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Research article

Banking market competition in Europe—financial stability or fragility enhancing?

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Abstract: Considering the importance of the competition-stability trade-off, contradictory theoretical predictions, and empirical evidence, its re-investigation from the angle of non-linearity is needed. Therefore, this paper focuses on the association between bank stability and competition in Europe by employing a Boone indicator and alternative competition measures. Bank stability is measured with the z-score and loan loss reserves ratio. System-GMM estimations are carried out on a panel of banks from 27 European Union member countries over the period of 2004–2014. The results confirm that when a linear association between bank stability and competition is assumed, competition-stability argument prevails. However, when potential non-linearity of this association is assumed, the results appear more diverse and complex across different competition proxies. We observe signs of U-shape association between bank stability and competition for the Boone indicator and weaker signs of an inverse U-shape association with Lerner index. This indicates that before taking policy measures, it is important to consider the potentially non-linear association between bank stability and competition and to define which aspect of competition regulators want to address. The results concerning mature and emerging Europe exhibit also some differences, indicating that suitable regulatory approaches applied even within the EU could be rather different.

Keywords: banks; competition; Boone indicator; bank stability; financial stability

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1. Introduction

The 2008 financial crisis exemplified the negative consequences that excessive risk-taking of banks may have on financial stability. Banks experienced rapid deterioration in credit quality and weakening of their balance sheets. As a result, during 2008–2014 European Union member states approved state aid in the amount of 4.8 trillion euros in the form of recapitalisations, impaired assets measures, guarantees on liabilities, and on other liquidity measures.[1] 1.9 trillion euros of this amount was actually used during the same period. Significant government intervention has increased concerns over the impact of bank bail-out mechanisms on banking market competition and has revived the debate over competition's potential impact on bank stability (e.g., Beck et al., 2010; Fiordelisi et al., 2015). There through it has also led to a rapid increase in the amount of theoretical and empirical literature on the matter.

According to the traditional industrial organisation approach, more competitive banking markets would enable to improve the efficiency of production of financial services, increase the quality of financial products, and raise the degree of innovation in the sector (Claessens, 2009). Still, the early theoretical models show that competition decreases the stability of individual banks and there through the fragility of the banking system increases, i.e. the association between bank stability and competition is negative (for a review see Carletti, 2008). This result refers to the competition-fragility view. However, the theoretical model by Boyd and De Nicoló (2005) predicts that increasing banking market competition may instead increase the stability of banks and thereby the stability of the banking system should increase. This result refers to the competition-stability view. The latter view ignited a theoretical debate. Theoretical models by Wagner (2010) and Inderst (2013) emerged, uncovering a rather complex nature of the association between banking market competition and bank stability. Martínez-Miera and Repullo (2010), in turn, pointed at the nonlinear association between bank stability and competition. If the latter model depicts reality accurately enough, it would provide important insight for policy-makers.

The majority of empirical papers have so far focused on the expected linear association between banking stability and competition providing contradicting results irrespective to whether global, European, or Asian samples of banks are considered (e.g., De Nicolo and Loukoianova, 2007; Andrieş and Căpraru, 2012; Beck et al., 2013; Jiménez et al., 2013; Soedarmono et al., 2011, 2013; Fu et al., 2014; Schaeck and Cihák, 2014; Leroy and Lucotte, 2017).[2] However, the non-linearity arguments have been tested in a limited number of papers. Liu et al. (2013), Samantas (2013) and Lapteacru (2017) observe non-linearity in the association between bank stability and competition in Europe and Noman (2017) in ASEAN countries. Tabak (2012) finds empirical evidence that supports the U-shape association between bank stability and competition in Latin America.

Considering the undesirable consequences that higher riskiness of banks may have on financial stability, this paper attempts to shed further light on the disparity of previous results from

[1] Based on the European Commission's State Aid Scoreboard http://ec.europa.eu/competition/state_aid/scoreboard/financial_economic_crisis_aid_en.html.

[2] Studies focusing on Latin-America and Africa tend to support the competition-fragility view (e.g., Yeyati and Micco 2007; Tabak et al., 2012; Hope et al., 2013).

non-linearity aspect. The objective of this paper is to investigate the association between bank stability and competition within Europe by employing a Boone indicator and alternative competition measures. Boone indicator (Boone, 2008) provides better possibilities for overcoming the limitations of standard market concentration measures (Herfindahl-Hirschman index, market shares of top3, or top5 banks) or non-structural measures such as Lerner index and Panzar and Rosse H-statistic. The latter measures have been used in most previous bank stability studies with a European focus.

Our study contributes to the literature in several ways. Firstly, despite the theoretical advantages of the Boone indicator, relatively few papers have applied it to study competition-stability nexus in Europe and have used samples containing data from only 10 countries (Schaeck and Cihák, 2014; Lapteacru, 2017). As our sample covers 27 European countries, such a focus enables to investigate whether banking sector development or country banking sector stability influence the association between bank stability and competition, as reported in some previous studies (e.g., Agoraki et al., 2011; Andrieș and Căpraru, 2012). Secondly, we derive Boone indicator from multi-output translog cost function estimated from the full dual system with cost and cost-share equations using iterative Zellner seemingly unrelated regressions (SUR). The use of cost share equations enables to gain additional degrees of freedom for country-wise cost function estimation, which is important when considering relatively small banking markets in emerging Europe. Most previous studies, which investigate the stability competition nexus have relied on a single-output cost function estimations for both Boone indicator and Lerner indexes and there are no papers, which have applied SUR approach. Thirdly, this paper contributes to the debate on the non-linearity of the association between banking market competition and bank stability by investigating the empirical relevance of the theoretical predictions of the Martínez-Miera and Repullo (2010) model. The non-linearity aspect has only recently gained wider attention and has previously been tested in European samples mainly by employing Lerner index (e.g., Jiménez et al., 2013; Liu et al., 2013; Samantas, 2013). Only Lapteacru (2017) has applied Boone indicator to study the potentially non-linear association between bank stability and competition with the study restricted to 10 CEE countries.

The results of this paper confirm that when a linear association between bank stability and competition is assumed, competition-stability argument prevails. However, when potential non-linearity of this association is considered, the results appear more diverse and complex across different competition proxies. We observe that with the Boone indicator there exist signs of a U-shape and with Lerner index weaker signs of an inverse U-shape association between bank stability and competition. This indicates that before taking policy measures, it is important to consider the potentially non-linear association between bank stability and competition and to define which aspect of competition regulators want to address. The results concerning mature and emerging Europe exhibit also some differences, indicating that suitable regulatory approaches applied even within the EU could be rather different.

This paper is divided as follows. Theoretical background and the results of the previous empirical studies are reviewed in section 2. Data and methodology are presented in section 3, results and discussion in section 4. Finally, section 5 concludes.

2. Theoretical and empirical background

2.1. Overview of theoretical literature

Theoretical literature proposes two contradicting views on the association between banking market competition and bank stability.[3] The first strand of literature supports the competition-fragility view—higher competition is expected to be accompanied by lower stability of banks which in turn may increase the fragility of the banking system. This literature relies on the assumption that competition occurs either on the liability or asset side of the balance sheet. In the former case, competition on deposit markets is expected to reduce the franchise value[4] of the bank and by increasing the agency problems, this would lead to greater gambling by bank managers (Keeley, 1990; Hellmann et al., 2000).[5] Greater gambling can lead to failures of individual banks and can propagate, creating a systemic crisis (Repullo, 2004). This applies especially to competitive markets which have been shown to be vulnerable to financial contagion (Allen and Gale, 2000, 2004). Theoretical models focusing on the asset side of the balance sheet, concentrate on the impact that loan market competition has on the ease of getting loans. Broecker (1990) shows that loan market competition increases the proportion of applicants who get a positive loan decision from at least one bank. Due to adverse selection, this, in turn, leads to the deterioration in the credit quality of banks. A similar result is supported by Shaffer (1998) and Bolt and Tieman (2004). Ease of access to loans is likely to fluctuate in the course of the business cycle. During boom periods, price competition intensifies and banks are likely to lower their credit standards (Ruckes, 2004). As a result, low-quality borrowers are financed and this may lead to loan losses when the market outlook worsens. The latter would weaken the balance sheets of banks. The extent to which bank stability decreases depends on the bank's capital buffers.

The second strand of theoretical literature supports the competition-stability argument—higher banking market competition is expected to increase bank stability and there through increase the stability of the financial system. Boyd and De Nicoló (2005) show that lower competition on both loan and deposit markets leads to higher loan rates. This, in turn, increases borrowers' desire to choose riskier projects and there through increases their risk of bankruptcy. For a bank, it refers to higher loan losses and an increase in bank fragility. This result coincides with Stiglitz and Weiss (1981) which supports the notion that increasing interest rates or collateral requirements can either deter safer borrowers or increase borrowers' desire to invest in higher-risk projects. A similar result appears in a model by Allen and Gale (2004) which shows that no financial fragility occurs if there exists perfect competition on banking markets because then the contracts between banks and their customers are complete.

The two lines of theoretical literature have received a different amount of attention. The competition-fragility view has a longer tradition and has dominated the thinking of most policymakers. The competition-stability argument began to gain greater popularity after Boyd and

[3] Most of the theoretical and empirical literature on the association between competition and stability focuses on the bank level stability and does not explicitly consider banks' actual contribution to systemic risk (Anginer et al., 2014).

[4] Franchise value or charter value refers to the present value of the bank's future rents.

[5] For a more detailed discussion see Carletti (2008).

De Nicoló (2005). As a result, the predictions of Boyd and De Nicoló (2005) model have raised significant debate over the contradictory results of the two strands of theoretical literature. Berger et al. (2009) suggest that although the competition in loan markets may lead to riskier loan portfolios, it may not necessarily lead to a higher overall risk of the bank. This could occur if the bank maintains higher equity levels or uses different risk-mitigation devices. Three theoretical papers have attempted to shed some further light on the competition-stability result.

Wagner (2010) extends the model by Boyd and De Nicoló (2005) by allowing banks to choose between borrowers. This relaxation creates a situation where decreasing loan interest rates increase a bank's willingness to grant loans to higher-risk customers. At the same time competition on the loan market reduces the bank's franchise value by increasing the bank's incentive to take risks. These developments lead to a decrease in bank stability (the competition-fragility argument continues to hold). This result also refers that loan market competition may reinforce the decrease in bank stability arising from deposit market competition.[6]

Inderst (2013) focuses, similarly to Wagner (2010), on the bank's incentives to take risks. Their model predicts that if borrowers consider bank riskiness as an important attribute, an increase in competition has an asymmetric impact on the riskiness of banks. It increases the risk-taking incentives of prudent banks less than it increases the risk-taking of less prudent banks. This indicates that the overall impact of competition on financial stability may depend on the interplay of these contradicting influences.

Martínez-Miera and Repullo (2010) extend the model by Boyd and De Nicoló (2005) by allowing loan defaults to exhibit imperfect correlation. This relaxation allows to distinguish two effects: risk shifting and margin effect. Risk shifting indicates that a decrease in loan rates (due to high competition) leads to lower default probability of the borrower (this is similar to the effect identified in Boyd and De Nicoló, 2005). Margin effect is based on the idea that higher competition is associated with lower loan rates which in turn reduces interest income and there through the bank's ability to cover losses decreases. While risk shifting refers to a positive association between competition and bank stability (competition-stability argument), the margin effect refers to a negative association (competition-fragility argument). The level of banking market competition determines which effect dominates. In highly competitive markets risk-shifting effect is dominated by margin effect and on the very concentrated market, an opposite result occurs. As in their model competition is proxied by the number of banks, this refers to a U-shaped association between the number of banks and bank failure risk.

The latter three papers show that the robustness of the competition-stability argument of Boyd and De Nicoló (2005) hinges significantly on the assumptions of the model. This means that competition-fragility argument that most regulators are concerned about is expected to continue to hold for many real-life settings. The result of Martínez-Miera and Repullo (2010) model also specifies that the association between bank stability and competition may be nonlinear referring to a situation where competition-fragility view holds in highly competitive markets and

[6] Boyd and De Nicoló (2005) model shows that the impact of loan market competition on financial stability counteracts that of deposit market competition.

competition-stability view on less competitive markets. If this expectation holds, regulators should choose their policy responses based on the existing bank competition levels in a country.

2.2. Overview of the empirical literature

The association between bank stability and competition has received significant attention in previous empirical research. We focus here only on the more recent papers which have concentrated on bank-level data and have employed accounting-based measures of bank risk (z-score or credit risk indicators).[7] This is because the accounting data on banks is more widely available compared to market-based data which is restricted to listed banks. Therefore, in order to test the association between bank stability and competition, the samples should be representative of the banking sector of the whole country.

Competition can be measured either with structural or non-structural competition measures. Structural measures are based on traditional industrial organisation theory and the structure-conduct-performance (SCP) paradigm (Bain, 1956). Such competition proxies include Herfindahl-Hirschman Index (HHI) or market share of top *k* firms in the industry. Non-structural measures based on New Empirical Industrial Organisation (NEIO) attempt to gauge competition directly. The latter includes the first generation of non-structural measures such as Panzar and Rosse H-statistic and Lerner index, and Boone indicator as an example of second generation non-structural measure (Carbó et al., 2009). Most of the previous empirical papers focusing on the association between bank stability and competition use either structural measures of competition or Lerner index (e.g., Berger et al., 2009; Agoraki et al., 2011; Andrieş and Căpraru, 2012; Beck et al., 2013; Hope et al., 2013; Liu et al., 2013; Samantas, 2013; Soedarmono et al., 2013; Leroy and Lucotte, 2017). Boone indicator (Boone, 2008) has been applied more frequently in recent research (e.g., Tabak et al., 2012; Jeon and Lim, 2013; Schaeck and Cihák, 2014; Kasman and Kasman, 2015; Kick and Prieto, 2015; Lapteacru, 2017).

Majority of the empirical papers assume that the association between bank stability and competition remains linear, as forecasted by earlier theoretical models. Such studies have supported the competition-fragility view while focusing on the U.S. or using global samples of banks and when employing Lerner indices (e.g., Keeley, 1990; Berger et al., 2009; Turk Ariss, 2010; Beck et al., 2013; Forssbæck and Shehzad, 2015).[8] Berger et al. (2009) support the competition-fragility view also when using HHI. However, Goetz (2018) refers to competition-stability view in the U.S., as have some working papers using global samples of banks (e.g., Boyd et al., 2006; De Nicolo and Loukoianova, 2007; Hesse and Čihák, 2007). Although the latter papers employed HHI as a competition measure, the controversies in results in Berger et al. (2009), which used both HHI and Lerner index, are evident.

Similar controversies in reported results have been observed in studies with a regional focus. Within Europe, these differences have exhibited patterns related to financial market development. Very strong support has been found for the competition-stability view in the samples of European

[7] There exist also papers which focus on country-level results (e.g., Uhde and Heimeshoff, 2009) or employ market-based risk indicators including volatility of stock returns, systematic risk etc. (e.g., Anginer et al., 2014; Brůha and Kočenda, 2018).

[8] As an exception, Keeley (1990) used Tobin's q as a measure of market power.

mature economies and within the whole Europe (e.g., Andrieş and Căpraru, 2012; Liu et al., 2013; Samantas, 2013; Schaeck and Cihák, 2014). However, in samples covering emerging Europe and Spain, the competition-fragility view has been shown to prevail (e.g., Agoraki et al., 2011; Andrieş and Căpraru, 2012; Jiménez et al., 2013). What is interesting is that despite the fact that the composition of samples in these studies differs (in terms of countries and years), both results have been observed with both structural and non-structural competition proxies. In Asian countries, the support for the competition-stability view is, similarly to European countries, somewhat stronger (e.g., Soedarmono et al., 2011, 2013; Jeon and Lim, 2013). However, some papers do support the competition-stability view (e.g., Fu et al., 2014). In other developing regions like Latin America and Africa, the competition-fragility view tends to receive stronger support, irrespective to whether H-statistic (e.g., Yeyati and Micco, 2007), Boone indicator (e.g. Tabak et al., 2012), Lerner index or HHI (e.g., Hope et al., 2013) is considered.

Abovementioned empirical results indicate that the linear association between bank stability and competition has been either positive or negative. Contradictions in results are further highlighted by the fact that the use of different competition indicators in the same dataset may lead to opposite significant results (e.g., Liu et al., 2012; Kick and Prieto, 2015).

Given the more recent theoretical developments, several empirical papers have attempted to test the non-linearity in the association between bank stability and competition. In the European context, the non-linearity argument has been tested and supported by Liu et al. (2013), and Samantas (2013). They show that if the Lerner index is used as a competition indicator, there exists an inverse U-shape association between bank stability and competition while Samantas (2017) finds an evidence of U-shape association using Lerner index in a sample of 27 EU countries. Non-linearity is also observed in Lapteacru (2017) when using a Boone indicator and Jiménez et al. (2013) for Spanish banks. However, the latter result is not robust to the chosen competition measures, appearing only when using standard concentration measures. Non-linearity aspect has been also tested in the Latin American context by Tabak et al. (2012). They find signs of a different type of non-linearity—at both high and low competition levels competition (measured by the Boone indicator) increases stability, however, at average levels, fragility is observed. The latter finding contradicts the predictions of the model developed by Martínez-Miera and Repullo (2010). The results of the non-linearity test have been shown to depend on the characteristics of the sample. A non-linearity test conducted with a Lerner index in a European sample of global listed banks by Forssbæck and Shehzad (2015), shows no support for its presence. However, when the sample is split into developed and developing countries, there exist signs of non-linearity. This indicates that although the previous results tend to support the presence of non-linearity in the association between bank stability and competition, the precise nature of that non-linearity remains dependent on the given sample.

Previous studies with a European focus have paid limited attention to the competition-stability association in the context of the Boone indicator. Only Schaeck and Cihák (2014) focused on 10 Western European countries during the 1995–2005 and Lapteacru (2017) on 10 Central and Eastern European countries during 1995–2013. Considering the limited geographical coverage of the previous papers in terms of the number of European countries, this paper applies Boone indicator in the sample of banks from wider Europe during a time period covering the full boom-bust cycle. Considering the more recent theoretical predictions and some contradictions in empirical findings, special attention is also paid to testing the non-linearity argument.

3. Methodology and data

3.1. Indicators of bank risk and banking market competition

We use z-score as the main bank stability indicator in this paper. This indicator was introduced by Boyd and Graham (1988) and has been thereafter used in numerous empirical papers focusing on the association between bank stability and competition (e.g., Boyd et al., 2006; Agoraki et al., 2011; Liu et al., 2013; Samantas, 2013; Schaeck and Cihák, 2014). Z-score (Z_{it}) represents an indicator of bankruptcy and it is equivalent to the number of standard deviations that bank's return on assets should have to fall in order to eliminate equity. It is defined as:

$$Z_{it} = \frac{ROA_{it} + E_{it} / TA_{it}}{\sigma_{\overline{ROA}i}} \tag{1}$$

In this paper 3-year rolling standard deviation of return on assets $(\sigma_{\overline{ROA}i})$ of bank *i* is combined with current period *t* equity to assets (E_{it}/TA_{it}) and current period return on assets (ROA_{it}). Greater profitability and capitalization lead to a higher z-score and higher standard deviation of return on assets leads to a lower z-score. Therefore, the greater the z-score, the lower the probability of insolvency and the more stable is the bank. As z-score is highly skewed, we employ a natural logarithm of the z-score $(lnZ1)$ as the dependent variable in the regression models. As summarised in Lepetit and Strobel (2013), there exist numerous other ways for calculating this indicator. As a robustness test, we employ also a z-score calculated based on return on equity (ROE, noted as ln*Z2*) and consider loan loss reserves ratio $(lnLLR)$ as an alternative risk indicator of a bank. The main drawback of z-score is that it is based on backward-looking accounting data and can be distorted by the financial cycle. This limitation could be overcome by the use of market-based bank risk indicators. However, that would require limiting the sample to only listed banks. Therefore, the use of z-score remains the best option for retaining the sample size.

We use the Boone indicator as our main measure of competition. According to the Boone's model (Boone, 2008), more efficient firms (e.g., firms with lower marginal costs) gain higher market shares or profits and this effect will be stronger in the environment where the competition is more intense. In this paper we estimate the following dynamic model separately for each country in the sample:

$$\ln(MS)_{ilt} = \delta + \sum_{t=1,\ldots,T} \beta_{lt} D_t \times \ln(MC)_{ilt} + \sum_{t=1,\ldots,(T-1)} \theta_t D_t + \upsilon_{ilt} \tag{2}$$

where MS_{ilt} represents the market share of output *l* of bank *i* in year *t.* The output is measured in terms of total loans. MC_{ilt} refers to the marginal costs and D_t to year dummies. Year dummies enable to control for time-specific effects. This specification yields country level annual estimates of the Boone indicator which is captured by the β_{lt} coefficient and is expected to have a negative

value. The stronger the impact of efficiency on the market share, the more competitive the banking market is. Therefore, lower estimated values of beta suggest a higher level of competition.[9]

Since marginal costs cannot be directly observed, some studies approximate marginal costs by the ratio of average variable costs to total income (e.g., Schaeck and Cihák, 2014). Others estimate the translog cost function (e.g., van Leuvensteijn et al., 2011; Tabak et al., 2012; Kasman and Kasman, 2015). Direct estimation of marginal cost is more precise and more closely in line with the theory. In this paper we estimate the following translog cost function for the Boone indicator:

$$\begin{aligned}\ln(C)_{it} = \alpha_0 + \sum_r^n \alpha_r \ln Y_{rit} + \sum_s^m \beta_s \ln P_{sit} + \frac{1}{2}\sum_r^n \sum_k^n \alpha_{rk} \ln Y_{rit} \ln Y_{kit} \\ + \frac{1}{2}\sum_s^m \sum_k^m \beta_{sk} \ln P_{sit} \ln P_{kit} + \sum_r^n \sum_s^m \chi_{rs} \ln Y_{rit} \ln P_{sit} + X_{it} + D_t + \varepsilon_{it}\end{aligned} \tag{3}$$

Equation (3) is estimated separately for each of the countries in the sample. C_{it} stands for the total cost of bank *i* in year *t*. The explanatory variables Y and P contain output and input components respectively.

We use four outputs: total loans, total deposits, other earning assets, and non-interest income. Two input prices include interest expense to total bank funding (the price of funds) and non-interest expense to total assets (this can be regarded as the price of both human and physical capital). The set of control variables include equity and squared equity ratios for controlling the differences in risk profiles and business models of banks (X_{it}) and year dummies (D_t).

Within estimations, standard regularity conditions such as symmetry restrictions and input price homogeneity of degree one are required to estimate (3). Linear homogeneity is imposed by dividing factor prices and total cost by one input price (the price of funds is chosen as a numeraire). We also require that all the squared and cross terms add up to zero and the second order parameters are symmetric (for further details see Kumbhakar and Lovell, 2000; Kumbhakar et al., 2014). One problem with multi-output, multi-input cost functions is that the number of parameters to be estimated can be quite large and the estimations are prone to multicollinearity problems. Therefore, in this paper parameter restrictions are applied and the translog cost function is reformulated with a lower number of parameters and estimated as the full dual system with cost and cost-share equations implied by Shepherd lemma. Iterative least squares procedure is applied to resulting SUR equations (for further details see Greene, 1993; Coelli et al., 2005).

Similarly to van Leuvensteijn et al. (2011) and Tabak et al. (2012), the level of competition is proxied by the competition in loan markets. The marginal cost of loans is derived from the translog cost function of Equation (3) by taking the derivative with respect to output Y_{ilt} (loans): $MC_{ilt} = \frac{\partial(C_{it}/P_2)}{\partial Y_{ilt}} = \left(\frac{C_{it}/P_2}{Y_{ilt}}\right)\frac{\partial \ln(C_{it}/P_2)}{\partial \ln Y_{ilt}}$. This allows the estimation of marginal costs for each

[9] Positive values of Boone indicator can be also supported in empirical applications. According to Tabak et al. (2012), the banks may choose to compete in terms of quality, which may imply positive values for Boone indicators. Positive values of Boone indicator may also be an indicator of extreme collusion in the market as inefficient banks are not punished by market forces (Kick and Prieto, 2015).

bank-year observation, which in turn will be used as a regressor in the dynamic model of Boone indicator in Equation (2).

Boone indicator allows to view competition as a complex process of rivalry between firms and not as a static state and as such it has a more solid theoretical foundation than other structural and other non-structural measures of competition. According to Carbó et al. (2009) and Bolt and Humphrey (2015), different competition measures (both structural and non-structural) are only weakly related to each other and may provide conflicting predictions about the level of competition. These measures tend to gauge potentially different aspects of competition and are influenced by cross-country differences in cost efficiency, the structure of revenues, and macroeconomic variables (e.g., economic growth, inflation). Therefore, we also employ alternative measures of competition, including the Herfindahl-Hirschman index (HHI) and Lerner index.

HHI is computed as the sum of all squared market shares of banks based on their total assets.[10] Compared to traditional concentration ratios its use avoids the arbitrary cut-off and enables to capture the full distribution of bank sizes.

We also use the Lerner index which is a popular measure of bank level market power. It is calculated as the difference between price and a marginal cost as a percentage of the price. In this paper, we apply a conventional Lerner index[11] to loan markets. The price for loans is estimated as interest income on loans over net loans. To obtain the marginal costs, we essentially follow an approach similar to Boone indicator estimation based on an equivalent translog cost function which is described above. Simple aggregation of bank level Lerner indexes is used to arrive at country level annual estimates of competition which are comparable to estimates of Boone indicator.

3.2. Regression models

The baseline regression models M1 and M2 used in this paper are the following:

$$\ln Z_{ijt} = f\left(\ln Z_{ijt-1}; GDP_{jt}; Comp_{jt}; \ln TA_{ijt}; CI_{ijt}; DIV_{ijt}\right) \tag{4}$$

[10] We did initially consider also Top5 concentration ratio as an additional structural measure. However, in order to save space, it is not presented in tables included in this article.

[11] Alternative specifications to conventional approach are also suggested by the literature. As suggested by Koetter et.al. (2012), the conventional Lerner index implicitly assumes full bank efficiency in exploiting the pricing power and suggest an estimation of the efficiency adjusted Lerner index. However, there is not yet a consensus in empirical literature whether banks with market power enjoy "quiet life". According to Koetter et al. (2012), there is an empirical support for the positive association of the market power and profit inefficiencies. However, Maudos and De Guevara (2007) find a positive association between market power and cost X-efficiency based on a large European sample. The latter authors also suggest funding adjusted measure of Lerner index because the estimation of marginal costs through an approach introduced also in this article may create another bias which reflects potential monopoly power exercised in deposit markets. Nonetheless, we estimate the conventional Lerner index in this paper as fully ignoring the cost of funds may create yet another bias to our estimations.

$$\ln Z_{ijt} = f\left(\ln Z_{ijt-1}; GDP_{jt}; Comp_{jt}; Comp_{jt}^{2}; \ln TA_{ijt}; CI_{ijt}; DIV_{ijt}\right) \quad (5)$$

where lnZ_{ijt} refers to either ln*Z1* or ln*Z2* of bank i from country j on year t. Lagged z-score captures the persistence in bank stability. If persistence is present, it is expected to exhibit a positive association with a contemporaneous z-score. Macroeconomic conditions of a country are captured by the real GDP growth (*GDP*) and it is expected to exhibit a positive coefficient in the contemporaneous context. It captures the business cycle developments which have been shown to significantly affect the lending policies of banks and may have a delayed impact on bank stability indicator. In order to reduce the number of instruments, no other controls for the country's macro economy were considered.

Comp refers to competition indicators. As already discussed in section 3.1., several competition indicators are considered in this paper. These are included in the model one by one and their association with z-score is expected to remain ambiguous. To account for the potential non-linearity in the association between bank stability and competition, the squared indicator ($Comp^2$) is used simultaneously. If non-linearity is present, its sign should be opposite to the unsquared indicator.

Bank-specific controls cover several variables. These have been selected amongst the most popular indicators employed in previous empirical studies focusing on the association between bank competition and z-score (e.g., Boyd et al., 2006; Hesse and Čihák, 2007; Agoraki et al., 2011; Beck et al., 2013; Liu et al., 2013; Schaeck and Cihák, 2014). Bank size (ln*TA*) is proxied by the natural log of total assets. Bigger banks may have better diversification possibilities and better risk management systems. However, they may also be willing to take on more risk if they can be considered too-big-to-fail. Therefore, the association between bank size and z-score is expected to remain ambiguous. Differences in bank efficiency levels are captured by the cost-to-income ratio (*CI*). As less efficient banks are expected to take on more risk to improve their performance at similar capital levels, the association between cost-to-income ratio and z-score should be negative. Income diversity of a bank is proxied with diversification indicator proposed by Laeven and Levine (2007). It is calculated as:

$$DIV_{it} = 1 - \left| \frac{Net\ interest income - Other operating income}{Total operating income} \right| \quad (6)$$

The greater the indicator, the higher the level of diversification. Its association with z-score is expected to remain ambiguous. This is because greater dependence on other operating income may entail both lower and higher risks for the bank (depending on the riskiness of non-operating activities).

As a robustness test, equation 5 is estimated also with loan loss reserves ratio ($lnLLR$) as a dependent variable. Considering that higher loan loss reserves refer to higher risk, all associations with explanatory variables should be opposite to the ones described above for the z-score.

Similarly to Tabak et al. (2012), the precise nature of non-linearity in the association between the competition indicator (*CompC*) and z-score is tested with the following regression model[12]:

[12] This test is necessary because Boone can take both negative and positive values meaning that its squared value can be positive either because of very high or very low competition.

$$\ln Z_{ijt} = f\left(\ln Z_{ijt-1}; GDP_{jt}; CompC_{jt}; \ln TA_{ijt}; CI_{ijt}; DIV_{ijt}\right) \quad (7)$$

This model (marked as M3) is initially run three times so that *CompC* refers to the strength of competition denoted by 1, 2, or 3. In the first model *Comp1* refers to a dummy variable which is set equal to 1 if the competition indicator of a country refers to high competition, and 0 otherwise. In the second model dummy *Comp2* refers to medium competition and in the third model, *Comp3* refers to low competition. These dummies are created for both the Boone indicator and the Lerner index. High competition refers to a situation where the competition indicator of a country is lower than average competition indicator of the sample minus 0.5 standard deviations of the competition indicator. Low refers to a situation where the competition indicator value for a country is higher than the sample average plus 0.5 standard deviations of the competition indicator. Medium competition refers to the cases where the competition indicator is above the limit set for the high and below the limit set for the low competition. All other explanatory variables are the same as in models M1 and M2 (equations 4 and 5). An additional modification of this model (marked as M4) is used to determine whether the difference in high and low competition's impact on the z-score is statistically significant when compared to the medium level of competition (*Comp2*). For these purposes, *Comp1* and *Comp3* are included simultaneously.

In order to test the robustness of the baseline estimation results, two additional models are used. The first of these models (M5) includes additional controls for the country's regulative context:

$$\ln Z1_{ijt} = f\left(\ln Z1_{ijt-1}; GDP_{jt}; Cactr_{jt}; Ccapr_{jt}; Comp_{jt}; Comp^{2}_{jt}; \ln TA_{ijt}; CI_{ijt}; DIV_{ijt}\right) \quad (8)$$

Cactr refers to activity restrictions set to banks operating within a given country. This indicator has been taken from the World Bank and it ranges from 3 to 12. The higher the indicator, the more restricted are the banking activities within the country. One would expect this indicator to exhibit a positive coefficient. *Ccapr* refers to the stringency of capital requirements within a country. This indicator has been taken from the World Bank and it ranges from 0 to 10, with a greater value corresponding to greater stringency. This indicator should exhibit a positive coefficient or at least as shown by Beck et al. (2013) stricter activity restrictions on banks should reinforce the impact higher competition has on stability.

The second model (M6) for the robustness tests considers the possible non-linearity in the association between bank size and stability and also controls for bank ownership:

$$\ln Z1_{ijt} = f\left(\ln Z1_{ijt-1}; GDP_{jt}; Comp_{jt}; Comp^{2}_{jt}; \ln TA_{ijt}; \ln TA^{2}_{ijt}; CI_{ijt}; DIV_{ijt}; d\_for_{ijt}; d\_gov_{ijt}\right) \quad (9)$$

Foreign ownership is captured by a dummy variable (*d_for*) which takes value 1 if the bank is at least 50.1% owned by foreigners, 0 otherwise. Its association with z-score is expected to remain ambiguous because it could increase or decrease the riskiness of a bank depending on the strategy chosen by the foreign owner. State ownership is measured by a dummy variable (*d_gov*) which takes value 1 if at least 20.1% of the bank's shares belong to the state, 0 otherwise. Similar to foreign ownership, its association with bank stability is expected to remain ambiguous. State ownership may induce higher bank risk due to lower monitoring capacities of the state. However, during crisis periods the state may inject additional capital into the bank to save it.

We estimate all regression models with two-step system GMM estimator of Arellano-Bover (1995)/Blundell-Bond (1998). For avoiding instrument proliferation, we report the GMM estimates with "collapsed" instruments (Roodman, 2009). This estimation approach has become a standard in recent empirical literature focusing on bank competition and stability. It provides clear benefits when dealing with a dynamic model and with explanatory variables (especially competition) which are potentially endogenous. We treat the lagged dependent variable as endogenous and instrument it with its 3rd and 4th lag. Year dummies are treated as strictly exogenous and the remaining control variables as pre-determined. All competition variables and country-specific macroeconomic and regulative indicators are instrumented with their 2nd lag and all bank-specific variables with their 1st lag. Lags are restricted to reduce the number of instruments. For avoiding downward bias in finite samples, we report standard errors with the Windmeijer (2005) correction. As our panel data includes gaps, the estimation sample is maximised through the use of orthogonal deviations instead of first differences. The negative aspect of the use of the system GMM approach is that due to instrumentation issues we cannot include too many potential control variables in the baseline models. This is also the reason why we consider many potential control variables only in the robustness test.

3.3. Sample and data

This paper focuses on 27 European countries which are all part of the European Union (hereafter EU) as at the end of 2015. The only EU country which was excluded, due to too few observations for estimating the Boone indicator, was Ireland. Two types of sub-samples are formed from this set of countries based on financial market development. The first set of 16 countries is referred to as mature economies (hereafter referred to as ME) and includes Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Italy, Luxembourg, Malta, Netherlands, Portugal, Spain, Sweden, and the UK. The second group containing 11 countries from emerging Europe is referred to as EE. This set includes Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia. The second set of sub-samples is formed based on the banking sector risk of a country measured in terms of country z-score taken from the World Bank. Hierarchical clustering of countries was carried out based on the average z-score of each country during 2004–2014. This led to the formation of 3 sets of countries based on their stability: high (Austria, France, Germany, Finland, Italy, Luxembourg, Malta, Portugal, Slovakia, Spain), medium (Belgium, Denmark, Estonia, Netherlands, Poland, Sweden, UK), and low (Bulgaria, the Czech Republic, Croatia, Cyprus, Greece, Hungary, Latvia, Lithuania, Romania, Slovenia).

Macroeconomic indicators for these countries were obtained from the IMF database and banking sector HHI measures from the ECB. Banking market indicators were taken from ECB and Central Banks' web-pages. Regulatory indicators were taken from the World Bank Survey of Bank Regulation and Supervision.

Bank-level data from 2004 to 2014 was obtained from the Orbis Bank Focus database. Dataset remains unbalanced, because of bankruptcies, mergers, or new starters. The focus is on unconsolidated statements in order to avoid double-counting the statistics of the same bank in its home country. If available, annual unconsolidated financial data following IFRS is used. If not, unconsolidated statements following local GAAP are used. Extreme observations are eliminated. The final dataset covers 1088 to 1111 banks depending on the model. Table 1 presents the descriptive statistics of all variables.

Table 1. Descriptive statistics of the EU sample.

Variable	Description	Mean	Std. Dev.	Min	Max
	Panel A: Bank-specific indicators				
$lnZ1$	Natural log of z-score based on ROA	3.427	1.180	−3.750	6.198
$lnZ2$	Natural log of z-score based on ROE	3.440	1.183	−3.801	6.364
$lnLLR$	Natural log of loan loss reserves to loans, %	0.913	1.165	−6.967	4.091
$lnTA$	Natural log of total assets	14.472	1.944	7.128	21.533
CI	Cost to income ratio, %	65.078	30.804	1.220	718.100
DIV	Diversification index	0.601	0.246	0.000	1.000
d_for	Dummy equal to 1, if the bank is majority foreign-owned, 0 otherwise	0.454	0.498	0.000	1.000
d_gov	Dummy equal to 1, if the bank is at least 20.1% state-owned, 0 otherwise	0.018	0.134	0.000	1.000
	Panel B: Country-specific indicators				
GDP	Real GDP growth, %	1.072	3.345	−14.814	11.621
$Boone$	Boone indicator	−0.123	0.205	−0.690	0.718
$Lerner$	Lerner index	0.520	0.137	0.128	0.899
HHI	Herfindahl-Hirschman index	0.074	0.051	0.018	0.370
$TOP5$	Top5 concentration ratio based on total assets, %	48.962	16.326	21.991	97.110
$Cactr$	Indicator of activity restrictions of banks	6.364	1.767	3.000	11.000
$Ccapr$	Indicator of stringency of capital requirements	6.477	1.763	3.000	10.000

Notes: This table reports descriptive statistics of the regression sample presented in Table 2 as the model M1 with the Boone indicator.

Bank specific indicators exhibit rather significant dispersion. The assets of banks range from 1 million euros to 2246 billion euros. The proportion of foreign-owned banks is rather large remaining close to 45% of all banks included in the dataset. However, the proportion of state-owned banks remains modest (below 2%).

Banking market competition indicators reveal significant differences across countries.[13] The average estimated value for the Boone indicator is −0.123 which is in line with the theoretical prediction that an increase in marginal costs is associated with the loss of market share. When looking at the intertemporal changes in the Boone indicator (see Table C.4 in Online Appendix), it is possible to see that the level of competition in the EU sample has decreased significantly over time, especially during and after the financial crisis. In mature economies, the competition has been somewhat higher compared to emerging economies. We also observe positive significant estimates for the Boone indicator for Estonia,

[13] The estimates of marginal costs for each bank in the sample exhibit consistently positive values with only a very few observations regarded as outliers indicating the robustness of translog cost function specification. The estimated country-specific average values of marginal costs range from 0.025 in Finland to 0.068 in Hungary with the average estimate being 0.0428 for the EU sample. Detailed summary statistics of the EU sample by countries and country-specific estimates of competition indicators are available in the Online Appendix (see Tables C.1-C.5 in http://www.aimspress.com/article/10.3934/QFE.2019.2.257/supplementry.html).

Slovenia, and Portugal. This may indicate that banks in these countries may experience high level of collusion or that banks are competing in quality.

Another structural measure of competition, the Lerner index also reveals substantial differences across countries. We report aggregated unweighted[14] Lerner indexes for the full sample in Table 1. The average Lerner index value 0.52 refers to a relatively low level of competition. However, as the Lerner index is computed for the loan markets, its value might not be directly comparable to empirical cross-country studies which predominantly measure the average level of competition based on total assets as an output in marginal cost estimations.

The structural competition indicators also refer to significant differences across countries. Average *HHI* is 0.074 referring to low concentration by current screening guidelines. Average *TOP5* remains at 49%. However, the maximum values of *TOP5* reaching 97% refer to very high market concentration.

4. Results and discussion

4.1. Results of the baseline models

Table 2 presents the results from the estimation of regression models M1 and M2, corresponding to Equation (4) and (5). The dependent variables in these models correspond to ln*Z1* and competition indicators are either *Boone, Lerner*, or *HHI*. All competition indicators (Boone indicator, Lerner index, *HHI)* exhibit a significant negative coefficient in M1 specifications, i.e. if competition or market concentration increases, so does the stability of banks. This indicates support for the competition-stability argument. A similar result has been observed in many studies focusing on European banks and using either HHI or Lerner indices (e.g., Andrieş and Căpraru, 2012; Liu et al., 2013; Samantas, 2013; Schaeck and Cihák, 2014).[15] Schaeck and Cihák (2014) have reported, similarly, negative coefficients for the Boone indicators when focusing on 10 European countries during 1995–2005. It also confirms that the association between bank stability and competition measured with a Boone indicator on a period beyond 2005 remains similar to that on the pre-2005 period.

When squared competition terms are added (specification M2), the squared terms exhibit an opposite association when either Boone indicator or *HHI* are considered. This refers to non-linearity in the association between competition and bank stability. Non-linearity has been previously observed also in the European context by Liu et al. (2013) and Samantas (2013) when using the Lerner index.[16] What is rather interesting, is that in this paper the squared term of the country Lerner index does exhibit a sign opposite to that of the unsquared term. However, the sign of the coefficient of the squared Lerner index is negative while it is positive for the Boone indicator and *HHI*. Also, the coefficient of the unsquared Lerner index becomes statistically insignificant, creating a situation where there is no clear-cut support for the presence of non-linearity. The opposite sign for squared Lerner index could be explained by the

[14] An unweighted Lerner index helps to deal with potential biases created by reallocation effects from inefficient to efficient firms which may support higher Lerner index value even in the presence of heightened competition.

[15] Uhde and Heimeshoff (2009) report a similar result in a country-level analysis.

[16] Less robust signs of non-linearity have also been observed in Jiménez et al. (2013), however, this result was not robust to the chosen competition measures, appearing only when using standard concentration indicators.

fact that different competition indicators tend to measure different aspects of competition. Similar inconsistencies in results obtained with different competition indicators within the same sample have been observed also in some previous studies, e.g., Liu et al. (2012); Kick and Prieto, (2015). As reported by De Jonghe et al. (2016) Boone indicator constantly exhibits a low and negative but statistically significant correlation coefficient with other competition indicators. In our paper, the Pearson correlation coefficient between the Lerner index and the Boone indicator is −0.13 and statistically significant.

Overall, these results show that if the association between stability and competition is assumed to be linear, competition-stability argument prevails. This means that steps taken to increase the competition amongst banks would potentially enable to improve financial stability. After controlling for potential non-linearity in the association, we observe that there might exist certain limits beyond which an increase in competition could begin to harm financial stability. We will focus on these limits in the following tests and discussion.

Table 2. Results of the baseline models.

Sample	EU		EU		EU		EU		EU		EU	
Dependent variable	ln*Z1*		ln*Z1*		ln*Z1*		ln*Z1*		ln*Z1*		ln*Z1*	
Model	M1		M2		M1		M2		M1		M2	
Competition indicator *Comp*	*Boone*		*Boone*		*Lerner*		*Lerner*		*HHI*		*HHI*	
	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.
$lnZ1_{t-1}$	0.501	***	0.559	***	0.578	***	0.572	***	0.568	***	0.562	***
	(0.047)		(0.029)		(0.028)		(0.026)		(0.028)		(0.027)	
GDP	0.054	***	0.065	***	0.073	***	0.078	***	0.061	***	0.059	***
	(0.015)		(0.016)		(0.016)		(0.016)		(0.016)		(0.017)	
$Comp$	−0.721	*	−0.549	**	−1.544	***	2.242		−3.181	**	−5.625	**
	(0.379)		(0.223)		(0.441)		(1.900)		(1.450)		(2.404)	
$Comp^2$			2.365	**			−3.827	**			18.920	***
			(1.126)				(1.910)				(7.331)	
$lnTA$	0.027		0.062		0.119		0.122	*	0.065		−0.015	
	(0.072)		(0.072)		(0.073)		(0.072)		(0.078)		(0.069)	
CI	−0.005	***	−0.005	**	−0.004	**	−0.005	***	−0.006	**	−0.001	
	(0.002)		(0.002)		(0.002)		(0.002)		(0.002)		(0.003)	
DIV	0.239		0.227		0.115		0.153		0.133		0.149	
	(0.179)		(0.184)		(0.205)		(0.209)		(0.206)		(0.389)	
Constant	1.491		0.695		0.608		−0.281		0.957		1.867	*
	(1.088)		(1.085)		(1.152)		(1.304)		(1.199)		(1.049)	
Obs.	5,756		5,756		5,917		5,917		5,917		5,917	
No. of banks	1,088		1,088		1,111		1,111		1,111		1,111	
Hansen p	0.791		0.164		0.422		0.525		0.811		0.175	
F statistic	22.33	***	42.92	***	56.10	***	55.76	***	48.29	***	47.08	***

Notes: This table reports system GMM estimates of Equation (4) in panels marked with M1 and estimates of Equation (5) in panels marked with M2. For abbreviations of variables see Table 1. Robust standard errors in parentheses. Sign. refers to statistical significance: *** p < 0.01, ** p < 0.05, and * p < 0.1.

The results in Table 2 show that bank stability is also dependent on previous bank stability levels, macroeconomic conditions and bank efficiency. The lagged z-score exhibits a strong positive association with contemporaneous z-score. This refers to strong persistence in the stability of banks, as has been observed in most papers which have employed dynamic z-score models (e.g., Agoraki et al., 2011; Jiménez, et al., 2013; Liu et al., 2013; Cubillas and González, 2014; Kasman and Kasman, 2015). In line with expectations, GDP growth exhibits a statistically significant positive coefficient. This result coincides with most of the previous studies using European samples (e.g., Agoraki et al., 2011; Samantas, 2013; Jiménez et al., 2013). The only bank-specific indicator which exhibits a consistent statistically significant association with the z-score is the cost-to-income ratio. If its coefficient is significant, it tends to be negative. A similar result has been observed in several previous studies (e.g., Hesse and Čihák, 2007; Agoraki et al., 2011; Samantas, 2013). Bank size has a significant positive coefficient only in model M2 with the Lerner index. Low robustness of this result could be explained by the ambiguous expectations regarding this variable. Previous papers have supported positive association mainly when using global, Asian, or Latin American samples of banks (e.g., Berger et al., 2009; Soedarmono et al., 2011; Beck et al., 2013; Tabak et al., 2012).

Further tests of the precise nature of non-linearity with the Boone indicator and Lerner index were conducted using regression model M3, corresponding to Equation (7). The results of the non-linearity test are presented in Table 3. For the Boone indicator, the results are the following. If competition is high (*Boone1*), European banks are more stable. If competition is at a medium level (*Boone2*), the association reverses—instead of the competition-stability view, competition-fragility view prevails. Although the coefficients of *Boone3* remain insignificant, their positive coefficients tend to indicate that at very low competition levels competition-stability view could prevail again. When both *Boone1* and *Boone3* indicators are included (model M4), there exist clear signs that compared to the medium competition, high level of competition increases bank stability significantly. Similar, yet statistically insignificant, the effect is observed when comparing low competition with medium competition. These results seem to support the presence of a U-shape association between competition and bank stability.

When similar calculations are done with the Lerner index, the results for the low and medium competition levels resemble the ones for the Boone indicator—competition-stability view prevails at the low and competition-fragility view at the medium competition level. Although the coefficient for the high competition level (*Lerner3*) remains insignificant, it exhibits a negative sign which is opposite to what was observed in the case of the Boone indicator (*Boone3*).

Table 3. Non-linearity tests for the Boone and Lerner indicators.

Sample	EU		EU		EU		EU		EU		EU		EU		EU	
Dependent variable	ln*Z1*		ln*Z1*		ln*Z1*		ln*Z1*		ln*Z1*		ln*Z1*		ln*Z1*		ln*Z1*	
Model	M3		M3		M3		M4		M3		M3		M3		M4	
Competition indicator *Comp*	*Boone*		*Boone*		*Boone*		*Boone*		*Lerner*		*Lerner*		*Lerner*		*Lerner*	
	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.
$lnZ1_{t-1}$	0.502	***	0.500	***	0.499	***	0.504	***	0.567	***	0.573	***	0.567	***	0.570	***
	(0.049)		(0.048)		(0.047)		(0.049)		(0.029)		(0.028)		(0.028)		(0.029)	
GDP	0.072	***	0.062	***	0.057	***	0.071	***	0.071	***	0.061	***	0.066	***	0.071	***
	(0.017)		(0.015)		(0.015)		(0.016)		(0.016)		(0.016)		(0.016)		(0.015)	
Comp1	0.426	***					0.389	***	0.208	**					0.202	**
	(0.132)						(0.129)		(0.082)						(0.080)	
Comp2			−0.202	**							−0.086	*				
			(0.081)								(0.048)					
Comp3					0.041		0.124						−0.083		−0.044	
					(0.119)		(0.110)						(0.055)		(0.054)	
ln*TA*	0.030		0.021		0.027		0.025		0.026		0.057		0.075		0.027	
	(0.074)		(0.076)		(0.075)		(0.074)		(0.070)		(0.071)		(0.075)		(0.068)	
CI	−0.005	***	−0.005	***	−0.004	**	−0.005	***	−0.004	**	−0.005	**	−0.004	**	−0.004	**
	(0.002)		(0.002)		(0.002)		(0.002)		(0.002)		(0.002)		(0.002)		(0.002)	
DIV	0.291		0.267		0.190		0.296		−0.096		0.129		0.066		−0.081	
	(0.185)		(0.183)		(0.200)		(0.187)		(0.193)		(0.209)		(0.198)		(0.191)	
Constant	1.476		1.799		1.563		1.508		1.211		0.803		0.490		1.207	
	(1.122)		(1.165)		(1.151)		(1.122)		(1.053)		(1.083)		(1.133)		(1.034)	
Obs.	5,756		5,756		5,917		5,756		5,917		5,917		5,917		5,917	
No. of banks	1,088		1,088		1,111		1,088		1,111		1,111		1,111		1,111	
Hansen p	0.607		0.680		0.820		0.663		0.026		0.507		0.530		0.048	
F statistic	22.47	***	23.71	***	23.43	***	21.62	***	54.44	***	56.54	***	50.86	***	51.48	***

Notes: This table reports system GMM estimates of Equation (7). Comp1—dummy equal to 1 if the competition indicator of a country refers to high competition, 0 otherwise. Comp2—dummy equal to 1 if the competition indicator of a country refers to medium competition, 0 otherwise. Comp3—dummy equal to 1 if the competition indicator of a country refers to low competition, 0 otherwise. Panels marked with M3 present results of models where only one competition dummy is included at a time. In panels marked with M4 both low and high competition dummies are included simultaneously. For abbreviations of other variables see Table 1. Robust standard errors in parentheses. Sign. refers to statistical significance: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

When both *Lerner1* and *Lerner3* are included in the model (model M4), it appears that the low competition level improves bank stability compared to the medium level and high competition tends to increase fragility. Although the latter difference is not statistically significant, the association between the Lerner index and bank stability appears more linear than in the case of the Boone indicator.

In order to shed more light on the results reported in Table 3, marginal effects were calculated using Equation (5) at the means of all other explanatory variables besides the Boone indicator and Lerner index. The results are presented in Figure 1.

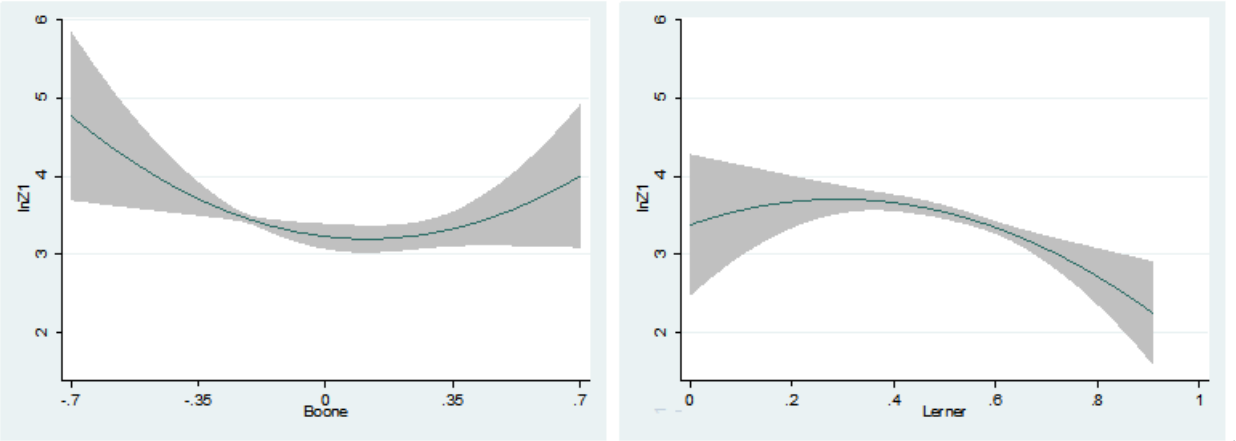

Figure 1. Marginal effects of competition on bank stability in the EU sample. Notes: ln*Z1* is the measure of bank stability and it represents the natural log of z-score based on ROA. On the left-hand figure, competition is measured with a Boone indicator and on the right-hand figure with Lerner index. Marginal effects have been calculated using Equation (5) at the means of all other explanatory variables besides the competition indicators.

Competition indicator ranges are limited by the maximum and minimum values of the EU sample. Although the confidence intervals are wide both at very low and high Boone indicator levels, there is indeed some support for a U-shape association between competition and bank stability. This finding contradicts the conclusions of Liu et al. (2013) and Samantas (2013) who both found support for an inverse U-shape association between competition and bank stability in Europe. Both of these papers measured competition with a Lerner index and focused on the earlier time period.[17] In the context of this paper, when a similar figure is drawn for the Lerner index, there is also weak support for the inverse U-shape. As the upper bound of the confidence level exhibits almost linear association, there do appear significantly stronger signs of non-linearity in the case of the Boone indicator. The contradictory associations presented in Figure 1 confirm the differences reported for the Boone indicator and Lerner index in Table 2 for model M2.

Overall, the results presented in Table 3 and Figure 1 provide further support for the non-linear association between banks stability and competition. Still, the non-linearity may not be equally strong when using different competition proxies. This indicates that before taking policy measures, it

[17] Liu et al. (2013) concentrated on banks from 10 European countries during 2000–2008 and Samantas (2013) covered banks from 27 European countries during 2002–2010.

is important to define which aspect of competition regulators want to address. For regulators, it is a rather clear sign that medium-level competition in EU may be less desirable if Boone-type competition measures are used. Inflection point computed from the respective quadratic function for the Boone indicator is at 0.116 for the EU sample suggesting that beyond that point, lower level of competition tends to increase the stability of a banking sector. The inflection point lies approximately at the 84th percentile of the distribution for Boone indicator implying that 16% of the data lies above the inflection point. This indicates that increasing competition for most EU banks tends to be associated with an increase in the fragility of the financial system. When using Lerner type measures, the inflection point is at 0.293, which lies approximately at the 3rd percentile indicating that vast majority of banks operate on the domain characterised by a negative association between bank stability and pricing power. This indicates that regulators should support pricing power of most banks in order to improve financial stability.

Previous papers have shown that European countries with different financial market development level can exhibit differences in the association between bank stability and competition. Considering that the sample composition may explain some of the differences in results reported above compared to those of previous studies, Table A.1 in Appendix A[18] presents the results of the baseline models with the Boone indicator for ME and EE sub-samples separately. The lagged z-score continues to exhibit a significant positive coefficient in all specifications. However, as the sample size drops, GDP growth loses its statistical significance in several specifications as does the cost-to-income ratio. This affects also the significance of un-squared Boone indicators which in both models M1 and M2 remain statistically insignificant. However, the statistical significance of squared Boone indicators is on the borderline.[19] All Boone indicator coefficients in ME sub-sample exhibit signs opposite to those observed in EE sub-sample. This tendency coincides with similar differences shown by Andrieş and Căpraru (2012) and Agoraki et al. (2011). When competition levels are distinguished in model M3, the results for significant Boone coefficients for the ME sub-sample follow those of the EU sample reported in Table 3. The competition-stability view is strongly supported in ME sub-sample at high competition level and competition-fragility view at medium competition level. However, the results for the EE sub-sample exhibit some differences—competition stability view is supported in EE sample at low competition level. A similar difference remains when coefficients of high and low competition (*Boone1* and *Boone3*) are compared to those of medium competition (*Boone2*). There exist weak signs that in EE at higher competition levels the fragility increases compared to medium competition level. However, in ME sub-sample stability clearly increases under the same circumstances. This could be potentially explained by the fact that EE banking markets have been under greater competitive pressure due to the entry of foreign-owned ME banking groups.

In order to elaborate on the results reported above, marginal effects at means were calculated for the ME and EE sub-samples. The results are presented in Appendix A (Figure A.1). The findings support the view that in ME sub-sample there is, similarly to the EU sample, a tendency towards a U-shape association between competition and stability. At higher competition levels, the risks are higher, as also reported in Table A.1. However, the results for the low competition levels support the

[18] Appendix as supplementary material is available at (http://www.aimspress.com/article/10.3934/QFE.2019.2.257/supplementry.html)

[19] The coefficient of $Boone^2$ in ME sub-sample has a p-value of 0.11 and in EE sample 0.13.

competition-fragility view. The latter result is opposite to what was shown in Table A.1. One possible explanation is that the few observations for extremely low competition levels in EE sub-sample make the results of the regression model less robust.[20] This is also reflected in very wide confidence intervals for high Boone indicator values in Figure A.1.

The results presented in Appendix A show that regulators may have to approach the regulation of competition from different perspectives even within the EU. Based on the Boone indicator and financial development levels in mature economies (ME), the attention should be more on managing the medium level of competition which could harm financial stability. In emerging Europe (EE), the attention should be on policies that do not foster competition among banks in order to improve financial stability. Further robustness tests were conducted with the baseline regression models. The results of these are presented in the following sub-section.

4.2. Robustness tests

Table 4 presents the results from the estimation of regression models M5 and M6, corresponding to Equation (8) and (9). The dependent variable in these models remains ln*Z1*. However, additional control variables are added. This leads to a decrease in the p-value of the Hansen statistic.

Although the size of the competition indicator coefficients in model M5 somewhat changes compared to those reported in Table 2 model M2, the statistical significance of *Boone* and *HHI* coefficients remains. In model M5 the unsquared Lerner index becomes statistically significant and positive (was insignificant in other specifications). Therefore, in this specification Lerner index exhibits signs of non-linearity which is opposite to that of the Boone indicator and HHI—signs of inverse U-shape association between bank stability and competition.

Compared to the results reported in Table 2 for model M2, the addition of controls does not significantly affect the coefficients of the lagged dependent variable and GDP growth. The inclusion of additional controls (see model M5) reduces the significance of the cost-to-income ratio. At the same time activity restrictions (*Cactr*) have a significant positive association with bank stability. This result remains in line with expectations. However, it remains opposite to what Samantas (2013) reported for the period of 2000–2010 for 27 European countries and what Agoraki et al. (2011) reported over a period of 1998–2005 for 13 Central and Eastern European countries. The stringency of capital requirements (*Ccapr*) is significant only in models using the Boone indicator. Its sign is in line with expectations and results reported for the same indicator in Samantas (2013) and Houston et al. (2010). These results indicate that more stringent regulations may increase bank stability.

[20] The distinction of high, medium and low competition levels in Appendix A relies on the assumption that Boone indicators within the (sub-)sample are normally distributed. Marginal effects graphed in Appendix A (Figure A.1) assume the presence of all possible values of Boone indicators between their sample maximum and minimum.

Table 4. Results of the baseline models with additional control variables.

Sample	EU		EU		EU		EU		EU		EU	
Dependent variable	ln*Z1*		ln*Z1*		ln*Z1*		ln*Z1*		ln*Z1*		ln*Z1*	
Competition indicator *Comp*	*Boone*		*Lerner*		*HHI*		*Boone*		*Lerner*		*HHI*	
Model	M5		M5		M5		M6		M6		M6	
	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.
$lnZ1_{t-1}$	0.546	***	0.571	***	0.545	***	0.531	***	0.548	***	0.552	***
	(0.029)		(0.026)		(0.026)		(0.026)		(0.025)		(0.025)	
GDP	0.060	***	0.074	***	0.044	***	0.059	***	0.074	***	0.069	***
	(0.017)		(0.017)		(0.014)		(0.016)		(0.016)		(0.017)	
Cactr	0.068	***	0.057	***	0.073	***						
	(0.024)		(0.022)		(0.021)							
Ccapr	0.038	*	0.032		0.006							
	(0.020)		(0.021)		(0.019)							
Comp	−0.907	***	4.419	**	−8.897	***	−0.571	**	−1.048		−2.396	
	(0.227)		(1.943)		(2.461)		(0.246)		(1.654)		(3.041)	
$Comp^2$	2.730	**	−5.136	***	29.710	***	2.266	**	−0.687		8.892	
	(1.092)		(1.967)		(7.517)		(1.110)		(1.622)		(9.153)	
ln*TA*	0.013		0.088		−0.117		−1.253		−1.267	*	−1.436	*
	(0.080)		(0.079)		(0.078)		(0.774)		(0.729)		(0.808)	
$\ln TA^2$							0.041		0.043	*	0.049	*
							(0.026)		(0.024)		(0.027)	
CI	−0.006	***	−0.006	***	−0.002		−0.007	***	−0.006	***	−0.007	*
	(0.002)		(0.002)		(0.003)		(0.002)		(0.002)		(0.003)	
DIV	0.074		−0.027		0.266		0.096		−0.220		−0.556	
	(0.187)		(0.213)		(0.297)		(0.179)		(0.195)		(0.458)	
d_for							−0.272		−0.043		−0.454	**
							(0.204)		(0.155)		(0.216)	
d_gov							0.636		0.939		0.390	
							(0.666)		(0.612)		(0.558)	
Constant	0.811		−0.936		3.126	***	11.270	*	11.930	**	12.840	**
	(1.260)		(1.384)		(1.169)		(5.762)		(5.469)		(6.120)	
Obs.	5,437		5,598		5,598		5,756		5,917		5,917	
No. of banks	1,032		1,055		1,055		1,088		1,111		1,111	
Hansen p	0.055		0.175		0.127		0.120		0.063		0.335	
F statistic	32.53	***	43.62	***	40.75	***	34.93	***	44.63	***	39.55	***

Notes: This table reports system GMM estimates of Equation (8) in panels marked with M5 and estimates of Equation (9) in panels marked with M6. For abbreviations of variables see Table 1. Robust standard errors in parentheses. Sign. refers to statistical significance *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 5. Results of the baseline models with alternative bank stability measures.

Sample	EU		EU		EU		EU		EU		EU	
Dependent variable	ln*Z2*		ln*Z2*		ln*Z2*		ln*LLR*		ln*LLR*		ln*LLR*	
Model	M2		M2		M2		M2		M2		M2	
Competition indicator *Comp*	*Boone*		*Lerner*		*HHI*		*Boone*		*Lerner*		*HHI*	
	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.
Dependent variable $_{t-1}$	0.591	***	0.602	***	0.599	***	0.856	***	0.861	***	0.891	***
	(0.030)		(0.027)		(0.028)		(0.040)		(0.037)		(0.038)	
GDP	0.079	***	0.086	***	0.078	***	−0.054	***	−0.054	***	−0.049	***
	(0.016)		(0.016)		(0.017)		(0.008)		(0.008)		(0.009)	
Comp	−0.497	**	0.525		−4.569	**	−0.029		−0.267		7.038	***
	(0.217)		(2.003)		(2.288)		(0.146)		(0.877)		(1.876)	
$Comp^2$	1.282		−2.407		12.240	*	−0.151		0.813		−15.170	***
	(0.995)		(2.021)		(7.183)		(0.613)		(1.026)		(4.954)	
ln*TA*	0.038		0.081		0.025		−0.070		−0.135	**	−0.043	
	(0.091)		(0.085)		(0.073)		(0.073)		(0.058)		(0.049)	
CI	−0.006	***	−0.005	***	−0.004		−0.002		−0.001		−0.001	
	(0.002)		(0.002)		(0.003)		(0.001)		(0.001)		(0.001)	
DIV	0.175		0.171		−0.011		0.042		−0.098		−0.122	
	(0.188)		(0.208)		(0.480)		(0.155)		(0.176)		(0.303)	
Constant	1.068		0.692		1.390		1.505		2.369	***	0.661	
	(1.409)		(1.591)		(1.150)		(1.126)		(0.905)		(0.793)	
Obs.	5,794		5,977		5,977		4,666		4,719		4,719	
No. of banks	1,089		1,113		1,113		824		828		828	
Hansen p	0.056		0.620		0.041		0.109		0.236		0.038	
F statistic	55.85	***	72.21	***	59.48	***	134.3	***	167.5	***	184.4	***

Notes: This table reports system GMM estimates of Equation (5) in panels marked with M2. For abbreviations of variables see Table 1. Robust standard errors in parentheses. Sign. refers to statistical significance *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

When ownership indicators are included in the baseline model (see Model M6), the Boone indicator maintains its statistical significance. However, the significance of the Lerner index disappears completely. This is further proof that the nonlinearity in the context of the Lerner index is not very robust. There also appears a significant negative coefficient for foreign ownership when *HHI* is considered. As the baseline indicator is domestic private ownership, it refers that foreign ownership tends to decrease bank stability. Previous European studies have not investigated that aspect.[21] However, in global and Latin American samples similar results have been reported (e.g., De Nicolò and Loukoianova, 2007; Yeyati and Micco, 2007; Berger et al., 2009; Tabak et al., 2012).

[21] The exception is Rumler and Waschiczek (2016) which focused on Austrian banks and failed to find a significant association between foreign ownership and z-score. Still, several papers focusing on other aspects of bank risk have shown the importance of ownership as a factor driving the credit risk of banks (see Samantas, 2013; Laidroo, 2016).

Table 5 presents the results from the estimation of the regression model M2, corresponding to Equation (5). The dependent variables in these models are replaced with ln*Z2* and ln*LLR*. The former is a z-score indicator based on ROE and the latter is a credit risk indicator. The over-identification tests give somewhat poorer results than for the previous estimations. The estimations with ln*Z2* give results rather similar to those for ln*Z1* presented in Table 2. The statistical significance of competition indicator coefficients somewhat decreases, the most for the Lerner index. When risk is measured solely on the basis of credit risk ($lnLLR$), the coefficients of all explanatory variables should reverse compared to what is observed for the z-score. The coefficient of GDP growth turns statistically significant and negative in all specifications with $lnLLR$. Still, the only competition indicator which remains statistically significant is *HHI*.

Overall, the robustness tests reveal that after adding additional control variables the significant results for competition indicators remain in line with those reported in 4.1. It implies that the regulatory responses should rely on the points raised earlier.

The distribution of countries into subsamples based on their financial market development is rather arbitrary. Previous studies have also shown that banks from different European countries exhibit very different risk levels (e.g., Laidroo and Männasoo, 2017). Therefore, as a further robustness test, country groups were formed based on the stability of their banking systems (measured by a z-score). Marginal effects calculated for the banking sector stability sub-samples are presented in Appendix B Figure B.1. In high stability countries, the association exhibits a positive association between bank stability and competition. In low stability countries, the association refers to a very flat inverse-U and in medium risk countries more of a J-shape association. Considering that country banking sector stability should be rather strongly correlated with bank-level stability, the three figures should represent the situation where we would slice Figure 1 ln*Z1* axis into three parts. This is indeed the case—high stability sub-sample re-enforces the left-hand-side of the U-shape in medium stability sub-sample and low stability sub-sample lowers the right-hand side of the U-shape in the medium stability sub-sample. It does indicate that the nonlinearities observed in the EU sample tend to arise from the diversity in country risk levels within the region, especially from medium risk countries. As shown in Appendix A (Figure A.1), these are also more strongly driven by the EE sub-sample. This means that if the differences in bank risk levels within the sample are smaller (as in the case of low and high stability countries), the association between competition and bank stability may appear more linear or even non-existent (almost parallel to the x-axis). This explains why regressions run on different samples may provide very different results. For policymakers, it stresses the importance of basing their recommendations concerning "desirable" competition levels on a reasonably diverse sample of countries or, in case of bank-level Lerner index, on a diverse sample of banks.

Still, it should be borne in mind that the results and conclusions of this paper remain vulnerable to several limitations. First, the system GMM setup limits the possibility of using many control variables simultaneously. The robustness test showed that the inclusion of additional variables increased over identification concerns. Second, the results do exhibit some minor differences depending on which competition and risk indicators are used. This indicates that the selection of competition indicators and their identification methods may affect the conclusions drawn. Third, in order to calculate Boone indicators, many bank-year observations had to be dropped due to the unavailability of suitable proxies. This may affect the accuracy of country-level Boone indicators. Fourth, the results reported for sub-samples remain less robust due to data issues and limitations of the used estimation method.

5. Conclusion

The objective of this paper was to investigate the association between bank stability and competition within Europe by employing a Boone indicator and alternative competition measures. The results show that when a linear association between bank stability and competition is assumed, competition-stability argument prevails. This result remains robust across different competition proxies (Boone indicator, Lerner index, HHI), and is in line with the findings of most previous studies focusing on Europe. It refers that if regulators would take steps to increase the competition among banks, it would potentially enable to improve financial stability.

When the potential non-linearity between banking market competition and bank stability is considered, empirical support for it is observed for the Boone indicator, HHI and to a lesser extent for Lerner index. We observe signs of U-shape association between banks stability and competition for the Boone indicator and weaker signs of an inverse U-shape association with Lerner index. This indicates that before taking policy measures, it is important to define which aspect of competition regulators want to address. In the case of preferring Boone type of competition measures, it implies that medium-level competition may be less desirable than the very low or high competition. When considering the actual distribution of competition indicators, increasing competition (measured by Boone indicator) for most EU banks would tend to increase the fragility of the financial system. If the focus is on pricing power (measured by Lerner index), the advice would be just the opposite.

The results also show that regulators may have to approach the regulation of competition from a different perspective even within the EU. Based on the Boone indicator and financial development levels in mature economies (ME), the attention should be more on managing the medium level of competition which could harm financial stability. In emerging Europe (EE), the attention should be more on decreasing competition in order to improve financial stability. The robustness test with sub-samples formed based on banking system stability illustrates further that the sample composition may have a strong impact on the observed associations between bank stability and competition. This can explain some of the controversies reported in previous empirical papers. The latter in turn stresses the importance of understanding sample characteristics as well as competition measurement approach before providing policy suggestions.

Overall, we observe that the association between bank stability and competition remains a complex issue which needs to consider the potential non-linearity. It is not possible to develop one-size-fits-all policy suggestions. The identification of suitable regulatory approaches relies on the proper definition of the type of competition being targeted as well as on a sufficiently diverse sample of banks. In the context of EU there exist clear signs that mature economies and emerging Europe may require different policy responses.

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Conflict of interest

The authors declare no conflict of interest.

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