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The bank capital-competition-risk nexus – A global perspective ☆

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ABSTRACT

Empirical studies of banking risk, be it at the institution or sector level, typically focus on either the relationship of competition to risk or bank capital adequacy to risk, but only a subset of studies integrate the two. Lack of integration entails potential bias arising from omission of relevant control variables, and accurate assessment of the interrelations is particularly important in the light of the introduction of a regulatory leverage ratio alongside risk-adjusted capital adequacy in Basel III, as well as macroprudential surveillance and policy which seeks to forecast, assess and control risk at a sectoral level. To advance the literature, we provide estimates for the relation between capital adequacy, bank competition and four measures of aggregate bank risk for different country groups and time periods. Our modelling approach uses control variables that capture aspects of banks' business models that contribute to financial stability, aggregated to the level of the banking sector. We use macro data from the World Bank's Global Financial Development Database over 1999–2015 for up to 112 countries globally. We contend that use of macro data means our results are of particular relevance to regulators undertaking macroprudential surveillance, because such data gives a greater weight to large systemic institutions than the more commonly-used bank-by-bank data. Results largely support "competition-fragility", i.e. a positive relation of competition to risk controlling for capital; both capital measures controlling for competition are significant predictors of risk, but signs vary across risk measures; the leverage ratio is just as widely relevant as the risk-adjusted capital ratio; and there are some differences in results between advanced countries and emerging market economies. Finally, we find competition drives capital ratios lower in a Panel VAR.

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1. Introduction

Empirical studies of banking risk typically focus on either the relationship of competition to risk or bank capital adequacy to risk, but only a subset of studies integrate the two. Lack of integration raises an issue of potential bias arising from omission of relevant control variables (capital or competition, respectively), and is of particular importance in the light of the introduction of a regulatory leverage ratio (bank capital to unadjusted assets) in Basel III, as well as the growing importance of macroprudential surveillance and policy which seek to forecast, assess and control risk at a sectoral level.

To advance the literature, we undertake empirical research which assesses the effectiveness of an aggregate leverage ratio[4] relative to a measure of the risk-adjusted capital ratio in affecting banking-sector risk given competition. We carry out estimation for different country groups before and after the global financial crisis (GFC), using country-level macro data for up to 112 countries from the World Bank's Global Financial Development Database over 1999–2015. Our modelling approach is to choose banking sector independent variables that characterise aspects of banks' business models that contribute to financial stability, aggregated to the level of the banking sector, as used in the key competition-risk study of Beck et al. (2013). We utilise both appropriate single equation methods (Logit and Generalised Method of Moments (GMM)) and Panel Vector-Autoregressive (Panel VAR) approaches.

Our approach enables us to address afresh a number of unresolved empirical issues in the field of financial stability. First, there is the relation of capital adequacy of banks to risk, where two opposing points of view can be discerned, that capital and risk are inversely related ("skin in the game") or that there is a positive relation of capital to risk ("the regulatory hypothesis"). Then, there is the observation that bank leverage ratios often predicted risk in the crisis better than the risk-adjusted capital ratio. This prompted the introduction of a leverage ratio in Basel III, but its effectiveness is still not fully tested. Third, there is the relationship between bank competition[5] and financial stability, where the opposing points of view are that competition prompts risk taking ("competition-fragility") and that it rather leads to stability ("competition-stability"). Our results permit us to also address a fourth issue, namely the relative stability of Advanced versus Emerging Market Economy financial systems, and whether similar factors lead to risk. Finally we assess the nature of the relation between bank competition and bank capital.

Our advance from most existing work in the fields of capital and risk and competition and risk is to include both competition and capital in all estimates of risk. Our distinctive contribution also compared with studies that do assess capital, competition and risk together (as summarised in Section 2) is first, by use of macro data, our work is more appropriate for macroprudential assessment. This is the case inter alia because macro data provides weighted average information, thus implicitly giving greater importance to large systemic institutions, while micro work typically weights institutions equally. Second, our approach is global rather than regional or country-specific, enabling results to be analysed both globally and separately for groups of countries at different stages of economic development. Third, to our knowledge this is the first study in this area to undertake Panel VAR estimation that allows the three variables competition, capital and risk to be jointly endogenously determined. Further advances are detailed in Section 3.1.

The paper is structured as follows: in Section 2 we provide an overview of the existing literature in the bank capital-competition-risk nexus, Section 3 introduces the methodology and data, Section 4 provides the main results which are summarised in Section 5. Section 6 provides robustness checks, Section 7 gives complementary Panel VAR estimates which address the competition/capital relation and Section 8 concludes.

2. Existing literature

Our work derives largely from two distinct strands of the empirical literature on banking risk, be it at an institution or a sectoral level. First there are empirical estimates of the effect of capital on risk, which generally does not include competition as a control variable.[6] There are two distinct hypotheses. 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, so obliging banks to hold more capital via regulation improves screening and monitoring and reduces the risk of bailouts (Demirgüç Kunt et al., 2013). For results supporting this view see, for example, Lee and Hseih (2013) who investigated individual banks in Asian countries, Tan and Floros (2013) with a sample of Chinese banks, and Anginer and Demirgüç Kunt (2014) with a global sample of individual banks.

[4] The variable we employ is distinct from the leverage ratio as defined in Basel III, as we include all regulatory capital in the numerator and on-balance-sheet assets only in the denominator, in contrast to the Basel III definition of Tier 1 capital divided by the bank's average total consolidated assets (sum of the exposures of all assets and non-balance-sheet items).

[5] Competition also plays a critical role in the efficient operation of the financial system and is therefore important for economic growth. As such, its regulation should be one of the key challenges of financial policy.

[6] Some of the papers cited below (such as Tan and Floros, 2013) do include market structure variables such as the 3 or 5 firm concentration ratio, but it can be argued that this is not a satisfactory measure of competition, not least because it does not allow for the effect of potential competition and contestable markets.

The alternative is the "regulatory hypothesis" which would suggest that regulators require higher capital in response to higher risk, and so a positive relation of capital to risk would be expected.[7] This is, for example, found by Iannotta et al. (2007) for European banks and Bitar et al. (2018), whose sample covered banks in OECD countries.

A particular area of interest in the bank capital-risk literature, given the recent introduction of leverage ratios to global regulation in Basel III, is whether leverage ratios[8] or risk-adjusted capital ratios are better predictors of bank risk. Empirical work[9] on leverage ratios as a regulatory instrument in the Basel context is quite recent and rather sparse, particularly outside the US. It has been mostly undertaken since the 2007–2008 global financial crisis, as excess bank leverage was identified as one of the causes of the crisis. Examples include Yang (2016) who looked at leverage and risk-weighted capital as predictors in 417 US bank failures between 2008 and 2012 using logit. The key finding was that 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 for major global banks is a superior failure predictor to the risk-adjusted capital ratio, see also Aikman et al. (2018).[10]

Bitar et al. (2018) found risk-based capital measures are unrelated to bank risk, whereas unadjusted measures such as the leverage ratio are significantly positively related to risk (measured by loan-loss reserves). They suggest that the ineffectiveness of risk-adjusted measures may relate to untruthful assessment of banks' real risk exposure.[11] Davis et al. (2019a), using data from individual banks in Europe and the US, found leverage ratios to be more often significant than risk-adjusted capital in determination of bank risk. Brei and Gambacorta (2014) tested for procyclicality of capital ratios for international banks headquartered in advanced countries and found the leverage ratio is significantly more countercyclical than the risk-adjusted capital ratio; it is a tighter constraint for banks in booms and a looser constraint in recessions. Berger and Bouwman (2013) looked at the effect of the leverage ratio on survival probabilities of US commercial banks and market share and found some differences with results for the risk-adjusted capital ratio.

The second background to our work is the literature on the relation of bank competition to risk which is summarised in Davis and Karim (2018); Zigraiova and Havranek (2016). The competition/risk literature is divided between those works which support "competition-fragility", that more competition leads to higher risk, and "competition-stability", which suggests more competition leads to lower risk. Capital adequacy is generally not included as a control variable.

According to "competition-fragility" (Keeley, 1990), institutions in an uncompetitive banking system have incentives to avoid risk, because a banking licence is valuable in such a context, with restricted entry and probably large capital cushions. When deregulation arises, the value of the licence declines, as excess returns are competed away both by new entrants (including from abroad, where permitted) and by more intense competition between existing players. This situation gives incentives to increase balance-sheet risk to recover the previous level of profitability, since banks effectively shift risks to depositors (or deposit insurers). Some analyses of the Global Financial Crisis (such as Financial Crisis Inquiry Commission (FCIC), 2011) cite competition as a key causal factor. A key study finding "competition-fragility", whose approach to modelling we follow in this paper, is that of Beck et al. (2013) with a global sample of individual banks. They found cross-country variation in the relationship between bank competition and bank stability measured by the Z-score, linked to market, regulatory and institutional features.[12] Other empirical work supporting "competition-fragility" includes studies by Yeyati and Micco (2007) of Latin American banks and Davis and Karim (2018) for European banks.[13]

An alternative view is that of "competition-stability", that increased competition reduces risk in the banking system (Boyd and De Nicolo, 2005). The argument is that, on the one hand, lower lending rates in competitive banking markets increase borrowers' scope for repayment, while on the other hand, higher lending rates in uncompetitive markets lead to adverse selection, with only riskier borrowers seeking funds, and moral hazard inducing borrowing firms to take greater risks. Large banks may be harder to supervise. Empirical studies supporting this view include Anginer et al. (2012) with a global sample of individual banks. Some theoretical work suggests a U-shaped relation between competition and risk, with high and low competition being potentially adverse (Martinez-Miera and Repullo, 2010). See also empirical work in Tabak et al. (2012) noted below.

[7] Note, however, that the "regulatory hypothesis" is not the only possible explanation for a positive relation of capital to risk. Blum (1999) suggests 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. 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.

[8] In policy terms, the leverage ratio is widely considered to complement the risk-adjusted capital ratio (Basel Committee, 2014, revisions proposed 2016). It can prevent excessive leverage building up both for individual institutions and for the system as a whole (D'Hulster, 2009). It acts against procyclicality and against regulatory arbitrage and has the benefit of simplicity. However, it also has limitations – it may have difficulty capturing "embedded leverage" and may give wrong incentives, encouraging banks to take risks, given the lack of risk weighting (Kellermann and Schlag, 2013), implying the risk-adjusted capital ratio is also vital. We note also the potential need for careful design of complementary contingent capital requirements as argued by a number of authors (such as Calomiris and Herring, 2013).

[9] An overview of related theoretical work is provided in Davis et al. (2019a).

[10] Hambusch and Shaffer (2012) sought to forecast bank leverage as an alternative tool for assessing the likelihood of failure. Results support the use of leverage as an indicator for such likelihood. They did not test the risk-adjusted capital ratio as an alternative, however.

[11] See also Bayoumi (2017) for a discussion of the particular role played by banks' internal risk models in underestimation of risk to save capital, which benefited in particular the competitive position of large European banks prior to the Global Financial Crisis.

[12] They found that an increase in competition will have a larger impact on banks' fragility in countries with stricter activity restrictions, lower systemic fragility, better developed stock exchanges, more generous deposit insurance and more effective systems of credit information sharing.

[13] Davis and Karim (2018) did, however, find competition-stability for the long run effect of competition as measured by the H statistic.

We analyse the relation of both capital and competition together to risk, as well as between competition and capital, thus bringing together these two strands of the literature. In doing so, we also follow a relatively small number of authors including theoretical work by Freixas and Ma (2015) who looked at the relation of bank competition to financial stability with a theoretical model and found the effect depends crucially on a bank's type of funding (retail versus wholesale) and whether leverage is exogenous or endogenous. Further theoretical modelling work by Hakenes and Schnabel (2011) suggested that stricter capital adequacy regulations may prevent excessive risk taking if there is competition-fragility but not necessarily in the case of competition–stability.

Concerning empirical work on capital, competition and risk together, Berger et al. (2009) undertook estimation for a sample of largely US banks over 1999–2005, using Z-score, non-performing loans (NPLs), and the leverage ratio as dependent variables. They found that competition increases overall bank risk and decreases capital adequacy, although the relation of the level of the Lerner index with capital adequacy was not significant. Schaeck and Cihák (2012) looked at the effect of competition on capital adequacy for banks from European countries over 1999–2005, and found higher competition gives rise to higher capital ratios. Although they found their result is robust to adjustment for risk-taking, the work did not assess risk per se as a dependent variable, focusing on the competition/capital link only.

Tabak et al. (2012) with a sample of banks in Latin American countries over 2003–8 and the Z-score as a dependent variable, found a U shaped relation of competition to risk - high and low competition benefit stability while average competition gives rise to instability. Larger banks tend to benefit more in terms of stability from competition. Capital benefits stability of all banks in less competitive markets but only large banks in markets with average and high competition. Kick and Prieto (2015) looked at the determinants of bank distress with a focus on the effect of competition at a bank, county and state level within Germany over 1994–2010. They found that at a bank level, market power enhances stability, but at a market level the relation of competition to risk was negative. Capital is one of the control variables but is not a focus of the analysis. De-Ramon et al. (2018) using a sample of UK banks over 1991–2013 found that higher competition in the UK leads to lower leverage ratios, although the effect on stability measured by the Z-score and its subcomponents may be offset by higher profitability. Finally, Barrell and Karim (2019) found that competition measures such as concentration and the Lerner Index did help to predict banking crises in advanced countries, along with aggregate leverage ratios and property prices.

These are some of the few analyses of capital ratios and risk that integrate competition, which is a paradox given the sizeable literatures on capital and risk, and bank competition and risk cited above. In light of the above, we now go on to cast light on issues in the capital-competition-risk nexus globally using single equation panels and panel VARs, contending that our work makes considerable advances on the literature to date.

In undertaking our work, we also address the issue of differences in determination of bank risk between advanced countries and emerging market economies. Most studies of financial stability cited in reviews such as Davis and Karim (2018); Bitar et al. (2018); Zigraiova and Havranek (2016) cover individual countries or only one subgroup (regions, advanced or emerging market economies). The number of studies assessing the differences and similarities between the two groups is relatively small; however, we note recent work by Fratzscher et al. (2016) that does look at post-crisis supervisory changes' effects on risk, comparing advanced and emerging market economies. Meanwhile, Meng and Gonzalez (2017) looks at differences in credit booms between advanced countries, emerging market economies and developing countries.

3. Methodology and data

We commence with a single-equation panel econometric investigation of the relationship of the leverage ratio to risk relative to a risk-adjusted measure of capital adequacy, with competition as an independent variable alongside capital and control variables. We estimate generally from 1999 to 2015, using macro data from the World Bank's Global Financial Development Database (GFDD) (Čihák et al. (2012); World Bank (2017)). We test a global sample and also test for high income countries and emerging markets plus developing economies separately, as well as before and after the financial crisis. (For brevity, we refer to the group of emerging markets plus developing economies simply as emerging market economies.) We offer robustness checks, adding further macroeconomic variables and banking crises. Thereafter in Section 7, we present results of Panel VARs for the interrelation of competition, risk and capital that cast further light on the transmission between these key variables for financial stability analysis.

3.1. Modelling approach and distinctive contribution

Our model follows the modelling approach of the key competition-risk study by Beck et al. (2013), as also employed in Davis and Karim (2018). The vector of independent variables characterizes aspects of a banking sector's weighted average business model that contribute to financial stability. In particular, we include proxies for the funding structure linked to liquidity risk (deposits to assets, which shows the degree to which banks are funded from low cost and stable sources), asset structure and resultant credit risk (loans to assets ratio) and revenue mix which also captures market risk exposure as well as scope for diversification (share of non-interest income in total income). With our additional of aggregate capital ratios (allowing in the case of the risk-adjusted ratio for the Basel measure of balance sheet risk) and banking sector competition, these are key measures that are relevant for macroprudential surveillance.

Comparing our approach with other studies focused on capital, competition and risk, our banking control variables[14] are similar to those in de-Ramon et al. (2018) and somewhat wider than most other studies. Tabak et al. (2012), for example, have control variables that focus on proxies for credit risk and liquidity risk as well as the leverage ratio, which they see as inefficiency correlates. Berger et al. (2009) use only loans to assets and fixed assets to assets, while Schaeck and Cihák (2012) include the interbank ratio, a measure of profitability and a credit risk proxy in their equations for capital ratio determination.

Kick and Prieto (2015) have a somewhat wider set of control variables and use the CAMELS taxonomy to guide choice of controls used by supervisors to assess financial soundness of banks, (with the components of the mnemonic being Capital-Assets-Management-Earnings-Liquidity-Sensitivity to market risk). For comparison, we have in our model measures of capital, assets, liquidity and market risk where the non-interest share can also be seen as a measure of the management choice for income diversification. Note that we do not include as control variables the return on equity (earnings) or cost-income ratio (used for management) as they are outcomes of the banking model choices shown by the independent variables rather than a chosen aspect of the bank business model.[15]

We note that in most cases, extant empirical work focuses on micro data for the dependent variable and most independent variables. Such an approach is clearly relevant for microprudential policy as it provides warning signs of individual bank risk or failure. However, we contend that macro data at a banking sector level as we employ here may be more helpful for macroprudential assessment of economy-wide financial stability, which has come to the fore since the Global Financial Crisis. This is because macro data provides weighted average information, thus implicitly giving greater importance to large systemic institutions, while micro work typically weights institutions equally. If, for example, major institutions are more prone to risk-taking than the more numerous small ones, for example due to too-big-to fail protection, then empirical estimates using micro data would understate the systemic risk.[16] Macro data for financial stability analysis is widely used in the Financial Stability Reports produced by central banks (Cihák, 2006) as well as international organisations such as the IMF. The production since 2002 of the Financial Soundness Indicators data by the IMF (IMF, 2019) (as well as the GFDD that we use by the World Bank (Cihák et al., 2012)), both of which are weighted average macro data, shows the importance accorded to macro data in international policy circles. Macro banking sector data can be embedded in national or global macroeconomic models for simulation and forecasting purposes, as for example in the macroeconomic modelling of effects of macroprudential policy in Davis et al. (2019b). Banking sector level data is also less likely to be affected by merger activity among banks and the issue of survivor bias.

As examples of research work undertaken with such banking sector data see, for example, Sorge and Virolainen (2006) who approximated banking sector soundness in Finland by the aggregate ratio of loan-loss provisions to total loans, and estimated the relationship between this variable and a set of macroeconomic and other explanatory variables. Fratzscher et al. (2016) used a country panel for 50 advanced and emerging market economies drawing the dependent variable (the banking sector level Z-score) from the GFDD to analyse how the post-crisis tightening in supervision and regulation affected aggregate bank stability and aggregate credit growth. They found that higher capital buffers improved aggregate bank stability after the GFC, whereas a strengthening of supervisory independence helped to reduce the decline in domestic credit and improved the stability of banks. Albulescu (2015) looked at the determinants of banking sector profitability in 6 Latin American countries using the IMF Financial Soundness data. Diallo and Al-Mansour (2017) used the banking sector Z-score as a measure of financial stability and assessed the contribution of insurance assets/GDP to it for 26 countries over 1998–2011.

Our advance from most existing work in the fields of capital and risk and competition and risk is to include both competition and capital in all estimates of risk. Our distinctive contribution also compared with the studies cited in Section 2 that do assess capital, competition and risk together is first, by use of macro data, our work is more appropriate for macroprudential assessment. This is the case inter alia because, as outlined above, macro data provides weighted average information, thus implicitly giving greater importance to large systemic institutions, while micro work typically weights institutions equally. Second, our approach is global rather than regional or country-specific, enabling results to be analysed both globally and separately for groups of countries at different stages of economic development. Third, to our knowledge this is the first study in this area to undertake Panel VAR estimation that allows the three variables competition, capital and risk to be jointly endogenously determined.

Fourth, we are able to utilise a much more recent dataset than earlier studies, which allows us specifically to compare pre- and post-crisis periods. This helps to enhance understanding of changes in behaviour related to the crisis and subsequent regulatory changes. Fifth, most of the existing studies do not compare the leverage ratio and risk-adjusted measures of capital adequacy, which is of crucial importance to regulators following Basel III's introduction of the leverage ratio to global regulation. Sixth, we assess multiple measures of risk while most other studies focus on one, with other risk measures being at most for robustness checks. Seventh, we instrument capital for estimation of the Z-score, since capital ratios enter the calculation of the Z-score. Absence of this in certain other studies may lead to false inferences. Finally, our work focuses equally on relations of capital and competition to risk while most studies are largely focused on one of them with the other as a control variable. This approach enables us to address afresh a number of unresolved empirical issues in the field of financial stability, as summarised in the conclusion.

[14] We omit bank size from this discussion as it is in effect used as a form of weighting in the transition from micro to our macro data.

[15] We did, however, test for inclusion of the return on equity (instrumented) and the cost income ratio. This gave broadly similar results to those in the main case. This is similar to the approach of Kick and Prieto (2015) with a set of CAMELS variables. Results are available from the authors on request.

[16] Indeed, for the UK de-Ramon et al (2018) found that a small number of large firms drives the outcomes for the competition-risk relation.

3.2. Dependent variables

Four dependent variables of macroprudential relevance were drawn from the World Bank Global Financial Development Database (GFDD), following Davis (2017). The first three are standard bank risk variables aggregated to the banking sector level (the NPL/loans ratio, provisions/loans ratio and Z-score). The NPL ratio and the provisions/loans ratios are most commonly used as macroprudential policy measures of aggregate bank risk by central banks, regulators or analysts, although many studies also use them as dependent variables (such as Sorge and Virolainen (2006) cited above). The Z-score is most commonly used in research, but less so in macroprudential policy circles. The Z-score is arguably the most general banking risk measure as it reflects the profit and capital cover for the whole of the bank's operations, while the other measures are focused on the loan book. Meanwhile the fourth risk variable, systemic banking crises, is a pure macro variable. It may be seen as a consequence of adverse risk management by banks in aggregate as shown by the other three variables. We also include it for its prominence in the literature on bank competition and risk, while noting its difference in nature from the other three variables, which warrants a different approach to estimation using logit rather than GMM. The variables codes and definitions in the database are provided in Appendix Table A1.

In more detail, our first dependent variable is the non-performing loans (NPL)/Gross loans ratio which may show problems with asset quality in the loan portfolio across the banking-sector as a whole. Its common use in macroprudential policy is reflected inter alia in its inclusion as a Financial Soundness Indicator by the IMF, unlike the other variables (IMF, 2019). It is also widely used in empirical work such as Sorge and Virolainen (2006); Shehzad et al. (2010). 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.[17]

Second, the aggregate Provisions/Gross Loans ratio[18] (PROVLOAN) is an indicator of how well protected a banking-sector is against future losses. It is a measure of loan quality, being an indicator of a precautionary reserves policy and also an anticipation of high future losses, where accounting rules such as IFRS allow. It takes the past and future performance of the loan portfolio into account and is used in studies such as Lee and Hseih (2013) and Bitar et al. (2018).

Third is the Z-score, which as noted is most commonly used in the research literature, for example , Beck et al. (2013), Tabak et al. (2012), Fratzscher et al. (2016), Davis and Karim (2018) and de-Ramon et al. (2018). At an aggregate level, it captures the probability of default of a country's commercial banking system, aggregated across banks. By comparing the buffer of a country's commercial banking system (capitalization and return on assets (ROA)) with the volatility (standard deviation (SD)) of those returns. Hence Z-score = (ROA + (Capital/Assets))/SD(ROA)).[19] As noted by Liu et al. (2013), it is appropriate to log the Z-score as the level is highly skewed, whereas the log is normally distributed.

Fourth, there is the incidence of financial crises per se (CRISIS), with the GFDD being updated to 2015 using Laeven and Valencia (2018). It is 1 for each period a crisis lasted, and 0 otherwise. There is a considerable literature on crisis determination, although only a few studies such as Barrell and Karim (2019) include both capital and competition as independent variables.

3.3. Independent variables

We use the aggregate leverage ratio[20] (LEVERAGE) and the regulatory capital/risk-adjusted assets ratio[21] (REGCAP) measures to test for the link of capital ratios to risk. Note throughout that a higher banking sector leverage ratio implies a higher capital/assets ratio that is consistent with lower leverage in the conventional sense.

The key additional variable is banking-sector competition, namely the Lerner index of bank competition (LERNER). The Lerner Index is a measure of market power in the banking market. It compares output pricing and marginal costs (that is, mark-up). An increase in the Lerner index indicates a decline in the competitive conduct of financial intermediaries, as reflected in wider margins. Note that we do not employ the Panzar-Rosse H statistic unlike Schaeck and Cihák (2012), Davis and Karim (2018) and others, owing to the short data on the GFDD, and also some technical issues arising with this measure.[22] We note that the aggregate GFDD Lerner index we utilise, in common with our other variables, gives a greater

[17] 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.

[18] Provisions/gross loans is constructed as the ratio of provisions to non-performing loans times the ratio of non-performing loans to gross loans.

[19] 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.

[20] Note that the definition is "Ratio of bank capital and reserves to total assets. Capital and reserves include funds contributed by owners, retained earnings, general and special reserves, provisions, and valuation adjustments. Capital includes regulatory capital (paid-up shares and common stock), which is a common feature in all countries' banking systems, and total regulatory capital, which includes several specified types of subordinated debt instruments that need not be repaid if the funds are required to maintain minimum capital levels (these comprise tier 2 and tier 3 capital). Total assets include all nonfinancial and financial assets". Hence it differs from the Basel leverage ratio of Tier 1 capital/total consolidated assets.

[21] Note that the definition is "The capital adequacy of deposit takers. It is a ratio of total regulatory capital to its assets held, weighted according to risk of those assets. Reported by IMF staff. Note that due to differences in national accounting, taxation, and supervisory regimes, these data are not strictly comparable across countries."

[22] Notably, 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.

Table 1
Statistical measures for dependent variables.

	Crises	NPL/loans (%)	Log Z-score	Provisions/Loans (%)
Mean	0.043	6.84	2.33	4.20
Median	0.00	4.42	2.36	2.96
Maximum	1.00	21.95	3.31	12.62
Minimum	0.00	0.70	1.12	0.33
Std. Dev.	0.2	6.14	0.61	3.54
Skewness	4.51	1.17	−0.25	1.04
Kurtosis	21.38	3.29	2.21	3.02
Jarque-Bera	187212.1	433.49	127.9477	306.53
Probability	0.00	0.00	0.00	0.00
Sum	459.00	12864.30	8124.49	7140.52
Sum Sq. Dev.	439.33	70751.76	1319.18	21279.04
Observations	10,712	1880	3493	1701

Note: variables are winsorised at 95% except for crisis.

weight to larger institutions. Accordingly, a small number of large firms may tend to drive the outcomes for the competition-risk relation, as was indeed found in de-Ramon et al. (2018).

As explained in Section 3.1, our other control variables capture aspects of a banking sector's weighted average business model that contribute to financial stability, similar to Beck et al. (2013); Davis and Karim (2018). These are the share of non-interest income in total income (NONINT)[23], the ratio of bank loans of deposit money banks to assets for deposit money banks (LOANASS),[24]; and the ratio of deposits of deposit money banks to their assets (DEPASS) [25].

3.4. Econometric approach and descriptive statistics

For the banking risk variables, in light of autocorrelation in the dependent variables, we use panel difference generalised method of moments estimation (GMM) as in Arellano and Bond (1991), with a lagged dependent variable and cross-section difference fixed effects, where the latter should capture market, regulatory and institutional features of each country. The instruments are the lagged differences of the dependent variable and second lag levels of the independent variables. A White period instrument weighting matrix and White period standard errors and covariance are used to reduce the impact of heteroskedasticity. The leverage ratio and regulatory capital variables in the Z-score equation are instrumented separately by two lags as separate prior estimates, since they enter the measure on the left hand side directly.

We consider GMM better than OLS since the lagged dependent variable and fixed effects may bias coefficients. All variables are entered as 1-year lags to assess indicator predictive properties and reduce the risk of simultaneity. For the crisis estimation, we use the traditional logit as in Barrell et al. (2010); Karim et al. (2013).

In line with other studies on global financial and macroeconomic data such as Cihák et al. (2012); Cerutti et al. (2017), we winsorise the data at 95% to minimise the effect of outliers, with the exception of the crisis variable which is not winsorised and the capital adequacy variables (the leverage ratio and regulatory capital/risk-adjusted assets) which are winsorised at 99%.[26]

Table 1 shows the statistical properties of the dependent variables. Crises are seen to occur on average once every 23 years, but this reflects the fact that the sample includes quiescent years prior to the 1970s. In the regression sample, crises are much more frequent, accounting for 114/1416 observations, implying a crisis occurring or ongoing every 12 years or so. The mean ratio of NPL to loans is 6.8% while that of provisions is 4.2%, implying an average provisions/NPL ratio of just over 60%. The log Z-score averages 2.3. Note that in a typical regression with Lerner and leverage, such as that for the NPL ratio, we have around 109 countries and 1144 observations, of which 45 are advanced countries and 63 are emerging market or developing countries.

[23] 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.

[24] This is constructed as the ratio of domestic money banks' private credit to GDP to domestic money banks' assets to GDP. Loans are seen as the financial resources provided to the private sector by domestic money banks, while assets held by deposit money banks include claims on the domestic real nonfinancial sector which includes central, state and local governments, nonfinancial public enterprises and private sector enterprises. Deposit money banks comprise commercial banks and other financial institutions that accept transferable deposits, such as demand deposits.

[25] This is constructed as the ratio of domestic money banks' deposits to GDP to domestic money banks' assets to GDP.

[26] We found that winsorising these variables at 95% led to non-stationarity according to the Im et al. (2003) test, whereas at 99% winsorisation they are stationary at the 10% level, as shown in Table 3.

Table 2
Statistical measures for independent variables.

	Lerner index	Bank leverage (%)	Regulatory capital/risk-adjusted assets (%)	Deposit/asset ratio	Noninterest income/total income	Loan/asset ratio
Mean	0.26	9.70	16.39	0.96	36.57	0.80
Median	0.26	9.10	15.40	0.92	35.40	0.83
Maximum	0.51	21.57	35.42	1.85	66.06	0.99
Minimum	0.037	3.20	7.64	0.46	10.04	0.43
Std. Dev.	0.12	3.89	5.15	0.34	14.99	0.16
Skewness	0.18	0.81	1.41	0.94	0.19	−0.83
Kurtosis	2.46	3.49	5.42	3.61	2.37	2.78
Jarque-Bera	43.11	220.11	1089.24	1029.69	78.38	744.48
Probability	0.00	0.00	0.00	0.00	0.00	0.00
Sum	650.45	17811.21	31070.04	6087.76	126734.7	5092.78
Sum Sq. Dev.	37.71	27837.83	50305.46	751.63	778431.5	159.59
Observations	2468	1836	1896	6333	3466	6393

Note: variables are winsorised at 95% except for bank leverage and regulatory capital/risk-adjusted assets which are winsorised at 99%.

Table 3
Unit root tests for variables.

Variable	Im-Pesaran-Shin (2003) panel unit root test (probability)
NPL/loans	−40.1 (0.00)
Log Z-score	−15.2 (0.00)
Provisions/Loans	−11.1 (0.00)
Lerner Index	−7.6 (0.00)
Bank leverage	−1.44 (0.07)
Regulatory capital/risk-adjusted assets	−2.21 (0.01)
Deposit/asset ratio	−6.4 (0.00)
Noninterest income/total income	−4.5 (0.00)
Loan/asset ratio	−8.2 (0.00)

Table 2 shows the statistical measures for the independent variables, with the mean leverage ratio being 9.7% and regulatory capital ratio 16.4%. We note that the mean deposit/asset ratio is 0.96,[27] while the noninterest share is on average, 36.6%. Credit is on average 80% of assets while the mean of the Lerner index is 0.26.

Table 3 shows that all variables are stationary according to the Im et al. (2003) test (which allows for individual unit root processes between countries), mostly at the 1% level, apart from leverage which is stationary at the 7% level. They can hence be entered in our equations as levels.

4. Results

Baseline regression results using the leverage ratio for capital adequacy on the global sample are shown in Table 4, with the outcome for regulatory capital entered instead of the leverage ratio shown as a memo item. The GMM regressions start in 2000 or later owing to further lags being taken by the methodology. The crisis regressions cover 1999–2015.

Concerning the GMM estimates for the bank risk variables, the J-Statistics indicate that the null hypothesis of over-identifying restrictions is not rejected. Except for the Z-score[28], the lagged dependent variable is highly significant and positive, especially for both lags[29] of the NPL/loans ratio and for the provisions/loans ratio. There is autocorrelation at AR(1) but there is no autocorrelation at AR(2), as required for GMM.

As regards the NPL/loans regressions, there is a significant negative effect of Lerner, implying a positive effect of competition and hence "competition-fragility". This result is similar to Yeyati and Micco (2007), who found an increase in NPLs as bank competition increased in eight Latin American countries. The NPL ratio is higher when the leverage ratio is high (consistent with the "regulatory hypothesis"), when deposits/assets are low (higher liquidity risk), a lower noninterest ratio (so

[27] As noted, this series is the ratio of domestic money banks' deposits to GDP to domestic money banks' assets to GDP. Deposit money banks comprise commercial banks and other financial institutions that accept transferable deposits, such as demand deposits. Deposits are the total value of demand, time and saving deposits at domestic deposit money banks. Total assets held by deposit money banks include claims on the domestic real nonfinancial sector which includes central, state and local governments, nonfinancial public enterprises and private sector. The sectoral definitions accordingly vary in the numerator and the denominator (assets exclude claims to the domestic financial sector and foreign sector) and this explains why the ratio may at times exceed one. However, we consider it a viable proxy for the deposits/assets ratio and it is the closest that can be obtained using the GFDD.

[28] We note that the lagged dependent is significant in the regression with regulatory capital in Table 4 as well as a number of the subsamples shown in Table 7.

[29] We found that two lags of the dependent variable were needed for the NPL ratio to ensure no autocorrelation at AR(2) in the GMM estimate.

Table 4
Baseline regression results for leverage and competition (Lerner index) (1999–2015).

Equation number and dependent variable	(1) NPL/loans	(2) Provisions/Loans	(3) Log (Z-score)	(4) Crisis
Constant				−4.18***
				(3.9)
Dependent (−1)	0.807***	0.75***	0.103	
	(81.8)	(26.3)	(1.5)	
Dependent (−2)	−0.0962***			
	(10.4)			
Lerner (−1)	−3.84***	−2.73***	−0.0955	−5.33***
	(9.2)	(3.3)	(0.9)	(5.0)
Leverage (−1)	0.243***	0.00978	0.00722***	−0.0712**
	(11.3)		(2.8)	(2.4)
		(0.3)		
Deposits/Assets (−1)	−7.58***	−5.61***	−0.492***	−0.877**
	(15.4)	(3.7)	(2.6)	(2.1)
Noninterest income/total income (−1)	−0.0194***	−0.00786*	−0.00022	0.0127
	(6.5)	(1.7)	(0.5)	(1.6)
Loan/assets (−1)	−2.76***	1.97	−0.676***	4.49***
	(4.8)	(1.0)	(2.7)	(4.4)
Regression type	Panel GMM difference regression	Panel GMM difference regression	Panel GMM difference regression	ML - Binary logit
Effects	Cross section fixed (first difference)	Cross section fixed (first difference)	Cross section fixed (first difference)	
Sample (adjusted):	2001–2015	2000–2015	2002–2015	1999–2015
Periods included:	15	16	14	17
Countries included:	108	107	108	112
Observations:	1109	1049	1044	1416
R-squared				0.122
S.E. of regression	2.72	1.63	0.194	0.264
Sum of squared residuals	8132	2808	39.0	97.9
Sargan's J (probability)	82.4 (0.20)	53.3 (0.16)	45.8 (0.28)	
AR(1) (probability)	0.00	0.00	0.00	
AR(2) (probability)	0.10	0.62	0.64	
Memo: regulatory capital ratio (−1) instead of leverage (−1)	0.0521***	−0.0384*	−0.0014	−0.122***
	(2.6)	(1.7)	(1.0)	(3.8)

Note: T-values in parentheses (Z-statistics for logit) *** implies significance at 99%, ** at 95% and * at 90%. Regressions (1–3) estimated by difference-GMM with lagged dependent variables and cross section difference fixed effects. The instruments for equations (2) and (3) are the second, third and fourth lag difference of the dependent variable and second lag levels of the independent variables; in equation (1) the instruments for the independent variables are the same, while for the dependent variable they are the third to eighth lag difference of the dependent variable. White period instrument weighting matrix and White period standard errors and covariance are used. The leverage ratio and regulatory capital variables in the Z-score equation are instrumented separately by two lags as separate prior estimates. Regression (4) estimated by binary logit.

banks are more dependent on interest) and a lower loan/assets ratio. Regulatory capital is also significant and positive when substituted for the leverage ratio.

In respect of the provisions/loans ratio, the negative sign on the Lerner index indicates higher competition entails higher provisions and hence risk ("competition-fragility"). The leverage ratio is insignificant, as is the loan/asset ratio. A lower deposits/assets ratio as well as a lower noninterest share indicate a higher rate of provisioning, an indicator of risk. Bitar et al. (2018) found a similar negative effect of income diversification in advanced countries. Regulatory capital in place of the leverage ratio was significant at 90% across the whole sample with a negative sign, consistent with "skin in the game". Iannotta et al. (2007) found a positive effect of capital adequacy in Europe, in contrast to our result for regulatory capital (although as shown in Table 6 below, we also find a positive sign on capital for the subsample of advanced countries).

Note that the lower the log Z-score, the higher the risk to the banking-sector. The Z-score results have no significant effect of the noninterest income ratio or the Lerner measure of competition. A higher leverage ratio gives rise to a higher Z-score (note above that leverage is part of the Z-score, however the instrumental variables in GMM should reduce this difficulty and we have separately instrumented the leverage variable in the Z-score equation by two lags of itself). Lower deposit/asset ratios and loan/asset ratios also indicate a higher Z-score and thus lower risk. Regulatory capital (also instrumented) is not significant in the Z-score equation if it is substituted for leverage. The result for the loan/asset ratio is contrary to estimates for individual banks in the EU in Davis and Karim (2018). Besides the narrower geographic coverage, this which may link to different effects for small and large banks which are weighted equally in their sample of individual banks as compared to our macro data which weights the latter more heavily.

As noted, the crisis regressions are logit estimates. It can be seen that all of the variables for crisis are significant except for the noninterest income ratio (which just falls short of 10% significance with a positive sign). Hence, banking crises are more likely if there is a high level of competition (low Lerner and hence narrow margins, i.e. "competition-fragility"); low leverage (hence capital buffers are thin); a lower deposit/asset ratio (showing higher liquidity risk) and a higher ratio of credit to

Table 5
Regression results for NPL/loans using alternative measures of capital adequacy.

Panel GMM-Difference Regressions (cross section fixed effects)	Variable	Equation with leverage ratio	Equation with regulatory capital/risk-adjusted assets
Full sample (1999–2015)	Lerner (−1)	−3.84***	−2.99***
		(9.2)	(5.3)
	Capital ratio (−1)	0.243***	0.0521**
		(11.3)	(2.6)
Higher-income (advanced) countries (1999–2015)	Lerner (−1)	0.153	−1.23***
		(1.1)	(10.7)
	Capital ratio (−1)	0.108***	0.119***
		(24.6)	(78.9)
Emerging market economies (1999–2015)	Lerner (−1)	−5.7***	−4.58***
		(19.5)	(7.2)
	Capital ratio (−1)	0.186***	0.029***
		(13.3)	(48.2)
Pre-crisis (up to 2007)	Lerner (−1)	−8.02**	−7.98**
		(2.3)	(2.3)
	Capital ratio (−1)	0.204**	−0.011
		(2.1)	(0.2)
Post-crisis (2008 onwards)	Lerner (−1)	1.11	1.45*
		(1.1)	(1.8)
	Capital ratio (−1)	0.176***	0.0594***
		(5.0)	(2.8)

Note: T-values in parentheses. *** implies significance at 99%, ** at 95% and * at 90%. Regression estimated by difference-GMM with first and second lagged dependent variables and cross section difference fixed effects, the instruments are the third to eighth lag difference of the dependent variable and second lag levels of the independent variables; regressions include all control variables shown in Table 4, equation 1. White period instrument weighting matrix and White period standard errors and covariance are used.

Table 6
Regression results for Provisions/Loans using alternative measures of capital adequacy.

Panel GMM-Difference Regressions (cross section fixed effects)	Variable	Equation with leverage ratio	Equation with regulatory capital/risk-adjusted assets
Full sample (1999–2015)	Lerner (−1)	−2.73***	−2.19***
		(3.3)	(2.8)
	Capital ratio (−1)	0.0098	−0.0384*
		(0.3)	(1.7)
Higher-income (advanced) countries (1999–2015)	Lerner (−1)	−3.94***	−4.08***
		(20.7)	(58.7)
	Capital ratio (−1)	0.0441***	0.0136***
		(4.9)	(2.7)
Emerging market economies (1999–2015)	Lerner (−1)	−3.68***	−2.96***
		(3.8)	(4.5)
	Capital ratio (−1)	−0.0495	−0.0475***
		(1.5)	(2.8)
Pre-crisis (up to 2007)	Lerner (−1)	−5.55**	−4.87***
		(2.3)	(2.9)
	Capital ratio (−1)	−0.0982	−0.14*
		(0.9)	(1.8)
Post-crisis (2008 onwards)	Lerner (−1)	−0.0438	−0.445
		(0.3)	(0.4)
	Capital ratio (−1)	−0.104	−0.0558
		(1.2)	(1.4)

Note: T-values in parentheses *** implies significance at 99%, ** at 95% and * at 90%. Regression estimated by difference-GMM with lagged dependent variable and cross section difference fixed effects, the instruments are the second, third and fourth lag difference of the dependent variable and second lag levels of the independent variables; regressions include all control variables shown in Table 4, equation 2. White period instrument weighting matrix and White period standard errors and covariance are used.

assets (showing higher credit risk). The result for the leverage ratio is in line with earlier work on advanced countries in Barrell et al. (2010); Karim et al. (2013), while the results for competition are similar to Barrell and Karim (2019) who used a similar range of advanced countries. Finally, regulatory capital is also significant in the crisis equation if it is substituted for the leverage ratio, with the same sign.

Tables 5–8 all repeat the same form of regression and the same model specification as in Table 4 (as introduced in Section 3) for various measures of capital adequacy and competition, as well as across country groups and time periods. We ran

Table 7
Regression results for log (Z-score) using alternative measures of capital adequacy.

Panel GMM-Difference Regressions (cross section fixed effects)	Variable	Equation with leverage ratio (instrumented)	Equation with regulatory capital/risk-adjusted assets
Full sample (1999–2015)	Lerner (−1)	−0.0955	0.0464
		(0.9)	(0.5)
	Capital ratio (−1)	0.00722***	−0.00138
		(2.8)	(1.0)
Higher-income (advanced) countries (1999–2015)	Lerner (−1)	−0.546***	−0.227***
		(6.8)	(4.5)
	Capital ratio (−1)	0.0205***	0.00566***
		(7.3)	(5.8)
Emerging market economies (1999–2015)	Lerner (−1)	0.221***	0.223***
		(3.7)	(4.5)
	Capital ratio (−1)	0.00773***	0.00033
		(4.2)	(0.3)
Pre-crisis (up to 2007)	Lerner (−1)	0.317	0.636*
		(1.0)	(1.7)
	Capital ratio (−1)	0.00591	−0.0068
		(0.9)	(1.5)
Post-crisis (2008 onwards)	Lerner (−1)	−0.218	−0.114
		(1.0)	(0.6)
	Capital ratio (−1)	0.0145***	0.00175
		(3.1)	(1.1)

Note: T-values in parentheses *** implies significance at 99%, ** at 95% and * at 90%. Regressions estimated by difference-GMM with lagged dependent variable and cross section difference fixed effects, the instruments are the second, third and fourth lag difference of the dependent variable and second lag levels of the independent variables; regressions include all control variables shown in Table 4, equation 3. White period instrument weighting matrix and White period standard errors and covariance are used. The leverage ratio and regulatory capital variables in the Z-score equation are instrumented separately by two lags as separate prior estimates.

Table 8
Regression results for crises using alternative measures of capital adequacy.

Logit Regressions	Variable	Equation with leverage ratio	Equation with regulatory capital/risk-adjusted assets
Full sample (1999–2015)	Lerner (−1)	−5.33***	−4.92***
		(5.0)	(4.7)
	Capital ratio (−1)	−0.0712**	−0.122***
		(2.4)	(3.8)
Higher-income (advanced) countries (1999–2015)	Lerner (−1)	−4.37***	−3.74***
		(3.6)	(3.1)
	Capital ratio (−1)	−0.013	−0.0884*
		(0.1)	(1.8)
Emerging market economies (1999–2015)	Lerner (−1)	−7.66***	−6.75***
		(3.6)	(3.2)
	Capital ratio (−1)	−0.03	−0.121**
		(0.6)	(2.4)
Pre-crisis (up to 2007)	Lerner (−1)	−12.7***	−11.1***
		(5.0)	(4.5)
	Capital ratio (−1)	0.0812	−0.0383
		(1.6)	(0.8)
Post-crisis (2008 onwards)	Lerner (−1)	−4.43***	−4.77***
		(3.5)	(3.7)
	Capital ratio (−1)	−0.165***	−0.278***
		(4.1)	(5.8)
Crisis onset only (1999–2015)	Lerner (−1)	−3.15	−1.35
		(1.6)	(0.7)
	Capital ratio (−1)	−0.05	−0.213***
		(1.0)	(3.0)

Note: Logit regressions which also include all control variables shown in Table 4, equation 4. Z-statistics in parentheses. *** implies significance at 99%, ** at 95% and * at 90%.

the regressions for the full period 1999–2015 as in Table 4, for the higher-income countries, for the emerging market economies plus developing countries (including middle- and lower-income countries)[30], and for the pre-crisis period up to 2007

[30] The country classification used is that of the World Bank for "income group" as shown in the Global Financial Development Database.

and the post-crisis period from 2008 separately. For the crisis regression, we also ran the regression for the crisis onset only, given that the later years of a prolonged crisis may be affected by government measures and banks' risk aversion. For reasons of space, we focus on the results for competition and capital and omit the coefficients and significance for the other control variables and the equation diagnostics as shown in Table 4, these are available from the authors on request.

Looking at the results for the NPL/loans ratio in Table 5, we find in the full sample, as already seen in Table 4, both leverage and regulatory capital are significant (a higher level of capital adequacy implies higher NPLs) as is the Lerner index with a negative sign (high NPLs correspond to periods when competition is high, suggesting "competition-fragility"). The higher-income countries have a similar result, except that Lerner is only significant in the regulatory capital ratio estimate. The emerging markets are again similar to the global sample, with a positive effect of capital and also of competition on risk. There is a stronger competition effect than for advanced countries, which may reflect relatively recent financial deregulation. A similar result obtains for the pre-crisis sample where both equations have a negative sign for Lerner. Only the leverage ratio is significant with a positive sign pre-crisis, while the risk-adjusted measures is not, which may be consistent with the argument that there was mismeasurement of risk-adjusted capital over that period. Finally, for the post-crisis period all of the capital adequacy variables are significant with a positive Lerner coefficient for the regulatory capital estimate.

Overall, the results for the NPL ratio show a consistent positive relation of capital adequacy to risk in line with the "regulatory hypothesis" as in studies such as Iannotta et al. (2007); Bitar et al. (2018).[31] Regulatory capital is less often significant than the leverage ratio, again in line with Bitar et al. (2018). Meanwhile the competition/risk relation consistently supports "competition-fragility", albeit less so for advanced countries and with a partial reversal post-crisis. In the post-crisis period, low competition may have coincided with high NPLs as the effects of the crisis slowly manifested, whereas the pre-crisis pattern of "competition-fragility" may reflect the competition/NPL relation in more normal times.

Looking at the results for provisions/loans (Table 6), this is related negatively to competition in the full sample and in both the advanced countries and the emerging market economies, as well as pre-crisis. High competition may thus imply that banks need to provision as loans are riskier, suggesting "competition-fragility". This is consistent with the results above for NPLs, which also showed "competition fragility". The leverage ratio is less often significant than regulatory capital, in contrast to results such as those of Bitar et al. (2018) that found leverage more commonly significant. Both capital measures are significant with a positive sign for advanced countries but risk-adjusted capital is negative for the full sample, emerging markets and pre-crisis when leverage is insignificant. Accordingly, results for capital adequacy are mixed between the "regulatory hypothesis" and "skin in the game". Our results for advanced countries are consistent with Iannotta et al. (2007) for Europe and Bitar et al. (2018) for OECD countries who also found in favour of the "regulatory hypothesis". The emerging market result is in line with Lee and Hsieh (2013) whose results for Asia also favoured "skin in the game".

The results for (log) Z-score (Table 7) can be compared to those in studies such as Beck et al. (2013); Davis and Karim (2018); de-Ramon et al. (2018), where it is also the main independent variable. Unlike the other variables, note that a higher Z-score implies lower risk and hence a positive sign for capital (or a negative sign for Lerner) shows a negative relation to risk. The most consistent result across subsamples is the leverage ratio with a significant positive sign in each regression other than pre-crisis. This is consistent with a negative relation of capital to risk ("skin in the game"). Regulatory capital is only significant with a positive sign for the advanced countries. As noted, leverage is part of the Z-score, however the instrumental variables in GMM should reduce this difficulty and we have additionally instrumented the capital adequacy variables in the Z-score equation separately by two lags of themselves.

As regards the Lerner index, significant positive effects emerge for the emerging market economies and for the pre-crisis period 2000–2007 (with regulatory capital). These are both consistent with "competition-fragility" as in Beck et al. (2013); de-Ramon et al. (2018); Davis and Karim (2018), and are also comparable with the results shown above for NPLs and provisions. On the other hand, we find "competition-stability" for the advanced countries with this measure of risk.

Looking finally at results for crises, we see in Table 8 below, following the results from Table 4, that in the full sample both higher competition and lower measures of capital adequacy are significant advance predictors of a crisis year (consistent with "competition-fragility" and "skin in the game"). In advanced countries, however, the leverage ratio is not significant while the risk-adjusted measure is only significant at 90%. However, Lerner is again significant at 99% in each regression. This underlines the importance of banking competition as a crisis predictor.

For emerging markets, it is again risk-adjusted capital rather than leverage that is significant as a predictor, while the Lerner remains highly significant. For the pre-crisis years up to 2007 for the global sample only competition is significant. In the post-crisis period from 2008, all of the variables are significant, note however that this is giving the state of affairs after the onset of the global financial crisis rather than predicting it. Competition may be a particular issue where recent financial liberalisation and low levels of bank efficiency, which are features of some emerging market economies, may enhance vulnerability to banking crises.[32] A positive relation of competition to crisis-risk is consistent with results of recent

[31] Note, however, that these studies had loan loss reserves or provisions as a risk variable rather than non-performing loans.
[32] See Demirgüç-Kunt and Detragiache (1998).

Table 9
Summary of significance and signs.

Country group/time period	Risk indicator	Leverage ratio	Risk-adjusted capital ratio	Competition (Lerner)
Full sample (1999–2015)	NPL/loans	+***	+**	-***
	Provisions/loans		(-*)	-***
	Log Z-score	(+***)		
	Crises	(-**)	(-***)	-***
Higher income (advanced) countries (1999–2015)	NPL/loans	+***	+***	-***
	Provisions/loans	+***	+***	-***
	Log Z-score	(+***)	(+***)	(-***)
	Crises		(-*)	-***
Emerging market economies (1999–2015)	NPL/loans	+***	+***	-***
	Provisions/loans		(-***)	-***
	Log Z-score	(+***)		+***
	Crises		(-**)	-***
Pre-crisis (up to 2007)	NPL/loans	+**		-**
	Provisions/loans		(-*)	-***
	Log Z-score			+*
	Crises			-***
Post-crisis (2008 onwards)	NPL/loans	+***	+***	(+*)
	Provisions/loans			
	Log Z-score	(+***)		
	Crises	(-***)	(-***)	-***

Note: *** implies significance at 99%, ** at 95% and * at 90%. Results for competition shown in brackets show a negative relation of competition to risk ("competition-stability"), results for competition shown without brackets show a positive relation of competition to risk ("competition-fragility"). Results for capital shown in brackets show a negative relation of capital ratios to risk ("skin in the game"), results for capital shown without brackets show a positive relation of capital ratios to risk ("regulatory hypothesis"). As shown in Tables 5-8, for some subsamples, Lerner was only significant for one of the two capital-measure regressions.

work by Barrell and Karim (2019) for crises in advanced countries. Apart from their work, it is rarely tested as a predictor of crises, which suggests a need for further work in this area.

As regards our regression for the onset of the crises, competition is just below 10% significant for the leverage ratio estimation only. The risk-adjusted capital measure is significant while leverage is not. Nevertheless, the overall negative relation of capital adequacy to banking crisis is consistent with the results of Barrell et al. (2010); Karim et al. (2013), who found low banking-sector capital ratios to be a strong predictor of banking crises.

5. Summary of single equation results for issues in financial stability

We have presented above results for the determination of key banking-sector risk measures, using both capital ratios and competition as key independent variables. Summarising the results and their implications for the various identified issues in financial stability analysis, Table 9 provides a reference. To aid the reader, we have used brackets to indicate the direction of effects on risk. Results for competition shown in brackets show a negative relation of competition to risk ("competition-stability"), results for competition shown without brackets show a positive relation of competition to risk ("competition-fragility"). Results for capital ratios shown in brackets show a negative relation of capital ratios to risk ("skin in the game"), results for capital ratios shown without brackets show a positive relation of capital ratios to risk ("regulatory hypothesis"):

Regarding the relation of *capital to risk*, controlling for competition, we have mixed results. For the Z-score and crises there is a negative relation, so that less capital accompanies greater risk – or conversely more capital leads to lower risk. This is most apparent for crises, especially in the full sample and post-crisis, but also in respect of at least one capital measure for advanced countries and emerging markets. It is also the case for the Z-score in all cases except pre-crisis for the leverage ratio, and for advanced countries with regulatory capital. These results are consistent with the "skin in the game" hypothesis, whereby 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. The corollary is that a low capital ratio may give incentives to take risks and "gamble for resurrection" especially when there is generous and mispriced deposit insurance, and banks are "too big to fail". We note that the links of capital to these variables are stronger post crisis, which may reflect tighter regulation.

Results for NPLs and to a lesser extent provisions/loans tend, on the other hand, to show a positive relation of capital to risk. This applies to both capital measures in all cases except pre-crisis (where the regulatory capital ratio is not significant). For provisioning, it holds for the advanced countries for both capital measures. On the other hand, there are negative signs for capital for provisions in the global sample, emerging markets and pre-crisis. Apart from the last-mentioned cases[33],

[33] As noted above, there are results in the literature that do favour differential effects of capital on provisions in advanced and emerging market economies.

Table 10
Statistical properties of macro variables.

	GDP growth	Inflation	Rate of unemployment
Mean	3.90	8.49	8.40
Median	3.95	5.32	6.95
Maximum	11.90	36.57	21.65
Minimum	−4.65	−0.21	1.44
Std. Dev.	4.11	9.28	5.54
Skewness	−0.10	1.77	0.93
Kurtosis	2.72	5.54	3.03
Jarque-Bera	41.29	5663.06	655.48
Probability	0.00	0.00	0.00
Sum	32739.76	60844.26	38407.91
Sum Sq. Dev.	142034.4	616836.6	140419.9
Observations	8393	7164	4574
Im-Pesaran-Shin Unit root test (probability)	−48.0 (0.00)	−23.2 (0.00)	−24122 (0.00)

Note: variables are winsorised at 95%.

these results are consistent with the "regulatory hypothesis", suggesting that regulators require higher capital in response to higher risk, and so a positive relation of capital to risk would be expected. And it is notable that NPLs and provisions are direct targets of supervisory oversight in the way that crises and Z-scores are not; this may help explain differences in results.

The leverage ratio is clearly relevant for many cases that we have estimated, as is the regulatory capital ratio, thus justifying the Basel III focus on both measures. In some cases both measures are relevant. In the global sample this is the case of NPLs and crises; it is also true for NPLs, provisions and Z-score for advanced countries, for NPLs for emerging market economies and for NPLs and crises in the post-crisis period. In all cases the significant effect has the same sign. The leverage ratio is significant in a similar number of cases to the regulatory capital ratio.[34] This pattern of similar indicator properties for the leverage ratio and regulatory capital is somewhat contrary to the suggestion by Bitar et al. (2018) that the risk-adjusted measures are ineffective due to untruthful (or at least inaccurate) assessment of bank real risk exposure.

From the standpoint of *competition and risk*, after controlling for capital ratios, the competition measure is more often significant than either of the capital measures, being present in 17 cases, with the exceptions being the Z-score in the global and post-crisis samples and the provisions ratio post-crisis. The evidence strongly favours the "competition-fragility" hypothesis. This is apparent in all significant cases except for the Z-score in advanced countries and the NPL ratio in the post-crisis period, both of which suggest "competition-stability". In all other scenarios, a narrowing of margins (indicated by a lower Lerner Index) implies greater risk of financial instability for the economy in question. Weaker competition effects on risk post crisis may link to effects of regulatory tightening and risk aversion by banks (a similar pattern was found in Davis and Karim (2018)).

The overall result favouring competition-fragility is in line with results for the Lerner index in studies such as Beck et al. (2013); de-Ramon et al. (2018); Davis and Karim (2018). The implication is clearly that regulators need to take more note of competitive conditions in banking markets when assessing the stance of macroprudential policy and the risk of financial instability. We suggest that extant micro work results may at times point to "competition-stability" due to the behaviour of small banks, because they are given equal weight with large and systemic institutions and are typically much more numerous.

Bringing the above results together, for cases of "skin in the game" where we also find that there is "competition-fragility" there is a clear need to increase bank capital when competition rises. For the "regulatory hypothesis" and "competition-fragility" the case is more nuanced as there are found to be offsetting effects.

Finally, we see numerous contrasts between the *behaviour of advanced countries* versus *emerging market and developing economies* in the sample, in terms of the determinants of bank risk. In respect of competition controlling for capital, in emerging market economies it is relevant for all four risk indicators – in each case showing that higher competition entails higher risk, while for advanced countries it has a positive effect on the Z-score. Concerning capital measures controlling for competition, the main difference is the sign of the regulatory capital ratio effect on the provisions ratio, which shows "skin in the game " for emerging markets and the "regulatory hypothesis" for advanced countries. This may reflect differing regulatory approaches to timing and scope of provisioning. Capital ratios are more often significant for advanced countries than for emerging markets. We suggest that emerging market economy regulators should pay particularly close attention to competition, while both groups are justified in a focus on leverage as well as the risk-adjusted capital ratio. The lesser effect of capital for emerging market economies may reflect more recent introduction of the Basel accords.

[34] It is present for 12 cases as opposed to 13 for regulatory capital

Table 11
Robustness check with macro variables.

Dependent variable	Independent variables	Equation with leverage ratio	Equation with regulatory capital/risk-adjusted assets
NPL/loans (1)	Lerner (−1)	−2.79***	−2.47***
		(8.4)	(7.0)
	Capital ratio (−1)	0.274***	0.082***
		(14.1)	(6.2)
Provisions/loans (2)	Lerner (−1)	−3.08***	−1.89***
		(3.1)	(2.3)
	Capital ratio (−1)	−0.0297	−0.0801***
		(0.8)	(3.7)
Log Z-score (3)	Lerner (−1)	0.0327	0.182
		(0.2)	(1.6)
	Capital ratio (−1)	0.00925***	−0.00103
		(3.9)	(0.8)
Crises (4)	Lerner (−1)	−4.35***	−3.88***
		(4.0)	(3.6)
	Capital ratio (−1)	−0.0879**	−0.155***
		(2.5)	(4.4)
Crisis onset (5)	Lerner (−1)	−3.54*	−1.7
		(1.8)	(0.8)
	Capital ratio (−1)	−0.0311	−0.187***
		(0.5)	(2.6)

Note: Regressions (1–3) estimated by difference-GMM with lagged dependent variables and cross section difference fixed effects. Equation (1) has first and second lagged dependent variables while equations (2) and (3) have first lagged dependent variables only. The instruments for equation (1) are the third to eighth lag difference of the dependent variable and second lag levels of the independent variables; in equations (2) and (3) the instruments for the independent variables are the same, while for the dependent variable they are the second, third and fourth lag difference of the dependent variable. Regressions (4) and (5) estimated by binary logit. All equations include all control variables shown in Table 4 as well as lagged GDP growth, CPI inflation and unemployment rate (ILO definition). White period instrument weighting matrix and White period standard errors and covariance are used. T-values in parentheses (Z statistics for logit) *** implies significance at 99%, ** at 95% and * at 90%. The leverage ratio and regulatory capital variables in the Z-score equation are instrumented separately by two lags as separate prior estimates.

Table 12
Robustness check with crisis as independent variable.

Dependent variable	Independent variables	Equation with leverage ratio	Equation with regulatory capital/risk-adjusted assets
NPL/loans (1)	Lerner (−1)	−3.7***	−2.55***
		(7.9)	(4.4)
	Capital ratio (−1)	0.269***	0.0186
		(16.9)	(1.0)
Provisions/loans (2)	Lerner (−1)	−2.91***	−2.4***
		(3.1)	(3.4)
	Capital ratio (−1)	−0.0057	−0.0525**
		(0.2)	(2.4)
Log Z-score (3)	Lerner (−1)	−0.145	0.0417
		(1.4)	(0.4)
	Capital ratio (−1)	0.00623***	−0.0006
		(2.8)	(0.5)

Note: Regressions are estimated by difference-GMM with lagged dependent variables and cross section difference fixed effects. Equation (1) has first and second lagged dependent variables while equations (2) and (3) have first lagged dependent variables only. The instruments for equation (1) are the third to eighth lag difference of the dependent variable and second lag levels of the independent variables; in equations (2) and (3) the instruments for the independent variables are the same, while for the dependent variable they are the second, third and fourth lag difference of the dependent variable. All equations include all control variables shown in Table 4 as well as lagged crises. White period instrument weighting matrix and White period standard errors and covariance are used. T-values in parentheses: *** implies significance at 99%, ** at 95% and * at 90%. The leverage ratio and regulatory capital variables in the Z-score equation are instrumented separately by two lags as separate prior estimates.

6. Robustness checks

Robustness is already indicated in many of the results above, in terms of the similarity of results in subsamples and in advanced versus emerging market economies. In order to further check robustness, we first included the macroeconomic variables GDP growth, CPI inflation and the rate of unemployment (ILO definition) in each regression. These data came from the World Bank's World Development Indicators database. The variables codes and definitions in the database are provided in Appendix Table A1. We then include crises as an independent variable in our regressions. A further test, not shown in

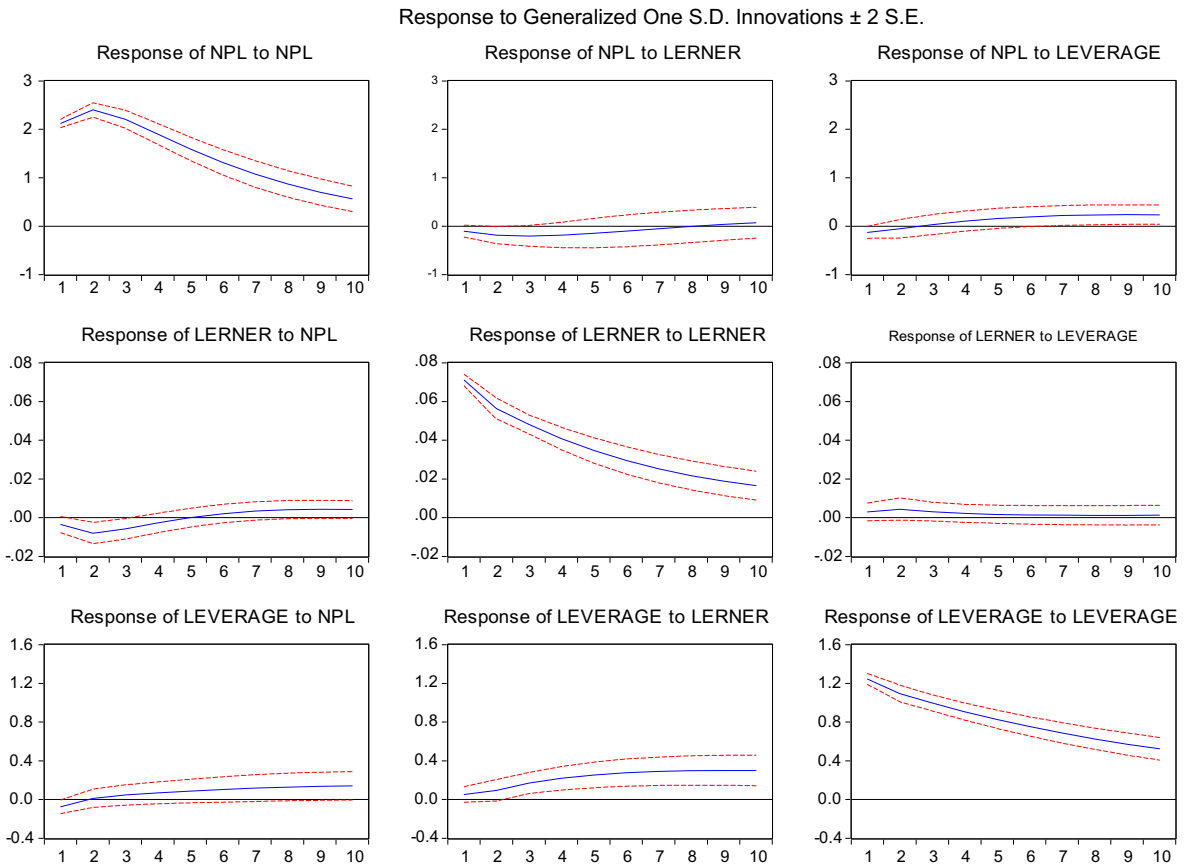

Fig. 1. Impulse responses for VAR of NPL, leverage ratio and competition (Lerner index), including also the other control variables (with 95% confidence intervals).

detail for the sake of brevity,[35] shows that inclusion of the return on equity[36] and the cost-income ratio gives broadly similar results to those in the main case. This can be seen as following the approach of Kick and Prieto (2015) with a set of CAMELS variables, as discussed in Section 3.1.

The statistical properties of the extra variables (again winsorised at 95%) are shown in Table 10 below, where it can also be seen that all are stationary according to the Im et al. (2003) test. It is notable that the mean rate of inflation is higher than the median even with winsorisation, which is likely to reflect the effect of hyperinflations.

The macro variables test should show whether the favourable results obtained are due to omission of such macroeconomic effects. We ran the tests for the full sample. As can be seen from Table 11 in comparison to Table 4, virtually all of the results previously obtained continue to hold in terms of sign and significance when the three macro variables are included. The exception is an additional negative and significant effect for competition on crisis onset in the leverage equation.

As a second check of robustness (Table 12) we included the crisis dummy, as used as a dependent variable in Tables 4 and 8, as an independent variable in the equations for NPL/loans, log Z-score and provisions/loans. This seeks to ensure that the main results are not proxying for the effects of ongoing crises. In fact, the outcome is very close to the original results in terms of sign and significance shown in Table 4, as shown below. The difference is that regulatory capital is now not significant for the determination of NPLs.

Overall, we contend that these checks underpin the validity of the results summarised in Table 9.

7. Panel VAR estimation

To complement our single equation work and investigate further the capital-competition-risk nexus, and in particular the relation of capital to competition, we ran a simple Panel Vector-Autoregressive (Panel VAR) model to assess the interrela-

[35] Results are available from the authors on request.

[36] This variable is instrumented for the Z-score equation since profitability is an element in the dependent variable. Both additional variables were winsorised at 95% and are stationary according to the Im et al. (2003) unit root test.

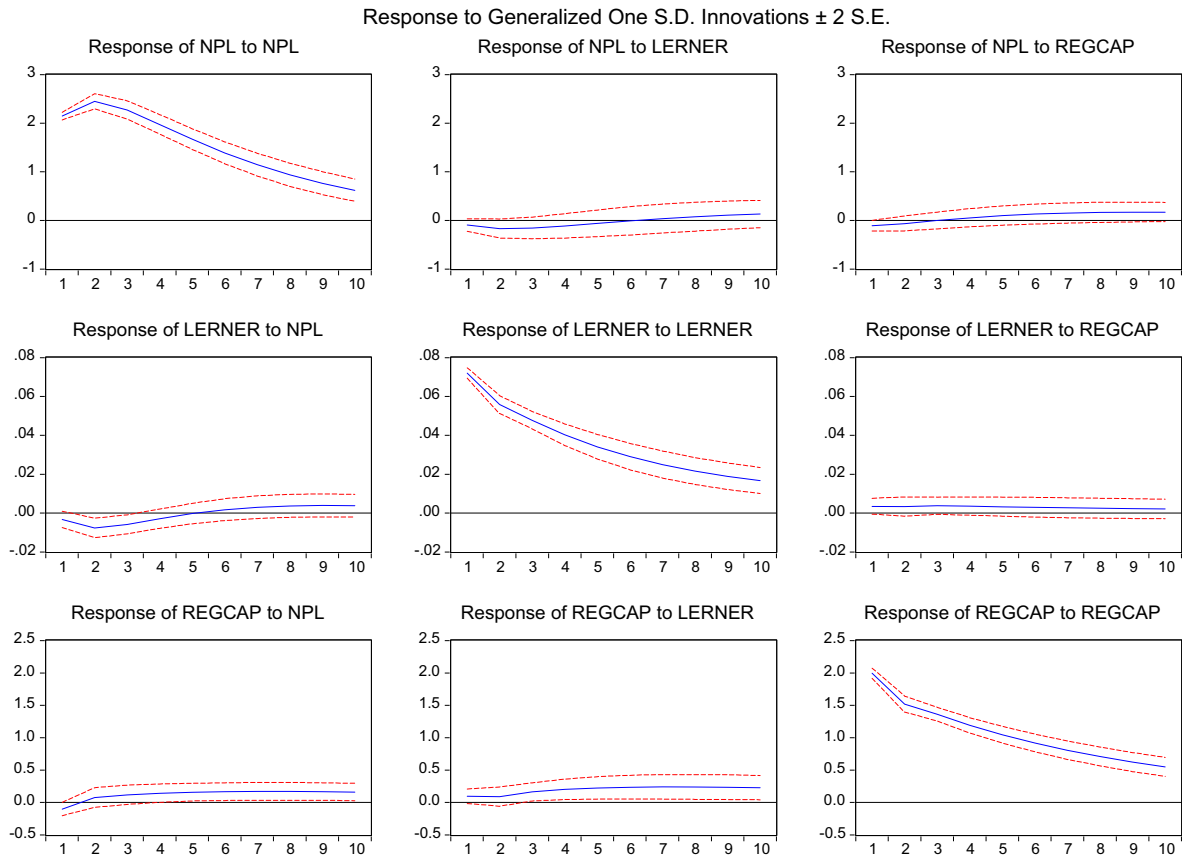

Fig. 2. Impulse responses for VAR of NPL, regulatory capital ratio and competition (Lerner index), including also the other control variables (with 95% confidence intervals).

Table 13
Variance decomposition for VAR of NPL ratio, leverage ratio and competition (Lerner index).

Variance Decomposition of NPL							
Period	S.E.	NPL	LERNER	LEVERAGE	DEPASS	NONINT	LOANASS
1	2.12	98.40	0.25	0.34	0.80	0.035	0.15
		(0.76)	(0.37)	(0.32)	(0.49)	(0.14)	(0.24)
5	4.67	95.04	0.64	0.26	3.30	0.58	0.15
		(1.81)	(0.64)	(0.28)	(1.42)	(0.67)	(0.38)
10	5.23	92.09	0.58	1.13	4.29	1.69	0.19
		(3.09)	(0.76)	(0.93)	(1.96)	(1.90)	(0.50)
Variance Decomposition of LERNER							
Period	S.E.	NPL	LERNER	LEVERAGE	DEPASS	NONINT	LOANASS
1	0.071	0.00	100.00	0.00	0.00	0.00	0.00
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
5	0.11	0.24	98.59	0.040	0.39	0.69	0.038
		(0.30)	(0.85)	(0.18)	(0.45)	(0.74)	(0.15)
10	0.12	0.81	96.55	0.037	0.87	1.54	0.17
		(0.91)	(1.84)	(0.39)	(0.54)	(1.56)	(0.42)
Variance Decomposition of LEVERAGE							
Period	S.E.	NPL	LERNER	LEVERAGE	DEPASS	NONINT	LOANASS
1	1.24	0.00	0.17	99.82	0.00	0.00	0.00
		(0.00)	(0.24)	(0.24)	(0.00)	(0.00)	(0.00)
5	2.32	1.17	2.82	95.70	0.078	0.17	0.036
		(0.73)	(1.46)	(1.63)	(0.20)	(0.50)	(0.14)
10	2.83	2.84	7.28	89.18	0.070	0.57	0.039
		(1.75)	(3.37)	(3.95)	(0.30)	(1.54)	(0.24)

Note; standard errors in parentheses.

Table 14
Variance decomposition for VAR of NPL ratio, regulatory capital ratio and competition (Lerner index).

Variance Decomposition of NPL							
Period	S.E.	NPL	LERNER	REGCAP	DEPASS	NONINT	LOANASS
1	2.14	98.72	0.20	0.24	0.68	0.010	0.13
		(0.74)	(0.28)	(0.39)	(0.45)	(0.11)	(0.25)
5	4.78	95.66	0.34	0.12	3.40	0.24	0.21
		(1.89)	(0.56)	(0.38)	(1.48)	(0.60)	(0.52)
10	5.36	93.35	0.39	0.51	4.66	0.68	0.38
		(2.97)	(0.64)	(0.88)	(2.12)	(1.61)	(0.75)
Variance Decomposition of LERNER							
Period	S.E.	NPL	LERNER	REGCAP	DEPASS	NONINT	LOANASS
1	0.072	0.00	100.00	0.00	0.00	0.00	0.00
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
5	0.11	0.26	98.34	0.055	0.35	0.94	0.033
		(0.28)	(0.84)	(0.17)	(0.31)	(0.68)	(0.14)
10	0.12	0.70	96.19	0.10	0.81	1.88	0.25
		(0.63)	(1.73)	(0.45)	(0.62)	(1.36)	(0.49)
Variance Decomposition of REGCAP							
Period	S.E.	NPL	LERNER	REGCAP	DEPASS	NONINT	LOANASS
1	1.99	0.00	0.23	99.76	0.00	0.00	0.00
		(0.00)	(0.27)	(0.27)	(0.00)	(0.00)	(0.00)
5	3.29	1.41	1.24	97.15	0.020	0.12	0.029
		(0.77)	(1.09)	(1.35)	(0.15)	(0.36)	(0.18)
10	3.74	2.63	2.94	94.01	0.26	0.10	0.027
		(1.62)	(2.35)	(2.86)	(0.52)	(0.89)	(0.33)

Note; standard errors in parentheses.

tions of these variables, where risk is measured by the NPL ratio. To our knowledge, this is the first study to use this approach in this field, allowing as it does for fully endogenous determination of competition, capital and risk.

Other control variables used in the principal regressions above (the deposit/asset ratio, the loan/asset ratio and the share of non-interest income) are also included but not detailed below[37]. We took two lags of each variable in the VAR following the result of the Schwartz Information Criterion (SIC) test.[38] The results of the impulse responses and variance decompositions are shown below. Impulse responses were run using Pesaran's generalised impulses, the variance decompositions with Cholesky ordering competition, capital, the deposit/asset ratio, the share of non-interest income, the loan/asset ratio then risk, but also tested with the reverse ordering, giving similar results.

The most striking feature of the impulse responses in Fig. 1 is that competition drives leverage ratios significantly, with more competition leading to lower capital ratios and vice versa, a similar result to de-Ramon et al. (2018) albeit contrary to Schaeck and Čihák (2012). Meanwhile, there is also a significant two-way relation between leverage and the NPL ratio; a shock to leverage affects NPLs positively after 5 years, although the reverse effect is only significant after 9 years. A shock to Lerner itself has just an initial significant direct negative effect on the NPL ratio. Effects of leverage and competition on NPLs are consistent with the single equation results in Tables 4 and 5. There is also a short run positive effect on competition from NPLs. In Fig. 2, where the risk-adjusted capital ratio is substituted for the leverage ratio in the VAR, there is again a significant impact of competition at 95% on regulatory capital, and there is again an interrelation of regulatory capital and risk.

In the variance decompositions (Tables 13 and 14), it is notable that competition is largely autonomous in both VARs, with over 96% of the variance self-determined even after 10 years. NPLs variance is also largely autonomous. In contrast, the variance of the leverage ratio is influenced by competition quite significantly (it accounts for 7% of the variance of leverage after 10 years, albeit only 3% with regulatory capital). Variance of regulatory capital and leverage do not majorly influence the NPL ratio, although the deposit-asset ratio does by 4%. Overall, this would appear to indicate weak exogeneity of competition in the system.

In Fig. 3 we show impulse responses for competition on the leverage ratio for a variety of subsamples and for different risk variables. We find that the effect of competition on capital is quite general. It applies in the cases of advanced countries, for emerging market economies, pre and post-crisis, with the provisions/loans and log Z-score measures of risk, and also with the additional macro variables for NPL/loans and for provisions/loans.

[37] Detailed results are available from the authors on request.

[38] In choosing to follow the SIC we note that Koehler and Murphree (1988) found that the alternative Akaike (AIC) criterion tends to overfit the data and choose higher order models for empirical analysis. They found that SIC is a better criterion to use. Similar results were found by Geweke and Meese (1981).

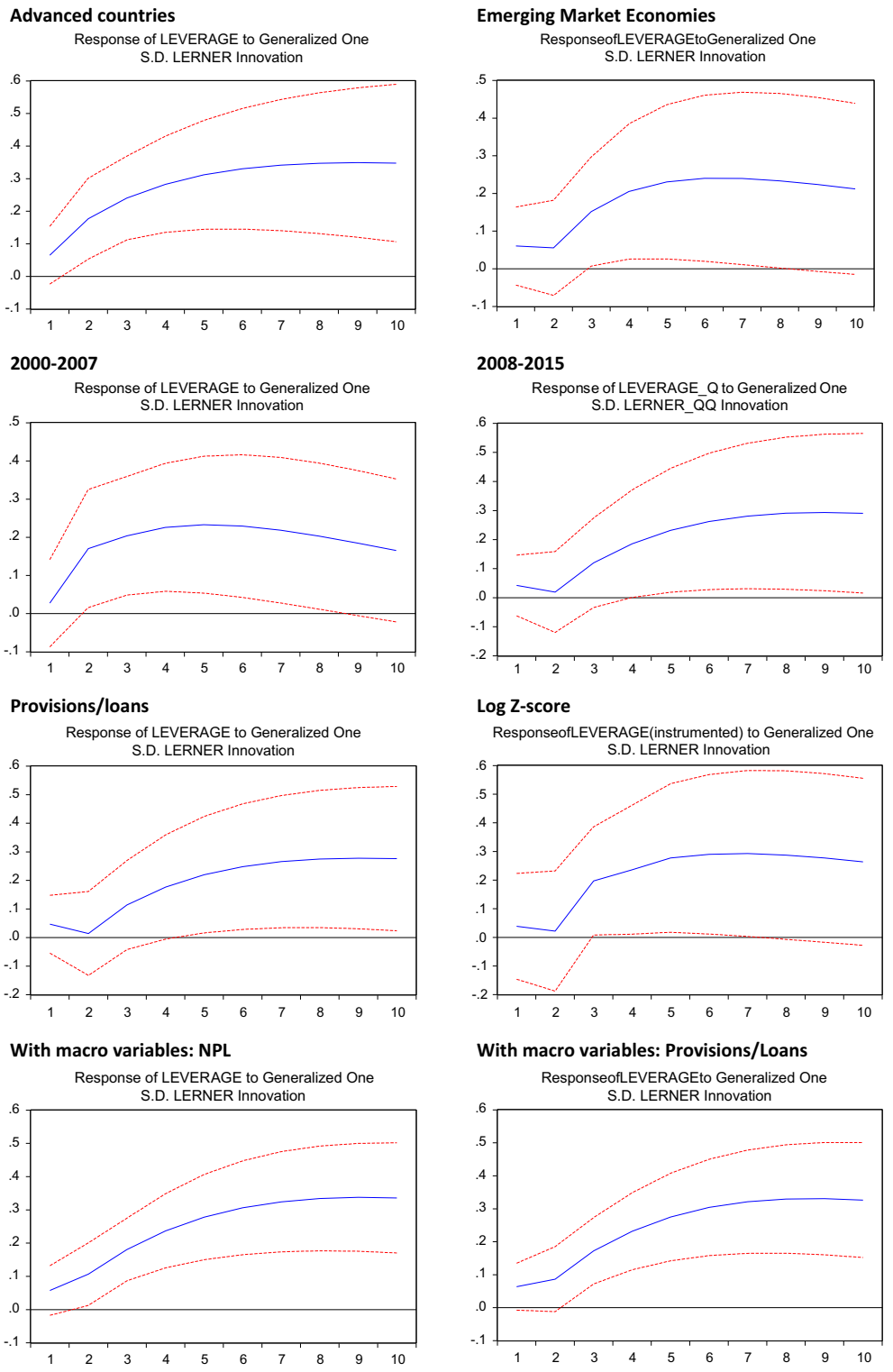

Fig. 3. Impulse response of leverage ratio to Lerner index for various samples (with 95% confidence intervals).

8. Conclusions

We have highlighted that empirical studies of banking-sector risk typically look at either the relationship of competition to risk or bank capital adequacy to risk, but only a subset integrate the two. This raises an issue for most of the literature of

potential bias arising from omission of relevant control variables, and is of particular importance in the light of the introduction of a regulatory leverage ratio in Basel III alongside risk-adjusted capital adequacy in Basel III as well as macroprudential surveillance and policy which seeks to forecast, assess and control risk at a sectoral level.

To advance the literature, we have undertaken empirical research which assesses the effectiveness of a leverage ratio[39] relative to a measure of the risk-adjusted capital ratio in affecting bank risk, controlling for competition in the banking-sector in a wide range of countries. We have used macro data from the World Bank's Global Financial Development Database over 1999–2015 for up to 112 countries globally. Our modelling approach has used control variables that capture aspects of banks' business models that contribute to financial stability, aggregated to the level of the banking sector.

Our advance from most existing work in the fields of banking capital and risk and banking competition and risk is to include both competition and capital in all estimates of risk. We also make a distinctive contribution compared with the studies that do assess capital, competition and risk together. First, by use of macro data, our work is more appropriate for macroprudential assessment. This is the case inter alia because macro data provides weighted average information, thus implicitly giving greater importance to large systemic institutions, while micro work typically weights institutions equally. Second, our approach is global rather than regional or country-specific, enabling results to be analysed both globally and separately for groups of countries at different stages of economic development. Third, to our knowledge this is the first study in this area to undertake Panel VAR estimation that allows the three variables competition, capital and risk to be jointly endogenously determined. A number of additional advances are detailed in Section 3.1.

Our work has obtained new evidence on five unresolved issues in financial stability analysis:

- There is a tendency for both the leverage ratio and the risk-adjusted capital ratio to be significant predictors of risk. For crises and Z-score they are supportive of the "skin in the game" hypothesis of a negative relation between capital and risk, whereas for NPLs and to a lesser extent provisions, they are generally consistent with the "regulatory hypothesis" of a positive relation of capital adequacy to risk.
- The leverage ratio is as often relevant as the risk-adjusted capital ratio, underlining its importance as a regulatory tool. The relative ineffectiveness of risk-adjusted capital for some risk measures may relate to untruthful or inaccurate assessments of bank real risk exposure.
- The results for the Lerner Index strongly underpin the "competition-fragility" hypothesis rather than "competition-stabi lity" and show a widespread impact of competition on risk generally.
- There are some differences between advanced countries and emerging market economies in the capital-risk-competition nexus, with for example a wider impact of competition in emerging market economies (although we suggest that both types of country need to pay careful attention to the evolution of competition in macroprudential surveillance).
- The Panel VAR results give some indication of the transmission mechanism from competition to risk and financial instability. It is shown that a shock to competition reduces leverage ratios and regulatory capital ratios significantly, giving a further reason for vigilance when competition increases. This result is consistent over a range of subsamples and risk variables. In the variance decomposition, we find that competition is autonomous, while the variance of the leverage ratio is significantly affected by competition.

Robustness checks show that the inclusion of key macroeconomic variables and crises do not amend the main results. Furthermore, we contend that results such as ours based on macroeconomic data may in some ways be superior to those with individual bank data which is more typical of the literature. This is the case not least in that the underlying macro data is a weighted average of individual institutions, thus implicitly giving greater importance to large systemic institutions, while micro work typically gives equal weight to each institution. For this reason, we contend that our results are of considerable relevance to regulators undertaking macroprudential surveillance and implementing macroprudential policy.

As regards further regulatory implications, perhaps the most important is the positive relation of bank competition to banking sector risk for most risk measures and subsamples, that has often been disregarded by regulators in the past. The fact that competition policy in the economy in general is often under separate anti-trust authorities makes control of banking competition at a macroprudential level more complex, but the results stress the importance of regulators at least monitoring such competition. Then, there is the widespread importance of the leverage ratio, that underlines the appropriateness of its inclusion in Basel III as a complement to risk-adjusted regulatory capital ratios. The fact that capital's relation to risk is negative ("skin in the game") for crises and Z-score underlines the importance of overall capital regulation. The contrasts in some results between advanced countries and emerging markets/developing countries underlines the fact that there is no "one size fits all" for regulation. Finally the effect of competition on capital indicates that there are indirect as well as direct effects of competition on risk, again emphasising the importance of the monitoring of competition for macroprudential purposes.

As regards further research, this could look inter alia at the further breakdown of results between emerging market economies against developing countries. It could also use coefficients that vary over different horizons for example using the functional coefficients approach as in Herwartz and Xu (2010). Since the GFDD is regularly updated, there will in due course be scope to assess robustness including the latest observations. Further work could also look at the interaction of

[39] As noted, the leverage variable we employ is distinct from the leverage ratio as defined in Basel III as we include all regulatory capital in the numerator and on-balance-sheet assets only in the denominator, in contrast to the Basel III definition of Tier 1 capital divided by the bank's average total consolidated assets (sum of the exposures of all assets and non-balance-sheet items).

the risk-adjusted capital ratio and the leverage ratio to see if this enhances stability (as it is expected to). This could be undertaken in future once Basel III is properly in place.[40] Also there could be assessment of possible nonlinearities in the relation of competition and capital to risk.

CRediT authorship contribution statement

E. Philip Davis: Conceptualization, Methodology, Software, Data curation, Visualization, Investigation, Supervision, Validation, Project administration, Funding acquisition. **Dilruba Karim:** Conceptualization, Methodology, Software, Data curation, Visualization, Investigation, Supervision, Validation, Project administration, Funding acquisition. **Dennison Noel:** Conceptualization, Methodology, Software, Data curation, Visualization, Investigation, Supervision, Validation, Project administration, Funding acquisition.

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Appendix

(See Table A1).

Table A1
Data codes from the World Bank for the variables used.

Variable type	Variable name	Acronym	Data code	Source
Dependent	Banking crisis dummy	CRISIS	GFDD.OI.19	Global Financial Development Database
	Bank non-performing loans/ gross loans (%)	NPL	GFDD.SI.02	Global Financial Development Database
	Bank Z-score	Z-SCORE	GFDD.SI.01	Global Financial Development Database
	Provisions/gross loans ratio	PROVLOAN	GFDD.SI.07*GFDD.SI.02	Global Financial Development Database
Independent (basic equations)	Lerner index	LERNER	GFDD.OI.04	Global Financial Development Database
	Bank capital to total assets (leverage ratio)	LEVERAGE	GFDD.SI.03	Global Financial Development Database
	Bank regulatory capital/risk weighted assets	REGCAP	GFDD.SI.05	Global Financial Development Database
	Deposit/asset ratio	DEPASS	GFDD.OI.02/ GFDD.DI.02	Global Financial Development Database
	Bank noninterest income/total income	NONINT	GFDD.EI.03	Global Financial Development Database
	Loan/asset ratio	LOANASS	GFDD.DI.01/ GFDD.DI.02	Global Financial Development Database
Independent (robustness equations)	Real GDP growth (annual %)	GDPG	NY.GDP.MKTP.KD.ZG	World Development Indicators Database
	Inflation, consumer prices (annual %)	INFCPI	FP.CPI.TOTL.ZG	World Development Indicators Database
	Unemployment, total (% of total labour force) (modelled ILO estimate)	URILO	SL.UEM.TOTL.ZS	World Development Indicators Database

Notes: The ratio of provisions/gross loans is constructed as provisions to non-performing loans times non-performing loans to gross loans. The deposit/assets ratio is constructed as the ratio of deposit money bank deposits/GDP to deposit money banks' assets/ GDP. The loan/assets ratio is constructed as the ratio of private credit by deposit money banks/GDP to deposit money banks' assets/GDP.

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[40] Such an investigation might also cast light on questions such as whether and when the leverage ratio should be a binding constraint on bank lending as opposed to risk-adjusted capital ratio, or whether it could lead to a "race to the bottom" if it is set lower than average bank ratios. Also whether the leverage ratio be varied over the cycle as a macroprudential tool.

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