage ratio	1.4*** (2.8)			2.0*** (3.3)	-0.74** (2.5)	
1998-2007	1.3* (1.9)					
2008-2016				2.8*** (3.8)	-1.2*** (4.5)	
Competition measure: H Statistic	**US**			**Europe**		
	Leverage	Total	Tier 1	Leverage	Total	Tier 1
Full sample (Table 4)	1.1*** (3.0)	0.4*** (2.7)	0.31* (1.9)	0.99*** (2.7)	-0.52*** (2.7)	
Low leverage ratio				4.5*** (3.4)	-1.8*** (4.2)	-1.1*** (2.9)
High leverage ratio	0.96** (2.3)			1.5*** (4.6)		
1998-2007	1.1** (2.2)				-1.1*** (4.8)	-1.2*** (6.1)
2008-2016				1.9*** (4.7)	-0.5** (2.1)	0.59** (2.1)

Note: Results are shown for capital ratios only, each regression includes all the additional control variables shown in Table 3. The division of high and low leverage ratios is at the sample median which is 0.096 for the US and 0.08 for Europe. Cells shown in grey show a negative relation of capital ratios to risk, cells shown in white show a positive relation of capital ratios to risk. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.

We first ran the test of low and high leverage and for subperiods for the provisions/loans ratio as a dependent variable (Table 5). In this case, as for all risk measures except Z-score, a positive sign implies a positive relation of capital to risk and a negative sign the opposite. For the US, the pattern for high leverage ratios is the same for the full sample, with a positive sign consistent with the “regulatory hypothesis”. The opposite is true for the risk-adjusted Tier 1 capital measures which are significant for banks with low leverage ratios with a negative sign, suggestive of “skin in the game” for such banks. In the US only the leverage ratio is significant pre-crisis, with a consistent positive sign.

For Europe, the leverage ratio is consistently positive across levels of leverage consistent with the “regulatory hypothesis” (high capital for high-risk). For low leverage ratios there is again some evidence of “skin in the game” with the risk-adjusted capital ratios being consistently significant with a negative sign. Pre and post-crisis results show mostly negative for the risk-adjusted measure (“skin in the game”) while the leverage ratio only emerges as significant and positive after the crisis, the time when it began to be a subject of regulatory focus.

Table 6: Regression results for capital measures in subsamples: Impaired loan ratio for low and high leverage and pre and post-crisis

Competition measure: Lerner Index	**US**			**Europe**		
	Leverage	Total	Tier 1	Leverage	Total	Tier 1
Full sample (Table 4)	-0.016** (2.4)			0.18*** (7.1)		0.04*** (4.4)
Low leverage ratio				0.13*** (7.9)	0.03* (1.8)	0.06*** (4.6)
High leverage ratio	-0.01** (2.0)					
1998-2007				0.073*** (5.3)		
2008-2016	-0.032*** (3.2)			0.23*** (8.6)		0.038*** (3.8)
Competition measure: H Statistic	**US**			**Europe**		
	Leverage	Total	Tier 1	Leverage	Total	Tier 1
Full sample (Table 4)	-0.016** (2.2)			0.11*** (6.0)		0.04*** (3.8)
Low leverage ratio		0.015** (2.1)	0.016* (1.9)	0.113*** (8.2)	0.035** (2.3)	0.049*** (3.5)
High leverage ratio	-0.016*** (3.3)					
1998-2007	-0.003* (1.7)		-0.003** (2.3)	0.039** (2.3)		0.018* (1.8)
2008-2016	-0.046*** (5.2)			0.133*** (7.0)		0.04*** (2.9)

Note: Results are shown for capital ratios only, each regression includes all the additional control variables shown in Table 3. The division of high and low leverage ratios is at the sample median which is 0.096 for the US and 0.08 for Europe. Cells shown in grey show a negative relation of capital ratios to risk, cells shown in white show a positive relation of capital ratios to risk. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.

A further test shown in Table 6 is of the impaired loan ratio as a risk measure. It shows largely consistent results for the US of a negative relation of capital ratios to risk (“skin in the game”), while the European results are consistently positive (“regulatory hypothesis”). The exception is the US result for H with low leverage which shows a positive sign. For Europe, only low leverage banks show a relationship of capital to impaired loans. It is notable that the leverage ratio and to a lesser extent the Tier 1 ratio shows more frequent significance than total risk weighted capital. Effects are generally larger for each zone post crisis than pre crisis. Table 7 shows the corresponding results for log loan growth and the log Z-score.

Table 7: Regression results for capital measures in subsamples: Log loan growth for low and high leverage and pre and post-crisis

Competition measure: Lerner index	**US**			**Europe**		
	Leverage	Total	Tier 1	Leverage	Total	Tier 1
Full sample (Table 4)		-0.09** (2.1)	-0.086** (2.0)	0.081** (2.2)		
Low leverage ratio		0.39** (2.2)	0.36** (2.3)	0.44* (1.8)		0.11* (1.8)
High leverage ratio		-0.13*** (2.7)	-0.12** (2.6)	0.08** (2.3)		
1998-2007		-0.13*** (3.6)	-0.12*** (3.4)	0.21*** (5.0)	0.1** (2.2)	
2008-2016						
Competition measure: H Statistic	**US**			**Europe**		
Full sample (Table 4)	Leverage	Total	Tier 1	Leverage	Total	Tier 1
Low leverage ratio		-0.12*** (3.1)	-0.11*** (3.0)	0.046* (1.7)		
High leverage ratio	0.52* (1.7)			0.57*** (3.6)		0.13* (1.8)
1998-2007		-0.14*** (3.5)	-0.13*** (3.4)			
2008-2016		-0.17*** (5.5)	-0.16*** (5.2)		0.12*** (3.1)	

Note: Results are shown for capital ratios only, each regression includes all the additional control variables shown in Table 3. The division of high and low leverage ratios is at the sample median which is 0.096 for the US and 0.08 for Europe. Cells shown in grey show a negative relation of capital ratios to risk, cells shown in white show a positive relation of capital ratios to risk. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.

The results for loan growth (Table 7) are consistent with the basic results for the full sample shown in Table 4 and repeated here. The US shows a negative relation of loan growth to regulatory capital consistent with "skin in the game" and no relation to the leverage ratio over the full sample, which is repeated for banks with high leverage ratios and for the 1998-2007 period. However, there is a difference for low leverage ratio banks where there is a positive relation of leverage and regulatory capital to loan growth. In Europe, the results consistently favour higher capital being a prerequisite for loan growth consistent with the "regulatory hypothesis". The effect appears to be greater for low leverage ratio banks and for the 1998-2007 period. Note that there is no significant effect with Lerner as the competition indicator for the 2008-2016 period for the US or Europe, perhaps consistent with banks' caution about loan growth and low demand for credit in the post-crisis period. We note that the regulatory capital measures show significance more often in the US for this risk measure, whereas in Europe it is the leverage ratio.

Table 8: Regression results for capital measures in subsamples: Log Z-score for low and high leverage and pre and post-crisis

Competition measure: Lerner index	**US**			**Europe**		
	Leverage	Total	Tier 1	Leverage	Total	Tier 1
Full sample (Table 5)	0.74*** (2.8)				0.46*** (2.9)	0.51*** (3.5)
Low leverage ratio	2.2** (2.2)	-2.2*** (3.1)	-2.1*** (2.8)			
High leverage ratio					0.6* (1.8)	
1998-2007				0.74*** (7.1)	0.47** (2.1)	0.86*** (2.7)
2008-2016	1.24*** (4.1)				0.6*** (3.6)	0.53*** (3.2)
Competition measure: H Statistic	**US**			**Europe**		
	Leverage	Total	Tier 1	Leverage	Total	Tier 1
Full sample (Table 5)	1.04*** (3.6)			0.84*** (5.1)	0.6*** (3.7)	0.53*** (3.0)
Low leverage ratio		-2.6*** (5.4)	-2.6*** (5.4)			
High leverage ratio				3.5*** (3.6)		-0.86** (2.6)
1998-2007	0.5*** (2.7)	-0.27* (1.8)	-0.32** (2.0)	1.19*** (9.7)	0.63*** (3.2)	1.04*** (4.8)
2008-2016	2.18*** (6.6)	0.43** (2.0)	0.47** (2.1)	0.69*** (2.8)	0.72*** (3.9)	0.5** (2.4)

Note: Results are shown for capital ratios only, each regression includes all the additional control variables shown in Table 3. The division of high and low leverage ratios is at the sample median which is 0.096 for the US and 0.08 for Europe. Cells shown in grey show a negative relation of capital ratios to risk, cells shown in white show a positive relation of capital ratios to risk. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.

Finally for log Z-score (Table 8), European banks show consistently positive signs except for the Tier 1 ratio for high leverage ratio banks. This is, as above, consistent with the “skin in the game” argument, that capital reduces the risk that would otherwise occur owing to moral hazard. Capital ratios are only significant for high leverage ratio banks, however, raising the question whether banks with low leverage were neglected and/or capital measures do not reflect risk. Results are broadly consistent pre and post-crisis.

The US pattern is more diverse, with effects only significant for low leverage ratio banks, on which the authorities may be expected to focus. The risk-adjusted measures are consistently negative for a low leverage ratio consistent with the “regulatory hypothesis”, whereas the leverage ratio for Lerner has a positive sign consistent with the “skin in the game” argument. There is no relation for high leverage ratio banks. It may be that the relation of risk to capital at high levels of capital adequacy relates with more market based arguments such as the “outsider equity effect”, or the Barth et al (2018) argument that new entrants come in when regulation requires high levels of leverage ratios. As regards pre and post-crisis, there is a consistent pattern of positive signs for the leverage ratio, but negative signs for risk-adjusted measures and H, become positive post-crisis. These are not significant for Lerner, however.

As a further test of the link of capital to risk in Europe, we ran the equations for the provisions/loans ratio showing effects of capital ratios for the four major countries.

Table 9: Country assessment of capital effects for provisions/loans

Provisions/loans	Lerner Index			H Statistic		
	Leverage	Total	Tier 1	Leverage	Total	Tier 1
UK full sample		-2.02** (2.2)	-2.58*** (3.2)		-2.2** (2.5)	-2.8*** (4.2)
France full sample	-2.34*** (5.5)	-1.88* (1.9)		-1.34*** (4.5)	-1.14* (1.7)	
Germany full sample	2.75*** (2.9)		1.68*** (4.1)	1.82*** (4.1)		1.85*** (4.4)
Italy full sample		-1.1*** (6.4)	-1.25*** (6.1)		-0.93*** (4.3)	-1.0*** (4.4)
UK 1998 -2007	2.42*** (3.6)		-2.8** (2.1)			-4.73*** (3.6)
UK 2008-2016	-1.25*** (2.8)	-3.9*** (3.5)	-2.7*** (3.1)		-4.65*** (4.9)	-3.16*** (4.6)
Memo: Europe full sample (Table 4)	1.32** (2.2)	-1.0*** (4.7)		0.99*** (2.7)	-0.52*** (2.7)	

Note: Results are shown for capital ratios only, each regression includes all the additional control variables shown in Table 3, with the exception of time dummies for H. Cells shown in grey show a negative relation of capital ratios to risk, cells shown in white show a positive relation of capital ratios to risk. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.

UK results over 1998-2016 (Table 9) are for a negative effect of regulatory capital on provisions/loans but no significant link for leverage. Italy has a similar pattern to the UK, while France has a negative effect for leverage and the total regulatory capital ratio. Germany differs in that there is a positive link from leverage and risk-adjusted capital to provisions. For all countries except Germany, these imply a negative relation of capital to risk and hence "skin in the game" while German results are consistent with the "regulatory hypothesis". Looking at the UK pre and post-crisis we see that the leverage ratio in the UK has a positive sign pre-crisis. This pattern is reversed post-crisis, consistent with a greater regulatory focus on the leverage ratio. Both the risk-adjusted measures also show a positive sign post-crisis, and the Tier 1 ratio pre-crisis. In Appendix 4 we show complementary results for log Z-score, showing a general pattern of positive relations to capital (skin in the game") except for leverage ratios in the UK prior to the crisis.

A further experiment is to investigate the impact of the introduction of Basel III on the effect of leverage on risk. Whereas the US already focused on the leverage ratio in its regulation, this was an innovation in Europe. We contend that the effect may begin in 2010 when Basel III was announced, in advance of its implementation. Accordingly, we added to the equations for leverage in Table 4 an additional lagged leverage ratio multiplied by a dummy which is one in 2010-16. The sum of the two coefficients, if significant, gives the effect after Basel III while the simple leverage term without the dummy gives the effect before Basel III. Results are as shown in Table 10 below.

Table 10: Estimating the effect of introduction of a regulatory leverage ratio in Europe

Competition measure	Lerner Index				H Statistic			
Risk measure	Provisions/ loans	Impaired loan ratio	Log loan growth	Log Z-score	Provisions/ loans	Impaired loan ratio	Log loan growth	Log Z-score
Leverage_Q99 (-1)		0.107*** (2.9)	0.128*** (2.7)			0.061** (2.1)	0.088** (2.3)	0.86*** (4.0)
Leverage_Q99 (-1) * Dummy 2010-2016	2.05** (2.1)	0.126*** (3.0)	-0.107* (1.9)		1.54** (2.4)	0.076** (2.5)	-0.091** (2.1)	

Note: Results are shown for capital ratios only, each regression includes all the additional control variables shown in Table 3. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.

The results suggest that behaviour in respect of the leverage ratio did indeed differ in Europe from 2010 onwards. For provisions/loans, the effect in the full sample is shown to be mainly in the post 2010 period, with the full sample variable being insignificant. This is consistent with closer regulatory attention to the leverage ratio. Equally, for the impaired loan ratio, there is an increase in the effect of the leverage ratio, consistent with greater capital requirements by this measure for risky banks. For loan growth there is a reversal, in that there is a significant positive relation between leverage and risk in the 2000s, but the coefficient becomes zero after 2010 with an equal negative significant coefficient on the dummied variable. The results for Z-score do not show any separate post 2010 effect, however.

Complementing the above analysis, we show in Table 11 the significant competition measures for equations as shown in Table 4 with capital ratios included. There are a large number of significant measures, showing the importance of competition to bank risk even when capital ratios are included in the equation. As above, note that Z-score is negatively related to risk, while the other measures are positively related. To aid interpretation, cells shown in white show a negative relation of competition to risk (competition-stability), cells shown in grey show a positive relation of competition to risk (competition-fragility).

Table 11: Regression results for competition measures: risk measures with capital ratios included

Risk measure	Lag of compe-tition	**US: Lerner index**			**Europe: Lerner Index**		
		Leverage	Total	Tier 1	Leverage	Total	Tier 1
Provisions ratio	Δt	-0.4** (2.6)	-0.4*** (2.7)	-0.43*** (2.9)	0.34** (2.4)		
	t-2						
	t-3	0.47* (1.8)	0.44* (1.7)	0.47* (1.8)	0.59** (2.2)	0.6* (1.6)	
Impaired loans ratio	Δt	-0.016*** (6.4)	-0.016*** (6.5)	-0.016*** (6.5)			
	t-2	-0.027*** (7.5)	-0.027*** (7.6)	-0.027*** (7.6)			
	t-3						
Loan growth	Δt	0.076*** (5.1)	0.076*** (4.9)	0.076*** (4.9)	0.053*** (6.5)	0.051* (1.8)	0.033*** (2.7)
	t-2	0.098*** (2.9)	0.103*** (3.0)	0.104*** (3.1)	0.037** (1.7)	0.072*** (4.7)	0.12*** (5.9)
	t-3	-0.074** (2.2)	-0.075** (2.1)	-0.075** (2.3)		-0.027** (2.3)	-0.068**Δ* (2.7)
Z-Score	Δt	0.73** (2.3)	0.73** (2.3)	0.73** (2.3)	0.33*** (2.7)	0.36** (2.3)	0.38** (2.4)
	t-2	1.69*** (7.8)	1.72*** (7.9)	1.72*** (8.0)	0.86*** (3.8)	0.81*** (4.4)	1.09*** (3.9)
	t-3					0.39* (1.7)	
		US: H Statistic			**Europe: H Statistic**		
		Leverage	Total	Tier 1	Leverage	Total	Tier 1
Provisions ratio	Δt						
	t-2				-0.1** (2.0)	-0.17*** (3.6)	-0.18*** (3.2)
	t-3	0.36* (1.8)	0.36* (1.8)	0.36* (1.8)		-0.19*** (3.0)	-0.19** (2.4)
Impaired loans ratio	Δt						
	t-2				-0.013*** (5.1)	-0.012*** (4.6)	-0.011*** (3.5)
	t-3				-0.009*** (3.8)	-0.009*** (3.8)	-0.01** (2.6)
Loan growth	Δt	0.026*** (3.0)	0.027*** (3.0)	0.027*** (2.9)			
	t-2						-0.0088* (1.9)
	t-3						
Z-Score	Δt						
	t-2		-0.23* (1.7)		0.092*** (3.5)		
	t-3				0.082** (2.5)		

Note: the table shows the competition measures from the equations underlying the results for capital ratios shown in Table 4. All other control variables are also included. Cells shown in white show a negative relation of competition to risk (competition-stability), cells shown in grey show a positive relation of competition to risk (competition-fragility). Δ means current first difference. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.

Bear in mind a rise in H implies higher competition as does a fall in Lerner (narrower margins). US results are consistent with more competition leading to more risk (competition-fragility), with the exception of the third lag of Lerner in provisions and the difference and second lag of Lerner for loan growth (these patterns may capture a timing effect, with for example higher competition leading to loan growth with a lag, but an immediate rise in provisioning). Accordingly US authorities should employ competition measures as an important aspect of macroprudential surveillance and stand ready to use prudential policy to counteract rises in risk that follow increases in competition.

In Europe patterns are more often consistent with competition-stability. The exception is that a wider margin as shown by Lerner, as in the US, raises the Z-score (as in Davis and Karim 2018) thus showing a positive relation of competition to risk (a similar result was found in Berger et al 2009). This is the exception, however; as also in Davis and Karim (2018) European results for the H Statistic consistently suggest that higher competition reduces risk with a higher Z-score and lower provisions and impaired loans as well as less loan growth. Also, the third lag of Lerner in provisions and the difference and second lag of Lerner for loan growth show increased competition reducing risk; only after three years is there a partial reversal. Accordingly for European regulators there is a need to use both measures in interpreting patterns of bank behaviour and their implications for risk.

5 Robustness checks

We ran a number of robustness checks on the basic regression results for capital as shown in Table 4, to see whether a variation in the approach would change the results. These robustness checks were fourfold. Firstly, we excluded competition to see whether the capital ratio results were highly dependent on competition's inclusion. Second, we included country dummies in the results for European countries, to see whether some aspect specific to the country influences capital's impact on risk. Third, we re-estimated the equations with country-clustered standard errors. A particular reason is that, since the H-statistic is a country-level variable, the error term should be clustered at the country level to allow for potential correlations in bank risk. We include similar results for Lerner for completeness. And finally, we excluded Germany as the largest contributor to the European bank results, not least in the light of some contrasts in the individual country effects shown in Table 9.

Table 12: Regression results for capital measures: risk measures – competition variables excluded

	US			**Europe**		
Risk measure	Leverage	Total	Tier 1	Leverage	Total	Tier 1
Provisions/ loans ratio	0.72** (2.5)			1.22*** (3.1)	-0.67*** (2.9)	
Impaired loans ratio	-0.028*** (3.5)			0.15 (6.7)		0.048*** (6.2)
Loan growth		-0.11*** (2.7)	-0.1** (2.5)	0.08** (2.2)		
Z-Score	1.35*** (5.0)			0.54*** (2.8)	0.53*** (3.2)	0.45*** (2.7)

Note: Results are shown for capital ratios only, each regression includes all the additional control variables shown in Table 3. Cells shown in grey show a significant negative relation of capital ratios to risk, cells shown in white show a positive relation of capital ratios to risk. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.

Comparing the results of excluding competition with the baseline in Table 4, it can be seen that the results are similar in terms of sign and significance, especially compared with our preferred competition measure, the Lerner index. The main difference is a significant result for leverage in the Z Score in Europe, a result consistent with the other capital measures and which does appear significant in Table 4 for the H Statistic.

Table 13: Regression results for capital measures: risk measures – country dummies included

		Europe		
Risk measure	**Competition Measure**	Leverage	Total	Tier 1
Provisions/ loans ratio	Lerner index	0.5 (1.2)	-1.6*** (8.3)	-1.5*** (9.1)
Impaired loans ratio	Lerner index	0.09*** (5.8)		
Loan growth	Lerner index			
Z-Score	Lerner index	1.51*** (10.6)	1.26*** (7.5)	1.86*** (8.7)
		Europe		
Risk measure	**Competition Measure**	Leverage	Total	Tier 1
Provisions/ loans ratio	H Statistic	0.68** (2.3)	-1.1*** (6.6)	-0.86*** (4.7)
Impaired loans ratio	H Statistic	0.085*** (6.4)		
Loan growth	H Statistic			
Z-Score	H Statistic	1.5*** (13.4)	1.35*** (8.9)	1.79*** (11.2)

Note: Results are shown for capital ratios only, each regression includes all the additional control variables shown in Table 3. Cells shown in grey show a significant negative relation of capital ratios to risk, cells shown in white show a positive relation of capital ratios to risk. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.

The other three robustness checks apply only to Europe, where country differences apply, unlike the US. As regards inclusion of country dummies, in Table 13, it can again be seen that results are largely consistent with the baseline for both Lerner and the H statistic. **Table 14: Regression results for capital measures: risk measures – country-clustered standard errors**

		Europe		
Risk measure	**Competition Measure**	Leverage	Total	Tier 1
Provisions/ loans ratio	Lerner index	1.32*** (12.4)	-1.0*** (8.5)	
Impaired loans ratio	Lerner index	0.18*** (23.6)		0.04*** (5.8)
Loan growth	Lerner index	0.081*** (5.8)	0.029** (2.1)	0.027* (1.7)
Z-Score	Lerner index	0.252*** (3.0)	0.46*** (4.6)	0.51*** (4.5)
		Europe		
Risk measure	**Competition Measure**	Leverage	Total	Tier 1
Provisions/ loans ratio	H Statistic	0.99*** (11.5)	-0.52*** (5.0)	0.04*** (3.7)
Impaired loans ratio	H Statistic	0.11*** (17.4)	0.011* (1.8)	0.04*** (6.7)
Loan growth	H Statistic	0.046*** (3.8)	0.04*** (3.1)	
Z-Score	H Statistic	0.84*** (12.0)	0.6*** (6.6)	0.53*** (5.1)

Note: Results are shown for capital ratios only, each regression includes all the additional control variables shown in Table 3. Cells shown in grey show a significant negative relation of capital ratios to risk, cells shown in white show a positive relation of capital ratios to risk. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.

The results for country clustered standard errors as shown in Table 14 are naturally the same in terms of the coefficients as in Table 4. The difference is a greater level of significance in most cases. This leads to some additional results that are nonetheless largely consistent with Table 4. For the Lerner index, we find significant effects for both total and Tier 1 regulatory capital in the case of loan growth, which is consistent with the positive sign for leverage that appears also in Table 4. These results are in line with the "regulatory hypothesis" of risk rising with capital ratios. In the case of the H Statistic, we find significant positive signs for the total regulatory capital ratio for the impaired loans ratio and loan growth, consistent with the existing results and with the regulatory hypothesis. We also find Tier 1 as significant and positive for the provisions ratio, which is in line with the leverage ratio (again "regulatory hypothesis"), but not with the total regulatory capital ratio.

Table 15: Regression results for capital measures: risk measures – excluding Germany

		Europe		
Risk measure	**Competition Measure**	Leverage	Total	Tier 1
Provisions/ loans ratio	Lerner index	1.12*** (3.0)	-1.98*** (6.8)	-2.26*** (8.2)
Impaired loans ratio	Lerner index	0.162*** (6.5)	-0.04*** (3.1)	
Loan growth	Lerner index			
Z-Score	Lerner index	0.62*** (5.2)	1.09*** (5.0)	1.55*** (7.4)
		Europe		
Risk measure	**Competition Measure**	Leverage	Total	Tier 1
Provisions/ loans ratio	H Statistic	0.99*** (3.8)	-1.1*** (5.3)	-1.5*** (6.1)
Impaired loans ratio	H Statistic	0.088*** (4.6)		
Loan growth	H Statistic		0.058** (2.3)	
Z-Score	H Statistic	1.18*** (9.0)	1.28*** (6.3)	1.58*** (8.8)

Note: Results are shown for capital ratios only, each regression includes all the additional control variables shown in Table 3. Cells shown in grey show a significant negative relation of capital ratios to risk, cells shown in white show a positive relation of capital ratios to risk. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.

Looking finally at the results for European banks excluding those in Germany in Table 15, the main contrast for Lerner is the impaired loan ratio, where the total regulatory capital ratio is now negative rather than insignificant, which is now in line with "skin in the game". For the H Statistic, the positive sign on capital for loan growth remains but it is now on the total regulatory capital ratio and not the leverage ratio.

In general, we would contend that the variants shown in this section indicate that the main results are robust to variation in sample and specification.

6 Quantile regressions

As a final assessment of the competition, risk and capital nexus, we undertook quantile regressions. The idea is to test whether the response of bank risk to competition and capital depends on the initial condition of the bank in terms of the risk indicators. As originally proposed by Koneke and Bassett (1978), quantile regression provides estimates of the linear relationship between regressors and a specified quantile of the dependent variable. It can be argued that quantile regression permits a more complete description of the conditional distribution than conditional mean analysis. This allows us, for example, to describe how the median, or specific percentiles of the response variable, are affected by regressors variables. Moreover, since the quantile regression approach does not require strong distributional assumptions, it offers a robust method of modelling these relationships.

Extant work using quantile regressions for assessing determinants of bank risk include for example Clomp and de Han (2012), who examine the impact of bank regulation and supervision on banking risk using quantile regressions with data for more than 200 banks from 21 OECD countries for the period 2002–2008. They used factor analysis to derive measures of bank risk, and found banking regulation and supervision has an effect on the risks of high-risk banks but does not have a significant effect on low-risk banks.

Meanwhile, Kohler (2013), analyses the impact of banks' non-interest income share on risk (including the Z-Score) in the German banking sector for the period between 2002 and 2010. Using linear and quantile regression estimators, they found that the impact of non-interest income on risk depends on the business model of a bank. Schaeck and Čihák (2014), focusing on European banks from 1995-2005, found that competition as measured by the Boone index increases stability on average but weaker banks may be less able to survive increases in competition. de-Ramon et al (2018) found competition in the UK over 1994-2013 reduces stability but that weaker banks may benefit, with capital and profitability both increasing. Meanwhile using macroeconomic data, Davis (2017) using the World Bank Global Financial Development Database as well as a pilot data sample by the IMF showed that concentration and distribution measures of standard financial soundness indicators such as the Tier 1 ratio and leverage ratio could be helpful in showing vulnerable national banking systems in multilateral surveillance.

Thus, we estimated quantile regressions using the same controls as in the main paper for the median, 90th percentile and 10th percentile of the distribution, with the leverage ratio used for the capital measure and Lerner for competition. Only significant variables are shown.

Table 16: Quantile regression results for Lerner Index and leverage: significant competition and leverage effects: four risk measures

Risk measure	Independent variable	**US: Lerner index, leverage**			**Europe: Lerner Index, leverage**		
Percentile		10	50	90	10	50	90
Provisions ratio	Short run competition	0.083	0.12	-0.5	0.37	0.33	0.66
	Long run competition	0.078	-0.35	-1.46	0.28	0.4	1.08
	Leverage	-0.73	-0.17	4.85	-0.67	-0.71	5.8
Impaired loans ratio	Short run competition		-0.0057	-0.017			
	Long run competition	-0.004	-0.016	-0.048		0.003	-0.041
	Leverage	-0.002	0.0078	0.046	0.027	0.14	0.49
Loan growth	Short run competition	0.064	0.05	0.039	0.074	0.02	0.03
	Long run competition	0.149	0.047	-0.042	0.149	-0.009	-0.115
	Leverage	-0.29	-0.073	0.57	-0.44	-0.12	0.6
Z-Score	Short run competition	1.09	0.89		0.54	0.38	0.25
	Long run competition	2.45	2.08	1.95	1.62	1.41	0.84
	Leverage		1.36		-0.84	0.56	1.7

Note: the table shows the significant competition measures and capital measures from the quantile equations with Lerner for competition and leverage for capital. The long run effect of competition is the sum of significant levels at lags 2 and 3. All other control variables are also included. Cells for competition shown in white show a negative relation of competition to risk ("competition-stability"), cells for competition shown in dark grey show a positive relation of competition to risk ("competition-fragility"). Cells for capital shown in light grey show a negative relation of capital ratios to risk ("skin in the game"), cells for capital shown in white show a positive relation of capital ratios to risk ("regulatory hypothesis"). Full results for these variables are shown in Appendix Table A6.

One striking result is that the impact of leverage ratios varies sharply across the level of risk of the institution. Bear in mind that the riskiest percentiles for provisions, impaired loans and loan growth is the 90th, while for the Z-score it is the 10th. What we find for both the US and Europe is that whereas at the 10th percentile and median for the provisions ratio and loan growth, there is a negative relation of leverage ratios to risk, at the 90th percentile it is positive. Meanwhile for the highest risk percentile of the log Z-Score, the effect of capital ratios is negative for European banks, while at the higher levels of Z-score it is positive. These results suggest a need for caution for regulators in assessing likely responses to higher capital – there may be switches from "the regulatory hypothesis" to "skin in the game", with a risk of moral hazard, and vice versa.

Meanwhile as regards competition, we find a tendency for the long run effect to become more negative with the shift from low-risk to high-risk, for the cases of the provisions ratio, impaired loans and loan growth. Indeed, in several cases there is a switch from "competition-stability" to "competition-fragility" with higher underlying risk. This is consistent with results for the UK in de-Ramon et al (2018) and suggests a particular need to focus on weaker banks. An exception is the provisions ratio in Europe, where the long run impact of competition is more consistent with stability at higher risk. Note that for Z-score the higher risk percentile is the 10th, and in this case the long run effect of competition ("competition-fragility") rises with greater risk. The short run effects are broadly consistent with these long run results, again declining in several cases with risk, albeit not for provisions in Europe.

6 Conclusions

An overview of the literature on bank risk determination shows that empirical testing of the leverage ratio, individually and relative to regulatory capital remains sparse, and empirical studies of bank capital ratios and the link to risk do not usually take into account the contribution that competition may make to risk, while competition-risk studies often do not highlight the complementary relation of capital to risk. We have sought to fill these lacunae by assessing the effectiveness of a leverage ratio relative to the risk-adjusted capital ratio (RAR) in predicting bank risk, while allowing for competition, for up to 8216 banks in the EU and 1270 in the US, using the Fitch-Connect database of banks' financial statements.

Using annual data over 1998-2016, and controlling for levels of bank competition, we have found that capital ratios are consistently significant as predictors of risk, but the relationship varies between positive (the "regulatory hypothesis") and negative ("skin in the game"). On balance, US banks tend to behave in a manner consistent with "skin in the game" while European banks tend to follow the "regulatory hypothesis", although there are exceptions to these generalisations. Accordingly, the expected effect of changes in capital on risk needs careful attention by regulators. There is a tendency for the leverage ratio to be more often significant than the risk-adjusted measure in a number of the regressions. This observation favours its use in macroprudential policy.

The effect of capital on risk varies considerably over time and cross sectionally for Europe vis a vis the US; effects often differ between low-leverage and high-leverage ratio banks as well as pre- and post-crisis. Looking at individual European country results for the relation of capital to the provisions ratio, they vary between Germany (positive relation of capital to risk) and the UK, France and Italy which have a negative relation. Nevertheless, the overall results are robust to a number of variations in sample and specification, namely exclusion of competition, inclusion of country dummies for Europe, country clustering of standard errors in Europe, and exclusion of Germany from the European sample.

We consider the inclusion of competition as a control variable to be a major contribution that adds to the relevance of our study. The results show that bank competition, allowing for capital, is a significant macroprudential indicator in virtually all regressions and hence more note should be taken of this by regulators, notably in the US where there is mainly evidence of competition-fragility. On the other hand there is a need for distinguishing the pattern of Lerner and H carefully in Europe, and we note that exclusion of competition does not markedly change the effect of capital.

Finally there are differences in the relation of risk both to competition and capital adequacy for banks at different levels of risk that need to be taken into account by regulators both in Europe and the US. There is some evidence of greater vulnerability of weaker banks to low capital and high competition than would be shown by the sample average or median.

As regards further research, we would suggest that this could include estimating possible nonlinear effects of capital ratios and competition as in Berger et al (2009). Individual country effects of competition and capital could be assessed in more detail, also in terms of groups such as EU new member states. Significance of macroeconomic variables could be assessed, such as stock market turnover and GDP growth. And detailed assessments could be made as to how appropriate capital ratios need to change when competition rises.

References

Adrian, T. and Shin, H. (2010), “Liquidity and leverage” Journal of Financial Intermediation, 19, 418-437

Allen, F., Carlotta, E. and Marquez, R. (2011), “Credit Market Competition and Capital Regulation”, Review of Financial Studies, Volume 24, Issue 4, 1 April

Altunbas, Y., Carbo, S., Gardner, E. and Molineux, P. (2007), “Examining the relationship between capital, risk and efficiency in European banking”, European Financial Management 13 (1), 49–70

Anginer, D. and Demiurgic-Kunt, A. (2014), “Bank capital and systemic stability” Policy Research Working Paper No. 6948. The World Bank, Washington, DC.

Anginer, D., Demiurgic-Kunt, A. and Zhu, M. (2014), “How does bank competition affect systemic stability?” Journal of Financial Intermediation 23 (1), 1–26.

Ashcraft, A. (2001), “Do tougher bank capital requirements matter? New evidence from the eighties”, Working Paper (Federal Reserve Bank of New York, 2001).

Barrell, R. and Davis, E.P. (2008), "The evolution of the financial crisis of 2007-8", National Institute Economic Review, 206, 5-14

Barrell, R., Davis, E.P., Fic, T., Holland, D., Kirby, S. and Liadze, I. (2009), "Optimal regulation of bank capital and liquidity: how to calibrate new international standards, FSA Occasional Paper No 38

Barrell, R., Davis, E.P., Karim, D. and Liadze, I. (2010), “Bank regulation, property prices and early warning systems for banking crises in OECD countries”. Journal of Banking and Finance, 34, 2255-2264

Barth, J.R., Caprio, G. and Levine, R. (2006), “Rethinking bank regulation: Till angels govern”, Cambridge University Press, Cambridge, UK.

Barth, A. and Steiniger, C. (2018), “Capital regulation with heterogeneous banks – unintended consequences of a too strict leverage ratio”, Journal of Banking and Finance, 88, 455-465

Basel Committee (2014), “Basel III leverage ratio framework and disclosure requirements”, Bank for International Settlements

Basel Committee (2016), “Consultative Document: Revisions to the Basel III leverage ratio framework”, Bank for International Settlements

Baumol, W.J., Panzar, J.C. and Willing, R.D. (1982). “Contestable Markets and the Theory of Industry Structure”, San Diego: Harcourt Brace Jovanovich.

Beck, T., De Jonghe, O. and Sheens, G. (2013), “Bank competition and stability: Cross-country heterogeneity”, Journal of Financial Intermediation, 22 (2013). 218–244.

Berger, A., Clapper, L.F. and Turk-Arises, R. (2009), “Bank competition and financial stability”, Journal of Financial Services Research, Vol. 35, pp. 99-118.

Bhagat, S., Bolton, B. and Lu, J. (2015), “Size, leverage and risk taking of financial institutions”, Journal of Banking and Finance, 59, 520-537

Bikker, J. (2004), “Competition and efficiency in a unified European banking market”, Cheltenham: Edward Elgar.

Bikker, J., Shaffer, S., and Spierdijk, L. (2012), “Assessing competition with the Panzar-Rosse model, the role of scale, costs and equilibrium”, Review of Economics and Statistics, 94, 1025–1044.

Bitar, M., Pukthuanthong, K. and Walker, T. (2018), “The effect of capital ratios on the risk, efficiency and profitability of banks: Evidence from OECD countries”, Journal of International Financial Markets, Institutions and Money, 53, 227-262

Blum, J. (1999), “Do capital adequacy requirements reduce risks in banking?” Journal of Banking and Finance, 23 (5), 755–771.

Brei, M. and Gambacorta, L. (2014), “The leverage ratio over the cycle“ BIS Working Papers No 471

Boyd, J.H. and Runkle, D.E. (1993), “Size and performance of banking firms – testing the predictions of theory”. Journal of Monetary Economics, 31 (1), 47–67.

Bruno, O., Cartapanis, A. and Nasica, E. (2014), “Bank leverage, financial fragility and prudential regulation”, GREDEG Working paper Series 2014-12

Cathcart, L., El-Jahel, L. and Jabbour, R. (2015), “Can regulators allow banks to set their own capital ratios?”, Journal of Banking and Finance, 53 (4), 112–123.

Claessens, S. and Laeven, L. (2004), “What drives bank competition? Some international evidence”, Journal of Money, Credit, and Banking, Vol. 36 (3), 2004, pp. 563–83

Davis, E.P. (1995), “Debt, financial fragility and systemic risk, revised and expanded edition”, Oxford University Press.

Davis, E.P. (2017), “Evaluating Concentration and Distribution Measures of IMF Financial Soundness Indicators” Brunel University Economics and Finance Working Paper No 17-23.

Davis, E.P. and Karim, D. (2013), “Exploring the short and long term relation between bank competition and risk – reconciling conflicting hypotheses?” NIESR Discussion Paper 421

Davis, E.P. and Karim, D. (2018), ”Exploring Short- and Long-Run Links from Bank Competition to Risk”, European Financial Management

Davis E.P., Karim, D. and Noel, D. (2019), "The bank capital-competition-risk nexus; a global perspective", Brunel Economics and Finance Working Paper No. 19-03

De Bandt, O., and Davis, E.P. (2000), "Competition, contestability and market structure in European banking on the eve of EMU", Journal of Banking and Finance, 24, 1045–66.

De Jonghe, O. (2010), "Back to the basics in banking? A micro-analysis of banking system stability". Journal of Financial Intermediation 19 (3), 387–417.

Demirgüç-Kunt, A., Detragiache, E. and Merrouche, O. (2013), "Bank capital: Lessons from the financial crisis", Journal of Money, Credit Banking, 45 (6), 1147–1164.

Demirgüç-Kunt, A. and Huizinga, H. (2010), "Bank activity and funding strategies: the impact on risk and returns", Journal of Financial Economics, 98 (3), 626–650.

de-Ramon, S., Francis, W. and Straughan, M. (2018), "Bank competition and stability in the United Kingdom" Bank of England Staff Working Paper No 748

Dermine, J. (2015), "Basel III leverage ratio requirement and the probability of bank runs", Journal of Banking and Finance, Volume 53, April 2015, Pages 266–277

D'Hulster, K. (2009), "The leverage ratio, a new binding limit on banks" Crisis Response Note No 11, The World Bank Group

Diamond, D. and Rajan, R. (2000), "A theory of bank capital", Journal of Finance, 55, 2431-2465

Flannery, M. and Rangan, K. (2008), "What caused the capital build-up of the 1990?" Review of Finance, Vol. 12, 2008, pp. 391–429.

Frazzini, A. and Pedersen, L.H. (2012), "Embedded Leverage", NBER Working Paper 18558

Freixas, X. and Ma, K. (2015), "Banking Competition and Stability: The Role of Leverage", Barcelona GSE Working Paper Series Working Paper nº 781

Grill, M., Lang, J.L. and Smith, J. (2015), "The impact of the Basel III leverage ratio on risk taking and bank stability", ECB Financial Stability Review, November 2015, 1-3

Hambusch, G. and Shaffer, S. (2012), "Forecasting bank leverage" Working paper 176, Finance Discipline Group, UTS Business School

Haldane, A. and Madouros, V. (2012), "The dog and the Frisbee". In Speech given at Jackson Hole, Wyoming.

Holmstrom, B. and Tirole, J. (1997), "Financial intermediation, loadable funds and the real sector", Quarterly Journal of Economics, 52, 663-692

Iannotta, G., Nocera, G. and Sironi, A. (2007), "Ownership structure, risk and performance in the European banking industry". Journal of Banking and Finance 31 (7), 2127–2149.

IJtsma, P., Spierdijk, L. and Shaffer, S. (2017), "The Concentration-stability controversy: new evidence from the EU-25", Journal of Financial Stability 33, pp. 27,3-284.

Karim, D., Liadze, I., Barrell, R. and Davis, E.P. (2013), “Off-balance sheet exposures and banking crises in OECD countries” Journal of Financial Stability, 9, 673-681

Kellermann K. and Schlag, C. (2013), “Occupy risk weighting, how the minimum leverage ratio dominates capital requirements”, Journal of Financial Regulation and Compliance, 21, 353-372.

Kiema, I. and Jokivuolle, E. (2014), “Does a leverage ratio requirement increase bank stability?” Journal of Banking and Finance, 39, 240-254.

Klomp, A. and de Haan, L. (2012), “Banking risk and regulation: Does one size fit all?” Journal of Banking & Finance, 36, 3197–3212

Köhler, M. (2013), “Does non-interest income make banks more risky? Retail- versus investment-oriented banks”, Discussion Paper 17/2013, Deutsche Bundesbank

Koenker, R. and Bassett, G. (1978), “Regression quantiles”, Econometrica, 46, 33-50

Lee, C. and Hsieh, M. (2013), “The impact of capital on profitability and risk in Asian banking”. Journal of International Money and Finance 32, 251–281.

Liu, H., Molyneux, P. and Wilson, J. (2013), “Competition and stability in European banking, a regional analysis”, Manchester School, 81, 176-201

Minsky, H.P. (1982), “Can it happen again?”, M E Sharpe New York.

Ondo-Ndong, S. and Rigot, S. (2011), “The aggregated leverage ratio and the detection of financial vulnerability, evidence for the US and European countries”, Brussels Economic Review, 54, 5-20

Panzar, J.C. and Rosse, J.N. (1987), “Testing for ‘Monopoly’ Equilibrium” Journal of Industrial Economics, 35 (4), 443–456.

Pfeifer, L., Holub, L., Pikhart, Z. and Hodula, M. (2015), “The role of the leverage ratio in capital regulation of the banking system”, Czech National Bank Financial Stability Report 2015/6

Schaeck, K. and Čihák, M. (2012), “Banking competition and capital ratios”. European Financial management, 18, 836-866.

Schaeck, K. and Čihák, M. (2014), “Competition, efficiency, and stability in banking”, Financial Management, Spring, pp. 215-241.

Shaffer, S. and Spierdijk, L. (2015), “The Panzar–Rosse revenue test and market power in banking”, Journal of Banking and Finance, 61, 340-7

Stackhouse, J.L. (2008), “Prompt Corrective Action: What Does It Mean for a Bank’s Liquidity?”, Central Banker, Federal Reserve Bank of St Louis, Fall 2008

Stiglitz, J.E. and Weiss, A.M. (1981), “Credit rationing in markets with incomplete information” American Economic Review, 71.393–410.

Tan, Y. and Floros, F. (2013), “Risk, capital and efficiency in Chinese banking”. Journal of International Financial Markets, Institutions and Money, 26, 378–393.

Tirole, J. (1988), “The theory of industrial organisation” MIT Press, Cambridge, Mass.

Weill, L. (2013), Bank competition in the EU: How has it evolved? Journal of International Financial Markets, Institutions and Money, 26, 100–112.

White, H. (1980), “Nonlinear regression on cross section data” Econometrica, 48, 721–746.

Yang, X. (2016), “Predicting bank failures: The leverage versus the risk-weighted capital ratio”, Working paper 2016-15, University of Paris-Nanterre

Zigraiova, D. and Havranek, T. (2016), “Bank competition and financial stability: much ado about nothing?”, Journal of Economic Surveys, Vol. 30, No. 5, pp. 944–981.

APPENDIX 1: STATISTICAL PROPERTIES OF VARIABLES

Table A1: Statistical measures for variables to derive competition

UNITED STATES	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
GROSSINTREV_Q99	6.45E+08	70300000	1.89E+10	500000	2.26E+09	14625
IED_Q99	0.022	0.021	0.061	0.00075	0.014	13653
PTA_Q99	0.016	0.014	0.11	0.00035	0.013	14569
OCF_Q99	4.66	1.06	185.0	0.25	20.55	14342
CDT_Q99	0.92	0.96	1	0.16	0.13	13786
LAR_Q99	0.64	0.67	0.94	1.00E-08	0.19	14664
OTA_Q99	0.096	0.072	0.62	0.015	0.09	14781
LEVERAGE_Q99	0.12	0.096	0.78	0.022	0.096	14704
TOTALCOST_Q99	6.78E+08	68200000	2.14E+10	1023750	2.52E+09	14625
IES_Q99	0.025	0.022	0.093	0.00073	0.018	13757
TOTALASSETS_Q99	1.36E+10	1.44E+09	3.64E+11	21057480	4.57E+10	14781
PRICE	0.076	0.062	6.36	-0.1	0.14	14622
MC99	0.054	0.047	5.46	7.29E-06	0.081	13495

EUROPE	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
GROSSINTREV_Q99	2.99E+08	23155715	1.06E+10	3375.07	1.27E+09	84540
IED_Q99	0.024	0.022	0.11	0.0015	0.016	64181
PTA_Q99	0.018	0.013	0.28	0.0002	0.033	82392
OCF_Q99	4.33	0.86	107.41	0.15	13.67	81403
CDT_Q99	0.74	0.81	0.99	0.002	0.24	75849
LAR_Q99	0.59	0.62	0.99	0.0016	0.24	83586
OTA_Q99	0.059	0.029	0.81	0.0011	0.11	86095
LEVERAGE_Q99	0.12	0.08	0.9	0.0062	0.15	86080
TOTALCOST_Q99	3.07E+08	25890376	1.10E+10	737910.9	1.30E+09	84455
IES_Q99	0.028	0.023	0.23	0.00045	0.03	75246
TOTALASSETS_Q99	7.61E+09	5.87E+08	2.84E+11	4939817	3.35E+10	86245
PRICE	0.079	0.054	14.94	-5.22	0.19	84221
MC99	0.049266	0.041379	5.857807	0.000314	0.063238	72418

Notes: GROSSINTREV is the gross interest revenue, IED is the ratio of interest expenses to total debt funding, PTA is personnel expenses divided by total assets, OCF is the ratio of other operating expenses to fixed assets, CDT is the ratio of customer deposits to total short term funding, LAR is the ratio of bank loans to assets, LEVERAGE is the leverage ratio, TOTALCOST is the total cost, IES is the ratio of interest expenses to the sum of total deposits and money market funding TOTALASSETS is the total assets of the bank, PRICE is the price of services and MC99 is the marginal cost, both as defined in the text. Q99 shows a variable winsorised at 99% and Q95 a variable winsorised at 95%.

Table A2: Statistical measures for risk regressions

UNITED STATES	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
H99_Q99	-0.25	-0.47	0.76	-1.19	0.55	24130
LERNER_Q99	0.24	0.25	0.55	-0.38	0.14	13491
LNZSCORE_Q99	3.75	3.82	6.77	0.37	1.2	13375
LEVERAGE_Q99	0.12	0.096	0.78	0.022	0.096	14704
TOTALREGCAPRATIO_Q99	17.24	13.73	106.74	8.09	12.76	13585
TIER1REGCAPRATIO_Q99	15.87	12.36	107.08	6.66	13.05	13487
NIR_Q99	0.25	0.21	0.99	-0.075	0.19	14614
LOG(TOTALASSETS_Q99)	21.2	21.09	26.62	16.86	2.03	14781
PII_Q99	12.1	5.36	128.39	-11.16	21.3	13014
LLPL_Q99	0.64	0.29	6.66	-0.59	1.12	13732
IMPLR_Q99	0.016	0.0075	0.15	0	0.025	13628

EUROPE	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
H99_Q95	0.122	0.31	1.47	-2.17	0.97	149354
LERNER_Q99	0.211	0.21	0.57	-0.4	0.14	72381
LNZSCORE_Q99	3.852	3.877	7.036	0.318	1.258	77056
LEVERAGE_Q99	0.120	0.08	0.9	0.006	0.15	86080
TOTALREGCAPRATIO_Q99	18.58	16.18	77.34	7.63	10.14	39431
TIER1REGCAPRATIO_Q99	16.41	14.02	70.63	5.4	9.79	30518
NIR_Q99	0.34	0.27	1.1	-0.27	0.26	84179
LOG(TOTALASSETS_Q99)	20.37	20.19	26.37	15.41	1.98	86245
PII_Q99	16.02	10.88	192.13	-73.76	31.47	68283
LLPL_Q99	0.74	0.43	10.9	-3.16	1.6	72092
IMPLR_Q99	0.057	0.031	0.39	0.00	0.072	32638

Notes: H is the H statistic for the country concerned, LERNER is the Lerner Index for the bank concerned, LNZSCORE is the log of the Z Score, LEVERAGE is the leverage ratio, TOTALREGCAPRATIO is the total risk adjusted capital ratio and TIER1 REGCAPRATIO is the corresponding Tier 1 ratio, NIR is the share of noninterest income in the total, TOTALASSETS is the total assets of the bank, PII is the loan loss provisions to income ratio, LLPL is the loan loss provisions to loans ratio, IMPLR is the non-performing loans to loans ratio.

APPENDIX 2: RESULTS FOR COMPETITION ESTIMATION

Table A3: Aggregate equations for the Lerner Index with homogeneity restrictions imposed (dependent variable: log total costs _q99) 1998-2016

LERNER INDEX:				
LOG(TOTALCOST_Q99)= B(1) + B(2)*LOG(TOTALASSETS_Q99) + B(3)				
*LOG(TOTALASSETS_Q99)^2 +B(4)*LOG(IES_Q99) +B(5)				
*LOG(PTA_Q99) +(1-B(4)-B(5))*LOG(IES_Q99) +B(7)				
*LOG(IES_Q99)*LOG(TOTALASSETS_Q99) +B(8)				
*LOG(PTA_Q99)*LOG(TOTALASSETS_Q99) + (0-B(7)-B(8))				
*LOG(OCF_Q99)*LOG(TOTALASSETS_Q99) + B(10)				
*LOG(IES_Q99)*LOG(IES_Q99) +B(11)				
*LOG(PTA_Q99)*LOG(PTA_Q99) + (0-(0-B(11)-B(13))				
-(0-B(10)-B(13)))*LOG(OCF_Q99)*LOG(OCF_Q99) +				
B(13)*LOG(IES_Q99)*LOG(PTA_Q99) + (0-B(11)				
-B(13))*LOG(PTA_Q99)*LOG(OCF_Q99) + (0-B(10)				
-B(13))*LOG(IES_Q99)*LOG(OCF_Q99)				
	UNITED		EUROPE	
	STATES			
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic
B(1)	1.60	9.0***	1.16	12.1***
B(2)	0.94	58.2***	0.92	103.7**
B(3)	0.000702	1.8*	0.0019	9.1***
B(4)	-0.033	-1.6	0.0024	0.2
B(5)	1.22	53.2***	0.85	80.1***
B(7)	0.015	16.9***	0.02	44.1***
B(8)	-0.023	-22.0***	-0.013	-25.2***
B(10)	0.018	17.0***	0.033	78.9***
B(11)	0.032	28.9***	0.031	65.8***
B(13)	-0.016	-23.2***	-0.027	-98.5***
Periods included	19		19	
Cross-sections included	1101		6327	
Observations	13495		72418	
R-squared	0.987		0.981	
Adjusted R-squared	0.987		0.98	
S.E. of regression	0.227		0.258	
Fixed effects	Period		Period	

Notes: For variable definitions see Appendix 1. *** implies significance at 99%, ** at 95% and * at 90%.

Table A4: Aggregate equations for the H statistic (dependent variable: log gross interest revenue_q99) 1998-2016

H Statistic	**UNITED STATES**		**EUROPE**	
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic
C	18.73	215.6***	17.01	538.2***
LOG(IED_Q99)	0.43	33.1***	0.49	112.1***
LOG(PTA_Q99)	-0.19	-13.5***	-0.34	-55.2***
LOG(OCF_Q99)	0.084	8.7***	-0.03	-10.8***
LOG(LAR_Q99)	0.15	19.5***	0.24	47.0***
LOG(OTA_Q99)	-0.065	-6.2***	-0.027	-8.9***
LOG(CDT_Q99)	-0.23	-6.3***	0.017	4.1**
LOG(LEVERAGE_Q99)	-0.13	-7.7***	-0.35	-65.4***
Periods included	19		19	
Cross-sections included	1084		5510	
Observations	13338		62162	
R-squared	0.952		0.974	
Adjusted R-squared	0.948		0.971	
S.E. of regression	0.459		0.320	
Fixed effects	Cross section and period		Cross section and period	
Estimated H				

Notes: For variable definitions see Appendix 1. *** implies significance at 99%, ** at 95% and * at 90%.

APPENDIX 3: LERNER INDICES FOR INDIVIDUAL EUROPEAN COUNTRIES

In this Appendix we show charts for individual European countries' Lerner Indices and provide comment on the differing patterns. Figure A1 shows margins in the UK were generally below those in France, Italy and Spain. A further fall in margins in Spain at the time of the Euro debt crisis is not repeated elsewhere, the other countries showing a pattern of recovery in margins after 2008 similar to the EU as a whole. A similar pattern to Spain can be seen in Cyprus, Greece and Portugal in Figure A2, while margins in Malta (on a small number of banks) are very volatile.

Figure A1: Lerner indices for four major EU countries

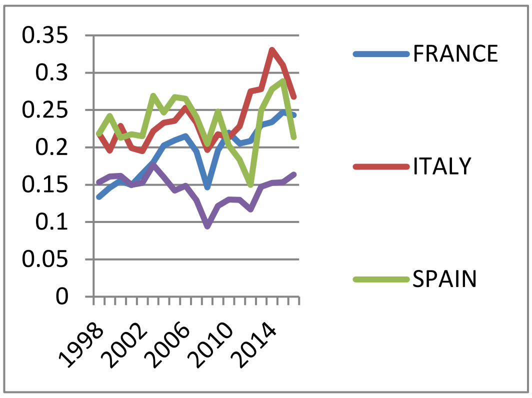


Figure A2: Lerner indices for Mediterranean EU countries

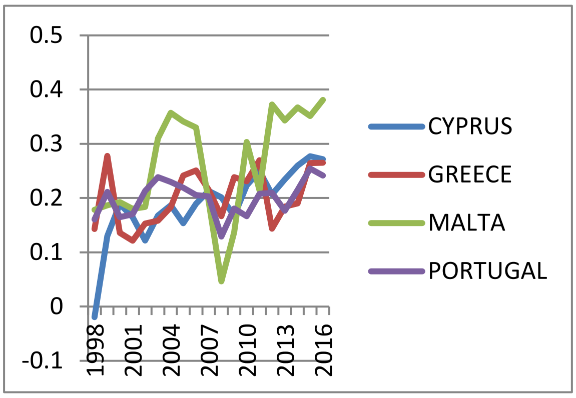


Figure A3 shows high volatility in Iceland also. The other Nordic countries follow the EU pattern, with a particular decline in Norway up to the subprime crisis. Figure A4 shows a low level of margins in Belgium and the Netherlands throughout the early 2000s, with a recovery after the GFC, while Ireland shows greater volatility.

Figure A3: Lerner indices for Nordic EU/EEA countries

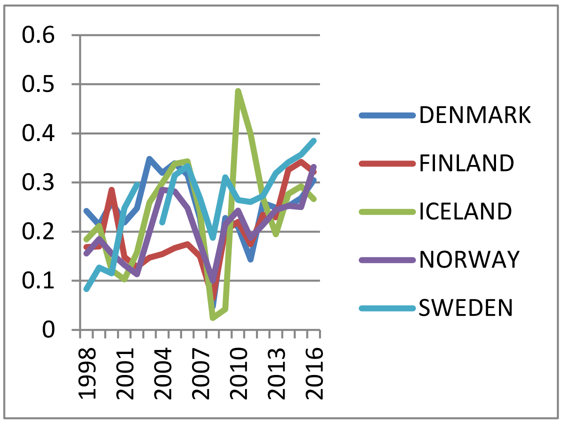
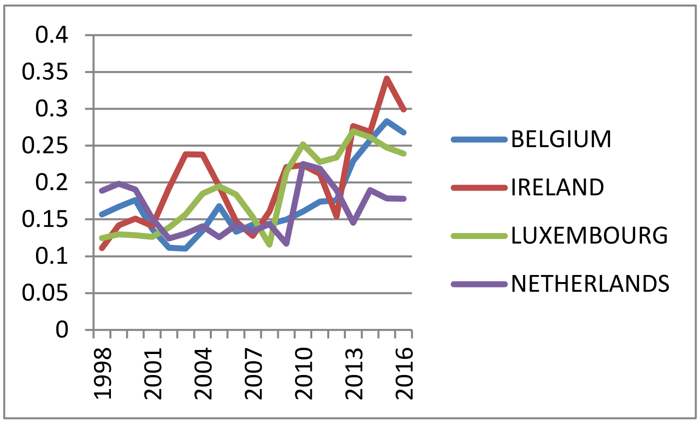


Figure A4: Lerner indices for smaller Western EU countries



In the four Alemannic countries (Figure A5), Germany shows an overall rise in margins throughout the sample while Austria and Switzerland exhibit more volatility, in the Swiss case varying fairly close to a constant mean. The Baltic countries in Figure A6 show at the beginning of the sample very low or negative margins that may reflect the end of transition. Thereafter the pattern is similar to the EU mean.

Figure A5: Lerner indices for Alemannic EU/EEA countries

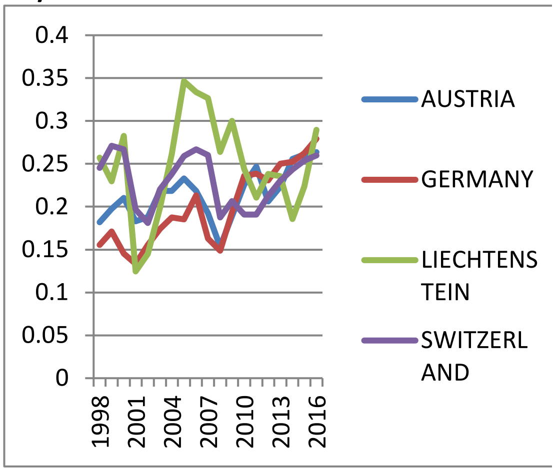


Figure A6: Lerner indices for Baltic EU countries

A similar pattern of very low margins for the early years is apparent for the Visegrad countries in Figure A7. There appears to be little effect of the GFC, with an ongoing rise in margins in the Czech Republic and Slovakia, flat in Poland since 2008 but a fall in Hungary. Finally in the Balkan countries (Figure A8) the margins in Romania are consistently low absolutely and relative to Bulgaria, while Slovenia and Croatia are intermediate.

Figure A7: Lerner indices for Visegrad EU countries

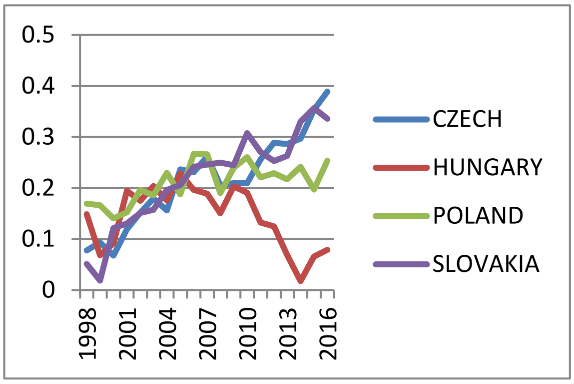
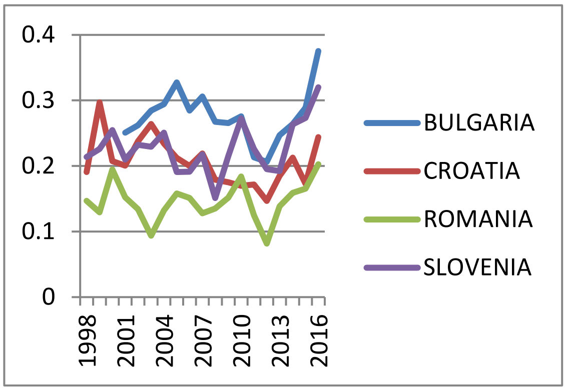


Figure A8: Lerner indices for Balkan EU countries



APPENDIX 4: CAPITAL COEFFICIENTS IN SUBSAMPLES

Table A5: Country assessment of capital effects for log Z-score

Log Z-Score	H statistic			Lerner index		
	LEV	TOT	TIER	LEV	TOT	TIER
UK full sample			1.64*** (2.8)	1.03* (1.7)		2.78*** (2.9)
France full sample	2.27*** (9.4)		1.79** (2.3)	2.94*** (7.5)		2.64*** (2.8)
Germany full sample	1.13*** (5.3)	1.36*** (6.8)	1.69*** (8.2)	1.09*** (4.5)	1.39*** (8.0)	1.91*** (10.8)
Italy full sample	2.31*** (8.1)	1.23*** (5.9)	1.46*** (7.1)	2.1*** (5.2)	1.3*** (5.8)	1.6*** (6.0)
UK 1998 -2007	-0.93** (2.6)	1.18*** (3.0)	4.5*** (3.6)	-0.67* (1.8)	1.43** (2.6)	3.0*** (2.8)
UK 2008-2016	2.0*** (3.3)	2.0** (2.4)	2.8*** (3.8)	2.27*** (3.6)		3.8*** (3.4)

Note: Results are shown for capital ratios only, each regression includes all the additional control variables shown in Tables 3 and 4. Cells shown in grey show a negative relation of capital ratios to risk, cells shown in white show a positive relation of capital ratios to risk. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.

APPENDIX 5: FULL RESULTS FOR QUANTILE REGRESSIONS

Table A6: Quantile regression results for Lerner Index and leverage: four risk measures

Risk measure	Independent variable	**US: Lerner index, leverage**			**Europe: Lerner Index, leverage**		
Percentile		10	50	90	10	50	90
Provisions ratio	D Lerner_q99 inst	0.083*** (3.9)	0.12*** (3.0)	-0.5*** (3.5)	0.37*** (10.3)	0.33*** (9.9)	0.66*** (8.7)
	Lerner_q99 (t-2)		-0.47*** (7.4)	-2.57*** (10.0)	-0.19*** (2.8)		
	Lerner_q99 (t-3)	0.078* (1.8)	0.12** (2.1)	1.11*** (7.6)	0.47*** (6.3)	0.4*** (7.3)	1.08*** (8.4)
	Long run effect	0.078	-0.35	-1.46	0.28	0.4	1.08
	Leverage (t-1)	-0.73*** (6.8)	-0.17* (1.9)	4.85*** (5.8)	-0.67*** (5.3)	-0.71*** (10.4)	5.8*** (10.1)
Impaired loans ratio	D Lerner_q99 inst		- 0.0057*** (5.9)	-0.017*** (8.7)			
	Lerner_q99 (t-2)	-0.004*** (4.9)	-0.019*** (10.2)	-0.048*** (8.3)		0.014*** (3.0)	-0.019* (1.9)
	Lerner_q99 (t-3)		0.003* (1.7)			-0.011 (2.3)	-0.022* (1.9)
	Long run effect	-0.004	-0.016	-0.048		0.003	-0.041
	Leverage (t-1)	-0.002** (2.2)	0.0078*** (3.7)	0.046* (1.8)	0.027*** (9.5)	0.14*** (12.3)	0.49*** (15.4)
Loan growth	D Lerner_q99 inst	0.064*** (7.8)	0.05*** (6.1)	0.039** (2.5)	0.074*** (9.2)	0.02*** (3.7)	0.03** (2.6)
	Lerner_q99 (t-2)	0.213*** (9.6)	0.103*** (6.9)	0.132*** (4.8)	0.097*** (7.4)	-0.053*** (4.4)	-0.19*** (7.9)
	Lerner_q99 (t-3)	-0.064*** (4.1)	-0.056*** (3.7)	-0.174*** (5.0)	0.052*** (3.5)	0.062*** (5.4)	0.075*** (3.4)
	Long run effect	0.149	0.047	-0.042	0.149	-0.009	-0.115
	Leverage (t-1)	-0.29*** (3.5)	-0.073** (2.4)	0.57** (2.6)	-0.44*** (11.6)	-0.12*** (6.3)	0.6*** (11.2)
Z-Score	D Lerner_q99 inst	1.09*** (22.8)	0.89*** (7.8)		0.54*** (15.8)	0.38*** (6.7)	0.25* (1.8)
	Lerner_q99 (t-2)	2.45*** (16.1)	2.08*** (12.0)	1.95*** (8.1)	1.44*** (17.8)	1.41*** (15.4)	0.84*** (3.5)
	Lerner_q99 (t-3)				0.18** (2.0)		
	Long run effect	2.45	2.08	1.95	1.62	1.41	0.84
	Leverage (t-1)		1.36*** (5.7)		-0.84*** (3.8)	0.56*** (5.5)	1.7*** (9.8)

Note: the table shows the competition measures and capital measures from the quantile equations with Lerner for competition and leverage for capital. All other control variables are also included. Cells for competition shown in white show a negative relation of competition to risk (competition-stability), cells for competition shown in dark grey show a positive relation of competition to risk (competition-fragility). Cells for capital shown in light grey show a negative relation of capital ratios to risk, cells for capital shown in white show a positive relation of capital ratios to risk. Δ means current first difference. t values in parentheses, *** implies significance at 99%, ** at 95% and * at 90%.