# The Bank Capitalization and the Nonlinear Concentration-Stability Nexus in the Euro Area: The PSTR Approach[1]

*Adriana NOVOTNA – Lubica STIBLAROVA – Kristina KOCISOVA**

**Abstract**

*This study explores the presence of a nonlinear relationship between concentration, indicated by market share, and banking stability, represented by the Z-score, in relation to different levels of bank capitalization, assessed by the capital adequacy ratio in accordance with Basel standards, in the Euro Area countries from 2009 to 2019. By employing the panel smoothing transition regression model, we do not find the statistical significance of the coefficients when bank capitalization is low. However, the concentration-stability paradigm is confirmed when capitalization exceeds the current minimum regulatory requirements. These findings suggest that strengthening bank capitalization is crucial for enhancing stability in the Euro Area banking sector, as higher capitalization enables banks to better withstand negative economic shocks during adverse conditions.*

**Keywords:** *bank capitalization, stability, concentration, panel smoothing transition regression model, Euro Area*

**JEL Classification:** G21, G28, C33

**DOI:** https://doi.org/10.31577/ekoncas.2024.05-06.02

**Article History:** *Received*: December 2022 *Accepted*: October 2024

## Introduction

Does a higher concentration in the Euro Area (EA) banking market promote bank stability or contribute to fragility? This question has become increasingly relevant since the introduction of the Euro. Existing studies on the concentration-

* Adriana NOVOTNA, corresponding author – Lubica STIBLAROVA – Kristina KOCISOVA, Technical University of Kosice, Faculty of Economics, Němcovej 32, 040 01 Košice, Slovak Republic; e-mail: adriana.novotna@tuke.sk, ORCID: 0000-0002-1132-6060; lubica.stiblarova@tuke.sk, ORCID: 0000-0002-6453-6758; kristina.kocisova@tuke.sk, ORCID: 0000-0003-0784-441X

[1] This work was supported by the Scientific Grant Agency VEGA under Grant No. 1/0444/23 and No. 1/0154/24.

stability nexus focus on examining the linear relationship, exploring how banks' risk-taking behavior influences their stability and, thus, the stability of the whole banking sector (e.g., Uhde and Heimeshoff, 2009; Degl'Innocenti et al., 2020; Ijaz et al., 2020; Moudud-Ul-Huq, 2020). Higher concentration in the banking sector can lead to either increased stability (through stronger, more resilient banks) or decreased stability (through systemic risk if large banks fail).

However, despite existing evidence, the divergent results have left it unanswered. The inconclusive evidence can suggest that the concentration-stability pattern is not the same over the whole sample and could change under specific conditions. Such issue is particularly significant considering substantial shifts in the EA bank concentration (Maudos and Vives, 2019). The EA is characterized by a moderately concentrated market structure (Figueiras et al., 2021), consisting of a small number of large banks (each with assets exceeding EUR 30 billion) and a wide network of smaller institutions (with total assets below EUR 5 billion). Data from Statistical Data Warehouse indicate that the level of concentration in the EA has increased over time. Specifically, the average Herfindahl-Hirschman index increased from 0.1229 in 2009 to 0.1446 in 2021, driven by a reduction in the number of small credit institutions, which declined from 2280 in 2009 to 1135 in 2021[2] (ECB, 2021a).

Moreover, significant differences exist in concentration and stability across different EA countries. For instance, some countries exhibit low level of concentration, as measured by the share of total bank assets held by the three leading banks (e.g. Austria, Germany, France) or stability, as indicated by the Z-score (e.g. Slovenia, Lithuania, Latvia), while others are more concentrated (e.g. Cyprus, Estonia, Greece) or stable (e.g. Luxembourg, Germany, Austria) banking system (Statista, 2021). While the countries with the most turbulent concentration development experienced the lowest stability in the last few years, the ones with the lowest concentration levels can be considered the most stable.

Bank stability in the EA has also undergone significant changes, as reflected in the Z-score indicator (World Bank, 2021; Statista, 2021). This issue is of particular interest to several central banks, including the European Central Bank (ECB), which are focused on ensuring financial stability. The financial crisis in 2008 – 2009 highlighted that banks that were not sufficiently endowed with equity were unable to withstand external shocks, which led to their failure. Due to the high interconnectedness of banks in the European market, these local failures were transmitted as a financial contagion to other countries, leading to a weakening of financial stability and changes in the structure of the banking market in several countries.

[2] Currently, more than 70% of assets are held by large institutions, while small banks hold only 2% of total assets within the EA banking sector.

As a result, individual regulators have started to introduce stricter regulatory measures in a number of areas, including capital adequacy. In 2010, the Basel Committee on Banking Supervision introduced the third Basel Accord, known as Basel III, aiming to enhance the resilience of the banking sector across the European Union within a three-pillar framework. This accord introduced stricter capital requirements and new regulatory measures, mandating higher levels of bank capitalization.

Given the heightened regulatory requirements, changes in market structure, and evolving risk profiles of banks, it is therefore necessary to re-evaluate the concentration-stability relationship in the context of current capital adequacy standards. Understanding how these changes affect the banking market and whether increased concentration leads to more robust or more fragile institutions is crucial for regulators. This analysis could be critical for policymakers and market participants to maintain a robust and resilient banking system in the face of future economic challenges.

To the best of our knowledge, this study presents the first attempt to analyze the nonlinear concentration-stability nexus in the EA, considering bank capitalization. We, therefore, contribute to the existing empirical literature by nesting two empirical strands – the one focused on the concentration-stability and concentration-fragility paradigms and the second one dedicated to the role of bank capital in the financial system, which has not been done in the previous works. Moreover, we provide evidence on the effects of bank capitalization on the concentration-stability relationship in the EA countries, which can have policy implications regarding future regulations regarding the increasing capital requirements – Basel 3.1 or Basel IV. We also fill the gap in the nonlinear concentration-stability literature by employing the panel smoothing transition regression model for the EA banking system, which, so far, has not been frequently applied.

The rest of this paper is organized as follows. In the next section, we provide a literature review explaining two theoretical concepts and the importance of bank capitalization. Next, we explain our panel smoothing transition regression model specification with the bank capitalization used as the transition variable in the EA countries from 2009 to 2019. We also describe the data. In the third section, we provide empirical results regarding the nonlinear concentration-stability relationship in the analyzed banking sector. The last section summarizes our findings, with policy recommendations and ideas for future research.

## 1. Literature Review

Theoretical concepts that explain the relationship between bank concentration and stability reveal two competing hypotheses – *the concentration-stability/competition-fragility* paradigm and *the concentration-fragility/competition-stability* paradigm. When discussing the theoretical concepts of the concentration-stability/competition-fragility and concentration-fragility/competition-stability paradigms, it is crucial to incorporate economic reasoning to clarify why these paradigms might exist. This reasoning helps to provide a more intuitive understanding of the forces at play beyond merely citing empirical evidence.

The existing literature considers the concentration-stability paradigm as a traditional approach (Berger et al., 2009), which refers to a situation in which a more concentrated banking sector leads to greater stability. In a concentrated banking sector, large banks often enjoy significant market power, allowing them to maintain higher profit margins (Tran et al., 2022). These higher profits function as a buffer against economic shocks, reducing the likelihood of bank failures. With greater profits, banks can build up capital reserves, enhancing their ability to absorb losses during downturns. Large, well-capitalized banks in a concentrated market can then exploit economies of scale, reducing their average costs and increasing operational efficiency. This not only enhances profitability but also allows these banks to better withstand economic shocks, further contributing to systemic stability. Regulatory authorities may find it easier to supervise and manage a smaller number of large banks compared to a fragmented market with numerous smaller institutions (Beck, 2008). Effective supervision can ensure that these banks maintain adequate capital levels and adhere to sound risk management practices, reducing the chances of systemic crises.

Initial research about the traditional concentration-stability/competition-fragility paradigm has been introduced by Keeley (1990), who finds that increasing competition led to a reduction in the franchise value of banks in the U.S. in the 1980s and increased risk-taking incentives of banks contributed to greater bank instability. Since that time, multiple authors have supported this view. For example, Agoraki et al. (2011) suggest that banks with higher market power (i.e., bank concentration) tend to take on lower credit risk and have a lower probability of default. Similarly, Moudud-Ul-Huq (2020), using a comprehensive dataset of BRICS countries, concludes that a higher market power leads to the bank's profitability and financial stability.

On the other hand, the concentration-fragility paradigm argues that a more competitive banking environment, characterized by less concentration, promotes financial stability. In a competitive market with many small and medium-sized banks, the risk of failure is more evenly distributed across institutions (Martinez-Miera and Repullo, 2010). The failure of one or a few banks is less likely to trigger a systemic crisis (Boyd and De Nicolo, 2005), as the impact is more localized and contained. This diversification of risk contributes to overall financial stability (Wagner, 2010). In a competitive market, banks must operate efficiently and manage risks carefully to survive. They cannot rely on market power to generate profits and must instead focus on sound lending practices, risk assessment, customer service to maintain profitability, and investments in innovations as banks strive to differentiate themselves from competitors. This competitive pressure leads to the development of new financial products and more efficient operations, encourages prudent behavior, and reduces the likelihood of risky activities that could destabilize the system, contributing to a more resilient banking system (Acharya and Yorulmazer, 2008).

The concentration-fragility/competition-stability view was first presented by Mishkin (1999), who argues that besides some benefits, financial consolidation leads larger institutions to risky activities. Maudos and Vives (2019) argue that there is a delicate balancing act between the preservation of financial stability and the maintenance of a competitive market structure. At the same time, Leroy and Lucotte (2017) claim the complete opposite: an increase in market power is associated with a greater systemic risk.

The results of the empirical studies support both hypotheses and produce mixed results. The rationale behind such contradictory findings could be attributed to study methodologies. The majority of the previous empirical studies investigating the relationship between bank stability and concentration have mostly relied on the linear regression models, which were used to verify the concentration-stability/fragility hypothesis, i.e., positive or negative linear relationship between concentration and stability (see e.g. Uhde and Heimeshoff, 2009; Ijaz et al., 2020; Degl'Innocenti et al., 2020), or find the potential U-shape curved link between these indicators through the inclusion of the quadratic term (see e.g. Cuestas et al., 2019; Albaity et al., 2019). Here, based on the methodology of Berger et al. (2009) and Martinez-Miera and Repullo (2010), the goal is to identify a turning point that represents an optimal threshold of the bank concentration, ensuring bank stability.

However, Haans et al. (2016) express some caution about assessing the presence of the U-shaped curve because of the absence of adequate formal procedures, including significant quadratic term, sufficiently steep slope at both ends of the data range, and the turning point located within the data range. Moreover, even though the authors refer to this approach as the one enabling them to reveal the nonlinear concentration-stability relationship, the regression coefficients in these models are assumed to be constant, i.e., the models are linear in the unknown parameters, and one cannot detect the nonlinear relationship between variables from such models, ignoring which could lead to biased, and contradictory estimates.[3]

[3] By definition, a general linear model is a model that is linear in the unknown parameters. This holds for the polynomial model, such as the quadratic regression model $y = a + bx + cx^2$ which is quadratic as a function of $x$, but linear in the coefficients $a$, $b$, and $c$.

The recent studies, however, emphasize the existence of the nonlinear relationship between concentration and bank stability (see, e.g., Carbó-Valverde et al., 2013; Djebali and Zaghdoudi, 2020; Calice et al., 2021). To analyze and answer what this nonlinear relationship is determined by, several econometric approaches have been used – from the simple ones in the form of investigating the effect of mediator variables at different levels of concentration (Calice et al., 2021) to more complex panel threshold models (Carbó-Valverde et al., 2013), and panel smoothing transition regression models (Djebali and Zaghdoudi, 2020).

Carbó-Valverde et al. (2013) apply a panel threshold regression model by Hansen (1999) to analyze the competition-stability nexus in 23 OECD countries from 1996 to 2010, while specific structural characteristics of the banking market are used to explain this nonlinear relationship. On the other hand, Wu et al. (2018) argue that such a two-regime switching process cannot satisfy the smooth regime-switching of the observations, especially for low-frequency data. To avoid these shortcomings, one can apply a panel smoothing transition regression developed by Gonzalez et al. (2017) as in Djebali and Zaghdoudi (2020). The authors examine the effects of liquidity, using the ratio of liquid assets to total assets, and credit risk measured by the ratio of non-performing loans to total loans and bank stability, measured by Z-score based on ROE. They show that the relationships are non-linear and characterized by the presence of threshold effects in the MENA region.

However, market structure is not the only factor that determines the stability of the banking sector. In the existing literature, numerous studies identify additional contributing factors, such as bank size, profitability, but also the macroeconomic variables like economic growth, inflation, or political stability (see, e.g., Abdesslem et al., 2023; Agoraki et al., 2011; Cuestas et al., 2019; Djebali and Zaghdoudi, 2020; Saif-Alyousfi et al., 2018).

Among these factors, capitalization, as measured by the capital adequacy ratio or the equity-to-assets ratio, frequently emerges as one of the most critical determinants of banking stability (e.g. Hakenes and Schnabel, 2011; Tabak et al., 2012; Rubio and Yao, 2020; Calice et al., 2021; Santoso et al., 2021). For instance, Rubio and Yao (2020) find that a better-capitalized banking system is expected to bring long-term benefits in terms of financial stability. The recent emphasis on capitalization as a critical factor in the development of the banking sector is essential for economic protection, particularly in the aftermath of the Great Recession (see, e.g., Soederhuizen et al., 2023).

As mentioned in the Introduction, the Euro Area banking sector has undergone significant changes following the financial crisis in 2008. A key change was the implementation of higher capital requirements (Basel I reform in 1998, Basel II in

2006, and Basel III in 2010), which were expected to yield long-term benefits for financial stability. The Basel III affected credit institutions by creating higher capital reserves and increasing the quality of capital held by the banks. For this reason, we can observe an increasing trend in bank capitalization from 2009 to 2019 in several Euro Area countries (Figure A1 in the Appendix).

A closer look at data published by ECB (2021b) can reveal that credit institutions increased their Tier 1 ratio, from 10.37% in 2009 to 16.79% in 2021. This presents the core capital the bank holds in its reserves and exists as the primary source of funds, especially when a bank wants to continue providing for its customers' business needs in crisis times.

At the same time, the related strand of literature considers bank capital as an essential instrument to absorb financial shocks and reduce the probability of banking crises to preserve stability in a financial system (Budnik et al., 2019). However, the nonlinear concentration-stability relationship has not been examined. Higher capital is expected to have a positive effect on bank stability (Abuzayed et al., 2018) by mitigating the risk-taking behavior of banks (Saif-Alyousfia et al., 2018) and increasing the level of efficiency and profitability in a banking system (Moudud-Ul-Huq, 2020).

On the other hand, stricter capital requirements may also translate into an increase in the bank's probability of default through its effect on competition between banks (Hakenes and Schnabel, 2011), an increase in the cost of capital (Bitar et al., 2018), or decline of bank performance (Santoso et al., 2021).

Berger et al. (2009) state that bank capitalization levels in twenty-three developed nations tend to be higher for banks with increased market power, arguing that such banks can cover increases in banks' non-performing loans. In the Euro Area countries, capitalization proxied by equity to total assets can be associated with more prudent bank behavior (Delis and Kouretas, 2011) or higher margins due to higher loan rates (Budnik et al., 2019).

Therefore, this study aims to fill this gap by analyzing the nonlinear concentration-stability nexus in the Euro Area, with a particular focus on bank capitalization as a transition variable. We analyze 172 credit institutions in the Euro Area countries during 2009 – 2019.

By employing advanced econometric technique like the panel smoothing transition regression model, this research will provide a more nuanced understanding of how relationship between bank concentration and stability changes regarding bank capitalization. This will offer valuable insights for policymakers, particularly in the context of ongoing regulatory changes under Basel III and future developments like Basel IV.

## 2. Methodology and Data

### 2.1. Modelling Strategy: Panel Smoothing Transition Regression (PSTR) Approach

As the empirical evidence provides arguments for the existence of the nonlinearity among the bank stability and concentration, ignoring this can lead to biased estimates. To avoid these shortcomings, this paper employs the panel smoothing transition regression (PSTR) model introduced by Gonzalez et al. (2017), which is the extension of the panel threshold regression (PTR) model formulated by Hansen (1999).

While Hansen's PTR model divides the panel data observations into a specific number of homogenous groups (regimes) with different regression coefficients based on the threshold of the chosen transition variable (i.e., threshold parameter), the switching between its regimes is sharp, and it may not be feasible in practice. We, therefore, prefer the newer PSTR model of Gonzalez et al. (2017), where the regression coefficients are continuous functions of the transition variable through its bounded transition function. Because of the individual-specific and time-varying transition variable, the regression coefficients may change over time and across the infinity of regimes, which are between a limited number of „*extreme regimes*“ (Gonzalez et al., 2017). Moreover, it has been shown that the PSTR approach reduces the potential endogeneity bias (Gharbi and Othmani, 2022), which could appear due to reverse causality between bank stability and concentration (see, e.g., Albaity et al., 2019). We can abstract from this problem because of the time variability of the PSTR coefficients, i.e., there exists a certain value of the estimated regression parameter for each level of the threshold variable, which limits this bias.

The generalized form of the PSTR model can be defined for $i = 1, \ldots, N$ individual units and $t = 1, \ldots, T$ time periods, as follows:

$$y_{it} = \mu_i + \beta_0^{'} x_{it} + \sum_{j=1}^{r} \beta_1^{'} x_{it} g_i \left( q_{it}^{(j)}, \gamma_j, c_j \right) + \varepsilon_{it} \tag{1}$$

where $y_{it}$ denotes the dependent variable (scalar), $\mu_{it}$ denotes the fixed individual effects, $x_{it}$ denotes the $k$-dimensional vector of time-varying regressors, and $\varepsilon_{it}$ is the error term. The nonlinearity of the model is presented by the $r$ transition functions $g_i\left(q_{it}^{(j)}, \gamma_j, c_j\right)$, $j = 1, \ldots r$ of the observable transition (threshold) variable $q_{it}^{(j)}$, depending on the slope parameter $\gamma_j$, and location parameter $c_j$.

Since the link between stability and concentration is unlikely to be linear and we expect that this relationship may change with the level of the bank capitalization, i.e., there might be a certain threshold level of bank capitalization ($CAR_{it}$), above which their relationship may change, presents the transition variable in our model specification. We estimate the PSTR model in the following form:

$$Stability_{it} = \mu_i + \beta_0^1 Concentration_{it} + \beta_0^2 SIZE_{it} + \beta_0^3 DIR_{it} + \beta_0^4 TLTA_{it} + \beta_0^5 GDP_{it} + \sum_{j=1}^{r} \begin{bmatrix} \beta_1^1 Concentration_{it} + \beta_1^2 SIZE_{it} + \\ +\beta_1^3 DIR_{it} + \beta_1^4 TLTA_{it} + \beta_1^5 GDP_{it} \end{bmatrix} g_i\left(CAR_{it}^{(j)}, \gamma_j, c_j\right) + \varepsilon_{it} \quad (2)$$

for $i$ = 1, ..., $N$ banks in the Euro Area and $t$ = 1, ..., $T$ years. The dependent variable ($Stability_{it}$) presents the bank stability measured as a Z-score based on return on assets and return on equity (see 2.2 Variables definition). The explanatory variable of our interest ($Concentration_{it}$) denotes bank concentration in the form of market share.[4] To avoid omitted variables bias, we consider a set of variables, namely bank size ($SIZE_{it}$), long-term interest rates ($DIR_{it}$), the share of total loans on total assets ($TLTA_{it}$), and economic growth ($GDP_{it}$). Similar to Eq. (1), $\mu_{it}$ stands for the fixed individual effects, and $\varepsilon_{it}$ presents the error term.

The transition function $g_i\left(CAR_{it}^{(j)}, \gamma_j, c_j\right)$ is continuous, normalized to [0,1], while these boundaries are related to the regression coefficients $\beta_0$ and $\beta_0 + \beta_1$. To operationalize this transition function, a logistic specification is used as proposed by Granger and Terasvirta (1993), Terasvirta (1994), Jansen and Terasvirta (1996), and Gonzalez et al. (2017):

$$g_i\left(CAR_{it}^{(j)}; \gamma_j, c_j\right) = \left(1 + exp\left(-\gamma_j \prod_{j=1}^{m}\left(CAR_{it}^{(j)} - c_j\right)\right)\right)^{-1}, \gamma_j > 0; c_1 \le c_2 \le \ldots \le c_m \quad (3)$$

where $c = \left(c_1,\ c_2,\ \ldots,\ c_m\right)'$ presents the $m$-dimensional vector of location parameters. For common practice, it is recommended to consider one or two switches ($m$ = 1 or $m$ = 2) in the transition function, which usually covers commonly occurring parameter variations (Gonzalez et al., 2017). The slope parameter $\gamma_j$ controls the smoothness (speed) of the transition from one regime to another. When $m = 1$ and $\gamma \to \infty$, the transition function (Eq. 3) turns into an indicator function, and the model (Eq. 1) becomes a PTR model with $r+1$ regimes. When $m > 1$ and

[4] We follow existing empirical research on the concentration-stability paradigm where the stability indicator is often used as a dependent variable while the concentration indicator presents the independent variable.

$\gamma \to \infty$ , the transition function switches between 0 and 1 at $c_1, c_2, \ldots, c_m$ , and the model (Eq. 1) retains two distinct regimes. Finally, for any value of m and $\gamma \to 0$ , the transition function (Eq. 3) becomes constant, and the model (Eq. 1) shrinks into a linear panel regression model with fixed effects (for more, see Gonzalez et al., 2017).

Our modelling strategy starts with testing the homogeneity, i.e., testing the linearity against the PSTR model.[5] This test is used to determine the suitable form of the transition function, and if the nonlinearity is confirmed, it is used to choose the appropriate order *m* of the transition function (Eq. 3). In the estimation stage, the individual effects $\mu_i$ are firstly eliminated by subtracting the individual-specific means. The parameters of the model are then estimated using the nonlinear least squares (NLS) method.[6] Finally, we evaluate the model by testing parameter constancy and no remaining nonlinearity (heterogeneity) in the PSTR model.[7]

### 2.2. Variables Definition

We measure bank stability (our dependent variable) using the Z-score, initially introduced by Boyd and Graham (1988). This indicator has been created to specify the distance to insolvency and reflect the probability of bank failure. Higher values of the Z-score indicates more bank stability as the distance from bank failure increases. It can be calculated as *ZROE* (see e.g., Phan et al., 2019; Djebali and Zaghdoudi, 2020) or *ZROA* (see, e.g., Leroy and Lucotte, 2017; Albaity et al., 2019). The *ZROE* is calculated as follows:

$$ZROE_{it} = \frac{ROE_{it} + \left(E / TA\right)_{it}}{\sigma(ROE_{it})} \tag{4}$$

where $ROE_{it}$ and $\sigma(ROE_{it})$ stands for return on equity and its standard deviation, respectively, while $\left(E / TA\right)_{it}$ presents the share of bank equity divided by total assets. $ZROA_{it}$ is calculated for the bank *i* and year *t*.

[5] The PSTR modeling procedure assumes that all considered variables are stationary. The results of panel unit root testing are available in Table A1 in the Appendix. Overall, this assumption is met, however, since our analysis is based on the short time series, the results of the panel unit root testing should be taken with caution.

[6] In the PSTR estimation, special attention should be placed on the selection of the starting values of parameters of the transition function – $\gamma$ and $c$. In this paper, we employ the grid search by creating a grid of values of $\gamma$ and $c$, such that $\gamma > 0$, and $c_{jmin} > min_{it}\{q_{it}\}$, $c_{jmax} < max_{it}\{q_{it}\}$, $j = 1, 2, \ldots m$. The optimal starting values of $\gamma$ and $c$ used in the nonlinear optimization algorithm are then those that minimize residuals sum of squares (RSS) in Eq. (1).

[7] All computations regarding PSTR estimation have been carried out in an R environment using the *PSTR* package (Yang, 2022).

$$ZROA_{it} = \frac{ROA_{it} + \left(E / TA\right)_{it}}{\sigma(ROA_{it})} \tag{5}$$

where $ROA_{it}$ and $\sigma\left(ROA_{it}\right)$ stand for return on assets ratio and its standard deviation. The variable is also calculated for the bank *i* and year *t*.

To ensure the robustness of our findings, we decided to use both indicators of stability as both metrics are important for different stakeholders in the financial sector, and they each serve a distinct purpose (Petria et al., 2015; Shair et al., 2019). The Z-score based on ROE is more relevant to shareholders and equity investors. It highlights how much of the bank's earnings are at risk in relation to the capital provided by shareholders. This indicator focuses on the stability relative to the bank's equity base. On the other hand, the Z-score based on ROA provides a broader perspective on the bank's efficiency in using its assets to generate income. It is more relevant for management when it comes to overall operational performance.

The concentration is measured as the market share – $MS_{it}$ (see, e.g., Cuestas et al., 2019; Degl'Innocenti et al., 2020) which presents the share of total assets of individual bank *i* in the year *t*, divided by consolidated total assets of the specified country for year *t* retrieved from Statistical Data Warehouse database of the European Central Bank. Here, higher values of the *MS* refer to a higher level of concentration of the specific institution. For the robustness check, we alter the concentration variable by the Lerner index ($LERNER_{it}$). The estimation of the proxy for bank concentration follows the standard methodology by Lerner (1934), which is presented in the Appendix.

Next, as the transition variable, we use bank capitalization ($CAR_{it}$), which represents the regulatory total capital ratio, computed as the sum of Tier 1 and Tier 2 capital divided by risk-weighted assets calculated according to the Basel Accord.

The several bank-specific variables ($SIZE_{it}$, $TLTA_{it}$) are included to control for bank assets composition, while the macroeconomic control variables ($GDPg_{it}$, $DIR_{it}$) are included to capture the position of the economy. We use the logarithm of total assets as a proxy of bank size ($SIZE_{it}$). The literature provides different effects of size on the banks' stability. Some authors conclude that larger banks are more stable and less risky (e.g., Saif-Alyousfia et al., 2018). In contrast, Daoud and Kammoun (2020) state that the relationship could be negative due to the difficulty of managing bigger banks, or Abdesslem et al. (2023) claim that larger banks have incentives to engage in more risky activities which decrease their stability, as they have an implicit guarantee from regulation authorities in case of failure (in line with the theory of „too big to fail"). Therefore, the effect of bank size on stability may vary, exhibiting either a positive or negative relationship depending on specific conditions.

A comparable situation could be seen in the case of the share of total loans to total assets ( $TLTA_{it}$ ). In the European banking market, providing loans is a traditional banking activity, and bank loans have the highest share on the total assets. This enables banks to earn a high income (mainly in the time of increasing interest rates) but exposes them to higher liquidity risk and the borrowers' moral hazard. This is in line with Sang (2021), who argue that a higher value of total loans to total assets leads to potential credit risk that involves an inability of borrowers to meet the terms of the loan agreement credit risk that potentially leads to higher default rates overall and bank fragility. On the other hand, Phan et al. (2019) find a positive link between loans to assets ratio and Z-score. A higher ratio may indicate a well-capitalized bank with strong earning potential, provided that the loan portfolio is managed prudently.

Economic growth ( $GDP_{it}$ ) also has the potential to further improve economic forecasts and provide a positive effect on bank stability (Kočišová, 2020). We suppose that demand and the supply of banking services are higher in times of economic growth. Also, the ability of the clients to pay their liabilities is better, which could have a positive effect on the creation of provision and, in this way, also a positive effect on the overall profit of commercial banks, which might be reflected in stability indicators.

$DIR_{it}$ represents long-term interest rates for convergence assessment purposes, reflecting if a country has a stable economic environment suitable for adopting the Euro. It also indicates that higher value induces a tighter monetary policy (Wang and Luo, 2022). We assume that an increase in *DIR* may indicate the implementation of more stringent monetary policies, which could potentially contribute to greater economic stability.

For the robustness check, we also alter control variables and additionally consider the bank's net interest income to operating revenue ( $NETIITI_{it}$ ), and inflation growth measured using HICP ( $HICPg_{it}$ ). While the banks with higher levels of non-traditional activities could possibly hamper the stability (see, e.g., Saif-Alyousfi et al., 2018), a similar scenario might occur with higher inflation due to increased market volatility that could lead to higher lending rates by banks resulting from a tightening monetary policy (see, e.g., Cuestas et al., 2019). Descriptive statistics for all considered variables are reported in Table 1.

To estimate the PSTR model, we use the BankFocus database consisting of various financial indicators of 182 significant and less significant credit institutions listed by the European Central Bank (ECB, 2019), supplemented with consolidated and macroeconomic variables from the secondary data sources – Eurostat and Statistical Data Warehouse.

T a b l e 1
**Descriptive Statistics**

| Variable | Obs. | Min. | Mean | Max. | S.D. |
|---|---|---|---|---|---|
| *ZROE* | 1892 | –33.349 | 0.360 | 5.488 | 1.106 |
| *ZROA* | 1892 | –7.486 | 7.146 | 31.194 | 3.878 |
| *MS* | 1892 | 0.013 | 8.365 | 138.873 | 12.798 |
| *LERNER* | 1869 | –4.000 | –0.029 | 0.632 | 0.385 |
| *CAR* | 1892 | 3.700 | 16.910 | 62.360 | 5.694 |
| *SIZE* | 1892 | 5.707 | 7.524 | 9.415 | 0.765 |
| *DIR* | 1870 | –0.250 | 2.486 | 22.500 | 2.422 |
| *TLTA* | 1892 | 2.640 | 59.250 | 96.850 | 17.796 |
| *GDPg* | 1892 | –14.600 | 1.241 | 22.300 | 2.867 |
| *HICPg* | 1892 | –2.600 | 1.392 | 5.400 | 1.116 |
| *NETIITI* | 1892 | 3.040 | 59.780 | 344.950 | 22.029 |

*Source:* Authors' calculations based on data from BankFocus, Eurostat, and Statistical Data Warehouse.

Our database covers all 20 Euro Area countries in the longest available period, 2009 – 2019, which resulted in 2288 observations. This approach allows us to capture variations across different countries, which might be masked if the data were aggregated at the EA level. The ECB (ECB, 2024) applies a similar approach, which analyses the financial health and stability of the significant banks in each country. We included all countries that were already members of the Euro Area prior to 2009, as well as those that adopted the Euro after 2009, such as Slovakia in 2009, Estonia in 2011, Latvia in 2014, and Lithuania in 2015. Although Croatia adopted the Euro in 2023, this falls outside the scope of our analyzed period; therefore, banks from Croatia were excluded from the study. As the PSTR model estimation requires balanced panel data, the final dataset had to be reduced to 1892 observations, so after meeting this condition, it contains 172 banks with balanced data in total.

## 3. Estimation Results and Discussion

The modelling procedure proposed by Gonzalez et al. (2017) begins with testing the linearity against the PSTR specification, i.e., investigating whether a nonlinear relationship exists between considered variables. For this purpose, we use LM tests with asymptotically $\chi^2$ and F distribution, alongside their heteroscedasticity and autocorrelation consistent versions. In our baseline model, we use a Z-score based on return on equity $\left(ZROE_{it}\right)$ as the dependent variable. The results are reported in Table 2.

According to the results, we find that the null hypothesis, which assumes linearity, can be rejected at a 1% significance level, suggesting that the PSTR methodology should be chosen. Therefore, the nonlinear concentration-stability nexus under different bank capitalizations has been confirmed in the Euro Area countries.

Table 2
**Linearity Tests for selecting Number of Switches (*m*)**

| **Dependent variable: ZROE** | | | | |
|---|---|---|---|---|
| **Threshold variable: CAR** | | | | |
| | $m = 1$ | | $m = 2$ | |
| | Statistic | p-value | Statistic | p-value |
| $LM_\chi$ | 194.000 | <0.001 | 170.400 | <0.001 |
| $LM_F$ | 35.070 | <0.001 | 30.700 | <0.001 |
| $HAC_\chi$ | 19.640 | 0.001 | 4.988 | 0.417 |
| $HAC_F$ | 3.550 | <0.001 | 0.899 | 0.481 |

*Note:* $LM_\chi$ stands for the linearity *LM* test with asymptotically $\chi^2$ distribution, and $LM_F$ stands for the linearity *LM* test with asymptotically *F* distribution. $HAC_\chi$ and $HAC_F$ represent their heteroscedasticity and autocorrelation consistent versions. The null hypothesis assumes linearity against the alternative of the PSTR model specification – $m = 1$ or $m = 2$, respectively.

*Source:* Authors' calculations based on data from ratios of the selected EA credit institutions from BankFocus, Eurostat, and Statistical Data Warehouse.

While selecting the number of switches ($m$) in the PSTR model, the results suggest the single transition function with one switch ($m = 1$). We also reject the null hypothesis at a 1% significance level while testing two switches ($m = 2$) with original $LM_\chi$ and $LM_F$ tests, although their heteroscedasticity and autocorrelation versions do not confirm this evidence. Since the results of these *HAC* test versions are preferable (Gonzalez et al., 2017), we continue by estimating the PSTR model with one switch ($m = 1$) and two extreme regimes.[8]

The estimation results of our baseline model where $ZROE_{it}$ measures the bank's stability and $MS_{it}$ serves as a proxy for the concentration are available in Table 3. The results confirm the nonlinear nature of the concentration-stability relationship regarding the level of bank capitalization in the Euro Area countries. While we do not confirm the statistical significance of the coefficients in the first regime in each variant of the model, the results regarding the second regime are statistically significant and robust across all model specifications (columns (I) – (V)). In the second extreme regime of the model, we confirm the concentration-stability paradigm in the Euro Area countries, such as Agoraki et al. (2011) and Moudud-Ul-Huq (2020), or Cuestas et al. (2017) and Ijaz et al. (2020) in European countries. It should be noted that authors of the previous studies have omitted nonlinearity, focusing solely on the relationship between concentration and stability. Based on our results, we argue that bank mergers and acquisitions in the Euro Area countries are likely to be beneficial in increasing bank stability if this is achieved under a specific condition: the relationship remains significant only with an increase in capitalization. It is therefore preferable to strengthen the value of equity in banks, which will lead to higher stability in relation to market share in the Euro Area banking system.

---

[8] For the sake of brevity, we do not present the results of the linear regression model estimation, but they are available upon request.

Table 3

**PSTR Model Estimation**

| | **Dependent variable: ZROE** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Threshold variable: CAR** | | | | | | | | | |
| | (I) | | (II) | | (III) | | (IV) | | (V) | |
| | First regime $\beta_0$ | Second regime $\beta_0+\beta_1$ | First regime $\beta_0$ | Second regime $\beta_0+\beta_1$ | First regime $\beta_0$ | Second regime $\beta_0+\beta_1$ | First regime $\beta_0$ | Second regime $\beta_0+\beta_1$ | First regime $\beta_0$ | Second regime $\beta_0+\beta_1$ |
| *MS* | 0.048 (0.039) | 0.077** (0.039) | 0.055 (0.042) | 0.064* (0.038) | 0.037 (0.037) | 0.025* (0.013) | 0.036 (0.038) | 0.027* (0.014) | 0.034 (0.035) | 0.024* (0.014) |
| *SIZE* | | | –0.687*** (0.272) | –0.655*** (0.271) | –0.953*** (0.282) | –1.094*** (0.265) | –0.896*** (0.337) | –1.246*** (0.358) | –0.872*** (0.303) | –1.210*** (0.337) |
| *DIR* | | | | | –0.253** (0.121) | 0.379*** (0.133) | –0.252** (0.120) | 0.368*** (0.115) | –0.236*** (0.096) | 0.368*** (0.151) |
| *TLTA* | | | | | | | –0.009*** (0.003) | 0.016** (0.007) | –0.008*** (0.003) | 0.016*** (0.006) |
| *GDPg* | | | | | | | | | 0.022 (0.017) | 0.007 (0.077) |
| *Transition parameters* | | | | | | | | | | |
| $\gamma$ | 1.369*** (0.532) | | 4.863 (8.037) | | 0.217* (0.123) | | 0.217* (0.128) | | 0.217* (0.120) | |
| $c$ | 28.560*** (1.019) | | 26.210*** (1.353) | | 25.000*** (9.989) | | 25.000*** (10.310) | | 25.000*** (9.422) | |
| *N* | 1848 | | 1848 | | 1848 | | 1848 | | 1848 | |
| *RSS* | 1822.814 | | 1812.922 | | 1577.094 | | 1569.936 | | 1566.873 | |

*Note:* ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively. The standard errors are reported in parentheses.

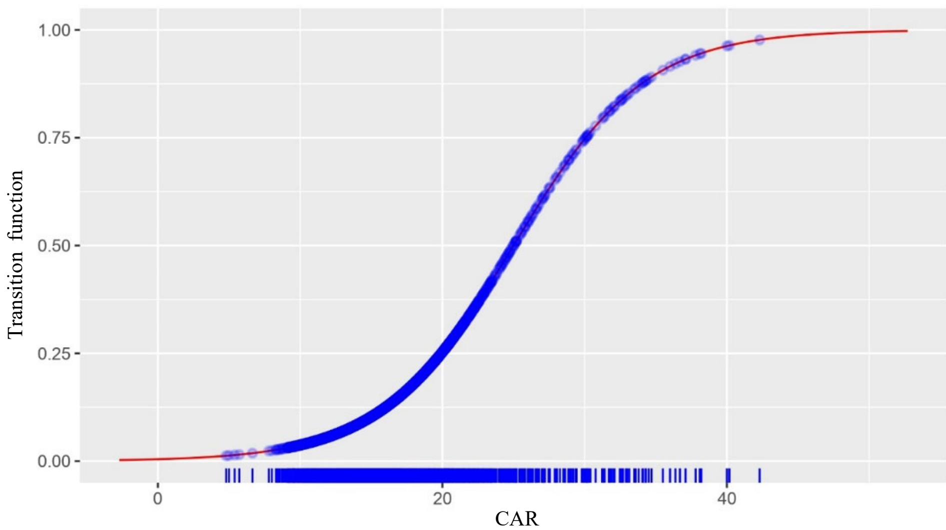
*Source:* Authors' calculations based on data from BankFocus, Eurostat, and Statistical Data Warehouse.

This statement is consistent with Berger et al. (2009), who confirmed that banks with more market power hold significantly more equity capital. However, we must be cautious about the concrete determination of the specific level of bank capitalization in a specific bank or country because of the substantial heterogeneities across member states related to the resilience of their economies and their ability to raise capital (see, e.g., Soederhuizen et al., 2023).

The estimated threshold level of bank capitalization indicates holding reserves that are higher than the current Basel III minimum requirements. In our baseline model (column (V)), the transition speed is $\gamma = 0.217$ and the estimated threshold value for $CAR_{it}$ is $c = 25.000$ which is beyond the mean value of the bank capital adequacy ratio in the sample (16.910). The suggestion of increasing the level of bank capitalization seems to be in line with several other studies (see, e.g., Moudud-Ul-Huq, 2020 or Santoso et al., 2021). Additionally, capital increase in the Euro Area countries is recommended by Soederhuizen et al. (2023), who estimated a range of optimal ratios of around 23%, and Budnik et al. (2019), who suggest increasing the level of capital ratios by beefing up capital buffers rather than reducing assets.

Even though we observe more credit institutions with capitalization below 25%, the observations are distributed evenly across the infinity of the regimes. The estimated transition function of the PSTR model is depicted in Figure 1.

Figure 1
**Estimated Transition Function of the PSTR Model**




*Note:* We depict the estimated transition function of the PSTR model specification from column (V), Table 3.
*Source:* Authors' calculations based on data from BankFocus, Eurostat, and Statistical Data Warehouse.

While referring to control variables, we note a negative and significant effect of bank size ($SIZE_{it}$) on bank stability. This result is in line with Daoud and Kammoun (2020). Our findings indicate that while consolidation tends to enhance overall system stability, an increase in the size of individual banks appears to reduce stability. This suggests that the benefits of consolidation may be offset by the risks associated with managing larger institutions, such as increased complexity, the potential for mismanagement, and greater systemic risk due to the „too big to fail" phenomenon (Vo, 2009). Therefore, while consolidation can lead to a more stable banking system, this implies that the relationship between size and stability needs to be carefully managed, ensuring that the increase in capital is proportionate to the risks associated with larger asset bases.

Long-term interest rates ($DIR_{it}$) and the share of total loans to total assets $\left(TLTA_{it}\right)$, are in a negative relationship with bank stability when the level of capitalization is low. In contrast, it turns out positive when there is a high level of capitalization. This two-side effect of $TLTA_{it}$ on bank stability confirmed our expectations. We can see that low-capitalized banks with higher shares of loans were not able to provide high-quality loans, which resulted in higher default rates and bank fragility. On the other hand, well-capitalized banks were able to create strong capital reserves that can buffer against the risks associated with changes in long-term interest rates, as well as cover potential loan losses, which enhances their resilience and stability. The robust capital buffers mitigate the risks associated with a high proportion of loans or manage the increased cost of borrowing and potential loan defaults more effectively, thereby enhancing their stability even under tighter monetary conditions. Results of $DIR_{it}$ might indicate that stricter monetary policies, and its effect on bank stability is also nuanced by the level of capitalization. Specifically, for banks with low capitalization, higher interest rates may pose additional risks rather than enhancing stability. Well-capitalized banks allow them to manage risks effectively and benefit from a more stringent monetary policy, leading to improved stability. Additionally, we do not find a statistically significant effect of GDPg (column (V)) in the PSTR model.

As a final part of the analysis, we provide the evaluation tests of the PSTR model in Table 4. According to the results of the heteroscedasticity and autocorrelation consistent versions of tests, we confirm that the PSTR model is valid, i.e., the parameters of the model are not time-varying ($HAC_F$), and there is no remaining nonlinearity in the model ($HAC_\chi$, $HAC_F$).

To check the robustness of our results, we follow Phan et al. (2019) and alter the dependent variable measuring bank stability $ZROE_{it}$ by $ZROA_{it}$. The independent variable measuring the concentration on the bank market $MS_{it}$ is replaced by the Lerner index ( $LERNER_{it}$ ). Moreover, several control variables are added to the regression – the bank's net interest income to operating revenues ( $NETIITI_{it}$ ) and inflation ( $HICPg_{it}$ ), namely. The robustness check is presented in Table A2 in the Appendix, where it is confirmed that our results are robust. In a similar fashion, we confirm the statistically significant and positive effect of concentration on bank stability in the second extreme regime, i.e., when the bank capitalization is high. The threshold of the bank capitalization has not changed significantly compared to the estimation findings provided in Table 3.

Table 4

**Evaluation Tests**

| **Dependent variable: ZROE** | | | | |
|---|---|---|---|---|
| **Threshold variable: CAR** | | | | |
| | *Parameter constancy* | | *No remaining nonlinearity* | |
| | Statistic | p-value | Statistic | p-value |
| $LM_{\chi}$ | 102.4 | <0.001 | 343.400 | <0.001 |
| $LM_F$ | 9.199 | <0.001 | 30.850 | <0.001 |
| $HAC_{\chi}$ | 20.360 | 0.026 | 13.650 | 0.190 |
| $HAC_F$ | 1.829 | 0.051 | 1.226 | 0.269 |

*Note:* We evaluate the PSTR model specification from column (V), Table 3. LM $_{\chi}$ stands for the linearity LM test with asymptotically $\chi^2$ distribution, and $LM_F$ stands for the linearity LM test with asymptotically F distribution. $HAC_{\chi}$ and $HAC_F$ represent their heteroscedasticity and autocorrelation consistent versions. The evaluation tests are conducted against two alternatives: 1. the parameters are time-varying (column 2 and 3), and 2. There is remaining nonlinearity (heterogeneity) in the model (column 4 and 5).

*Source:* Authors' calculations based on data from BankFocus, Eurostat, and Statistical Data Warehouse.

## Conclusion

This paper provides novel empirical evidence on the contentious relationship between bank concentration and stability in Euro Area countries. While previous studies employed linear regression models, often relying on a quadratic term to explore potential U-shaped links, such models may fail to capture the complexity of nonlinear relationships like that between bank concentration and stability. To address this limitation, we employ the nonlinear PSTR model proposed by Gonzalez et al. (2017), using the bank capital adequacy ratio as the transition variable. This approach allows for a more differentiated examination of the concentration-stability nexus, marking the first attempt of its kind in the Euro Area context.

Our findings confirm the existence of a nonlinear relationship between bank concentration and stability. Specifically, we find a statistically significant and positive relationship between bank stability and concentration when bank capitalization is sufficiently high, consistent with the concentration-stability paradigm, as supported by Agoraki et al. (2011), Leroy and Lucotte (2017) and Ijaz et al. (2020). The results, which are robust across different model specifications, suggest that elevated levels of bank capitalization (measured by capital adequacy ratio), particularly above the Basel III minimum requirements, enhance stability in more concentrated banking markets. Our identified threshold value of bank capitalization ($c$ = 25.000) indicates a positive effect on the concentration-stability nexus with a capitalization level above the current Basel III minimum requirements, reinforcing the role of capital adequacy as a critical factor in banking stability. The increased level of bank capitalization is consistent with findings of recent empirical studies, even in a different context (see, e.g., Moudud-Ul-Huq, 2020 or Santoso et al., 2021).

Our study contributes to the literature by showing that higher capitalization, particularly in more concentrated banking systems, amplifies bank stability. The findings imply that policymakers, including the ECB and national central banks, should consider policies that simultaneously promote higher bank capitalization and increased market concentration to foster systemic stability in the Euro Area banking sector.

Nevertheless, our study has limitations. First, determining an optimal level of capitalization remains challenging due to heterogeneities across Euro Area member states as presented by several authors (Soederhuizen et al., 2023). Second, our analysis does not account for the economic shocks and structural changes post-2019, such as those related to the COVID-19 pandemic or more recent regulatory reforms. Future research should explore these dynamics by analyzing more recent data and investigating country-specific contexts to better understand how concentration and stability interact across different national banking systems. Additionally, examining how changes in macroeconomic conditions and regulatory frameworks affect the concentration-stability nexus could offer further insights into maintaining financial resilience in the Euro Area.

## References

ABDESSLEM, R. B. – DABBOU, H. – GALLALI, M. I. (2023): The Impact of Market Concentration on Bank Risk-Taking: Evidence from a Panel Threshold Model. Journal of the Knowledge Economy, *14*, No. 4, pp. 4170 – 4194.

ABUZAYED, B. – AL-FAYOUMI, N. – MOLYNEUX, P. (2018): Diversification and Bank Stability in the GCC. Journal of International Financial Markets, Institutions and Money, *57,* pp. 17 – 43.

ACHARYA, V. V. – YORULMAZER, T. (2008): Cash-in-the-Market Pricing and Optimal Resolution of Bank Failures. The Review of Financial Studies, *21*, No. 6, pp. 2705 – 2742.

AGORAKI, M.-E. K. – DELIS, M. D. – PASIOURAS, F. (2011): Regulations, Competition and Bank Risk-Taking in Transition Countries. Journal of Financial Stability, *7*, No. 1, pp. 38 – 48.

ALBAITY, M. – MALLEK, R. S. – NOMAN, A. H. Md. (2019): Competition and Bank Stability in the MENA Region: The Moderating Effect of Islamic versus Conventional Banks. Emerging Markets Review, *38*, pp. 310 – 325.

BECK, T. (2008): Bank Competition and Financial Stability: Friends or Foes? [World Bank Policy Research Working Paper, (4656).]

BERGER, A. N. – KLAPPER, L. F. – TURK-ARISS, R. (2009): Bank Competition and Financial Stability. Journal of Financial Services Research, *35*, No. 2, pp. 99 – 118.

BITAR, M. – PUKTHUANTHONG, K. – WALKER, T. (2020): Efficiency in Islamic vs. Conventional Banking: The Role of Capital and Liquidity. Global Finance Journal, *46*, 100487.

BOYD, J. H. – De NICOLO, G. (2005): The Theory of Bank Risk Taking and Competition Revisited. The Journal of finance, *60*, No. 3, pp. 1329 – 1343.

BOYD, J. H. – GRAHAM, S. L. (1988): The Profitability and Risk Effects of Allowing Bank Holding Companies to Merge with Other Financial Firms: A Simulation Study. Quarterly Review, *12*, No. 2, pp. 3 – 20.

BUDNIK, K. – AFFINITO, M. – BARBIC, G. … VELASCO, S. (2019): The Benefits and Costs of Adjusting Bank Capitalization: Evidence from Euro Area Countries. [Working Paper Series, No. 2261.] Frankfurt am Main: European Central Bank.

CALICE, P. – LEONIDA, L. – MUZZUPAPPA, E. (2021): Concentration-Stability vs Concentration-Fragility. New Cross-Country Evidence. Journal of International Financial Markets, Institutions and Money, *74*, 101411.

CARBÓ-VALVERDE, S. – PEDAUGA, L. E. – RODRÍGUEZ-FERNÁNDEZ, F. (2013): Another Look at Bank Consolidation and Financial Stability. [Working Paper.]

CUESTAS, J. C. – LUCOTTE, Y. – REIGL, N. (2019): Banking Sector Concentration, Competition and Financial Stability: The Case of the Baltic Countries. Post-Communist Economies, *32*, pp. 215 – 249.

DAOUD, Y. – KAMMOUN, A. (2020): Financial Stability and Bank Capital: The Case of Islamic Banks. International Journal of Economics and Financial Issues, *10,* No. 5, pp. 361.

DELIS, M. D. – KOURETAS, G. P. (2011): Interest Rates and Bank Risk-Taking. Journal of Banking – Finance, *35*, No. 4, pp. 840 – 855.

DJEBALI, N. – ZAGHDOUDI, K. (2020): Threshold Effects of Liquidity Risk and Credit Risk on Bank Stability in the MENA Region. Journal of Policy Modeling, *42*, No. 5, pp. 1049 – 1063.

ECB (2021a): Banking Structural Financial Indicators. Frankfurt am Main: European Central Bank. Available at: <https://sdw.ecb.europa.eu/browse.do?node=9689719>.

ECB (2021b): Consolidated Banking Data. Frankfurt am Main: European Central Bank. Available at: <https://sdw.ecb.europa.eu/browse.do?node=9689685>.

ECB (2024): Criteria for Assessing Significance. Frankfurt am Main: European Central Bank. Available at: <https://www.bankingsupervision.europa.eu/banking/list/criteria/html/>.

FIGUEIRAS, I. – GARDÓ, S. – GRODZICKI, M. – KLAUS, B. – LEBASTARD, L. (2021): Bank Mergers and Acquisitions in the Euro Area: Drivers and Implications for Bank Performance. Financial Stability Review, *2*, November.

GHARBI, S. – OTHMANI, H. (2022): Threshold Effect in the Relationship between Family Ownership and Firm Performance: A Panel Smooth Transition Regression Analysis. Cogent Economics – Finance, *10*, No. 1, 2023264.

GONZALEZ, A. – TERASVIRTA, T. – van DIJK, D. – YANG, Y. (2017): Panel Smooth Transition Regression Models. [SSE/EFI Working Paper Series in Economics and Finance, No. 604.] Stockholm: Stockholm School of Economics.

GRANGER, C. – TERÄSVIRTA, T. (1993): Modelling Non-Linear Economic Relationships [OUP Catalogue]. Oxford: Oxford University Press.

HAANS, R. F. J. – PIETERS, C. – HE, Z.-L. (2016): Thinking about U: Theorizing and Testing U- and Inverted U-Shaped Relationships in Strategy Research. Strategic Management Journal, *37*, No. 7, pp. 1177 – 1195.

HAKENES, H. – SCHNABEL, I. (2011): Capital Regulation, Bank Competition, and Financial Stability. Economics Letters, *113*, No. 3, pp. 256 – 258.

HANSEN, B. E. (1999): Threshold Effects in Non-Dynamic Panels: Estimation, Testing, and Inference. Journal of Econometrics, *93*, No. 2, pp. 345 – 368.

IJAZ, S. – HASSAN, A. – TARAZI, A. – FRAZ, A. (2020): Linking Bank Competition, Financial Stability, and Economic Growth. Journal of Business Economics and Management, *21*, No. 1, pp. 200 – 221.

JANSEN, E. S. – TERÄSVIRTA, T. (1996): Testing Parameter Constancy and Super Exogeneity in Econometric Equations. Oxford Bulletin of Economics and Statistics, *58*, No. 4, pp. 735 – 763.

KEELEY, M. C. (1990): Deposit Insurance, Risk, and Market Power in Banking. American Economic Review, *80*, No. 5, pp. 1183 – 1200.

KOČIŠOVÁ, K. (2020): Competition and Stability in the European Global Systemically Important Banks. Ekonomický časopis/Journal of Economics, *68*, No. 05, pp. 431 – 454.

LERNER, A. P. (1934): The Concept of Monopoly and the Measurement of Monopoly Power. Review of Economic Studies, *1*, No. 3, pp. 157 – 175.

LEROY, A. – LUCOTTE, Y. (2017): Is There a Competition-Stability Trade-Off in European Banking? Journal of International Financial Markets, Institutions and Money, *46*, pp. 199 – 215.

MARTINEZ-MIERA, D. – REPULLO, R. (2010): Does Competition Reduce the Risk of Bank Failure? Review of Financial Studies, *23*, No. 10, pp. 3638 – 3664.

MAUDOS, J. – VIVES, X. (2019): Competition Policy in Banking in the European Union. Review of Industrial Organization, *55*, No. 1, pp. 27 – 46.

MISHKIN, F. S. (1999): Financial Consolidation: Dangers and Opportunities. Journal of Banking – Finance, *23*, No. 2 – 4, pp. 675 – 691.

MOUDUD-UL-HUQ, S. (2020): Does Bank Competition Matter for Performance and Risk-Taking? Empirical Evidence from BRICS Countries. International Journal of Emerging Markets, *16*, No. 3, pp. 409 – 447.

PETRIA, N. – CAPRARU, B. – IHNATOV, I. (2015): Determinants of Banks' Profitability: Evidence from EU27 Banking Systems. Procedia Economics and Finance, *20*, pp. 518 – 524.

PHAN, H. T. – ANWAR, S. – ALEXANDER, W. R. J. – PHAN, H. T. M. (2019): Competition, Efficiency and Stability: An Empirical Study of East Asian Commercial Banks. The North American Journal of Economics and Finance, *50*, 100990.

RUBIO, M. – YAO, F. (2020): Bank Capital, Financial Stability and Basel Regulation in a Low Interest-Rate Environment. International Review of Economics – Finance, *67*, pp. 378 – 392.

SAIF-ALYOUSFI, A. Y. H. – SAHA, A. – MD-RUS, R. (2018): The Impact of Bank Competition and Concentration on Bank Risk-Taking Behavior and Stability: Evidence from GCC Countries. The North American Journal of Economics and Finance, *51*, 100867.

SANG, N. M. (2021): Capital Adequacy Ratio and a Bank's Financial Stability in Vietnam. Banks and Bank Systems, *16*, No. 4, pp. 61 – 71.

SANTOSO, W. – YUSGIANTORO, I. – SOEDARMONO, W. – PRASETYANTOKO, A. (2021): The Bright Side of Market Power in Asian Banking: Implications of Bank Capitalization and Financial Freedom. Research in International Business and Finance, *56*, 101358.

SHAIR, F. – SUN, N. – SHAORONG, S. – ATTA, F. – HUSSAIN, M. (2019): Impacts of Risk and Competition on the Profitability of Banks: Empirical Evidence from Pakistan. PloS One, *14*, No. 11, e0224378.

SOEDERHUIZEN, B. – van HEUVELEN, G. H. – LUGINBUHL, R. – van STIPHOUT-KRAMER, B. (2023): Optimal Capital Ratios for Banks in the Euro Area. Journal of Financial Stability, *69*, 101164.

STATISTA (2021): Probability of Default of a Country's Banking System (Z-score) of Banks in Europe 2017, by Country. Available at: <https://www.statista.com/statistics/1078384/bank-z-score-in-europe-by-country/>.

TABAK, B. M. – FAZIO, D. M. – CAJUEIRO, D. O. (2012): The Relationship between Banking Market Competition and Risk-Taking: Do Size and Capitalization Matter? Journal of Banking – Finance, *36*, No. 12, pp. 3366 – 3381.

TERÄSVIRTA, T. (1994): Specification, Estimation, and Evaluation of Smooth Transition Autoregressive Models. Journal of the American Statistical Association, *89*, No. 425, pp. 208 – 218.

TRAN, S. – NGUYEN, D. – NGUYEN, L. (2022): Concentration, Capital, and Bank Stability in Emerging and Developing Countries. Borsa Istanbul Review, *22*, No. 6, pp. 1251 – 1259.

UHDE, A. – HEIMESHOFF, U. (2009): Consolidation in Banking and Financial Stability in Europe: Empirical Evidence. Journal of Banking – Finance, *33*, No. 7, pp. 1299 – 1311.

VO, Q. A. (2009): Banking Competition, Monitoring Incentives and Financial Stability. Monitoring Incentives and Financial Stability. June 19, 2009.

WAGNER, W. (2010): Diversification at Financial Institutions and Systemic Crises. Journal of Financial Intermediation, *19*, No. 3, pp. 373 – 386.

WANG, R. – LUO, H. R. (2022): How Does Financial Inclusion Affect Bank Stability in Emerging Economies? Emerging Markets Review, *51*, 100876.

WEILL, L. (2013): Bank Competition in the EU: How Has It Evolved? Journal of International Financial Markets, Institutions and Money, *26*, pp. 100 – 112.

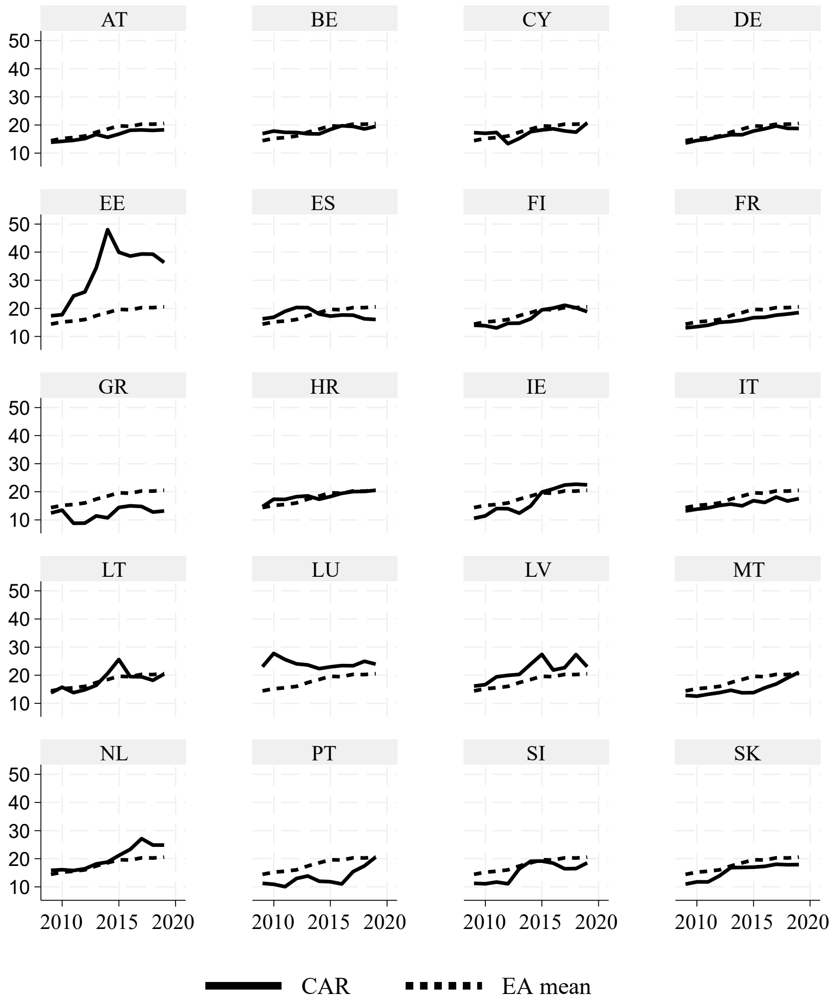
WORLD BANK (2021): World Development Indicators. Available at: <https://databank.worldbank.org/source/world-development-indicators>.

WU, X. – CHEN, Y. – GUO, J. – GAO, G. (2018): Inputs Optimization to Reduce the Undesirable Outputs by Environmental Hazards: A DEA Model with Data of PM2.5 in China. Natural Hazards, *90*, No. 1, pp. 1 – 25.

YANG, Y. (2022): Panel Smooth Transition Regression Modelling. R package. Available at: <https://github.com/yukai-yang/PSTR>.

# Appendix

Figure A1
**Capitalization of the Euro Area Banks**




*Source:* Authors' calculations based on data from the financial statements of the selected EA credit institutions, Eurostat, and Statistical Data Warehouse.

T a b l e A1

**Panel Unit Root Testing**

| **Variable** | **LLC** | | **IPS** | | **Pesaran's CADF** | |
|---|---|---|---|---|---|---|
| | *No trend* | *Trend* | *No trend* | *Trend* | *No trend* | *Trend* |
| *ZROE* | –48.007*** | –54.093*** | –26.694*** | –33.519*** | –2.597*** | –3.056*** |
| *ZROA* | –16.329*** | –32.208*** | –7.004*** | –17.326*** | –2.764*** | –2.991*** |
| *MS* | –9.517*** | –32.377*** | –0.472 | –10.386*** | –1.651 | –1.963 |
| *LERNER* | –32.804*** | –34.029*** | –13.588*** | –15.364*** | –1.808 | –1.759 |
| *CAR* | –11.090*** | –23.537*** | –2.724*** | –12.485*** | –2.470*** | –2.245 |
| *SIZE* | –12.121*** | –129.170*** | 0.819 | –20.262*** | –1.661 | –2.012 |
| *DIR* | –14.577*** | –66.962*** | 0.865 | –28.516*** | –3.635*** | –4.395*** |
| *TLTA* | –37.480*** | –64.413*** | –9.804*** | –16.031*** | –1.708 | –2.703*** |
| *GDPg* | –34.979*** | –46.546*** | –37.276*** | –34.136*** | –2.202*** | –2.957*** |
| *HICPg* | –32.55.3*** | –29.671*** | –22.162*** | –16.207*** | –2.154*** | –2.914*** |
| *NETIITI* | –21.168*** | –36.383*** | –13.381*** | –22.373*** | –2.354*** | –2.450*** |

*Note:* ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively. LLC stands for Levin-Lin-Chu panel unit root test, IPS stands for Im-Pesaran-Shin panel unit root test, and Pesaran's CADF stands for Pesaran's CADF panel unit root test. While LLC and IPS assume that the time series under scrutiny are cross-sectionally independent, Pesaran's CADF allows for cross-dependence across the panel units. In all performed tests, the null hypothesis assumes that all the time series have one unit root, i.e., series are non-stationary – I(1).

*Source:* Authors' calculations based on data from BankFocus, Eurostat, and Statistical Data Warehouse.

Table A2

**Robustness Check – PSTR Model Estimation with Additional Control Variables and Different Variants of the Stability (ZROA/ZROE) and Concentration Variables (MS/LERNER)**

| | **Threshold variable: CAR** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Dependent variable: ZROA** | | | | | | **Dependent variable: ZROE** | | | | | |
| | (I) | | (II) | | (III) | | (IV) | | (V) | | (VI) | |
| | First regime $\beta_0$ | Second regime $\beta_0+\beta_1$ | First regime $\beta_0$ | Second regime $\beta_0+\beta_1$ | First regime $\beta_0$ | Second regime $\beta_0+\beta_1$ | First regime $\beta_0$ | Second regime $\beta_0+\beta_1$ | First regime $\beta_0$ | Second regime $\beta_0+\beta_1$ | First regime $\beta_0$ | Second regime $\beta_0+\beta_1$ |
| *MS* | 0.048 (0.035) | 0.193*** (0.056) | 0.061 (0.041) | 0.230** (0.109) | 0.064 (0.042) | 0.324*** (0.123) | | | | | | |
| *LERNER* | | | | | | | 0.323 (0.238) | 1.014** (0.514) | 0.272 (0.379) | 1.034** (0.048) | 0.447 (0.279) | 1.173* (0.645) |
| *SIZE* | –6.485*** (0.909) | –6.662*** (1.118) | –6.817*** (0.923) | –6.741*** (1.192) | –6.935*** (0.998) | –7.126*** (1.213) | –0.830*** (0.235) | –0.995*** (0.235) | –0.808*** (0.233) | –0.967*** (0.260) | –0.810*** (0.218) | –1.065*** (0.237) |
| *DIR* | –0.501*** (0.045) | 0.416* (0.253) | –0.574*** (0.042) | –0.030 (0.379) | –0.551*** (0.040) | –0.324*** (0.124) | –0.196*** (0.029) | 0.034 (0.043) | –0.236*** (0.030) | 0.041 (0.028) | –0.216*** (0.019) | 0.118*** (0.039) |
| *TLTA* | 0.016* (0.009) | 0.007 (0.035) | 0.011 (0.010) | 0.003 (0.036) | 0.010 (0.009) | 0.016 (0.037) | –0.010** (0.005) | 0.001 (0.004) | –0.010 (0.008) | 0.001 (0.003) | –0.011** (0.006) | –0.001 (0.005) |
| *GDPg* | 0.074*** (0.027) | 0.714*** (0.130) | | | | | 0.025*** (0.010) | 0.006 (0.024) | | | | |
| *HICPg* | | | 0.088* (0.047) | 0.076 (1.043) | | | | | 0.057 (0.046) | –0.039 (0.040) | | |
| *NETIITI* | | | | | –0.017*** (0.005) | –0.002 (0.027) | | | | | –0.009*** (0.002) | –0.001 (0.006) |
| *Transition parameters* | | | | | | | | | | | | |
| $\gamma$ | 15.220*** (4.369) | | 26.530*** (4.845) | | 26.530*** (5.659) | | 0.629*** (0.158) | | 0.629*** (0.185) | | 0.426*** (0.144) | |
| *c* | 27.690*** (0.047) | | 27.700*** (0.016) | | 29.560*** (0.114) | | 19.560*** (3.881) | | 18.560*** (5.663) | | 20.560*** (4.671) | |
| *N* | 1848 | | 1848 | | 1848 | | 1815 | | 1815 | | 1815 | |
| *RSS* | 4406.448 | | 4661.004 | | 4590.871 | | 1561.327 | | 1546.556 | | 1540.868 | |

*Note:* ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively. The standard errors are reported in parentheses.

*Source:* Authors' calculations based on data from BankFocus, Eurostat, and Statistical Data Warehouse.

T a b l e A3

**Correlation Matrix**

| | *ZROE* | *ZROA* | *MS* | *LERNER* | *CAR* | *SIZE* | *DIR* | *TLTA* | *GDPg* | *HICPg* | *NETIITI* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *ZROE* | | | | | | | | | | | |
| *ZROA* | 0.354 | | | | | | | | | | |
| *MS* | –0.019 | –0.002 | | | | | | | | | |
| *LERNER* | 0.089 | 0.174 | 0.102 | | | | | | | | |
| *CAR* | 0.162 | 0.349 | –0.005 | 0.069 | | | | | | | |
| *SIZE* | –0.082 | –0.432 | 0.408 | –0.012 | –0.112 | | | | | | |
| *DIR* | –0.338 | –0.071 | 0.106 | –0.106 | –0.329 | –0.117 | | | | | |
| *TLTA* | –0.016 | 0.113 | –0.122 | 0.003 | –0.042 | –0.306 | 0.046 | | | | |
| *GDPg* | 0.218 | 0.172 | 0.031 | 0.103 | 0.215 | –0.019 | –0.477 | 0.007 | | | |
| *HICPg* | 0.008 | –0.026 | –0.044 | 0.015 | –0.031 | –0.079 | 0.081 | 0.003 | –0.092 | | |
| *NETIITI* | –0.140 | –0.205 | 0.052 | 0.067 | –0.034 | 0.013 | 0.069 | 0.327 | 0.060 | 0.000 | |

*Source:* Authors' calculations based on based on data from BankFocus, Eurostat, and Statistical Data Warehouse.

## Calculation of the Lerner Index

Lerner (1934) calculated competition as the difference between price and marginal costs being a derivation of the translog production function:

$$LERNER_{it} = \frac{P_{it} - MC_{it}}{P_{it}} \quad (6)$$

where $P_{it}$ is the average price of production for bank *i* and year *t*, and $MC_{it}$ denotes marginal costs for bank *i* and year *t*. Similar to Weill (2013), we substitute the price of bank production with the ratio of total revenues (interest and non-interest income) to total assets.

The Eq. (6) requires calculating the marginal cost $\left(MC_{it}\right)$ function. Here, we follow the approach of Tabak et al. (2012), who estimate $MC_{it}$ based on production technology with one aggregate output and three input proxies. Marginal cost $\left(MC_{it}\right)$ is specified as follows:

$$MC_{it} = \frac{TC_{it}}{TA_{it}}\left[\beta_1 + \beta_2 \ln TA_{it} + \beta_8 \ln\left(\frac{w_{1,it}}{w_{3,it}}\right) + \beta_9 \ln\left(\frac{w_{2,it}}{w_{3,it}}\right)\right] \quad (7)$$

where we divide the total costs $\left(TC_{it}\right)$ for bank *i* and year *t* and input prices by the price of a borrowed fund represented by $w_3$ to correct for heteroscedasticity. In this model (Eq. (7)), the aggregated output presents the total assets $\left(TA_{it}\right)$ for bank *i* and year *t* and three input prices, specifically, the price of labor ($w_{1,it}$), price of physical capital $(w_{2,it})$, and the price of borrowed funds $(w_{3,it})$.