Banking sector concentration, competition and financial stability: the case of the Baltic countries

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ABSTRACT
This paper empirically assesses the potential nonlinear relationship between competition and bank risk for a sample of commercial banks in the Baltic countries over the period 2000–2014. Competition is measured by two alternative indexes, the Lerner index and the market share, while we consider the Z-score and loan loss reserves as proxies for bank risk. In line with the theoretical predictions, we find an inverse U-shaped relationship between competition and financial stability. This then means that above a certain threshold, the lack of competition is likely to exacerbate the individual risk-taking behaviour of banks, and could be detrimental to the stability of the banking sector in the Baltic countries. The threshold is around 0.60 for the Lerner index, and close to 50% for market share in terms of assets. The policy implications are that the existence of such a threshold suggests that the future evolution of the structure of the banking industry in these countries is of critical importance. Specifically, this implies that policy-makers should place greater emphasis on mergers and acquisitions to avoid any significant increase of banking sector concentration.

1. Introduction

After the collapse of Lehman Brothers in the US in 2008, and the consequent need for a number of European banks to be bailed out, there has been concern recently about the relationship between banking sector concentration and financial stability within a country. According to Schinasi (2004), financial stability is a combination of three important characteristics. First, a stable financial system is capable of efficiently facilitating the spatial and intertemporal allocation of economic resources. Second, financial risks are assessed and priced reasonably accurately and are also relatively well managed. Third, the financial system is in such a condition that it can effectively absorb financial and real economic shocks. If any one or a combination of these characteristics is not maintained, then it is likely that the financial system exhibits instability. In such periods of financial instability, asset prices deviate excessively from their intrinsic values, banks are reluctant to finance profitable projects, and payments may not arrive on time.

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A number of studies have attempted to answer whether highly concentrated banking markets have an impact on financial stability. However, the results are far from conclusive since they vary with the period and countries analysed. The importance of a healthy banking sector for the successful functioning of an economy makes this subject topical for academics and policy-making institutions alike. Proper analysis of the degree of causality from banking concentration to banking sector stability can help institutions deploy the right measures to enhance stability, while it is a priority for academics to investigate how to measure banking competition and financial stability, and how to help policy-making promote stability and economic growth. Basic industrial organisation theory assumes that competition in markets tends to reduce the prices paid by consumers and increases efficiency, as only the most efficient firms could survive in a perfect competitive market. However, this prevailing assumption might be misguided for the banking sector, since fierce competition among banks can result in increased instability in the banking sector, leading to a financial crisis with fatal consequences for the banks. In this scenario, pro-competition policies that are targeted to enhance the efficiency of the financial sector might have strong adverse effects for the whole economy. Whether they do or not depends on whether tight competition enhances or reduces financial stability. The empirical literature does not provide a clear answer to this question, and theoretical papers do not reach a consensus either. This highlights the importance of establishing what the effect of bank competition on the risk-taking behaviour of financial institutions is, and then what its effect on financial stability is.

The literature offers two opposing views of the relationship between competition in the banking sector and financial stability (see, for instance, Beck, 2008). These views are the traditional ‘competition-fragility’ view, and the ‘competition-stability’ view.

The competition-fragility view argues that high levels of competition in the banking sector may increase financial instability and the fragility of banks. In a highly competitive banking sector, bank managers may have an incentive to take on high-risk operations in the search to make big profits quickly to meet profit objectives. This may lead them to put together a riskier portfolio of assets, which may end up in bankruptcies if there is a case of financial distress (see Keeley, 1990 amongst others for a theoretical model). In contrast, a less competitive environment where banks can afford higher capital buffers and less aggressive operations means the incentive to take increased unnecessary risk diminishes, enhancing the stability of the banking sector overall. Bergantino and Capozza (2013) say that bigger banks can afford to give low interest rates to new start-ups and share future profits. In addition, it is easier for the financial authorities to monitor a banking sector with fewer and bigger banks. Finally, bigger banks with a higher level of market concentration can access better conditions in international markets than they can find in domestic ones, making them able to lend more cheaply and reducing the cost of capital for firms and households (Beck, Demirgüc-Kunt, & Levine, 2006).

The competition-stability view claims, on the contrary, that if a reduced number of banks have greater market power, it may increase the risks to their portfolios, as they will tend to set higher margins on loan interest rates. In this case, clients will have to pay a higher cost for borrowing, which may make non-performing loans more likely to increase in number. Linked to this, increased competition may affect the cost of capital, giving firms and individuals access to lower interest rates, which would boost the profitability of investment projects, thus reducing credit risks and ultimately enhancing
financial stability. In addition, big banks may believe that they are ‘too big to fail’, which comes from the moral hazard effect of the authorities providing bailouts when problems arise (Mishkin, 1999). In this case a lack of competition may give banks an incentive to engage in riskier operations.

Our analysis in this paper focuses on the relationship between the competition and concentration in the banking sector and financial stability in the Baltic countries, which are Estonia, Latvia and Lithuania. The Baltic countries are a textbook example of an area with a highly concentrated banking sector, with a small number of large, mostly foreign, banks. In Figure 1 we illustrate the share of assets held by the three largest banks in the Baltic countries and in other Central and Eastern European Countries (CEECs). Estonia and Lithuania stand out for the high degree of concentration in their banking sectors, as it is significantly higher than in Latvia or the other CEECs. The three largest banks in Lithuania had around 80% of total banking-sector assets in 2013, and in Estonia the three largest had more than 96%. Most of the larger financial institutions in Estonia, Latvia, and Lithuania are Nordic banks. This high level of banking sector concentration in the Baltic countries is a result of privatisation and mergers following the banking crises in Estonia (1992–1994), Latvia (1995) and Lithuania (1995–1996). During this period, some banks were liquidated, while others were recapitalised, and the primary outcome was that the Baltic banking sector has become highly concentrated and largely foreign-owned because the governments encouraged bank mergers and foreign takeovers for fear of bank runs and credit contraction.

Since the empirical literature does not seem to provide a clear answer as to which view holds empirically, this paper addresses this well-worn debate for this group of countries. Understanding whether the high concentration levels in the banking sector in the Baltic countries affect the risk-taking behaviour of banks, and consequently the stability of the banking sector, is of key importance for regulation and competition policies.

![Figure 1](image_url)

**Figure 1.** Concentration of banking sector assets: Baltic countries and other CEECs.

Source: Authors’ calculations, Global Financial Development Database, The World Bank. Other CEECs: Albania, Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania, Slovak Republic, Slovenia.
This paper investigates empirically at bank level the relationship between competition and risk for a sample of forty commercial banks in the Baltic countries from 2000 to 2014. Rather than simply analysing the potential trade-off between competition and financial stability in a linear fashion though, we follow the recent theoretical predictions from Martinez-Miera and Repullo (2010), and allow for the possibility of an inverse U-shaped relationship between competition and financial stability. The most recent literature on banking sector competition and concentration and financial stability highlights the importance of accounting for a U-shaped relationship between both measures. Doing so could let us identify an optimal degree of concentration and competition, and may indicate that both the competition-stability and the competition-fragility views are appropriate, depending on the level of concentration and competition.¹

Martinez-Miera and Repullo (2010) establish that there may indeed be two separate effects in operation. One is the risk-shifting effect found by Boyd and De Nicoló (2005) where risk is reduced as competition increases, provided that there is a negative correlation between loan interest rates and competition, as this reduces the risk of loan defaults. The second effect is the margin effect, which implies that greater bank competition reduces interest payments, reducing the buffer against losses. According to Martinez-Miera and Repullo (2010) the risk-shifting effect dominates in less competitive banking markets, so the marginal effect of a new bank entry is negative for financial stability, whereas in more competitive markets the margin effect overwhelms the risk-shifting effect, so a new entry increases financial risk.

In the empirical literature, U-shaped relationships are usually tested by including a quadratic term in a standard regression model. If the estimated coefficient associated with this term is statistically significant and the estimated extremum point is within the data range, then it is common to conclude that there is a U-shaped relationship. In our paper, we go a step further and test the existence of a U-shaped relationship between bank competition and financial stability formally with the U-shape test developed by Lind and Mehlum (2010). This procedure also gives us a confidence interval for the optimal point. Such a confidence interval can be very useful for policy making, as it lets the regulatory authorities assess whether any financial institution has passed the upper bound, given the existence of a U-shaped relationship. It can be particularly useful for assessing whether the entry of new financial institutions or mergers could exacerbate financial instability.

We do this using balance-sheet data taken from the Bankscope database and we consider two types of bank risk proxy, the Z-score and the loan loss reserves. We also consider two different measures of competition, a structural measure derived from market share, and a non-structural measure from the Lerner index. As we will show in this paper, these two alternative measures of banking competition are not necessarily highly correlated, and they seem to capture different aspects of competition.

The remainder of the paper is organised as follows. Section 2 reviews the theoretical and empirical literature the on link between banking competition and financial (in) stability. Section 3 presents the data and the measures of competition and bank risk used. Section 4 presents the methodology and discusses the results. Section 5 concludes and gives some policy recommendations.
2. Literature review

A number of empirical papers have investigated the relationship between banking sector competition and concentration and financial stability. However, the empirical findings do not all lead to the same conclusion. Indeed, while some cross-country analyses (see, for instance, Beck et al., 2006) argue that banking crises are less likely in economies with more concentrated banking systems, others show on the contrary that competitive banking sectors are less prone to systemic banking crises and exhibit increased time to crisis (see, for instance, Schaeck, Čihák, & Wolfe, 2009). The recent empirical investigation by Diallo (2015) seems to support the competition-fragility view, as it considers a large sample of emerging and industrial economies and uses different measures of bank competition and finds the opposite results to those of Schaeck et al. (2009). Diallo (2015) shows that bank competition increases the probability of a systemic banking crisis occurring and that it is also positively related to the duration of the crisis.

More recent evidence from studies with a European perspective also offers mixed results. The first paper to study the link between banking sector concentration and financial stability in Europe is that of Uhde and Heimeshoff (2009). They use an aggregate z-score as a measure of banking sector fragility for 25 European countries and show that banking market concentration that has a significant negative effect on financial stability. Their results suggest this negative relationship between concentration and stability may be explained by the higher volatility of the returns of larger banks in concentrated markets. In a recent paper, IJtsma, Spierdijk, and Shaffer (2017) re-investigate this issue for the same sample of countries, but unlike Uhde and Heimeshoff (2009), they analyse them at both country level and bank level. Indeed, they show that if returns on assets of the banks are not perfectly correlated, the aggregated and bank-level z-scores measure different aspects of financial stability. Notably, the aggregate z-score accounts for systemic risk. In line with Uhde and Heimeshoff (2009), the results that they obtain suggest that concentration has a significant negative effect on stability. However, their findings also indicate that this effect is economically small at both levels of analysis. A similar result is obtained by Cifter (2015) for Central and Eastern European Countries (CEECs), as no robust relationship is found between bank concentration and non-performing loans.

Finally, a focus on empirical studies that investigate the competition-stability nexus using bank-level data also finds conflicting results. For instance, results obtained by Agoraki, Delis, and Pasiouras (2011) for a sample of CEECs suggest that a weak competitive environment is not necessarily synonymous with financial instability. Indeed, they find that banks with relatively high market power tend to take on lower credit risk and have a lower probability of default. The opposite is found by Schaeck and Čihák (2014), who show that competition in the banking sector enhances financial stability. They say that efficiency is the transmission mechanism through which competition contributes to stability. Using the Boone index as a proxy for banking sector competition and considering a large sample of European banks, Schaeck and Čihák (2014) find that competition is stability-enhancing, but that this effect of competition on stability is greater for efficient banks than for inefficient ones.
However, Leroy and Lucotte (2017) show from a large sample of European listed banks that bank competition can have opposite effects on individual risk and systemic risk, which they proxy using the SRISK measure. Indeed, the results that they obtain suggest that competition encourages banks to take risks and then increases individual bank fragility, but tends to enhance financial stability by decreasing systemic risk. We also find two further studies for individual countries in the papers of Kick and Prieto (2015) and Jimenez, Lopez, and Saurina (2013), who analyse the relationship between competition and concentration and stability for the cases of Germany and Spain respectively. In the German case, the authors find evidence pointing towards the competition-fragility view, while for Spain nonlinear effects are found, which is in line with the theoretical predictions of Martinez-Miera and Repullo (2010).

Although most of the existing literature indicates that the competition-fragility hypothesis seems to hold empirically, we focus in our paper on the Baltic countries, which have not been studied much, and where concentration is among the highest in Europe. In addition, we also look at the potential nonlinear relationship between competition and bank risk.

3. Data and stylised facts

3.1. Data, measures of competition, concentration and risk

We consider all the commercial banks in the Baltic countries for which we have balance-sheet data over the period 2000–2014, giving an unbalanced panel data of 40 banks. Table 1 shows the list of banks, with their country and the period available. Our sample contains 21 banks in Latvia, 10 banks in Lithuania, and 9 banks in Estonia. All the data are taken from Bankscope, which is a database computed by Bureau Van Dijk.

Since our analysis aims to investigate the relationship between banking competition and risk-taking by banks, we first need to choose a bank-level measure of competition. The literature traditionally distinguishes two types of measure of competition: structural and non-structural measures. As Northcott (2004) argued however, there is no consensus in the literature about the best indicator for gauging competition. Moreover, a number of empirical studies (see e.g. Bikker & Haaf, 2002; Carbó, Humphrey, Maudos, & Molyneux, 2009; Claessens & Laeven, 2004; Lapteacruz, 2014) show that the existing indicators of competition give conflicting predictions across countries, within countries, and over time, even if they seem to provide similar rankings.

Against this background, we adopt a conservative approach and choose to use both a structural measure of bank-level competition and a non-structural one. The structural measure we consider is market share, and the non-structural measure is the Lerner index. The market share corresponds to the amount of assets held by each bank divided by the total assets of the national banking sector. This ratio is comprised between 0 and 100%. It is an inverse proxy for bank competition. A low value indicates a high degree of competition and vice versa.

The Lerner index is also an inverse proxy for competition. It is designed to measure the pricing power of firms and corresponds to the mark-up of price over marginal cost. The Lerner index is bounded between 0 and 1, with the extreme value of zero corresponding to perfect competition, and the value of one to a pure monopoly. As stated by
### Table 1. List of commercial banks located in the Baltic countries.

| Bank Name                                      | Country code | Period          | Bank Name                                      | Country code | Period          |
|------------------------------------------------|--------------|-----------------|------------------------------------------------|--------------|-----------------|
| Swedbank AS<sup>sub</sup>                      | LV           | 2001–2014       | Swedbank AS<sup>sub</sup>                      | EE           | 2000–2014       |
| ABLV Bank AS<sup>cor</sup>                     | LV           | 2002–2014       | SEB Pank<sup>sub</sup>                         | EE           | 2000–2014       |
| SEB banka AS<sup>sub</sup>                     | LV           | 2000–2014       | Danske Bank A/S Estonia Branch<sup>bra</sup>   | EE           | 2000–2007       |
| Rietumu Bank Group-Rietumu Banka<sup>cor</sup> | LV           | 2000–2014       | DNB Pank AS<sup>sub</sup>                      | EE           | 2011–2014       |
| AS Citadele Banka<sup>sub</sup>                | LV           | 2010–2014       | AS LHV Pank<sup>sub</sup>                      | EE           | 2012–2014       |
| AS DnB Banka<sup>sub</sup>                     | LV           | 2004–2014       | BIGBANK AS<sup>cor</sup>                       | EE           | 2006–2014       |
| Norvik Banka AS<sup>sub</sup>                  | LV           | 2006–2014       | Estonian Credit Bank-Eesti Krediidipank<sup>sub</sup> | EE | 2000–2014 |
| Latvijas Kraj Banka AS-Latvian Savings Bank<sup>sub</sup> | LV | 2005–2010 | Versobank AS<sup>sub</sup> | EE | 2011–2014 |
| As PrivatBank<sup>sub</sup>                    | LV           | 2004–2014       | Tallinn Business Bank Ltd-Tallinna Äripanga AS<sup>cor</sup> | EE | 2010–2013 |
| Baltikum Bank AS<sup>sub</sup>                 | LV           | 2005–2014       | AB SEB Bankas<sup>sub</sup>                    | LT           | 2000–2014       |
| Regionala investiciju banka-Regional Investment Bank<sup>sub</sup> | LV | 2003–2014 | Swedbank AB<sup>sub</sup> | LT | 2003–2014 |
| Trasta Komercbanka-Trust Commercial Bank<sup>cor</sup> | LV | 2000–2014 | AB DNB Bankas<sup>sub</sup> | LT | 2000–2014 |
| Baltic International Bank- Baltijas Starptautiska Banka<sup>sub</sup> | LV | 2009–2014 | AB Bankas Snoras<sup>ide</sup> | LT | 2000–2010 |
| AS Expobank<sup>sub</sup>                      | LV           | 2012–2014       | Danske Bank A/S<sup>sub</sup>                 | LT           | 2000–2014       |
| Danske Bank A/S<sup>sub</sup>                  | LV           | 2000–2007       | Siauliu Bankas<sup>cor</sup>                  | LT           | 2000–2014       |
| Jsc Latvijan Development Financial Institution Altum<sup>ind</sup> | LV | 2003–2013 | Citadele Bankas AB<sup>sub</sup> | LT | 2006–2014 |
| Meridian Trade Bank AS<sup>ind</sup>           | LV           | 2003–2014       | UAB Medicinos Bankas<sup>sub</sup>            | LT           | 2000–2014       |
| AS Reverta<sup>sub</sup>                       | LV           | 2000–2014       | AB Bankas FINASTA<sup>sub</sup>               | LT           | 2009–2014       |
| Bank M2M Europe AS<sup>sub</sup>               | LV           | 2005–2009, 2013–2014 | Skandinaviska Enskilda Banken AB; Vilniaus Filialia<sup>sin</sup> | LT | 2009–2014 |
| JSC Latvijas Pasta banka<sup>sub</sup>         | LV           | 2009–2014       |                                               |               |                 |
| GE Capital Latvia<sup>sub</sup>                | LV           | 2004–2012       |                                               |               |                 |

Source: Bankscope, Bureau Van Dijk. Type of bank entity: sub - controlled subsidiary, cor - corporate group, bra - branch, sin - single location, ind - independent, ide - not identified.
Leroy and Lucotte (2017), the main advantage of the Lerner index is that it is the only time-varying non-structural measure of competition that can be computed at the disaggregated level of the firm. This certainly explains why the Lerner index has been used as a proxy for firm-level competition by a number of recent empirical studies in the banking literature (see Table A1 in the Appendix).

Formally, the Lerner index corresponds to the difference between price and marginal cost as a percentage of price. It can be written as follows:

\[
Lerner_{it} = \frac{p_{it} - mc_{it}}{p_{it}}
\]  

(1)

with \( p_{it} \) the price and \( mc_{it} \) the marginal cost for the bank \( i \) in period \( t \). Under the assumption that the heterogeneous flow of services produced by a bank is proportional to its total assets, the price \( p_{it} \) is calculated as the ratio of total revenue (the sum of interest and non-interest income) to total assets.

To obtain the marginal cost, we adopt an approach that is conventional in the literature (see, e.g., Berger, Klapper, & Turk-Ariss, 2009 or Beck, Jonghe, & Schepens, 2013) and model the total operating cost of running the bank as a function of a single, aggregate output proxy, \( Q_{it} \), and three input prices, \( W_{1, it} \), \( W_{2, it} \), and \( W_{3, it} \). More precisely, we estimate the following translog cost function:

\[
\ln C_{it} = \beta_0 + \beta_1 \ln Q_{it} + \frac{\beta_2}{2} \ln Q_{it}^2 + \sum_{k=1}^{3} \gamma_k \ln W_{k, it} + \sum_{k=1}^{3} \phi_k \ln Q_{it} \ln W_{k, it} \\
+ \sum_{k=1}^{3} \sum_{j=1}^{3} \frac{\rho_{kj}}{2} \ln W_{k, it} \ln W_{j, it} + \delta_1 T + \frac{\delta_2}{2} T^2 + \delta_3 T \ln Q_{it} + \sum_{k=4}^{6} \delta_k T \ln W_{k, it} + \epsilon_{it}
\]  

(2)

in which \( C_{it} \) measures the total operating costs from interest expenses, personnel costs, and other administrative and operating costs for bank \( i \) at the period \( t \), and \( Q_{it} \) represents a proxy for bank output and corresponds to the total assets. \( W_{1, it} \), \( W_{2, it} \) and \( W_{3, it} \) are the prices of inputs. \( W_{1, it} \) is the ratio of interest expenses to total assets, \( W_{2, it} \) is the ratio of personnel expenses to total assets, and \( W_{3, it} \) is the ratio of administrative and other operating expenses to total assets. \( T \) is a trend that is included to capture technical changes and potential movements in the cost function over time. Furthermore, to reduce the influence of outliers, all variables are winsorised at the 1st and 99th percentile levels (see, e.g., Berger et al., 2009 or Anginer, Demirguc-Kunt, & Zhu, 2014). Following Turk-Ariss (2010) and Liu, Molyneux, and Wilson (2013), we also scale cost and input prices by \( W_{3, it} \) to correct for heteroscedasticity and scale biases. We further impose the following restrictions on regression coefficients to ensure homogeneity of degree one in input prices: \( \sum_{k=1}^{3} \gamma_{k, it} = 1 \), \( \sum_{k=1}^{3} \phi_k = 0 \) and \( \sum_{k=1}^{3} \sum_{j=1}^{3} \rho_{kj} = 0 \).

Because there are a relatively low number of observations, the Equation (2) is not estimated separately for each Baltic country. We estimate the translog cost function on the whole sample of commercial banks in the Baltic countries, and we include country fixed effects in the regression to control for potential differences in technology across economies. The coefficient estimates from Equation (2) are then used to calculate the marginal cost for each bank \( i \) at each period \( t \):
\[
mc_{it} = \frac{\partial C_{it}}{\partial Q_{it}} = \frac{C_{it}}{Q_{it}} \left( \beta_1 + \beta_2 \ln Q_{it} + \sum_{k=1}^{3} \hat{\theta}_k \ln W_{k,it} + \hat{\delta}_3 T \right)
\]

(3)

However, as argued by Turk-Ariss (2010), one important problem associated with the estimation of the conventional Lerner index is that it implicitly assumes full bank efficiency and does not consider the possibility that banks may not exploit the pricing opportunities that result from market power. Indeed, banks with a large amount of market power could choose the quiet life and reduce their cost efficiency (Hicks, 1935 or Berger & Hannan, 1998).\(^3\) Alternatively, efficiency could also lead to the market being concentrated in the hands of the most efficient banks (Demsetz, 1973; Peltzman, 1977). Consequently, as shown by Koetter, Kolari, and Spierdijk (2012), not controlling for inefficiency is problematic because it can affect the difference between price and marginal cost, and this then biases the estimation of the Lerner index.

We account for this bias by not proxying the market power of banks using the conventional Lerner index, but instead by considering the efficiency-adjusted Lerner index proposed by Koetter et al. (2012), defined as:

\[
AdjustedLerner_{it} = \frac{(\hat{n}_{it} + \hat{C}_{it}) - \hat{mc}_{it}}{(\hat{n}_{it} + \hat{C}_{it})}
\]

(4)

where \(\hat{n}_{it}\) is the estimated profit, \(\hat{C}_{it}\) the estimated total cost, and \(\hat{mc}_{it}\) the estimated marginal cost.

To calculate this adjusted Lerner index, we follow Koetter et al. (2012) and first estimate the translog cost function (Equation 2) using a Stochastic Frontier Analysis (SFA). We then obtain \(\hat{C}_{it}\) and \(\hat{mc}_{it}\). This an approach has the advantage of taking into account banks’ cost inefficiency, defined as the distance of a bank from a cost frontier accepted as the benchmark. Second, we specify an alternative profit function (Berger & Hannan, 1998), that we estimate using a SFA to obtain \(\hat{n}_{it}\).

Finally, we evaluate financial stability at the firm-level by considering two alternative proxies for bank risk: the Z-score and the loan loss reserves as a percentage of gross loans. The loan loss reserves are a measure of credit risk, while the Z-score is a commonly-used accounting-based measure of bank stability. Financial stability is usually defined as the absence of system-wide episodes in which the banking and financial system fails to function. In particular, according to the Federal Reserve Bank of St. Louis (2002), financial stability can be simply defined as the smooth and uninterrupted operation of both credit and payment mechanisms. Balance sheet disturbances faced by banks can then be viewed as a source of risk and vulnerability that might threaten the maintenance of financial stability. Consequently, even if these two measures evaluate the fragility of each financial institution separately, they give an idea of the vulnerability of the banking sector as a whole.

The Z-score explicitly compares the buffers of capitalisation and returns with risk from the volatility of returns to measure how far a bank is from insolvency. It is defined as:

\[
Zscore_{it} = \frac{E_{it}/A_{it} + \mu_{ROA_{it}}}{\sigma_{ROA_{it}}}
\]

(5)
where $\mu_{\text{ROA}_t}$ is the expected return on assets, $E_t/A_t$ is the equity to total assets ratio, and $\sigma_{\text{ROA}_t}$ is the standard deviation of the return on assets.

The Z-score is inversely related to the probability of a bank becoming insolvent. A higher Z-score implies a lower probability of this happening. Because a bank becomes insolvent when the value of its assets drops below that of its debt, the Z-score can be interpreted as the number of standard deviations that a bank’s return must fall below its expected value by to wipe out all the equity in the bank and render it insolvent (Boyd & Runkle, 1993). This study opts for the approach used by Beck et al. (2013) to compute the standard deviation of ROA. This approach uses a three-year rolling time window to compute the standard deviation of ROA rather than the full sample period, whereas the return on assets and the equity to total assets ratio are contemporaneous. As argued by Beck et al. (2013), this approach has two main advantages. First, it avoids the variation in the Z-score within banks that is exclusively driven over time by variation in the levels of capital and profitability. Second, given the unbalanced nature of our panel dataset, it avoids the denominator being computed at different window lengths for different banks.

### 3.2. Stylised facts

Before turning to the econometric analysis, we present the main cross-sectional and times series features of the Lerner index and the market share variable, and analyse whether they are linked to our proxies for bank risk. Table 2 reports the mean of the Lerner index and the bank market share for the Baltic countries for different sub-periods and for the overall period. We can observe in all the Baltic countries that the market power of commercial banks seems to have decreased between 2000 and 2014. This evolution is the most pronounced for Latvia, where the average of the Lerner index went from 0.72 in 2000–04 to 0.33 in 2010–14, and the average market share went from 13.73% in 2000–04 to 5.63% in 2010–14. We find that, in any case, Estonia is the Baltic country with the highest values for the Lerner index and the bank market share, which is consistent with the findings reported in Figure 1.

In Table 3 we report the value of the Lerner index and of the market share in 2014 for all the commercial banks considered in our sample. For the market share, we can see that the distribution of activity across banks is relatively more homogeneous in Latvia than in Lithuania and Estonia. Indeed two banks in Lithuania, AB SEB Bankas and Swedbank AB, have a market share of more than 30%, while in Latvia Swedbank AS had the largest market share at 18.75% in 2014. More importantly, fewer than one quarter of the banks in Latvia had a market share of more than 10%. In Estonia, the

### Table 2. Evolution of the Lerner index and the market share in Baltic countries.

| Sub-periods   | Lerner index (mean) | Market share in% (mean) |
|---------------|---------------------|-------------------------|
|               | Estonia | Lithuania | Latvia | Estonia | Lithuania | Latvia |
| 2000–2004     | 0.652   | 0.512     | 0.716  | 25.00   | 15.718    | 13.73  |
| 2005–2009     | 0.608   | 0.428     | 0.532  | 22.95   | 12.358    | 5.964  |
| 2010–2014     | 0.562   | 0.35      | 0.334  | 14.268  | 10.888    | 5.628  |
| Overall period| 0.6     | 0.41      | 0.48   | 19.26   | 12.61     | 7.01   |

Source: Authors’ calculation based on the Bankscope database. Note: The Lerner index refers to the adjusted Lerner index proposed by Koetter et al. (2012).
### Table 3. Lerner index and market share of commercial banks located in Baltic countries in 2014.

|            | Latvia              | Lithuania                         | Estonia                       |
|------------|---------------------|-----------------------------------|-------------------------------|
|            | Lerner index | Market share | Lerner index | Market share | Lerner index | Market share |
| ABLV Bank AS | 0.76       | 15.78      | AB Bankas FINAST | 0.05       | 0.30      | AS LHV Pank | 0.61       | 3.13  |
| AS Citadele Banka | 0.66       | 10.55      | AB Bankas Snoras | n.a.   | n.a.      | BIGBANK AS | 0.21       | 1.88  |
| AS DNB Banka  | 0.64       | 8.73       | AB DNB Bankas | 0.42      | 17.97     | DNB Pank AS | 0.68       | 3.75  |
| AS Expobank   | 0.61       | 1.81       | AB SEB Bankas | 0.73      | 32.21     | Danske Bank A/S | n.a.   | n.a.  |
| AS Reventa    | −0.04      | 0.85       | Citadele Bankas AB | 0.01 | 2.04     | Estonian Credit Bank | 0.31       | 1.48  |
| Baltic International Bank | 0.03       | 1.96       | Danske Bank A/S | 0.66      | 8.44      | SEB Pank | 0.90       | 30.03 |
| Baltikums Bank AS | 0.57       | 2.31       | Siauliu Bankas | 0.45      | 7.83      | Swedbank As | 0.91       | 54.00 |
| Bank M2M Europe AS | 0.31       | 0.57       | Skandinaviska Enskilda Banken AB | 0.09 | 0.01 | Tallinn Business Bank Ltd | 0.60* | 1.12* |
| Danske Bank A/S | n.a.       | n.a.       | Swedbank AB | 0.71      | 30.02     | Versobank AS | 0.65       | 1.48  |
| GE Capital Latvia | 0.01**   | 0.46**     | UAB Medicinos Bankas | −0.01 | 1.17     |                   |                   |       |
| JSC Latvijas Pasa Banka | 0.27      | 0.52       |                   |                   |                   |                   |                   |       |
| Jsc Latvian Dev. Fin. Inst. Altum | −0.01* | 1.17* |                   |                   |                   |                   |                   |       |
| Latvijas Krajbanka | n.a.       | n.a.       |                   |                   |                   |                   |                   |       |
| Meridien Trade Bank AS | 0.02      | 0.93       |                   |                   |                   |                   |                   |       |
| Novik Banka AS | 0.02       | 4.28       |                   |                   |                   |                   |                   |       |
| PrivatBank    | 0.54       | 2.51       |                   |                   |                   |                   |                   |       |
| Regionala Investiciju Banka | 0.02 | 2.19 |                   |                   |                   |                   |                   |       |
| Rietumu Bank Group | 0.73      | 12.86      |                   |                   |                   |                   |                   |       |
| SEB Banka AS  | 0.72       | 13.29      |                   |                   |                   |                   |                   |       |
| Swedbank AS   | 0.76       | 18.75      |                   |                   |                   |                   |                   |       |
| Trasta Komercbanka | 0.01       | 2.12       |                   |                   |                   |                   |                   |       |

Source: Authors’ calculation based on the Bankscope database. Note: The Lerner index refers to the adjusted Lerner index proposed by Koetter et al. (2012). Due to data availability, *refers to the Lerner index and the market share in 2013, and **to the Lerner index and the market share in 2012. N.A. means that balance sheet data are not available for those years.
banking industry is dominated by two foreign banks, SEB Pank and Swedbank AS, which between them hold nearly 85% of the banking sector assets. Furthermore, these two banks are also notable for the high values they recorded for the Lerner index in 2014 at 0.90 or more, which would indicate that our two proxies for market power give similar patterns. However, the picture for small banks is less clear, since four of them, AS LHV Pank, DNB Pank AS, Tallinn Business Bank Ltd and Versobank AS, had a Lerner index above 0.60 in 2014.

The low correlation between our two proxies for market power in Estonia is confirmed by Figure 2. In contrast to the results for Latvia and Lithuania, the Estonian data suggest a non-significant correlation between market share and the Lerner index for the Estonian banking sector. This reinforces our decision to consider two alternative measures of bank market power.

Finally, in Figure 3 we plot the Lerner index (x-axis) against the Z-score and the loan loss reserves (y-axis), while in Figure 4 we plot market share (x-axis) against our alternative measures of bank risk-taking. In each case, we consider both linear and nonlinear fitted values. The R-squared are obtained by regressing each measure of risk on the Lerner index or the market share, and by considering a linear or a quadratic function. The result shows that a relatively tight relationship exists between the Lerner index and the risk measures, while the link is less clear when we consider the market share of the banks. This relationship is negative with loan loss reserves, and positive with the Z-score, which is an inverse proxy for bank-individual risk. This preliminary result is in line with the competition-fragility view.

More importantly, bottom scatter plots reported in Figure 3 indicate a potential nonlinear relationship between the Lerner index and the Z-score, and between the Lerner index and the loan loss reserves. The next section provides an in-depth assessment of this issue.

Figure 2. Correlation between the market share and the Lerner index.
Note: The Lerner index refers to the adjusted Lerner index proposed by Koetter et al. (2012).
Figure 3. Scatterplots between the Lerner index and alternative measures of risk.  
Note: The shaded area represents the 95% confidence interval. The Lerner index refers to the adjusted Lerner index proposed by Koetter et al. (2012).

Figure 4. Scatterplots between market share and alternative measures of risk.  
Note: The shaded area represents the 95% confidence interval.
4. Methodology and results

4.1. Econometric approach

Following the theoretical results from Martinez-Miera and Repullo (2010), we examine whether nonlinear causality exists between the proxies for concentration and competition and our alternative measures of risk. To this end, we include the squared term of the Lerner index or of the market share. Such a nonlinear investigation is useful from a policy point of view, as it allows an optimal threshold to be identified beyond which bank competition, or inversely a lack of competition, becomes dangerous for the stability of the banking sector. Our analysis is based upon the following regression:

\[
\text{risk}_{it} = \alpha + \beta_1 \text{Comp}_{it-1} + \beta_2 \text{Comp}_{it-1}^2 + \beta_3 \text{Crisis}_t + \sum_{k=4}^{n} \beta_k X_{it-1} + \mu_i + \gamma_t + \varepsilon_{it}
\]

where \(i\) and \(t\) are respectively the bank and time period indicators, \(\text{risk}_{it}\) represents one or another of our measures of risk, \(\text{Comp}_{it-1}\) represents one or another of our measures of market power, either the Lerner index or the bank market share, \(\text{Crisis}_t\) is a dummy variable capturing the subprime crisis episode, equal to 1 from 2008 to 2012 and zero otherwise, and \(X_{it-1}\) is the vector of control variables (See Table 3 and Table 4). The term \(\mu_i\) is an individual specific effect, \(\gamma_t\) is an unobserved time effect included to capture common time-varying factors, and \(\varepsilon_{it}\) is the random error term. This specification is similar in many ways to that considered by recent studies that have investigated the competition-stability trade-off (see, for instance, Leroy & Lucotte, 2017). Equation (6) is estimated using the fixed effects (FE) estimator.

However, examining whether market power influences risk-taking by banks raises the question of endogeneity bias. Indeed, Schaeck and Čihák (2008) argued that the level of risk-taking could affect the competitiveness of banks, which could then impact our measures of market power. Banks might have an incentive to gamble in the hope of resurrection when they face a high probability of default. They may even be more inclined to change the price of their products so as to access new financial resources and attract new customers, thus affecting the existing market power. To address this potential endogeneity issue, we lag our proxies for market power by one period and do the same for all the control variables. We further consider an instrumental variable approach using the two-stage least squares (2SLS) estimator. We consider three instrumental variables, which are the first lag of the market power proxy considered, and two variables proxying cost inefficiency, these being the ratio of overhead expenses to total assets and the cost-to-income ratio.

4.2. Baseline estimates

The results obtained are reported in Tables 4 and 5 when we consider the Lerner index as right-hand side variable, and in Tables 6 and 7 when we consider the market share as a proxy for competition. For each specification, we report the turning point, representing the optimal threshold, when the U-shape test developed by Lind and Mehlum (2010) indicates a statistically significant nonlinear relationship between our proxies for bank market power and our alternative measures of risk. In
In this case, we also report the confidence interval for the extreme point, using the Fieller method.

Table 4 reveals that the results for each specification show an inverse U-shaped relationship between the Lerner index and the Z-score. The turning points vary between 0.57 and 0.64, suggesting that market power tends to increase the fragility of the banking sector beyond this threshold. The results that we obtain between the Lerner index and loan loss reserves are more mixed. Indeed, the results reported in Table 5 only indicate a U-shaped relationship between these two variables when we estimate Equation (6) using a 2SLS estimator. In this case, the turning points vary between 0.66 and 0.70.

We do not find a significant nonlinear relationship between the market share and the Z-score (see Table 6). More interestingly, the results reported in Table 7 suggest a U-shaped relationship between the market share of the bank and its loan loss reserves.

### Table 4. Market power and bank risk-taking: The nonlinear relationship between the Lerner index and the Z-score.

| Dependent variable | (1) | (2) | (3) | (4) | (5) | (6) |
|--------------------|-----|-----|-----|-----|-----|-----|
| **Lerner**         | 5.014*** | 5.031*** | 5.056*** | 13.924*** | 14.067*** | 14.922*** |
|                    | (1.102) | (1.135) | (1.212) | (3.490) | (3.523) | (3.310) |
| **Lerner*Lerner** | -4.306*** | -4.368*** | -4.344*** | -10.916*** | -10.906*** | -12.088*** |
|                    | (1.258) | (1.327) | (1.439) | (3.140) | (3.218) | (3.182) |
| **Inflation**      | 0.033 | 0.006 | 0.063 | -0.027 | -0.025 | -0.027 |
|                    | (0.065) | (0.063) | (0.077) | (0.077) | (0.077) | (0.077) |
| **GDP growth**     | -0.027 | -0.025 | 0.050 | -0.027 | -0.038 | -0.021 |
|                    | (0.049) | (0.050) | (0.056) | (0.056) | (0.056) | (0.056) |
| **Crisis dummy**   | -2.743*** | -1.263** | -1.367 | -1.621*** | -1.397** | -1.529*** |
|                    | (0.438) | (0.551) | (0.858) | (0.462) | (0.597) | (0.529) |
| **Size**           | 0.023 | 0.023 | 0.023 | 0.023 | 0.023 | 0.023 |
|                    | (0.132) | (0.132) | (0.132) | (0.132) | (0.132) | (0.132) |
| **Non-interest income/total income** | -0.577 | -0.577 | -0.577 | -0.577 | -0.577 | -0.577 |
|                    | (0.600) | (0.600) | (0.600) | (0.600) | (0.600) | (0.600) |
| **Fixed assets/total assets** | 4.767 | 4.767 | 4.767 | 4.767 | 4.767 | 4.767 |
|                    | (8.028) | (8.028) | (8.028) | (8.028) | (8.028) | (8.028) |
| **Loans/total assets** | 2.122 | 2.122 | 2.122 | 2.122 | 2.122 | 2.122 |
|                    | (1.464) | (1.464) | (1.464) | (1.464) | (1.464) | (1.464) |
| **Liquidity**      | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
|                    | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) |
| **U-shape test**   | 2.30 | 2.21 | 2.00 | 2.44 | 2.27 | 2.69 |
|                    | [0.013] | [0.016] | [0.026] | [0.007] | [0.011] | [0.003] |
| **Turning point**  | 0.582 | 0.576 | 0.582 | 0.638 | 0.645 | 0.617 |
| 95% confidence interval, Fieller method | [0.485; 0.862] | [0.474; 0.889] | [0.478; 0.983] | [0.540; 0.838] | [0.541; 0.877] | [0.533; 0.789] |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations       | 350 | 350 | 346 | 343 | 343 | 339 |
| R-squared          | 0.430 | 0.431 | 0.447 | 0.187 | 0.171 | 0.188 |
| Number of banks    | 40 | 40 | 39 | 40 | 40 | 39 |
| Hansen J-OverID test | – | – | – | 0.0980 | 0.130 | 0.162 |
| [p-value]          | – | – | – | – | – | – |

Note: Constant included but not reported. Robust standard errors clustered at bank level are reported below their coefficient estimates. The Hansen test evaluates the joint validity of instruments used. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively. The Lerner index refers to the adjusted Lerner index proposed by Koetter et al. (2012). The U-shape test is based on Lind and Mehlum (2010) and the p-value of the test statistic is reported between square brackets.
For each specification, the coefficient estimates associated with the market share and the interaction term appear statistically significant at the conventional levels. The turning points vary between 44% and 52% (See Figure A1).

Consequently, our nonlinear analysis suggests that a low degree of bank competition is likely to exacerbate risk-taking by banks and then be detrimental to the stability of the banking sector in the Baltic countries. In line with the theoretical predictions of Martinez-Miera and Repullo (2010), we find a very stable and statistically significant inverse U-shaped relationship between the Lerner index and the Z-score, a measure of solvency risk. This means that banking sector fragility is higher in either very competitive or very monopolistic markets, and lowest when there are moderate levels of competition.

If we now compare each commercial bank in the Baltic countries in 2014 with the average optimal thresholds for the Lerner index and the market share, we can see from Figure A2 that only one financial institution, Swedbank AS in Estonia, lies above both threshold values. The situation is more mixed for Lithuania and Latvia.

### Table 5. Market power and bank risk-taking: the nonlinear relationship between the Lerner index and loan loss reserves.

| Dependent variable       | (1)         | (2)         | (3)         | (4)         | (5)         | (6)         |
|--------------------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Lerner                   | -28.659     | -29.232     | -19.250**   | -59.703***  | -58.714***  | -51.906***  |
|                          | (17.547)    | (17.495)    | (8.709)     | (21.534)    | (20.474)    | (15.712)    |
| Lerner*Lerner            | 24.365      | 26.052      | 13.090      | 42.663**    | 42.568**    | 39.232**    |
|                          | (18.393)    | (18.689)    | (9.821)     | (19.790)    | (19.187)    | (15.614)    |
| Inflation                | -0.774*     | -0.842*     | -0.169      | 0.102       | -0.102      | -0.102      |
|                          | (0.398)     | (0.419)     | (0.309)     | (0.280)     | (0.280)     | (0.280)     |
| GDP growth               | -0.116      | 0.036       | 0.185       | 0.175       | 0.175       | 0.175       |
|                          | (0.124)     | (0.163)     | (0.143)     | (0.138)     | (0.138)     | (0.138)     |
| Crisis dummy             | 4.666***    | 4.822       | 13.002      | 4.593***    | 5.824***    | 6.439***    |
|                          | (1.391)     | (4.095)     | (8.514)     | (1.608)     | (2.256)     | (1.888)     |
| Size                     | 3.585       | 1.035       | 1.035       | 1.035       | 1.035       | 1.035       |
|                          | (2.901)     | (1.133)     | (1.133)     | (1.133)     | (1.133)     | (1.133)     |
| Non-interest income/total income | -3.860* | -3.860* | -0.842* | 4.861** | 4.861** | 4.861** |
|                          | (2.069)     | (1.955)     | (1.955)     | (1.955)     | (1.955)     | (1.955)     |
| Fixed assets/total assets | 23.219     | 19.324      | 19.324      | 19.324      | 19.324      | 19.324      |
|                          | (20.720)    | (22.169)    | (22.169)    | (22.169)    | (22.169)    | (22.169)    |
| Loans/total assets       | 6.614       | -4.208      | -4.208      | -4.208      | -4.208      | -4.208      |
|                          | (10.228)    | (5.203)     | (5.203)     | (5.203)     | (5.203)     | (5.203)     |
| Liquidity                | 0.036       | 0.035       | 0.035       | 0.035       | 0.035       | 0.035       |
|                          | (0.055)     | (0.023)     | (0.023)     | (0.023)     | (0.023)     | (0.023)     |
| U-shape test             | 1.00        | 1.11        | 1.29        | 1.33        | 1.56        |
|                          | [0.162]     | [0.137]     | [0.099]     | [0.091]     | [0.060]     |
| Turning point            | -           | -           | -           | 0.669       | 0.669       | 0.669       |
|                          | -           | -           | [0.585;]    | [0.571;]    | [0.552;]    |
| 95% confidence interval, Fieller method | - | - | [0.585;] | [0.571;] | [0.552;] | [0.552;] |
|                          | -           | -           | [2.478]     | [2.057]     | [1.321]     |
| Year fixed effects       | Yes         | Yes         | Yes         | Yes         | Yes         | Yes         |
| Observations             | 349         | 349         | 349         | 341         | 341         | 341         |
| R-squared                | 0.462       | 0.484       | 0.553       | 0.035       | 0.084       | 0.306       |
| Number of banks          | 38          | 38          | 38          | 38          | 38          | 38          |
| Hansen J-OverID test [p-value] | - | - | - | 0.286 | 0.299 | 0.215 |

Note: Constant included but not reported. Robust standard errors clustered at bank level are reported below their coefficient estimates. The Hansen test evaluates the joint validity of instruments used. *, ** and ***indicate statistical significance at the 10%, 5% and 1% levels, respectively. The Lerner index refers to the adjusted Lerner index proposed by Koetter et al. (2012). The U-shape test is based on Lind and Mehlum (2010) and the p-value of the test statistic is reported between square brackets.
as a number of banks in Latvia exhibit a Lerner index that is higher than the optimal threshold but have market shares of between 10% and 20%, which appears relatively low next to the shares seen in Estonia and Lithuania.

### 4.3. Robustness checks

We test the robustness of our results in several ways. First, we consider two additional proxies for bank risk. Then, following Soedarmono, Machrouh, and Tarazi (2011), we use a Z-score measure based on the return on equity (ZROE). We also replace the loan loss reserves as a percentage of gross loans with impaired loans as a percentage of gross loans. The results obtained with these two alternative left-hand side variables are presented in Table 8. To save space, we do not report the coefficient estimates associated with the control variables, and we only focus on the results obtained with the FE...
Table 7. Market power and bank risk-taking: the nonlinear relationship between the market share and loan loss reserves.

| Dependent variable                              | (1)         | (2)         | (3)         | (4)         | (5)         | (6)         |
|------------------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Loan loss FE                                   | Loan loss FE| Loan loss FE| Loan loss 2SLS| Loan loss 2SLS| Loan loss 2SLS| Loan loss 2SLS|
| Market share                                   | −1.649**    | −1.611**    | −1.557***   | −0.798**    | −0.752**    | −0.694***    |
|                                                | (0.686)     | (0.676)     | (0.568)     | (0.317)     | (0.310)     | (0.204)     |
| Market share*Market share                      | 0.016**     | 0.016**     | 0.015***    | 0.009***    | 0.008***    | 0.007***    |
|                                                | (0.007)     | (0.007)     | (0.006)     | (0.003)     | (0.003)     | (0.002)     |
| Inflation                                      | −0.604**    | −0.679**    | −0.396*     | −0.276      | −0.026      | −0.098      |
|                                                | (0.286)     | (0.332)     | (0.108)     | (0.098)     |             |             |
| GDP growth                                     | 0.072       | 0.053       | −0.058      | −0.026      |             |             |
|                                                | (0.158)     | (0.143)     | (0.108)     | (0.098)     |             |             |
| Crisis dummy                                   | −1.699      | −4.874      | −1.811      | 2.296*      | 3.897**     | 4.407***    |
|                                                | (3.032)     | (3.352)     | (4.072)     | (1.302)     | (1.602)     | (1.513)     |
| Size                                           | −0.583      | −1.811      | 2.296*      | 3.897**     | 4.407***    |
|                                                | (1.180)     | (1.43)      | (1.302)     | (1.602)     | (1.513)     |
| Non-interest income/total income               | −4.438*     | −3.592      | −3.592      | −4.805      |             |             |
|                                                | (2.560)     | (5.070)     |             |             |             |             |
| Fixed assets/total assets                      | 16.946      | 16.915      |             |             |             |             |
|                                                | (33.153)    |             |             |             |             |             |
| Loans/total assets                             | −3.592      | −3.592      | −3.592      | −4.805      |             |             |
|                                                | (5.070)     | (5.070)     |             |             |             |             |
| Liquidity                                      | −0.041      | −0.041      | −0.041      | −0.047**    |             |             |
|                                                | (0.029)     | (0.029)     |             | (0.022)     |             |             |
| U-shape test                                   | 2.40        | 2.36        | 2.52        | 2.43        | 3.40        |             |
|                                                | [0.010]     | [0.011]     | [0.006]     | [0.007]     | [0.000]     |             |
| Turning point                                  | 50.90       | 51.58       | 51.50       | 45.69       | 47.15       | 47.21       |
| 95% confidence interval, Fieller method         | [44.48; 57.35] | [44.68; 59.89] | [46.16; 58.70] | [31.89; 50.88] | [31.54; 52.58] | [38.04; 53.08] |
| Year fixed effects                             | Yes         | Yes         | Yes         | Yes         | Yes         | Yes         |
| Observations                                   | 368         | 368         | 368         | 365         | 365         | 365         |
| R-squared                                      | 0.583       | 0.594       | 0.608       | 0.582       | 0.593       | 0.633       |
| Number of banks                                | 38          | 38          | 38          | 38          | 38          | 38          |
| Hansen J-OverID test [p-value]                 | –           | 0.196       | 0.194       | 0.0799      |             |             |

Note: Constant included but not reported. Robust standard errors clustered at bank level are reported below their coefficient estimates. The Hansen test evaluates the joint validity of instruments used. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively. The U-shape test is based on Lind and Mehlum (2010) and the p-value of the test statistic is reported between square brackets.
Table 8. Market power and bank risk-taking: results obtained with alternative measures of risk.

| Dependent variable | (1) | (2) | (3) | (1) | (2) | (3) |
|--------------------|-----|-----|-----|-----|-----|-----|
|                    | ZROE FE | ZROE FE | ZROE FE | Imp. Loans FE | Imp. Loans FE | Imp. Loans FE |
| Lerner             | 4.866*** | 4.817*** | 5.054*** | −33.889 | −38.433 | −22.507* |
|                    | (1.223) | (1.234) | (1.308) | (23.139) | (23.563) | (13.142) |
| Lerner*Lerner      | −3.930*** | −3.874*** | −4.020** | 19.313 | 27.620 | 6.435 |
|                    | (1.372) | (1.407) | (1.511) | (23.235) | (24.324) | (15.164) |
| U-shape test       | 1.77 | 1.67 | 1.58 | 0.16 | 0.62 | Ext. outside interval |
|                    | [0.042] | [0.051] | [0.061] | [0.438] | [0.27] | |
| Turning point      | 0.619 | 0.621 | 0.628 | – | – | – |
| 95% confidence interval, Fieller method | [0.500; 1.133] | [0.498; 1.232] | [0.504; 1.349] | – | – | – |
| Observations       | 304 | 304 | 299 | 253 | 253 | 253 |
| R-squared          | 0.428 | 0.428 | 0.466 | 0.479 | 0.506 | 0.574 |
| Number of banks    | 40 | 40 | 39 | 34 | 34 | 34 |
| Market share       | −0.022 | −0.020 | 0.036 | −2.354** | −2.270** | −1.918** |
|                    | (0.058) | (0.055) | (0.056) | (0.944) | (0.931) | (0.737) |
| Market share*Market share | 0.001 | 0.001 | 0.000 | 0.023** | 0.021** | 0.018** |
|                    | (0.001) | (0.001) | (0.001) | (0.009) | (0.009) | (0.007) |
| U-shape test       | 0.37 | 0.37 | Ext. outside | 2.49 | 2.42 | 2.60 |
|                    | [0.355] | [0.356] | interval | [0.009] | [0.010] | [0.007] |
| Turning point      | – | – | – | 52.30 | 53.32 | 51.85 |
| 95% confidence interval, Fieller method | – | – | – | [43.39; 59.06] | [43.61; 63.64] | [41.91; 60.66] |
| Observations       | 321 | 321 | 316 | 264 | 264 | 264 |
| R-squared          | 0.324 | 0.332 | 0.372 | 0.529 | 0.539 | 0.539 |
| Number of banks    | 40 | 40 | 39 | 34 | 34 | 34 |

Note: Constant included but not reported. Year fixed effects included. Robust standard errors clustered at bank level are reported below their coefficient estimates. *, ** and ***indicate statistical significance at the 10%, 5% and 1% levels, respectively. Specification (1) includes crisis dummy as control variable, specification (2) includes crisis dummy, inflation, and GDP growth as control variables, while specification (3) includes all control variables. Control variables are lagged one period. The Lerner index refers to the adjusted Lerner index proposed by Koetter et al. (2012). The U-shape test is based on Lind and Mehlum (2010) and the p-value of the test statistic is reported between square brackets. Ext. outside interval means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship.
estimator. Detailed results are available upon request. The results that we obtain are very similar to those reported above, and we still find an inverse U-shaped relationship between the Lerner index and our ZROE measure of bank stability, and a statistically significant U-shaped relationship between market share and our proxy for credit risk, which is impaired loans as a percentage of gross loans. Consistent with our previous findings, the turning points are close to 0.62 for the Lerner index and between 51% and 54% for the market share.

We also test the sensitivity of our results by considering three alternative measures of the Lerner index and one alternative measure of market share. The first alternative measure of the Lerner index uses a three-year moving average. This measure aims to smooth the cyclical fluctuations of the Lerner index because the market power of a bank is not likely to change radically in the short-run, as argued by Leroy and Lucotte (2017). Second, we follow Maudos and de Guevara (2007) and Turk-Ariss (2010) by re-estimating the translog cost function (Equation 2) with funding costs excluded. It may be expected that banks with a high level of market power, especially those with a high level of deposit market power, are able to raise funds at a cheap cost. In this case, as Maudos and de Guevara (2007) argue, including financial costs and consequently the price of deposits in the cost function captures the effect of market power in banking and may bias the results. By excluding funding costs, we are likely to get a clean proxy for pricing power that is not distorted by deposit market power (Turk-Ariss, 2010). As before, the two-input cost function is estimated using an SFA, and we apply the correction proposed by Koetter et al. (2012) to compute the funding-adjusted Lerner index. In a very few cases values can be obtained empirically for the Lerner index that are outside the 0 to 1 range. In our case, we have a total of 29 observations below zero, and no observations above one (see Figure A3 and Table A2 in Appendix). Rather than treating these observations as outliers and dropping them, we code them equal to zero, and then consider a left-censored Lerner index. Finally, we use an alternative measure of market share that does not only look at bank assets, but also considers deposit and loan market power. This index is called global market share and is equal for each bank to the average of its market shares for assets, loans, and deposits. Correlations between our different proxies for market power for each Baltic country are illustrated in Figure A5. The results are reported in Tables 9 and 10. As previously, we only report the coefficient estimates of our variables of interest. The results we obtain confirm our previous findings.

Third, we re-estimate our benchmark nonlinear specification (Equation 6) by considering a robust regression approach. The idea behind the robust regression is to down-weight the influence of high leverage data points and outliers to provide a better fit of the data. Our results, reported in Table 11, confirm the substance of the previous results. We find a very significant nonlinear relationship between the Lerner index and our two proxies for bank risk, though this relationship appears not to be statistically significant when we consider market share and its squared term as right-hand side variables. This last result could nonetheless easily be explained by the distribution of the market share series, where there is consistently a large left tail (see Figure A4), which implies that banks with a large market share are down-weighted.
Table 9. Market power and the Z-score: results obtained with alternative proxies for market power.

| Dependent variable | (1) Z-score FE | (2) Z-score IV | (1) Z-score FE | (2) Z-score IV | (1) Z-score FE | (2) Z-score IV | (1) Z-score FE | (2) Z-score IV |
|--------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Lerner 1           | 7.152***      | 9.565***      |               |               |               |               |               |               |
|                    | (1.534)       | (2.212)       |               |               |               |               |               |               |
| Lerner 1*Lerner 1  | −5.127***     | −6.572***     |               |               |               |               |               |               |
|                    | (1.612)       | (2.472)       |               |               |               |               |               |               |
| Lerner 2           |               |               | 5.370***      | 15.213***     |               |               |               |               |
|                    |               |               | (1.210)       | (3.122)       |               |               |               |               |
| Lerner 2*Lerner 2  | −4.759***     | −12.774***    |               |               |               |               |               |               |
|                    | (1.456)       | (2.984)       |               |               |               |               |               |               |
| Lerner 3           |               |               | 5.202***      | 14.894***     |               |               |               |               |
|                    |               |               | (1.247)       | (3.194)       |               |               |               |               |
| Lerner 3*Lerner 3  | −4.478***     | −12.323***    |               |               |               |               |               |               |
|                    | (1.473)       | (3.085)       |               |               |               |               |               |               |
| Global Market share|               |               | 0.078         | 0.133**       |               |               |               |               |
|                    |               |               | (0.060)       | (0.066)       |               |               |               |               |
| Global Market share*Global market share |               |               | −0.000        | −0.001        |               |               |               |               |
|                    |               |               | (0.001)       | (0.001)       |               |               |               |               |
| U-shape test       | 1.51          | 1.12          | 2.26          | 3.19          | 2.04          | 2.91          | 0.01          | 0.30          |
|                    | [0.069]       | [0.131]       | [0.014]       | [0.001]       | [0.024]       | [0.002]       | [0.001]       | [0.001]       |
| Turning point      | 0.697         | –             | 0.564         | 0.595         | 0.580         | 0.604         | –             | –             |
| 95% confidence interval, Fieller method | [0.561; 1.182] | – | [0.472; 0.865] | [0.518; 0.725] | [0.480; 0.964] | [0.525; 0.755] | – | – |
| Year fixed effects | Yes           | Yes           | Yes           | Yes           | Yes           | Yes           | Yes           | Yes           |
| Observations       | 351           | 350           | 346           | 339           | 346           | 339           | 364           | 363           |
| R-squared          | 0.444         | 0.497         | 0.451         | 0.218         | 0.448         | 0.228         | 0.375         | 0.381         |
| Number of banks    | 39            | 39            | 39            | 39            | 39            | 39            | 39            | 39            |
| Hansen J-OverID test [p-value] | – | 0.104 | – | 0.0927 | – | 0.108 | – | 0.256 |

Note: Constant included but not reported. Robust standard errors clustered at bank level are reported below their coefficient estimates. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively. Specifications (1) and (2) includes all control variables. Specification (1) is estimated using the FE estimator, while specification (2) is estimated using the 2SLS estimator. Control variables are lagged one period. Lerner 1 corresponds to the 3-year moving average Lerner index, Lerner 2 to the funding-adjusted Lerner index, Lerner 3 to the left-censored Lerner index, and Global market share to the market share calculated by considering assets, loans and deposits. The U-shape test is based on Lind and Mehlum (2010) and the p-value of the test statistic is reported between square brackets.
Table 10. Market power and loan loss reserves: results obtained with alternative proxies for market power.

| Dependent variable | (1)       | (2)       | (1)       | (2)       | (1)       | (2)       | (1)       | (2)       |
|--------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|                    | Loan loss FE | Loan loss IV | Loan loss FE | Loan loss IV | Loan loss FE | Loan loss IV | Loan loss FE | Loan loss IV |
| Lerner 1           | −54.098*** | −50.048*** | (17.699)  | (12.095)  | (15.154)  | (11.808)  |          |           |
| Lerner 1*Lerner 1  | 41.918***  | 39.118***  | (15.154)  | (11.808)  |          |           |          |           |
| Lerner 2           | −15.442**  | −51.876*** | (7.522)   | (16.980)  | (9.385)   | (16.209)  |          |           |
| Lerner 2*Lerner 2  | 8.634      | 38.018**   | (9.385)   | (16.209)  |          |           |          |           |
| Lerner 3           | −16.570**  | −51.129*** | (7.892)   | (16.748)  | (9.466)   | (16.092)  |          |           |
| Lerner 3*Lerner 3  | 9.712      | 37.320**   | (9.466)   | (16.092)  |          |           |          |           |
| Global Market share| −1.018**   | −0.821***  | (0.407)   | (0.194)   | (0.004)   | (0.002)   |          |           |
| Global Market share*Global market share | 0.010** | 0.009*** | (0.004) | (0.002) |          |           |          |           |
| U-shape test       | 2.09       | 2.22       | 0.11      | 1.42      | 0.19      | 1.38      | 2.50      | 4.24      |
|                   | [0.021]    | [0.013]    | [0.456]   | [0.078]   | [0.042]   | [0.084]   | [0.008]   | [0.000]   |
| Turning point      | 0.645      | 0.639      | –         | 0.682     | –         | 0.685     | 51.56     | 45.79     |
| 95% confidence interval, Fieller method | [0.543; 0.927] | [0.561; 0.871] | [0.568; 1.615] | [0.568; 1.721] | [45.59; 56.99] | [38.46; 51.86] |
| Year fixed effects | Yes        | Yes        | Yes       | Yes       | Yes       | Yes       | Yes       | Yes       |
| Observations       | 355        | 352        | 349       | 341       | 349       | 341       | 364       | 363       |
| R-squared          | 0.645      | 0.684      | 0.543     | 0.271     | 0.546     | 0.301     | 0.606     | 0.638     |
| Number of banks    | 38         | 38         | 38        | 38        | 38        | 38        | 38        | 38        |
| Hansen J-OverID test [p-value] | –         | 0.202      | 0.168     | –         | 0.156     | –         | 0.0867    |           |

Note: Constant included but not reported. Robust standard errors clustered at bank level are reported below their coefficient estimates. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively. Specifications (1) and (2) includes all control variables. Specification (1) is estimated using the FE estimator, while specification (2) is estimated using the 2SLS estimator. Control variables are lagged one period. Lerner 1 corresponds to the 3-year moving average Lerner index, Lerner 2 to the funding-adjusted Lerner index, Lerner 3 to the left-censored Lerner index, and Global market share to the market share calculated by considering assets, loans and deposits. The U-shape test is based on Lind and Mehlum (2010) and the p-value of the test statistic is reported between square brackets.
Table 11. Market power and bank risk-taking: results obtained using a robust regression approach.

| Dependent variable | (1)       | (2)       | (3)       | (1)       | (2)       | (3)       |
|--------------------|-----------|-----------|-----------|-----------|-----------|-----------|
|                    | Z-score   | Z-score   | Z-score   | Loan loss | Loan loss | Loan loss |
| Lerner             | 6.293***  | 6.251***  | 6.308***  | −7.279*** | −6.954*** | −9.560*** |
|                    | (0.754)   | (0.762)   | (0.714)   | (1.571)   | (1.535)   | (1.532)   |
| Lerner*Lerner      | −5.780*** | −5.709*** | −5.888*** | 4.667**   | 4.183**   | 6.717***  |
|                    | (0.854)   | (0.872)   | (0.822)   | (1.811)   | (1.785)   | (1.790)   |
| U-shape test       | 5.00      | 4.77      | 5.33      | 0.84      | 0.56      | 1.65      |
|                    | [0.000]   | [0.000]   | [0.000]   | [0.2]     | [0.289]   | [0.049]   |
| Turning point      | 0.544     | 0.547     | 0.535     | −         | −         | 0.711     |
| 95% confidence interval, Fieller method | [0.494; 0.618] | [0.495; 0.627] | [0.488; 0.604] | –     | –         | [0.587; 1.071] |
| Observations       | 350       | 350       | 346       | 349       | 349       | 349       |
| R-squared          | 0.442     | 0.443     | 0.520     | 0.650     | 0.660     | 0.713     |
| Market share       | 0.008     | 0.007     | −0.001    | −0.003    | −0.006    | −0.079**  |
|                    | (0.010)   | (0.011)   | (0.018)   | (0.020)   | (0.020)   | (0.039)   |
| Market share*Market share | 0.000 | 0.000 | 0.000 | −0.000 | −0.000 | 0.001 |
|                    | (0.000)   | (0.000)   | (0.000)   | (0.000)   | (0.000)   | (0.000)   |
| U-shape test       | Ext. outside interval | Ext. outside interval | 0.04 | Ext. outside interval | Ext. outside interval | 0.93 |
|                    | [0.483]   | [0.483]   | [0.483]   | [0.483]   | [0.483]   | [0.483]   |
| Turning point      | –         | –         | –         | –         | –         | –         |
| 95% confidence interval, Fieller method | – | – | – | – | – | [0.176] |
| Observations       | 370       | 370       | 366       | 368       | 368       | 368       |
| R-squared          | 0.320     | 0.324     | 0.423     | 0.581     | 0.575     | 0.573     |

Note: Constant included but not reported. Year fixed effects included. Standard errors are reported below their coefficient estimates. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively. Specification (1) includes crisis dummy as control variable, specification (2) includes crisis dummy, inflation, and GDP growth as control variables, while specification (3) includes all control variables. Control variables are lagged one period. The Lerner index refers to the adjusted Lerner index proposed by Koetter et al. (2012). The U-shape test is based on Lind and Mehlum (2010) and the p-value of the test statistic is reported between square brackets. Ext. outside interval means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship.
Table 12. Market power and bank risk-taking: results obtained with two proxies for competition in the same regression.

| Dependent variable                  | (1)        | (2)        | (3)        | (1)         | (2)         | (3)         |
|-------------------------------------|------------|------------|------------|-------------|-------------|-------------|
|                                     | Z-score FE | Z-score FE | Z-score FE | Loan loss FE | Loan loss FE | Loan loss FE |
| Lerner                             | 4.719***   | 4.742***   | 4.883***   | −17.486**   | −17.898**   | −17.667**   |
|                                     | (1.139)    | (1.167)    | (1.213)    | (6.639)     | (6.808)     | (6.513)     |
| Lerner*Lerner                      | −3.898***  | −3.970***  | −4.144***  | 13.612*     | 14.713*     | 14.727*     |
|                                     | (1.273)    | (1.330)    | (1.435)    | (8.003)     | (8.194)     | (8.297)     |
| Market share                       | 0.034      | 0.033      | 0.071      | −1.633***   | −1.588***   | −1.551***   |
|                                     | (0.058)    | (0.058)    | (0.057)    | (0.582)     | (0.573)     | (0.486)     |
| Market share*Market share           | −0.000     | −0.000     | −0.000     | 0.016**     | 0.015**     | 0.015***    |
|                                     | (0.001)    | (0.001)    | (0.001)    | (0.006)     | (0.006)     | (0.005)     |
| U-shape test (Lerner)              | 1.97       | 1.93       | 1.88       | 0.95        | 1.11        | 1.07        |
|                                     | (0.027)    | (0.030)    | (0.034)    | (0.174)     | (0.137)     | (0.146)     |
| Turning point (Lerner)             | 0.605      | 0.597      | 0.589      | –           | –           | –           |
| 95% confidence interval, Fieller method (Lerner) | [0.497; 0.995] | [0.485; 1.021] | [0.477; 1.067] | – | – | – |
| U-shape test (Market share)        | Ext. outside | Ext. outside | Ext. outside | [0.006] | [0.008] | [0.003] |
|                                     | interval | interval | interval | 2.60 | 2.52 | 2.82 |
| Turning point (Market share)       | – | – | – | 50.67 | 51.50 | 51.44 |
| 95% confidence interval, Fieller method (Market share) | – | – | – | [45.99; 60.21] | [46.07; 63.65] | [46.14; 61.73] |
| Observations                       | 350        | 350        | 346        | 349         | 349         | 349         |
| R-squared                          | 0.435      | 0.436      | 0.457      | 0.646       | 0.656       | 0.665       |
| Number of banks                    | 40         | 40         | 39         | 38          | 38          | 38          |

Note: Constant included but not reported. Year fixed effects included. Robust standard errors clustered at bank level are reported below their coefficient estimates. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively. Specification (1) includes crisis dummy as control variable, specification (2) includes crisis dummy, inflation, and GDP growth as control variables, while specification (3) includes all control variables. Control variables are lagged one period. The Lerner index refers to the adjusted Lerner index proposed by Koetter et al. (2012). The U-shape test is based on Lind and Mehlum (2010) and the p-value of the test statistic is reported between square brackets. Ext. outside interval means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship.
Finally, we investigate whether our results evolve when the same regression (Equation 6) includes our two proxies for bank competition, which are the Lerner index and market share. As argued by Carbó et al. (2009), structural and non-structural measures of competition tend to measure different things, and so they can be viewed as complementary proxies for competition. This is confirmed by the relatively low degree of correlation between the Lerner index and the market share for the Baltic countries (see Figure 2). The results that we obtain when we consider the Lerner index, market share, and their squared terms in the same regression are reported in Table 12. As is apparent, we still find a U-shaped relationship between bank competition and financial stability.

5. Conclusion

This paper is the first attempt to assess empirically the relationship between banking competition and financial stability in the Baltic countries. We do this using bank-level data and consider two alternative proxies for competition, the Lerner index and market share, with the Z-score and loan loss reserves as complementary measures of bank risk. We take a sample of 40 commercial banks in Estonia, Lithuania, and Latvia in 2000–2014, and our empirical results highlight an inverse and robust U-shaped relationship between the Lerner index and the Z-score, and a statistically significant U-shaped relationship between the Lerner index, market share and the loan loss reserves ratio. This means that a higher degree of market power arising from the low level of competition is associated with a decrease in risk-taking by banks and in the risk of insolvency for the banks up to a certain threshold, after which the relationship between competition and banking sector stability turns negative. We find that the optimal threshold for the Lerner index is 0.606 on average, and 49% is optimal for market share. The upper and lower values for the 95% confidence intervals are 0.508 and 0.873 for the Lerner index, and 39.46% and 55.41% for the market share.

The policy implications are that such a threshold implies that how the structure of the banking industry evolves is of critical importance for financial stability. This suggests that the policy-makers in charge of monitoring and regulating the banking industry should place greater emphasis on mergers and acquisitions, by encouraging them when competition is fierce, while preventing them in contrast in highly concentrated banking markets, at least for the largest banks.

This issue is especially important for the Baltic countries, which have a relatively high degree of concentration in the banking sector. As the low degree of correlation between the Lerner index and market share seems to suggest, permitting financial institutions to become larger might not necessarily lead to a lower degree of competition, but larger institutions might be encouraged to take more risk with their portfolios. Whatever the reason for financial institutions increasing risk, whether they are compensating for their improved diversification or exploiting their status as too big to fail, more attention should be devoted to the issue of the optimal size for them.
Notes

1. See, for instance, Berger et al. (2009), Fungáčová and Weill (2013), Jimenez et al. (2013), Liu et al. (2013), and Fu et al. (2014).
2. See Table A1 in the Appendix for an overview of bank-level analyses on the effect of bank competition on financial stability.
3. Note nonetheless that empirical results obtained by Maudos and de Guevara (2007) for a large sample of European banks do not confirm the quiet life hypothesis. On the contrary, they find a positive relationship between market power and the cost X-efficiency.
4. See Lepetit and Strobel (2013) for a review of different methodologies for computing the Z-score.
5. See Lind and Mehlum (2010) for more details concerning the U-shape test and the computation of the confidence interval. Please see Tables A2, A3 and A4 in the Appendix for more details concerning the control variables.
6. A graphical representation of the marginal effects is displayed in Figure A5 of the Appendix. Please see Figure A1 in the Appendix for a graphical representation of the conditional marginal effects.
7. A robust regression is an alternative approach used when the data contain some outliers or high leverage data points. It is a compromise between excluding these points entirely from the analysis and including all the data points and treating them all equally in the regression. In practice, robust regression works by assigning a weight to each data point. Weighting is done automatically and iteratively using a process called iteratively reweighted least squares. In the first iteration, each point is assigned an equal weight and model coefficients are estimated using ordinary least squares (OLS). At subsequent iterations, weights are recomputed so that points farther from the model predictions in the previous iteration are given a lower weight. The model coefficients are then recomputed using weighted least squares. The process continues until the values of the coefficient estimates converge within a specified tolerance.

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## Table A1. Overview of bank-level analyses on the effect of bank competition on financial stability.

| Paper | Study area | Competition measure(s) | Dependent variable(s) | Effect of competition on financial stability |
|-------|------------|-------------------------|------------------------|---------------------------------------------|
| Agoraki et al. (2011) | CEECs | Lerner index | Z-score, Nonperforming loans (NPL) | Negative |
| Almarzoqi, Naceur, and Scopelliti (2015) | MENA | Lerner index | Z-score, NPL | Negative |
| Amidu and Wolfe (2013) | Emerging countries | Lerner index | Z-score, NPL, Capitalization ratio | Positive |
| Anginer et al. (2014) | Mixed | Lerner index | Systemic risk measures | Positive |
| Baselga-Pascual, Trujillo-Ponce, and Cardone-Riportella (2015) | Euro area | Industry concentration | Z-score, NPL | Negative |
| Beck et al. (2013) | Mixed | Lerner index | Z-score | Negative |
| Berger et al. (2009) | Industrialised countries | Lemer, Industry concentration | Z-score, NPL, Capitalization ratio | Non-linear |
| Buch, Koch, and Koetter (2013) | Germany | Lemer index | Measure of bank distress | Negative |
| Craig and Dinger (2013) | USA | Deposit market competition | NPL, ROA volatility, Stock price volatility | Positive |
| Fiordelisi and Mare (2014) | 5 EU countries | Lemer index | Z-score | Positive |
| Forssbaek and Shehzad (2015) | Mixed | Lemer index | Z-score | Negative |
| Fu, Lin, and Molyneux (2014) | Asia Pacific | Lemer, Industry concentration | Z-score, Probability of bankruptcy | Ambiguous |
| Fungáčová and Weil (2013) | Russia | Lemer index | Bank failure | Negative |
| Ijtsma et al. (2017) | 25 EU countries | Industry concentration | Z-score | Positive |
| Jeon and Lim (2013) | Korea | Lemer index, Industry concentration | Z-score | Non-linear |
| Jimenez et al. (2013) | Spain | Industry concentration | NPL | Non-linear |
| Kasman and Kasman (2015) | Turkey | Lemer, Boone | Z-score, NPL | Non-linear |
| Kick and Prieto (2015) | Germany | Market share, Lemer, Boone | Bank distress, Bank default | Ambiguous |
| Kouki and Al-Nasser (2017) | Africa | Lemer index | Z-score | Negative |
| Leroy and Lucotte (2017) | Europe | Lemer index | Z-score, Distance-to-default (DD), SRISK | Negative: Z-score & DD, Positive: SRISK |
| Liu and Wilson (2013) | Japan | Lemer index | Z-score | Non-linear |
| Liu et al. (2013) | 10 EU countries | Lemer index | Z-score | Non-linear |
| Mirzaei, Moore, and Liu (2013) | Mixed | Bank market share, Industry concentration | Z-score | Ambiguous |
| Saadaoui (2014) | Emerging countries | Lemer index | NPL | Negative |
| Schaeck and Čihák (2014) | 10 EU countries | Boone index | Z-score | Positive |
| Soedarmono et al. (2011) | Asia | Lemer index | Z-score | Positive |

(Continued)
| Paper | Study area       | Competition measure(s) | Dependent variable(s) | Effect of competition on financial stability |
|-------|------------------|------------------------|------------------------|---------------------------------------------|
| Soedarmono, Machrouh, and Tarazi (2013) | Asia              | Lerner index           | Z-score                | Positive                                    |
| Tabak, Fazio, and Cajueiro (2012)      | Latin America     | Boone index            | Measure of "stability efficiency" | Non-linear                                  |
| Tabak, Fazio, and Cajueiro (2013)      | Latin America     | Industry concentration | Measure of "stability efficiency" | Positive                                    |
| Tabak, Gomes, and Da Silva Medeiros (2015) | Brazil            | H-statistic            | Z-score, NPL           | Negative                                    |
| Turk-Aris (2010)                       | Developing countries | Lerner index           | Z-score, Risk-adjusted rates of return | Negative                                    |
Table A2. Descriptive statistics.

| Variable                               | Obs | Mean  | Std. Dev. | Min   | Max   |
|----------------------------------------|-----|-------|-----------|-------|-------|
| Lerner index                           | 401 | 0.48  | 0.29      | −0.05 | 0.97  |
| 3-year MA Lerner index                 | 421 | 0.49  | 0.25      | −0.05 | 0.96  |
| Funding-adjusted Lerner index          | 401 | 0.48  | 0.28      | 0.00  | 0.97  |
| Left-censored Lerner index             | 401 | 0.49  | 0.28      | 0.00  | 0.97  |
| Market share                           | 410 | 10.93 | 16.03     | 0.00  | 80.72 |
| Global market share                    | 400 | 11.21 | 16.14     | 0.06  | 80.36 |
| Z-score                                | 370 | 2.74  | 1.50      | −2.99 | 7.27  |
| ZROE                                   | 321 | 1.39  | 1.41      | −4.27 | 6.86  |
| Loan loss reserves                     | 390 | 5.69  | 8.30      | 0.00  | 78.97 |
| Impaired loans                         | 273 | 13.04 | 15.34     | 0.07  | 89.05 |
| Size                                   | 410 | 13.52 | 1.79      | 6.65  | 17.45 |
| Non-interest income/total income       | 410 | 0.45  | 0.24      | −0.67 | 2.73  |
| Fixed assets/total assets              | 410 | 0.02  | 0.03      | 0.00  | 0.39  |
| Loans/total assets                     | 404 | 0.55  | 0.22      | 0.00  | 0.96  |
| Liquidity                              | 410 | 40.08 | 25.02     | 0.64  | 168.79|
| Annual inflation rate                  | 600 | 3.79  | 3.57      | −1.15 | 15.43 |
| Annual GDP growth rate                 | 600 | 4.24  | 6.39      | −14.81| 11.90 |

Table A3. Correlation matrix of bank-level variables.

| var1 | var2    | var3    | var4    | var5    | var6    | var7    |
|------|---------|---------|---------|---------|---------|---------|
| Lerner (var1) | 1       |         |         |         |         |         |
| Market share (var2) | 0.1671*| 1       |         |         |         |         |
| Size (var3) | 0.0674  | 0.6271*| 1       |         |         |         |
| Non-interest income/total income (var 4) | −0.1654* | −0.1098* | −0.1529* | 1       |         |         |
| Fixed assets/total assets (var 5) | −0.0960  | −0.0982*| −0.4610*| 0.2992*| 1       |         |
| Loans/total assets (var6) | 0.1006*  | 0.3239*| 0.4353*| −0.4343*| −0.1720*| 1       |
| Liquidity (var7) | 0.0529  | −0.2554*| −0.4303*| 0.3233* | 0.2119* | −0.8161*| 1       |

Note: *indicates statistical significance at the 5% level.

Table A4. Definition and source of variables.

| Variable               | Definition                                                                 |
|------------------------|-----------------------------------------------------------------------------|
| **Dependent variables**|                                                                             |
| Z-score                | Accounting bank-level measure of individual bank risk. A larger value indicates a higher bank stability and less bank risk-taking. Source: Authors’ calculations, Bankscope |
| ZROE                   | Return-on-equity based Z-score measure. A larger value indicates a higher bank stability and less bank risk-taking. Source: Authors’ calculations, Bankscope |
| Loan loss reserves     | Ratio indicating how much of the total portfolio of a bank has been provided for but not charged off. It is a reserve for losses expressed as percentage of total loans. Given a similar charge-off policy the higher the ratio the poorer the quality of the loan portfolio is. Source: Bankscope |
| Impaired loans          | Impaired loans (or non-performing loans) are loans that are unlikely to be paid back for the full amount. The impaired loans to gross loans ratio is used to measure bank's asset risk. Source: Bankscope |
| **Explanatory variables**|                                                                             |
| Lerner index           | A bank-level measure of bank market power following the methodology proposed by Koetter et al. (2012). A higher value indicates more market power and less bank competition. Source: Authors’ calculations, Bankscope |
| 3-year MA Lerner index | A 3-year rolling time window is used to compute the Lerner index. A higher value indicates more market power and less bank competition. Source: Authors’ calculations, Bankscope |

(Continued)
Table A4. (Continued).

| Variable                        | Definition                                                                                                                                                                                                 |
|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Funding-adjusted Lerner index   | Following Maudos and de Guevara (2007), a two-input cost function is considered to estimate the translog cost function. A higher value of the funding-adjusted Lerner index indicates more market power and less bank competition. Source: Authors’ calculations, Bankscope |
| Left-censored Lerner index      | Negative values of the Lerner index are truncated to zero. A higher value of the left-censored Lerner index indicates more market power and less bank competition. Source: Authors’ calculations, Bankscope |
| Bank size                       | The log value of total assets. Source: BankScope |
| Non-interest income/Total income| A bank-level measure of business diversification. Source: BankScope |
| Fixed assets/Total assets       | A bank-level measure of asset composition. Source: BankScope |
| Liquidity                       | A bank-level liquidity indicator, which corresponds to the ratio of liquid assets over deposits and short term funding. A higher value indicates less liquidity risk. Source: Bankscope |
| Loans/Total assets              | A bank-level measure of asset composition. Source: Bankscope |
| GDP growth                      | Annual real GDP growth. Source: World Development Indicators (WDI), World Bank |
| Inflation                       | Annual percentage change of consumer prices index. Source: World Development Indicators (WDI), World Bank |

Figure A1. Conditional marginal effects.

Note: The conditional marginal effects are computed by considering our benchmark nonlinear specification estimated using the fixed effects (FE) estimator, i.e. the specification (3) in Table 4 for the Lerner index, and the specification (3) in Table 7 for the market share. The Lerner index refers to the adjusted Lerner index proposed by Koetter et al. (2012). The grey lines correspond to the 95% confidence interval.
Figure A2. Average turning points and situation of banks in Baltic countries.

Note: The average turning point for the Lerner index and the market share is calculated by considering results obtained with our benchmark nonlinear specification, i.e. results reported in Tables 4–7. Also note that we only consider the specifications for which the U-shape test indicates a p-value below 0.05. The average ‘optimal’ threshold for the Lerner index is equal to 0.606, and to 49% for the market share. The Lerner index refers to the adjusted Lerner index proposed by Koetter et al. (2012). The red dash line corresponds to the 95% confidence interval for the Lerner index, while the blue dash line corresponds to the 95% confidence interval for the market share. More precisely, the confidence intervals reported in this graph correspond to the average of the upper and lower confidence bounds calculated by considering all specifications for which the U-shape test indicates a non-linear relationship statistically significant at the 5% level.

Figure A3. Histogram and kernel density plot of the Lerner index.

Note: The Lerner index refers to the adjusted Lerner index proposed by Koetter et al. (2012).
Figure A4. Histogram and kernel density plot of the market share.

Figure A5. Correlation between alternative measures of market power for each Baltic country.

Note: EE: Estonia; LT: Lithuania; LV: Latvia. Lerner refers to the adjusted Lerner index proposed by Koetter et al. (2012). Lerner 1 to the 3-year moving average Lerner index, Lerner 2 to the funding-adjusted Lerner index, Lerner 3 to the left-censored Lerner index, Market share to the market share based on assets, and global market share to the market share calculated by considering assets, loans and deposits.