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Bank Leverage and Risk-Taking Behavior: A Comparative Study of Large vs. Small Banks in Austria and Germany

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Abstract

The aim of this thesis is to examine the relationship between bank leverage and risk-taking behavior, while investigating how bank size influences this link. Using a dataset consisting of over 600 banks in Austria and Germany from 2014 to 2023, a panel data regression model is employed to investigate how leverage affects the risk appetite across banks of various sizes and how size moderates this relationship. In this thesis, the Z-score is calculated as a proxy for risk, capturing the risk of insolvency through return on assets, equity ratio, and the volatility of earnings. As an inverse proxy for financial leverage the total equity to total assets ratio is used, with lower values indicating higher leverage.

Three models are estimated sequentially. The baseline model shows that leverage is negatively associated with risk-taking and that there is a positive relationship between bank size and risk, while the benefits of higher equity (i.e., lower leverage) for reducing risk are greater for larger firms. The extended model includes non-linear terms to capture non-linear effects and reveals that the relationships between leverage and risk-taking, as well as between size and risk, follow a non-linear pattern. The final model, which includes bank and year fixed effects, confirms the significance of the positive impact of leverage on risk, meaning that higher leverage increases risk. Additionally, the interaction term indicates that lower leverage is associated with a higher Z-Score, especially at lower sizes, and the effect diminishes with the increase in size.

The findings contribute to the literature on capital structure and bank behavior by highlighting the heterogeneous impact of leverage on risk-taking across banks of different sizes and under varying economic conditions.

Kurzfassung

Ziel dieser Masterarbeit ist es, den Zusammenhang zwischen der Verschuldung von Banken (Leverage) und ihrem Risikoverhalten zu untersuchen und dabei zu analysieren, wie die Größe einer Bank diesen Zusammenhang beeinflusst. Auf Basis eines Datensatzes von über 600 Banken in Österreich und Deutschland im Zeitraum von 2014 bis 2023 wird ein Paneldaten-Regressionmodell angewendet, um zu analysieren, wie sich die Verschuldung auf die Risikobereitschaft von Banken unterschiedlicher Größen auswirkt und inwiefern die Größe diesen Effekt moderiert. Als Risikomaß dient in dieser Arbeit der Z-Score, der die Insolvenzgefahr anhand der Eigenkapitalquote, der Gesamtkapitalrendite und der Ergebnisvolatilität abbildet. Als inverser Proxy für finanzielle Leverage wird das Verhältnis von Eigenkapital zu Gesamtvermögen verwendet, wobei niedrigere Werte auf eine höhere Leverage hinweisen.

Es werden drei Modelle sequenziell geschätzt. Das Basismodell zeigt, dass Leverage negativ mit der Risikobereitschaft assoziiert ist und dass ein positiver Zusammenhang zwischen Bankgröße und Risiko besteht, während die Vorteile eines höheren Eigenkapitals (d. h. geringerer Leverage) zur Risikoreduzierung bei größeren Unternehmen stärker ausgeprägt sind. Das erweiterte Modell umfasst nichtlineare Terme, um nichtlineare Effekte abzubilden, und zeigt, dass sowohl der Zusammenhang zwischen Leverage und Risikobereitschaft als auch der zwischen Größe und Risiko einem nichtlinearen Muster folgen. Das finale Modell, das Banken- und Jahres-Fixed-Effects einschließt, bestätigt die Signifikanz des positiven Einflusses von Leverage auf das Risiko, was bedeutet, dass ein höherer Leverage das Risiko erhöht. Zudem zeigt der Interaktionsterm, dass ein geringerer Leverage mit einem höheren Z-Score verbunden ist, insbesondere bei kleineren Banken, wobei dieser Effekt mit zunehmender Größe abnimmt.

Die Ergebnisse leisten einen Beitrag zur wissenschaftlichen Literatur über Kapitalstruktur und Bankverhalten, indem sie die heterogene Wirkung von Leverage auf das Risikoverhalten von Banken unterschiedlicher Größe unter verschiedenen ökonomischen Rahmenbedingungen aufzeigen.

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1. Introduction

The banking sector plays a fundamental role in maintaining the stability of the economy. In current times of fast-evolving digital solutions and transformation, but also major macroeconomic challenges, it is important for financial institutions to stay adaptive and strong. Already in 2008, we experienced that solely complying with the requirements of capital regulation did not eliminate excessive risk. It has been a major concern of regulators to protect financial stability by potentially controlling risk-taking with the help of capital ratios.

Since Basel I was introduced, we have already witnessed several changes in regulations, currently complying with Basel III regulations, with proposed amendments for Basel IV already on the table. The probability of failure is often measured by the capital level, whose increase still remains the main anchor for banks' resilience (Abbas et al., 2021). However, in their study, Gropp and Heider (2010) note that inconsistent findings are present with regard to how capital ratios influence risk. While some papers suggest a negative correlation – meaning that higher capital ratios lead to diminished risk – other evidence provides proof of the opposite effect.

On the one hand, stricter measures were implemented with these regulations to protect financial stability, but on the other hand, systemic risk cannot be fully eliminated, which continuously poses the risk of economic disturbance. Understanding how capital structure is associated with well-managed risk behavior is an integral part of keeping the financial sector under control. In this research, the main focus lies on the total equity to total assets ratio as an inverse proxy for bank's financial leverage, with leverage also commonly known as the potential driving force of bank risk. Bank risk is proxied by a Z-Score, as for example used by Berger et al. (2009) or Bertay et al. (2013).

Additionally, other factors influencing banks' risk-taking should be taken into account. For example, Bitar et al. (2018) show evidence that characteristics like the business model or the bank's size have an influence on risk. They demonstrate in their research that the link between risk and capital structure is moderated by size and the operating environment. For instance, literature shows that such factors as portfolio diversification or economies of scale, which are present among larger banks, could decrease a bank's risk exposure which leads to the conclusion that bigger banks could be less risky

(Pasiouras, 2008; Chortareas et al., 2012; Abendifar et al., 2013; and others). From another angle, Bertay et al. (2013) concluded that neither systemic size nor absolute bank size, captured by the logarithm of total assets, is associated as a significant factor influencing bank risk in an international sample of banks over more than 10 years (Bertay et al., 2013, pp. 532-533).

The importance of bank size is a topic of ongoing debate. Large banks may be perceived as "too big to fail," which could lead to potential moral hazard and higher risk exposure, because of the belief that the government would help in times of crisis (Allen et al., 2008; Claessens & Van Horen, 2015; Bertay et al., 2013; Strahan, 2013). However, regulatory constraints and fierce competition may limit or even raise the risk appetite of smaller banks (Abbas et al., 2021).

The aim of this research work is to examine the relationship between a bank's leverage and risk-taking, focusing on how bank size interacts with this relationship. The analysis is done based on the dataset of over 600 German and Austrian banks in the period from 2014 to 2023. With the help of GLS and the panel data regression models this study shows how leverage influences risk among the institution, if this relationship is linear, and in what way it is moderated by size. Risk-taking behaviour is proxied by the Z-Score which incorporates the profitability of the bank, capitalization, and the volatility of returns (Berger et al., 2009). The central research question is, *how does bank size influence the relationship between leverage and risk-taking behavior?*

Three models are estimated one after the other. According to the baseline model, risk-taking is negatively correlated with leverage, whereas there is a positive impact of bank size on risk. The extended model, which includes non-linear components to account for non-linear effects, shows a U-shaped relationship between leverage and risk-taking as well as for bank size, with no significant effect of the moderation term. The final model, which accounts for bank and year fixed effects to capture macroeconomic shocks, confirms the significance of the positive relationship between leverage and risk. Additionally, the negative interaction term implies that positive effect of lower leverage and higher equity diminishies with the increase in banks size.

This study contributes to the literature in providing the new empirical evidence on the moderating effect of the bank size on the relationship between bank leverage and risk, whilst examining the post world crisis bank data from two major economic players in the Eurozone, Austria and Germany.

This research also adresses potential limitations of the previous studies not explicitely exploring the nonlinearity of the relationship between the bank size and and leverage (e.g. Gropp and Heider, 2010; Bitar et al, 2018).

This research differs from other study as it empahizes the moderating effect of the bank size on the levarage-risk relationship while examining its combined effect. The sample represents a homogeneous distribution of Austrian and German banks, which helps to minimize external factors such as legal, supervisory or government influnce, focusing on the structural analysis whithin institutions. This research also incorporates recents macroeconomic shocks, primarily the Covid-19 outbreak and the war in Ukraine.

The rest of the study is structured as follows. The thesis is divided into 7 chapters. Chapter 2 provides a review of the existing literature. Third chapter outlines the theoretical framework and presents the hypotheses. Chapter 4 explains the research methodology, data sources, variables and econometric models. Fifth chapter presents the empirical findings from the analysis. Chapter 6 discusses the interpretation of the findings, policy implications, and the limitations of the research. The last chapter finalises the research with conclusions and offers recommendations for future research.

Artificial Intelligence (Deepl, Quillbot, ChatGPT, etc.) is used to enhance text formulations to academic standards, support with text summaries and translations, as well as to perform grammar checks of the wording of this research.

2. Literature Review

Bank capital structure and its link to risk-taking behaviour has been a well-discussed topic in academic literature over the past few decades. This relationship became a greater concern after the first global financial crisis. As the experience showed, higher capital buffers alone may not be sufficient to optimise risk levels that could otherwise result in a systemic collapse. Since institutions also differ in size, it is logical to consider their heterogeneity, as well as the impact of regulations. As this research primarily focuses on the leverage component of the capital structure and its link to risk-taking, along with the moderating effect of bank size, the subsequent literature review will concentrate on these points, including the theoretical framework.

Literature provides a strong theoretical foundation for the link between bank capital structure and risk-taking. Bank capital plays an important role in mitigating agency problems arising from the limited liability of banks. It is argued that limited liability increases risk-taking, as losses incurred by bondholders and depositors are not internally covered, whereas when the bank's own capital is at stake, internal risk becomes more significant, leading to increased monitoring and control. Additionally, higher capital—implying lower leverage—signals decreased risk appetite to investors, which in turn reduces the cost of debt (Dell'Ariccia et al., 2014, p. 68).

Dell'Ariccia et al. (2014) show that increased risk-taking is indeed linked to higher leverage. In a low-interest rate environment, risk-taking behaviour becomes more pronounced, as it is easier for banks to adjust their leverage levels within the institution, also considering the availability of cheaper debt (Dell'Ariccia et al., 2014, pp. 68, 88). To summarise, they reach two key conclusions. First, banks tend to raise their leverage as risk-free interest rates decline. Second, reflecting this increase in debt, a decline in risk-free rates results in less bank oversight and more risk-taking (Dell'Ariccia et al., 2014, p. 66).

Other empirical findings also support the relationship between capital and risk. In their work dedicated to the determinants of bank capital structure, Gropp and Heider (2010) examine the explanatory power of institutional characteristics. Their regression results show that one of the key factors linked to leverage levels for both American and European banks is bank risk. Moreover, the results indicate that risk explains more than 12 percent of the variation in book leverage, which is higher than the explanatory power of other characteristics in the model, such as profits, size, collateral, and dividends (Gropp and Heider, 2010, p. 601, Table VII).

It is worth mentioning that the general logic suggests that riskier banks tend to increase their equity in order to reduce their leverage levels. Such behaviour, however, does not hold in situations where the bank's capital structure is already close to the regulatory minimum, such as under Basel regulations. The authors refer to this as the "buffer view", which states that even when their risk is increasing, banks that are already near the regulatory minimum do not decrease their leverage or raise their equity (Gropp and Heider, 2010, p. 614).

One of the foundational papers on the theory of bank risk-taking, written by Boyd and De Nicolo (2005), offers another view on the moral hazard problem, particularly in relation to deposit insurance. It is argued that internal decisions to take on more risk are reinforced by the existence of insurance. Banks tend to intentionally take on higher risk because they can rely on deposit insurance, which creates an asymmetric payoff: shareholders benefit in case of financial success, while in case of major losses, the government bears the cost (Boyd and De Nicolo, 2005, p. 1330).

If we look further back into the foundational literature on financial intermediation and moral hazard, the academic work of Holmström and Tirole (1997) is essential for understanding moral hazard among banks. When facing capital constraints, their model shows the link between information asymmetries and moral hazard, particularly in situations where regulatory monitoring is not thorough.

Deposit insurance is argued to play a safety-net role in the work of Berger et al. (1995). Their main observation is that undercapitalisation is associated with increased risk-taking behaviour. They show that banks tend to make riskier choices and pursue riskier strategies when there is insufficient equity in the bank—i.e., when the bank is undercapitalised—and when deposit insurance is in place (Berger et al., 1995, p. 406).

Berger, Herring and Szegö (1995) further elaborate this view. They confirm that undercapitalised banks are more likely to engage in excessive risk-taking, particularly when market discipline is weak. They emphasise the role of capital as both a buffer against losses and a mechanism to align managerial incentives with risk exposure (Berger et al., 1995, pp. 394–398).

The issue of moral hazard becomes even more pronounced in the case of systemically important institutions with significant market power due to their size. This concept, known as “too big to fail”, is discussed in many studies, including those by Allen et al. (2008), Berger et al. (2009), Claessens and Van Horen (2015), Strahan (2013), and Bertay et al. (2013). The core idea is that larger institutions, due to their systemic relevance and market dominance, tend to take on more risk under the assumption that the government will step in to bail them out if needed.

To provide further context, according to Allen et al. (2008), large international banks played two roles during the global financial crisis: due to their size and connectivity, they exacerbated systemic instability, but in certain areas, they also acted as stabilising forces by preserving local lending. This contradiction highlights the intricate connection between bank size, financial stability, and regulatory efficacy, especially in environments where coordination is lacking, and implicit guarantees exist.

In their paper, Berger et al. (2009) show that systemically important banks, defined as such based on their size relative to the country’s GDP (Bertay et al., 2013, p. 533), may be encouraged to undertake more risk because they anticipate implicit government support. The authors also suggest that banks with greater market power frequently use larger capital buffers or other risk-reduction techniques to counterbalance these risk exposures. Therefore, depending on how these institutions manage their exposures and protect franchise value, bank size may either increase or decrease risk. Furthermore, if banks believe they are too big to fail and expect to be covered, directly or indirectly, by the government safety net, a highly concentrated banking sector may incentivise them to take on greater risk. This view is supported by recent empirical evidence (Berger et al., 2009, p. 100).

Bertay et al. (2013) provide empirical research based on a sample of international banks, distinguishing between absolute size and systemic size. They argue that large banks benefit from their size, as it allows them to access lower funding costs due to the implicit “too big to fail” safety net. This, in turn, weakens market discipline and may encourage riskier strategies such as higher leverage, which is cheaper, and greater reliance on wholesale funding (Bertay et al., 2013, pp. 532, 534–546).

According to their research, systemic size is indeed associated with reduced profitability; however, it is not necessarily linked to higher risk-taking as measured by the Z-score. The same applies to absolute size (Bertay et al., 2013, pp. 532–533). The authors also note that large banks tend to adopt more diversified business models, including an increased share of non-interest income, suggesting that size can help mitigate certain risks (Bertay et al., 2013, p. 535). This implies that bank size can both heighten and buffer risk, depending on institutional structures and the regulatory environment.

The Z-score is a common measure of an institution's resilience against financial distress and is therefore often used as a proxy for risk in empirical studies. It incorporates multiple risk factors, which makes it a widely accepted measure for comparative research, particularly in the context of financial stability and insolvency resistance. This is especially useful in panel data and cross-country settings.

A more precise definition is provided by Bertay et al. (2013), who explain that the Z-score indicates how many standard deviations a bank's return on assets would need to fall in a given period before the bank becomes insolvent. A higher Z-score indicates greater financial stability based on the bank's capital structure and suggests a lower likelihood of failure (Bertay et al., 2013, p. 535). Similarly, Berger et al. (2009) define the Z-score as an "inverse proxy for the firm's probability of failure" (Berger et al., 2009, p. 105).

The score is calculated by dividing the sum of the return on assets and the equity-to-assets ratio by the standard deviation of return on assets (Berger et al., 2009, p. 105). Higher levels of profitability and capitalisation increase the Z-index, whereas profit volatility, indicated by a higher standard deviation of return on assets, reduces it. Thus, the Z-score serves as a firm-level measure of financial stability and inversely proxies the likelihood of bank collapse (Berger et al., 2009, p. 106). In this master's thesis, the Z-score is used to measure bank risk-taking behaviour.

Bank size plays a significant role in moderating bank risk-taking. However, it is important to distinguish between different measures of size, as mentioned previously. Bertay et al. (2013) use both absolute and systemic size in their study. Absolute size is measured by the logarithm of total assets for a given period, whereas systemic size represents a bank's size relative to the economy's GDP. In contrast to previously discussed studies on the "too big to fail" concept, Bertay et al. (2013) find no significant link between bank size and risk, as measured by the Z-score, in their international panel data sample covering the period from 1991 to 2011.

Bitar et al. (2018), in their study of OECD countries, find that higher capital ratios are generally associated with increased efficiency and profitability, especially in the case of common and tangible equity (Bitar et al., 2018, p. 228). However, the effect of capital ratios on risk is described as mixed. For example, Tier 2 capital does not show any significant effect on bank risk (Bitar et al., 2018, p. 228). A key finding of the authors is that these relationships vary depending on bank size. Larger banks exhibit stronger correlations between capital and risk mitigation compared to smaller banks, which the authors attribute to economies of scale and more sophisticated risk management models—indicating that capital behaviour differs across institutions (Bitar et al., 2018, pp. 229, 234).

In recent years, the global economy has been affected by several major macroeconomic shocks. In this research, particular attention is given to the recent COVID-19 pandemic and the onset of the war in Ukraine. Abbas et al. (2021) demonstrate that such macroeconomic shocks, although their primary focus was on the global financial crisis of 2007–2009 and its influence on capital and risk in the United States—can significantly affect capital structure and its relationship to risk-taking. They show that during crises, risk-based capital and capital buffers exhibit a progressively negative correlation with risk, underlining the importance of strong regulatory intervention (Abbas et al., 2021, p. 8).

On the contrary, traditional capital ratios remained positively associated with risk-taking, although not as significantly (Abbas et al., 2021, p. 8). Abbas et al. (2021) also demonstrate that this relationship varies across banks with different capital and liquidity levels. The risk-taking behaviours identified in their research exhibit temporal persistence, showing how synthetic uncertainty, provoked by a macroeconomic shock, can influence capital strategies over time. Their findings also highlight the importance of considering other bank characteristics, such as size (Abbas et al., 2021, pp. 8–13).

Another important contribution is the work of Borio and Zhu (2012) on capital regulation, which emphasises the role of monetary policy and its influence on the quality of risk-taking (Borio and Zhu, 2012, p. 236). They introduce the concept of the “risk-taking channel” of monetary policy, proposing that financial institutions' perception and pricing of risk are affected by persistently low interest rates (Borio and Zhu, 2012, p. 243). Under such circumstances, banks, especially those with limited revenue streams, may be incentivised to adopt riskier lending and investment strategies, such as lowering credit standards or increasing leverage, in an attempt to boost returns (Borio and Zhu, 2012, pp. 243–244).

As most existing studies on the capital - risk-taking link and size moderation focus primarily on international samples or U.S. banks, this research aims to contribute to the European context, thereby enriching the existing literature. Moreover, the purpose of this study is to provide a more conclusive picture of the relationship between leverage, size, and risk-taking behaviour.

The current body of literature offers a comprehensive overview of how capital can have both risk-increasing and risk-reducing effects, as demonstrated by various empirical studies with differing timeframes, geographical contexts, and institutional factors. Nonetheless, limited research exists on the direct link between leverage and risk-taking under the moderation of bank size. This study focuses specifically on the interaction between leverage and bank size in the regulatory and geographical context of Austria and Germany, addressing the identified research gap. It is believed that this regional focus offers a robust basis for the investigation.

The research is based on panel data spanning a 10-year period from 2014 to 2023 and uses the Z-score as a proxy for risk-taking to test linear, non-linear, and interaction effects between leverage and bank size on risk-taking behaviour. It also incorporates macroeconomic shocks and provides a comprehensive view of risk dynamics within the defined geographical region.

3. Theoretical Framework

This paper is based on several theoretical frameworks drawn from financial literature, which help explain the relationship between leverage, risk-taking, and the moderating effect of bank size. The theoretical framework of this research explores how information asymmetry, market power, and systemic importance influence decision-making patterns, such as the tendency for increased risk-taking as bank size grows. The underlying assumption is that strategic and capital decisions are not neutral; rather, they are shaped by the availability of information. These decisions actively affect banks' incentives to assume more risk, particularly in the context of moral hazard, market inefficiencies, and regulatory constraints.

The hypotheses developed in this research are based on several key theoretical frameworks, including moral hazard theory, the "too big to fail" theory, market competition theory, and the assumed non-linearity in the relationship between size, leverage, and risk-taking, the latter being proxied by the Z-score. Chapter 3 summarises the theoretical framework in conjunction with the literature review presented in Chapter 2 and is followed by the formulation of hypotheses. This theoretical background provides the foundation for addressing the central research question of this master's thesis: *How does bank size influence the relationship between leverage and risk-taking behaviour?*

3.1. Moral Hazard and Risk-Taking

Moral hazard is one of the central theories in the financial sector. Moral hazard arises when a financial institution is incentivised to increase its risk-taking because it does not bear the full cost of its risk exposure or is protected from its consequences. In one of the foundational papers on the theory of bank risk-taking, Boyd and De Nicolo (2005) discuss this issue from the perspective of deposit insurance. They argue that the role of deposit insurance and other government initiatives that contribute to moral hazard is a critical component in several models of bank risk-taking. Specifically, they state that deposit insurance creates incentives for banks to consciously engage in riskier activities that increase the probability of failure (Boyd and De Nicolo, 2005, p. 1330).

This view is supported by other studies that show, in cases where losses are covered by deposit insurance, higher leverage encourages equity holders to take on greater risk and pursue riskier strategies. For example, Berger et al. (1995) identify that higher leverage is associated with riskier behaviour from the perspective of equity holders (Berger et al., 1995, p. 398). From this, we can conclude that capital serves as a disciplinary factor, reducing the incentive to engage in excessive risk-taking as the share of shareholders' equity at risk increases.

Increased risk is also associated with weak monitoring. In environments characterised by limited observability, moral hazard tends to increase, leading agents to make unobserved choices that result in elevated risk (Holmström, 1979, pp. 74, 92). In their later research, Holmström and Tirole (1997) further demonstrate that weak monitoring is linked to risk-enhancing decisions, particularly under capital constraints. This behaviour is especially pronounced in highly leveraged firms (Holmström and Tirole, 1997, pp. 667–668, 673).

Additional evidence on the connection between leverage, risk-taking, and moral hazard incentives is provided by Berger and DeYoung (1997), who similarly argue that thinly capitalised banks may respond to moral hazard incentives by assuming greater risk in their portfolios (Berger and DeYoung, 1997, p. 863). In more recent research, Dell'Ariccia et al. (2014) explain how low interest rates reduce the cost of borrowing (i.e. cheaper debt), which further incentivises risk-taking.

We may therefore conclude that, since debt is generally cheaper and encourages increased risk-taking, particularly when losses are absorbed by deposit insurance, government support, or similar mechanisms, leverage emerges in the literature as a factor with potentially significant influence on overall bank risk performance. A consistent link is established between higher leverage and higher risk.

Following this discussion, the first hypothesis examined in this research is as follows:

H1: *Higher leverage is associated with increased risk-taking behavior in banks.*

3.2. The influence of the Bank Size

There are different perspectives in the literature regarding the influence of bank size on risk. The "too big to fail" framework was previously introduced as a moral hazard problem based on size, whereby institutions, recognising their systemic importance, may engage in excessive risk-taking in the expectation that the government will intervene to prevent their failure.

For example, although not directly referencing the “too big to fail” theory or its associated moral hazard implications, Allen et al. (2008) show that in situations of financial distress, central banks often intervene to support systemically important institutions (Allen et al., 2008, p. 88). This observation may support the assumption that, once a bank reaches a certain level of systemic importance, it might expect external support and, as a result, may be more inclined to take on additional risk.

Conversely, other studies suggest that larger banks tend to have more diversified business models, which reduce idiosyncratic risk, though not necessarily overall risk (Bertay et al., 2013, pp. 534–535). Furthermore, Bitar et al. (2018) find that in large banks, the negative effect of capital on overall risk is more pronounced. This may result from the presence of better systems and resources in larger banks, which enable more effective monitoring and risk management (Bitar et al., 2018, p. 241). Consequently, capital has a stronger risk-reducing effect in larger institutions, likely due to their broader diversification, stronger internal governance, and more advanced risk management practices (Bitar et al., 2018, p. 253). These findings suggest that with more robust resources and frameworks, larger banks may be better equipped to reduce risk compared to smaller institutions.

Nevertheless, the empirical findings of Bertay et al. (2013) indicate that neither systemic nor absolute bank size shows a statistically significant link to risk-taking when measured by the Z-score (Bertay et al., 2013, pp. 532–533).

The literature thus provides partial support for a link between size and the overall risk profile of a financial institution. This study seeks to examine this relationship more closely within the context of Austria and Germany. With a data set encompassing over 600 banks, this research aims to provide a comprehensive understanding of how the relationship between size and risk evolves as size increases. While there is evidence that “too big to fail” banks may engage in increased risk-taking, there is also theoretical support for the idea that larger institutions may be perceived as less risky, owing to greater diversification, superior managerial practices, and a more stable systemic presence.

Accordingly, the second hypothesis is outlined as follows:

H2: *Larger banks exhibit lower risk-taking behavior compared to smaller banks.*

3.3. Moderation effect of Bank Size

Existing literature provides limited insights into the moderating effect of size on the leverage–risk relationship. However, some suggestive evidence can be found in the studies discussed earlier. Several prior papers indicate that the effect of capital or leverage may differ across banks of different size groups.

For instance, while using the liabilities-to-GDP ratio as a proxy for bank size and equity as a proxy for risk, Bertay et al. (2013) investigate how bank interest costs are influenced by control variables, risk indices, and bank size in their regression analysis. They find that large banks face lower interest expenses, whereas the liabilities-to-GDP ratio and equity have statistically insignificant coefficients. This finding leads to the assumption that systemic size influences how risk is priced (Bertay et al., 2013, p. 545). Furthermore, although they do not explicitly examine the moderating effect of size in interaction terms, the authors find that as a bank's systemic size increases, so does the sensitivity of its interest expenses to its capitalisation rate and Z-score, indicating that market discipline may be more effective among systemically large banks. This observation indirectly suggests that bank size may moderate the leverage–risk relationship (Bertay et al., 2013, p. 557).

As a further development of Hypotheses 1 and 2, the third hypothesis is proposed as follows:

H3: *The interaction between leverage and bank size moderates the relationship between leverage and risk-taking.*

This hypothesis examines how the effect of leverage differs across various bank size groups. It proposes that the impact of leverage on risk varies depending on bank size, specifically, that an increase in bank size may diminish the effect of leverage changes on bank risk, which is inversely proxied by the Z-score. For example, if a small bank increases its leverage, the associated impact on risk may be more substantial due to its simpler structure and limited systemic capacity to absorb financial shocks. In contrast, a similar increase in leverage for a larger bank may not result in a significant rise in risk, owing to better access to capital, stricter regulatory oversight, and more robust risk management systems.

To assess this hypothesis, the interaction term between bank size and equity ratio as an inverse proxy for leverage, further detailed in the research methodology, serves to capture and explain the moderating influence of size on the leverage-risk relationship.

3.4. Non-Linearity and Interaction Effect

Furthermore, this research aims to examine the potential non-linearity in the relationship between both bank size and leverage – as independent variables – and risk-taking. Although the existing literature does not explicitly address the non-linear nature of these relationships, the following hypothesis is proposed to gain a more nuanced understanding of how each variable influences risk:

H4: *The inclusion of non-linear terms (equity_ratio² and size²) captures potential diminishing or increasing marginal effects on risk-taking.*

The objective of this hypothesis is to determine whether there is a statistically significant curved relationship between size and risk, as well as between leverage and risk, and to analyse the nature of these relationships.

4. Research Methodology

4.1. Research Design and Method

This study adopts a quantitative, deductive research design to examine how bank leverage influences risk-taking behaviour and whether this relationship is moderated by bank size – and if so, how. The analysis is based on a panel data regression model using financial indicators such as total assets, total debt, total equity, and return on assets from over 600 banks in Austria and Germany during the period from 2014 to 2023. Generalised Least Squares (GLS) regression is also employed for less saturated model specifications.

Altogether, three models are presented sequentially in increasing order of complexity. The analysis is structured to test the four hypotheses outlined in Chapter 3 through the following modelling approach: a baseline linear model, an extended model incorporating non-linear terms, and a final panel data regression model including year and bank fixed effects.

The dependent variable is the Z-score, a commonly used proxy for bank insolvency risk. It serves as an inverse measure of risk-taking, meaning that a higher Z-score (i.e., greater insolvency resistance) is associated with lower risk-taking by the bank. The independent variables include bank size, equity ratio (i.e., inverse proxy for leverage), the interaction term between size and equity ratio, and the squared terms of both bank characteristics to capture potential non-linear effects.

Bank fixed effects are included to control for time-invariant heterogeneity between bank entities, such as differences in customer base, marketing strategies, brand image, loan structure, etc. and that remain constant over time at the bank level. Year fixed effects are applied to account for year-specific shocks or trends that could have affected all banks, customers, or financial instruments simultaneously, particularly within the defined geographic area.

4.2. Data Sources and Sample Selection

The dataset for this study is obtained from the S&P Capital IQ databank. This platform was chosen due to its wide recognition in the financial sector and the availability of detailed historical data, reliable and comprehensive financial metrics for a broad range of banks, as well as public and private companies. The full sample for this study consists of 467 German banks and 160 Austrian banks, resulting in a total of 627 observations. Data is collected for a 10-year period from 2014 to 2023. Such a timeframe ensures that the research captures a sufficient range of economic cycles and external shocks, including two major events: the COVID-19 pandemic and the war in Ukraine.

The sample selection criteria included the availability of financial data for the selected period, whereby the completeness of financial statements was a crucial factor. The key variables required for this research included total assets, total debt, total equity, and return on assets. To allow for meaningful comparison of bank sizes, it was ensured that both large banks and smaller regional institutions were represented in the sample. Additionally, banks with excessive missing values or extreme outliers were removed to preserve data integrity. These steps were critical for establishing a balanced dataset that maintains consistency across years and provides a solid foundation for meaningful comparisons.

Furthermore, additional data preparation steps were carried out in R Studio to perform data transformations and clean-up. To enable proper regression analysis, a transformation from wide to long format was applied to the financial indicators, which is required for panel data analysis. A panel dataset was created with one entry per bank ID (a unique number assigned in the database of S&P Capital IQ) per year. Standard deviation of return on assets, along with the Z-score and leverage measures, were calculated and added to the dataset. Subsequently, banks with extreme outliers in Z-score (above 50) were excluded from the final analysis.

4.3. Variables and Measurement

The research is based on both provided and calculated variables. To enhance understanding of how the models are constructed, this section offers a clear explanation of each variable. Overall, the study utilises the following variables to examine the relationship between bank size, leverage, and risk-taking behaviour:

<u>Dependent Variable:</u>

a) Bank Risk-Taking ($ZScore_{i,t}$): measured using the Z-score (also referred to as the Z-index in some studies), this variable serves as a proxy for assessing a bank's resilience to failure. The Z-score incorporates three components: profitability (measured by return on assets), leverage (represented by the capital ratio of equity to total assets), and the volatility of returns. It is calculated as follows:

$$Z_{i,t} = \frac{ROA_{i,t} + E/TA_{i,t}}{\sigma_{ROA_{i,t}}}$$

where ROA represents return on assets, Equity/Total Assets denotes the bank's capitalisation ratio, and σ(ROA) is the standard deviation of ROA over the sample period. A higher Z-score indicates lower risk-taking behaviour. The indices *i* and *t* refer to the bank ID number and the year, respectively. The Z-score measures how many standard deviations a bank's return on assets can decline in a given period before the bank reaches insolvency, indirectly measuring for the banks resilience (Berger et al., 2009, pp. 105–106).

Independent Variables:

a) Bank Size ($Size_{i,t}$): measured as the natural logarithm of total assets, capturing the scale of banking operations, an indirect measure for Bank size (Bertay et al., 2013, pp. 533).

$$Size = \log\,(Total\ Assets)$$

b) Equity Ratio ($EquityRatio_{i,t}$): Calculated as the commonly used ratio of total equity to total assets, this variable serves as the inverse proxy for the financial leverage (i.e. debt levels) of the bank. Prior to computing the ratio, it was ensured that both total equity and total assets were denominated in the same units (in thousands) to maintain consistency in measurement.

$$Equity\ Ratio = \frac{Total\ Equity}{Total\ Assets}$$

Interaction and Non-Linear Terms:

a) Interaction term of size and equity ratio ($Size_{i,t} * EquityRatio_{i,t}$): this term is introduced to examine whether the effect of leverage on risk-taking varies with bank size – i.e., whether the risk-leverage relationship is moderated by bank size.

b) Equity Ratio squared ($EquityRatio^2_{i,t}$): added to capture potential non-linear effects and patterns of leverage on risk-taking.

c) Size squared ($Size^2_{i,t}$): included to assess whether the impact of bank size follows a non-linear pattern.

Fixed Effects:

a) Bank Fixed Effects (ϑ_i): Control for time-invariant characteristics such as governance structures, business models, brand identity, customer satisfaction and risk management practices.

b) Year Fixed Effects (η_t): are used to account for year-specific shocks or trends that may have affected all banks, clients, or financial products simultaneously. For instance, they capture macroeconomic shocks such as the COVID-19 pandemic and the war in Ukraine.

Macroeconomic Shocks:

a) COVID Dummy: Equals 1 for years 2020 and 2021; 0 otherwise.

b) War Dummy: Equals 1 for years 2022 and 2023; 0 otherwise.

Introduced to test for robustness of the model with the year fixed effects.

4.4. Econometric Model

This research is based on three econometric models. The models are sequentially saturated, meaning the analysis begins with simpler specifications and progresses to more complex ones. The first two models use Generalised Least Squares (GLS), accounting for autocorrelation on a year-by-year basis. The main model is a panel data regression model, estimated using the plm package in R Studio, which applies fixed-effects estimation to control for year- and bank-specific heterogeneity.

1. Baseline linear model (*model 1*):

$$Zscore_{i,t}=\beta_0+\beta_1 Size_{i,t}+\beta_2 EquityRatio_{i,t}+\beta_3\left(Size_{i,t}*EquityRatio_{i,t}\right)+\varepsilon_{i,t} \quad (1)$$

This model estimates a basic linear relationship between risk and size, risk and leverage (i.e., inversely proxied by equity ratio), and risk and the interaction term, using the GLS method with an AR(1) correlation structure to account for autocorrelation over time. A lag of one period is applied to reflect the fact that outcomes in the current period are influenced by those in the previous period.

2. Extended model with non-linear effects (*model 2*):

$$Zscore_{i,t}=\beta_0+\beta_1 Size_{i,t}+\beta_2 EquityRatio_{i,t}+\beta_3\left(Size_{i,t}*EquityRatio_{i,t}\right)+\beta_4 Size^2_{i,t}+\beta_5 EquityRatio^2_{i,t}+\varepsilon_{i,t} \quad (2)$$

This model accounts for potential non-linearities in the relationships between leverage and risk-taking, as well as between size and risk-taking.

3. Panel data regression model (*model 3*):

$$Zscore_{i,t}=\beta_0+\beta_1 Size_{i,t}+\beta_2 EquityRatio_{i,t}+\beta_3\left(Size_{i,t}*EquityRatio_{i,t}\right)+\beta_4 Size_{i,t}^2+\beta_5 EquityRatio_{i,t}^2+\left(\vartheta_i+\eta_t\right)+\varepsilon_{i,t}$$

(3)

Third model is a fully saturated model. This regression incorporates bank and year fixed effects to account for unobserved heterogeneity and macroeconomic influences. Model is estimated using the *plm ()* function in R Studio (*model = "within", effect = "twoways"*).

4.5. Validity and Reliability

To ensure the validity and reliability of the research, several methodological safeguards are implemented. Internal validity is addressed through the application of fixed-effects estimation techniques, which control for unobserved heterogeneity and reduce the risk of omitted variable bias. Additionally, robust standard errors are used to account for potential heteroskedasticity, enhancing the accuracy of the statistical inference. External validity is supported by the use of a large and comprehensive panel dataset comprising over 600 German and Austrian banks observed over a 10-year period. This extensive sample enhances the generalizability of the findings to comparable banking environments within the region. Finally, the reliability of the analysis is ensured by sourcing financial and risk-related variables from S&P Capital IQ, a widely recognized and reputable financial database, which provides consistent and accurate data across institutions and time.

Model fit was evaluated using multiple criteria to ensure the robustness of the analysis. For the GLS models, fit is assessed through the Akaike Information Criterion (AIC) and residual standard error and the predictors significance, allowing for an informed comparison of model performance between the first two models. In the case of the panel data regression model with fixed-effects, F-statistics and p-values were used to test the significance of the estimated coefficients and validate the formulated hypotheses. R^2 served as an exstimation for the model fit.

This methodological framework enables a comprehensive research of the relationship between bank size, leverage (i.e. proxied by equity ratio), and risk-taking behaviour within the Austrian and German banking sectors. By applying various precise econometric techniques to a big dataset, the study offers robust empirical insights that support the derivation of meaningful conclusions. These findings contribute to a better understanding of bank risk dynamics under the influene of size and leverage levels and provide valuable implications for the design of effective risk management strategies across different bank sizes and regulatory contexts.

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5. Results and Findings

This chapter presents the empirical results of the panel data analysis investigating the relationship between bank leverage (i.e., proxied by equity ratio) and risk-taking behaviour, with a particular focus on how this relationship is moderated by bank size. The results are presented sequentially in the order of increasing model complexity. First, the baseline Generalised Least Squares (GLS) linear model (*model 1*) is introduced. This is followed by an extended model that includes non-linear terms (*model 2*). Finally, the fully specified panel data regression model with fixed effects (*model 3*) is discussed. All estimations were carried out using R Studio, employing the gls() function for the GLS models and the plm() function for the panel fixed-effects model, depending on the specification.

5.1 Presentation of collected data

Before discussing the regression outcomes, Table 5.1 provides an overview of the key variables used in the analysis.

Table 5.1: *Summary Statistics (2014–2023)*

Variable	*Mean*	*Std. Dev.*	*Min*	*Max*
ZScore	6.432	5.936	-2.925	41.641
Equity Ratio	0.094	0.045	0.012	0.807
Size	14.952	1.481	8.612	21.655
ROA	0.254	0.495	-8.742	13.046
σ(ROA)	0.178	0.914	0.004	24.305

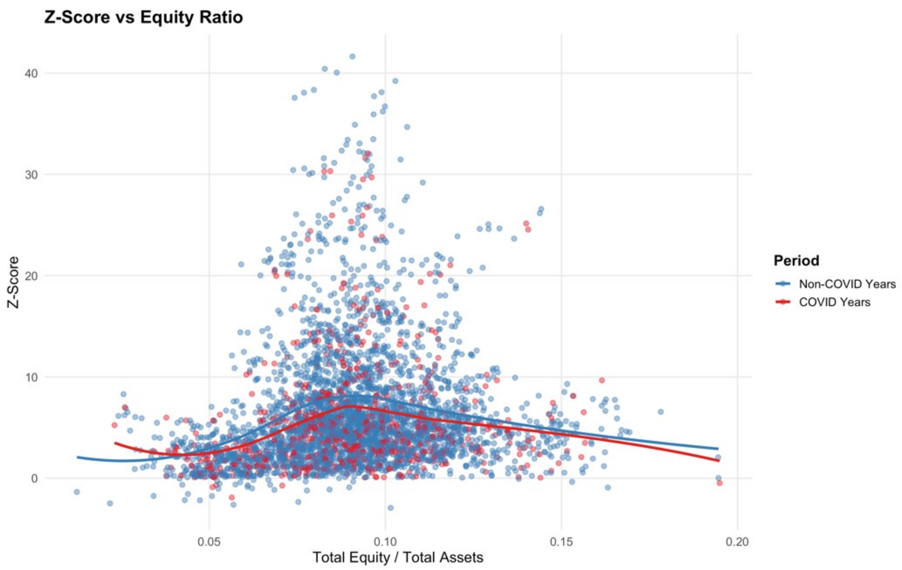
Note: Z-Score capped at 50 to remove extreme outliers.

To complement the regression analysis and provide a visual representation of the data, a series of graphical illustrations are used throughout this chapter to depict the relationships between leverage, bank size, and risk-taking. These plots offer preliminary evidence of observable trends, which are further examined in the results section, and help visualise some of the hypotheses tested in the econometric models.

Figure 5.1 illustrates the relationship between bank leverage, proxied by the total equity to total assets ratio, and bank risk-taking, inversely proxied by the Z-score. The data are presented across two distinct periods: COVID and non-COVID years. As defined in the methodology (Chapter 4), the COVID period includes the years 2020 and 2021.

The scatter plot displays individual bank-year observations (i.e., one bank in one year), filtered to include only equity ratio values between 0 and 0.2 for better graph readability. Blue points represent observations from non-COVID years, while red points correspond to the COVID years. To capture trends without assuming a specific functional form, LOESS curves are added separately for each period.

Figure 5.1: *Z-Score versus Equity Ratio: Covid and Non-Covid years*



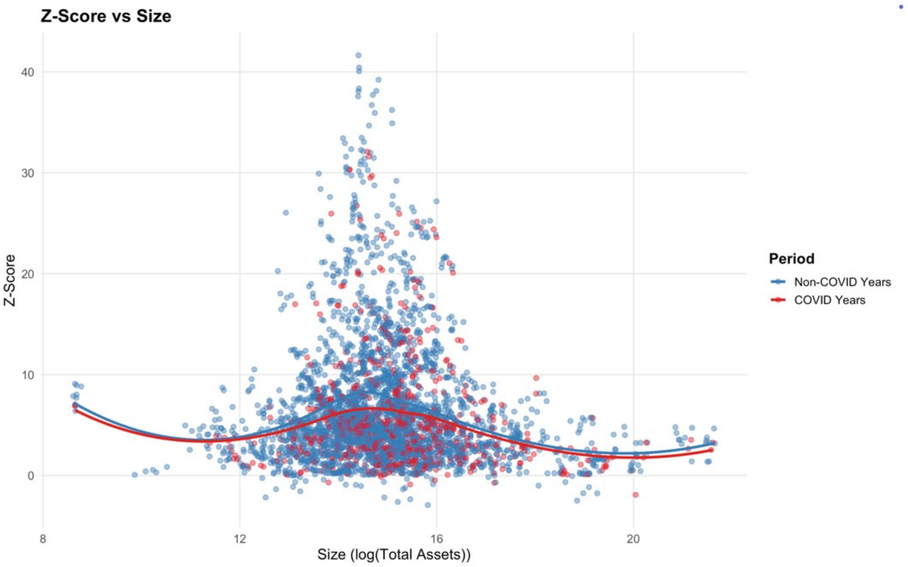
Note: Equity ratio values are capped at 0.2 to improve graph readability.

Both the blue and red LOESS lines exhibit a U-shaped relationship between equity ratio and the Z-score, suggesting a non-linear effect of leverage on bank stability. At lower levels of equity, the Z-score tends to increase, indicating diminishing risk. However, beyond a certain threshold, higher equity appears to be associated with decreasing Z-scores. This implies that debt levels are positively asscoaited with increase in risk to a certain threshhold where the effect changes. This may reflect strategic adjustments in capital structure or a survivor bias among more stable institutions that manage to operate at higher leverage levels. It is worth noting that several outliers appear isolated from the main data distribution, that have been filtered out for better data representation. Importantly, the COVID-specific trend lies mostly below the non-COVID trend. This indicates that during the COVID-19 period, banks experienced generally lower Z-scores (i.e., higher risk) at comparable equity levels (i.e. leverage).

In summary, this plot supports the hypothesis of a non-linear relationship between leverage and risk-taking. Furthermore, it suggests that macroeconomic shocks, such as the COVID-19 pandemic, may have shifted the leverage-risk relationship downward, thereby weakening bank stability regardless of capital structure. This visual evidence justifies the inclusion of quadratic equity ratio terms in the econometric model.

Similarly, Figure 5.2 reveals comparable dynamics in the relationship between the Z-score and bank size. The curved shapes of both trend lines support the appropriateness of testing for non-linearity in the influence of size on bank stability.

Figure 5.2: *Z-Score versus Bank Size: Covid and Non-Covid years*



It is also worth noting that the red line lies consistently below the blue line, reinforcing the earlier assumption that overall bank stability declines during periods of macroeconomic shock.

5.2 Baseline Linear Model

Model 1 estimates the direct relationship between leverage (i.e. measured by equity ratio), size, and their interaction on bank risk-taking. The model was estimated using the Generalised Least Squares method with an AR(1) autocorrelation structure, which accounts for year-to-year dependencies among the variables.

Table 5.2: Model 1 – Baseline Linear Model

Predictor	β	SE(β)	t-score	p-value
(Intercept)	11.245	2.156	5.217	<0.001
Size	-0.574	0.143	-4.015	<0.001***
EquityRatio	-66.609	9.191	-7.247	<0.001***
Size:EquityRatio	7.450	0.675	11.033	<0.001***

Note: Size = log(Total Assets), residuals modelled with autocorrelation with lag 1.
AIC = 12565.1
Residual Std. Error = 6.127602
AR(1) correlation structure: φ = 0.9864155
*Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1.*

The above-mentioned model investigates the linear relationship between bank risk-taking and the explanatory variables of equity ratio, size, and their interaction. Risk-taking is inversely proxied by the Z-score, which serves as a measure of bank stability. Equity Ratio inversely measures financial leverage, where the latter is defined by the amount of debt within the institution compared to total assets. Bank size is calculated as the logarithm of total assets. The model accounts for serial correlation using an AR(1) structure.

The coefficient for equity ratio is negative and statistically significant (β = –66.609, $p < 0.001^{***}$), indicating that higher leverage is associated with higher Z-scores, implying less risk-taking. This result is rather unexpected and does not align, for example, with theoretical expectations from the moral hazard literature, which suggests that increased risk-taking occurs when a financial institution does not bear the full cost of its risk exposure or is shielded from its consequences. At the same time, one can argue that equity holders perceive such capital sourcing as riskier, as they bear more risk in case of bankruptcy and are the last in line to get paid out. In later models, the negative relationship between equity ratio and Z-Score does not hold.

The coefficient for size is also negative (β = –0.574) and highly significant at the 1% level ($p = <0.001^{***}$), suggesting that, within this model specification, larger banks are associated with higher risk. This finding is somewhat counterintuitive, as larger banks are typically associated with greater diversification and more stable funding sources. However, the result may reflect implicit moral hazard stemming from “too big to fail” expectations. It is also worth noting that this effect does not persist in later models.

The interaction term between the equity ratio and size is positive (β = 7.450) and statistically significant ($p < 0.001^{***}$). To assess how the effect of the equity ratio – and therefore leverage – on the Z-Score depends on size, a partial derivative of the Z-Score with respect to the equity ratio is calculated to examine the dynamics.

$$\frac{\partial ZScore}{\partial EquityRatio} = -66.609 + 7.450 \cdot \text{Size}$$

The negative effect of the equity ratio is stronger for smaller firms. The benefits of higher equity (i.e., lower leverage) for improving financial stability (i.e., higher Z-Score) are greater for larger firms.

In addition, in smaller firms, increasing the equity ratio appears to reduce Z-Scores up until a certain threshold point. Such tendencies may reflect inefficiencies, underutilization of leverage, or other constraints.

The residuals exhibit strong autocorrelation, as indicated by the AR(1) coefficient ($\varphi = 0.9864$), which supports the use of an autocorrelated error structure in the estimation. The model's AIC of 12,565.1 serves as a benchmark for assessing relative model fit and will be used for comparison with alternative specifications introduced in subsequent models. Referring back to Figures 5.1 and 5.2, we can conclude that these results are only partially consistent with the graphical evidence, as both figures suggest the presence of non-linear relationships and therefore different dynamics.

5.3 Extended model with non-linear effects

Model 2 introduces non-linear terms to test for potential non-linearities or diminishing effects of leverage and size. It employs the same GLS estimation framework with an AR(1) correlation structure and is extended by the inclusion of squared terms for the size and equity ratio variables.

Table 5.3: Model 2 – Non-Linear GLS Regression

Predictor	**β**	**SE(β)**	**t-score**	**p-value**
(Intercept)	-43.142	10.091	-4.275	<0.001
Size	5.733	1.277	4.489	$<0.001^{***}$
EquityRatio	92.687	24.483	3.786	$<0.001^{***}$
EquityRatio^2	-69.019	10.467	-6.594	$<0.001^{***}$
Size^2	-0.182	0.041	-4.441	$<0.001^{***}$
Size:EquityRatio	-1.947	1.489	-1.308	0.191

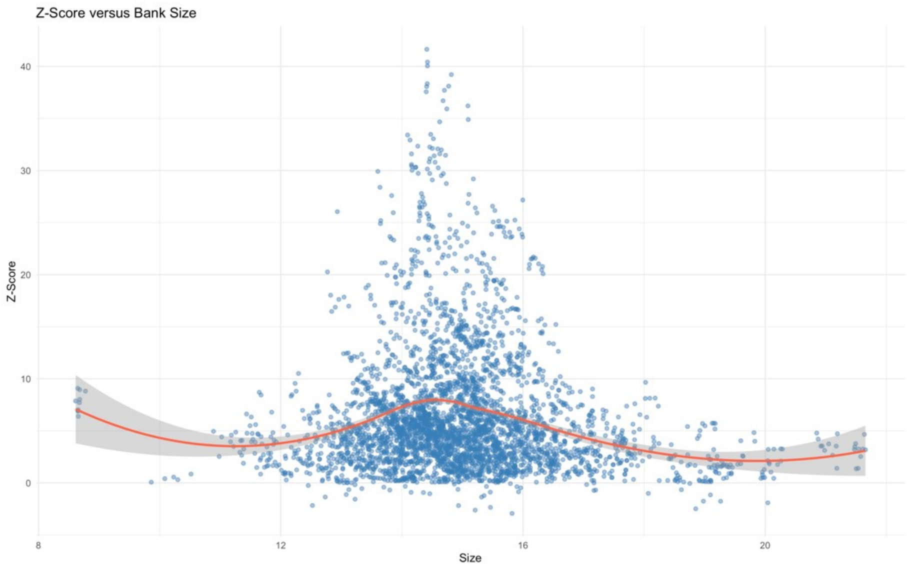
Note: Size = log(Total Assets), residuals modelled with autocorrelation with lag 1.
AIC = 12513.57
Residual Std. Error = 6.106059
AR(1) φ = 0.9865183
*Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1*

What stands out immediately is that, compared to Model 1, Size now has a positive coefficient ($\beta = 5.733$), and this result is statistically significant at the 1% significance level, indicating a strong effect. In Model 1, the negative coefficient for bank size on the Z-score suggested that larger banks were riskier. However, Model 2 includes quadratic terms, enhancing the analysis. Notably, Size^2 exhibits a negative and highly significant coefficient ($\beta = -0.182$; $p = < 0.001^{***}$).

The results for both Size and Size^2 indicate a non-linear relationship: initially, as bank size increases, the Z-score rises, signalling greater stability. However, beyond a certain threshold, the effect becomes negative, demonstrating a curvature in the relationship between bank size and risk. Therefore, the initial conclusion from model 1, that size has a negative impact on stability, is misleading unless non-linear patterns are taken into account.

For a better visualisation Figure 5.3. displays the relationship between the Z-Score and bank size. Banks size as previously defined is calculated as the logarithm of total assets.

Figure 5.3: Z-Score versus Bank Size

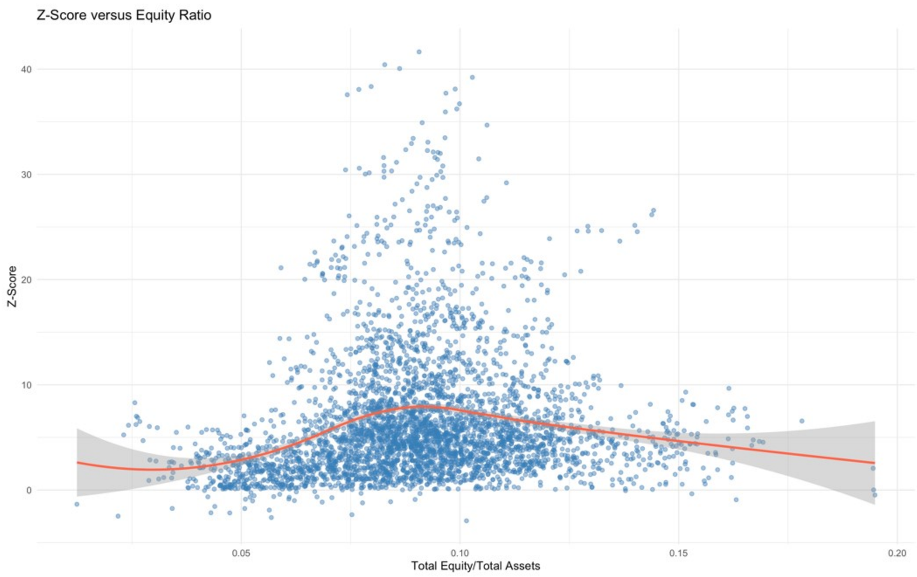


Note: Size is the logarithm of total assets

The scatter plot clearly confirms the pattern established statistically regarding the influence of bank size in the econometric model. The Z-score increases with bank size up to a certain point, after which it begins to decline. This inverted U-shaped relationship suggests that both very small and very large banks are associated with higher risk-taking, whereas mid-sized institutions tend to exhibit lower risk. The visual evidence supports the hypothesis that the relationship between bank size and risk is non-linear, thereby confirming the appropriateness of including non-linear specifications in the regression models.

The coefficient on equity ratio changes to a positive relationship and is statistically significant ($\beta = 92.687$, p = <0.001***), confirming that higher leverage is associated with increased risk-taking. At the same time, the EquityRatio² term is negative and also significant at the 1% level ($\beta = -69.019$, p = <0.001***), suggesting a potential U-shaped relationship between leverage and risk. Initially, increases in leverage are associated with rising risk, but beyond a certain threshold, further increases may lead to improved Z-scores. This could reflect internal capital optimisation by highly leveraged yet stable banks. However, given the relatively weak significance of the squared term, these results should be interpreted with caution and not overstated without further robustness checks. Figure 5.4 graphically confirms the statistical results on the U-shaped relationship between equity ratio and Z-Score and therefore leverage and risk.

Figure 5.4: Z-Score versus Equity Ratio



Note: Equity ratio values are capped at 0.2 to improve graph readability.

The interaction term between size and equity ratio is negative but statistically insignificant (β = -1.947, p = 0.191), indicating that the moderating effect of size on the leverage–risk relationship remains weak. As such, this model does not provide sufficient support for Hypothesis 3.

The slight improvement in the AIC suggests a marginally better model fit. Overall, Model 2 more effectively captures the non-linear effects of leverage and size on risk-taking behaviour, offering more nuanced insights than the baseline linear model.

5.4 Model 3: Fixed Effects Panel Data Regression Model

For Model 3, a panel data regression approach was chosen to compare the results with those obtained from the previous models. This specification incorporates both bank and year fixed effects using the plm package in R, allowing the model to control for for both unobserved bank-specific and time-specific heterogeneity. The model is estimated using the plm() function in R Studio, with the settings model = "within" and effect = "twoways".

Table 5.4: Model 3 – Fixed Effects Panel Regression

Predictor	β	SE(β)	t-score	p-value
Size	0.784	0.887	0.884	0.377
EquityRatio	103.562	16.948	6.110	$<0.000^{***}$
EquityRatio²	-65.305	7.359	-8.874	$<0.000^{***}$
Size²	-0.010	0.029	-0.351	0.725
Size:EquityRatio	-3.670	1.019	-3.601	$<0.000^{***}$

Note: Size = log(Total Assets), panel regression with bank and year fixed effects.
R-Squared: 0.088133
Adj. R-Squared: -0.047112
F-statistic: 63.7318 on 5 and 3297 DF, p-value: < 2.22e-16
*Significance levels: ***p < 0.001, **p < 0.01, *p < 0.05*

By adjusting for time-invariant characteristics at the bank level and year-specific factors, including macroeconomic shocks, this method enhances causal inference. This panel data regression model examines how size, equity ratio, and their interaction influence bank risk-taking, as measured by the Z-Score, within a controlled setting incorporating both bank fixed effects and year fixed effects. The relationship between the equity ratio and the Z-Score further provides insight into the connection between leverage and risk.

The main effect of bank size remains positive but is statistically insignificant (β = 0.784, p = 0.377). The squared term for size is also insignificant, which only partially aligns with the findings presented in the literature. The lack of significance of the size variable in Model 3 suggests that the variation in size may be largely absorbed by unobserved, time-invariant bank-specific characteristics once fixed effects are accounted for. As a result, the independent explanatory power of size is diminished in this specification. These results also do not align with the visual representation shown in Figure 5.3.

The coefficient for equity ratio is positive and highly significant (β = 103.562, p = $< 0.001^{***}$), confirming that higher leverage is strongly associated with lower Z-scores – and therefore with increased risk-taking. This effect is more pronounced than in Model 2 (β = 92.687, p = $< 0.001^{***}$), reinforcing the central role that leverage plays in shaping bank risk profiles.

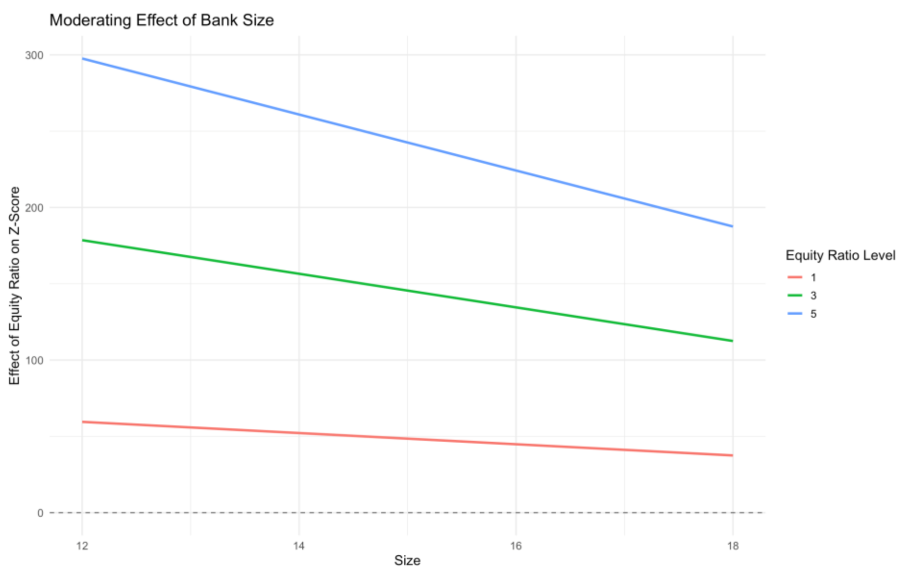
The squared term for equity ratio is negative and statistically significant (β = -65.305, p = $< 0.001^{***}$), providing strong evidence of a U-shaped relationship between leverage and risk. This pattern is also confirmed visually by Figure 5.4. The results imply that while moderate levels of leverage are associated with reduced stability, very high levels of leverage may correspond to improved Z-scores, potentially reflecting capital optimisation by more stable institutions. This finding reinforces a slightly weaker evidence for $EquityRatio^2$ observed in Model 2.

The interaction term between size and equity ratio is negative and statistically significant ($\beta = -3.670$, $p = < 0.001^{***}$), providing direct support for Hypothesis 3, which posits that bank size moderates the relationship between leverage and risk-taking. A partial derivative was taken for a clearer picture on the effect of size on the relationship between leverage and risk-taking:

$$\frac{\partial ZScore}{\partial EquityRatio} = 103.562 - 2 \cdot 65.305 \cdot \text{EquityRatio} - 3.670 \cdot \text{Size}$$

This finding suggests that as firm size increases, the positive effect of lower leverage weakens. In smaller firms, maintaining a high equity ratio (i.e., low leverage) significantly improves financial stability (i.e., higher Z-Scores), whereas in larger firms, this benefit from higher equity diminishes and, in some cases, may even reverse beyond a certain threshold. This suggests that large firms might not benefit as much—or at all—from maintaining low leverage. The non-linear and interaction effects together imply that the optimal capital structure is size-dependent. Figure 5.5 illustrates the diminishing positive effect of higher equity on bank resilience as firm size increases.

Figure 5.5: Moderating effect of Bank Size on Equity Ratio influence

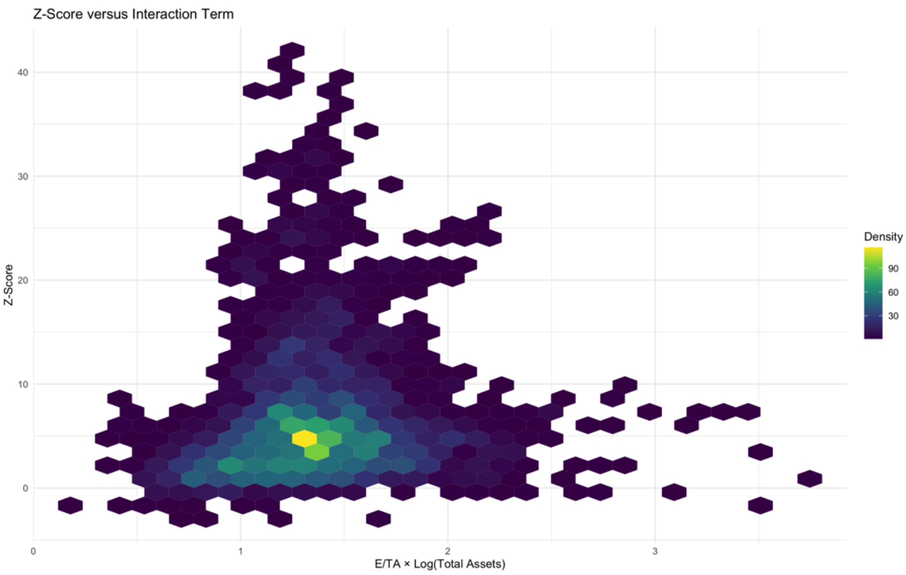


Based on the information above one can conclude that from the perspective of leverage increase, the negative coefficient on the interaction term shows that the negative impact of higher leverage on financial stability (Z-Score) is more pronounced in smaller firms. As firm size increases, this relationship weakens, suggesting that larger banks are more resilient to the risks associated with higher leverage. Possible explanations include their greater access to stable funding sources, more effective diversification, stronger governance structures, and potentially greater regulatory oversight or influence in decision-making processes.

A further robustness check was conducted by adding COVID and war dummy variables to the model. Consequengly, these variables dropped out after estimation, indicating that the year fixed effects had already accounted for this potentially omitted bias.

To further illustrate the moderating role of bank size on the effect of leverage, Figure 5.6 presents a density plot of the interaction term between equity ratio and size plotted against the Z-score. Bank risk is proxied by the Z-score.

Figure 5.6: Z-Score versus Interaction Term



Note: Equity Ratio = Total Equity/Total Assets; Size = log (total assets)

The figure uses a density plot to visualise densely clustered scatter data by aggregating observations, with colour intensity indicating the frequency of observations. The horizontal axis displays the values of the interaction term between equity ratio and size, while the vertical axis represents the Z-score. Darker shades denote areas of lower observation density, whereas bright yellow regions indicate higher concentrations of observations.

The distribution suggests that an increase in leverage (i.e., a reduction in the equity ratio) shifts an observation to the left along the X-axis. The density plot shows that banks with low interaction term values, reflecting high leverage and/or small size, display the widest dispersion in Z-scores, including many low values, which indicates higher risk and instability. As the interaction term increases, corresponding to lower leverage and/or larger size, Z-scores converge toward a moderate range, and extreme risk becomes less frequent. This supports the finding that higher leverage is particularly destabilising for smaller banks, while its adverse effect is less pronounced for larger institutions. This pattern aligns with the negative and highly significant coefficient on the interaction term in Model 3 ($\beta = -3.670$, $p < 0.001^{***}$), supporting the third hypothesis that size moderates the leverage–risk relationship, specifically by mitigating the risk-enhancing effect of leverage.

5.5 Summary of Empirical Results

Three models were presented earlier in this chapter, demonstrating a clear progression in both explanatory power and robustness. The following summary in the Table 5.5 provides a clearer overview of the results collectively.

Table 5.5: Model 1-3 – Z-Score and Capital Structure

Predictor	**M1: β**	**M1: SE(β)**	**M2: β**	**M2: SE(β)**	**M3: β**	**M3: SE(β)**
(Intercept)	11.245***	2.156	-43.142***	10.091	-	-
Size	-0.574***	0.143	5.733***	1.277	0.784	0.887
EquityRatio	-66.609***	9.191	92.687***	24.483	103.562***	16.948
EquityRatio²	-	-	-69.019***	10.467	-65.305***	7.359
Size²	-	-	-0.182***	0.041	-0.010	0.029
Size:EquityRatio	7.450***	0.675	-1.947	1.489	-3.670***	1.019
AIC	12565.1	-	12513.57	-	-	-
Residual SE	6.127602	-	6.106059	-	-	-
AR(1) Coefficient	0.9864	-	0.9865	-	-	-
R^2		-	-	-	0.088	-
Adj. R^2		-	-	-	-0.047	-
F-statistic		-	-	-	63.731***	-

Notes: Dependent variable is Z-Score. Model 1 and 2 estimated via GLS with AR(1) correction.
Model 3 estimated using two-way fixed effects (within) panel regression.
*Significance: ***p < 0.01, **p < 0.05, *p < 0.1.*

To summarise, Model 3 provides the strongest evidence for leverage-related risk and the moderating effect of bank size. However, it does not support a standalone influence of size on the Z-score, nor does it confirm a non-linear relationship between size and risk as observed in Models 1 and 2 respectively. While Model 2 captures non-linearities, it lacks robustness in the interaction terms. The significant results on bank size in Model 1 are meaningful only when considering the potential non-linearity in its relationship with risk. Otherwise, the statistical significance observed in Model 1 may be misleading if interpreted in isolation, as shown when the model is extended with squared terms.

These findings lay the empirical foundation for the discussion in Chapter 6, where the results are interpreted in the context of existing theories and previous research.

6. Discussion

This chapter interprets the empirical results of the thesis in light of the formulated hypotheses, the theoretical framework, and the relevant academic literature presented in earlier chapters. It critically links the findings to prior research, highlighting both areas of alignment and points of divergence. Furthermore, it outlines the practical implications of the results for regulatory policy and banking supervision. Finally, the chapter reflects on the methodological and empirical limitations of the study, providing context for the interpretation of results and avenues for future research.

6.1. Interpretation of Findings

The empirical results of this research contribute to the existing understanding in both the theoretical and empirical literature concerning the influence of bank size, leverage, and their interaction on banks' Z-scores among institutions of varying sizes in Austria and Germany. In the last two models presented earlier, the findings consistently support the first hypothesis: higher leverage (i.e., lower equity ratio) is associated with increased risk-taking behaviour in banks.

These results are fully aligned with the existing literature, which establishes a robust link between increases in leverage and enhanced risk-taking across different institutional and macroeconomic settings (Dell'Ariccia et al., 2014, pp. 68, 88; Bertay et al., 2013, pp. 532, 534–546; Berger et al., 1995, p. 398). The negative influence of leverage (i.e., lower equity ratio) on bank stability is most pronounced in the third model, which incorporates bank and year fixed effects, thereby accounting for both temporal and institutional heterogeneity. Notably, the model also reveals a downward-sloping curvature at significant equity ratio levels, which is an empirical pattern that is not fully explained by the existing literature referenced in this research and requires further research that is beyond the scope of this study.

The empirical findings also indicate that bank size plays a significant moderating role in the relationship between leverage and risk-taking behaviour. This effect is statistically significant in the first and third, fully saturated model. The interaction term between size and equity ratio is negative (β = -3.670) and statistically significant, suggesting that as bank size increases, the negative effect of leverage on overall bank stability diminishes. In contrast, smaller banks appear to experience a stronger adverse impact of leverage. On the other hand, the standalone effect of bank size is statistically significant only in Models 1 and 2, but not in the fully specified model. This finding is consistent with the results of Bertay et al. (2013, p. 532), who report that neither systemic nor absolute bank size has a significant effect on the Z-score.

These results support the view that larger banks may benefit from greater capital buffers, more stringent regulatory oversight, and more robust risk management practices, which help mitigate leverage-induced risks. From a different perspective, one could also argue that the "too big to fail" status provides certain implicit advantages to larger banks in managing leverage-related sensitivity. In contrast, smaller banks may lack sufficient diversification and may not possess equally strong governance structures, rendering them more sensitive to changes in leverage. This finding contributes to the understanding that regulatory approaches may need to be differentiated according to bank size, particularly in high-leverage environments.

The table below summarises the empirical results in relation to the hypotheses presented earlier in the thesis. Overall, the cumulative evidence provides strong empirical support for three out of the four hypotheses. However, the results regarding the direct effect of bank size on risk-taking behaviour remain inconclusive.

Table 6.1. Summary of Hypotheses Outcome

Hypothesis	Statement	Empirical Result	Conclusion
H1	Higher leverage is associated with increased risk-taking behavior in banks.	Significant negative effect of leverage on Z-Score in Model 2 and 3	Supported
H2	Larger banks exhibit lower risk-taking behavior compared to smaller banks.	Inverted U-shaped relationship confirmed only in model 2.	Inconclusive
H3	The interaction between leverage and bank size moderates the relationship with risk-taking.	Interaction term significant and positive in model 3	Supported
H4	Non-linear terms capture diminishing or increasing marginal effects on risk-taking.	Leverage^2 is significant in Models 2 and 3, Size^2 significant in Model 2.	Supported

6.2. Implications of Research Results

The findings of this study carry several important implications for an overall understanding of the banking sector in Austria and Germany as well as for the financial regulation, banking supervision, and institutional risk management practices.

The findings have several practical implications. Banks of all sizes should maintain sound capital structures and adhere to regulatory requirements, particularly concerning leverage ratios. However, the results also indicate that uniform leverage standards may not be suitable for all institutions. As demonstrated by Model 3, smaller banks tend to be more sensitive to leverage-induced risk as shown by the interaction term between the equity ratio and size and its impact on Z-Score. This highlights the potential value of a differentiated regulatory framework, where oversight is tailored according to bank size to enhance financial stability across the sector.

Moreover, the observed non-linearity in the relationship between leverage and risk-taking suggests that a more nuanced approach to capital regulation may be warranted. However, further research is needed to explore the nature and implications of this non-linearity in greater depth. Policymakers should carefully assess whether overly conservative capital buffers could lead to inefficiencies or provoke alternative, less visible forms of risk-taking. The empirical findings of this study may provide relevant insights for future discussions on capital buffer adjustments under Basel IV. Nonetheless, it is important to acknowledge that the scope of this research is limited to two geographical regions, Austria and Germany, and results may not be directly generalisable beyond this context.

From a supervisory perspective, the significant role of bank size in the first two models, as well as the significance of its moderating effect on the leverage-risk relationship, highlights the importance of incorporating bank-specific characteristics into risk assessment frameworks, particularly in institutions where this has not yet been adopted. Tailoring capital requirements, stress testing protocols, and supervisory practices by size category could be valuable regulatory implications. Furthermore, transparency in bank policies, market discipline, and capital decision-making empowers equity holders by granting them a degree of oversight and influence over banks' risk-taking behaviour.

6.3. Limitations of the Study

Several limitations must be acknowledged with regard to this research. The study relies on publicly available data provided by the S&P Capital IQ database, which may not fully capture off-balance-sheet exposures and may contain certain inaccuracies. Although the dataset is relatively large, these limitations should be considered when interpreting the conclusions and applying them to future research.

Another limitation lies in the geographic scope of the study, which is restricted to Austrian and German banks. While this focus helps to minimise the influence of unobserved regulatory heterogeneity, it also limits the generalisability of the findings to other regions or broader banking environments.

Additionally, potential endogeneity concerns may arise, particularly regarding reverse causality between capital structure and risk-taking behaviour. Although the use of bank and year fixed effects addresses some unobserved heterogeneity, the results could still be biased. Future studies could benefit from employing instrumental variable techniques or dynamic panel data models to better account for these concerns.

Lastly, macroeconomic shocks such as the COVID-19 pandemic and the war in Ukraine are only indirectly controlled for via time fixed effects. A more nuanced and crisis-specific analysis could offer deeper insights into banks' resilience and behavioural adjustments under conditions of elevated uncertainty.

Despite the strong coefficient-level findings in the main Model 3, the model's R-squared remains low, with only 8.8% of the variance in the Z-score explained by the independent variables. This is typical in banking risk models due to the complex and multifactorial nature of banks. The model prioritises identifying effects rather than precisely predicting individual Z-scores. Nevertheless, the F-statistic is highly significant ($p < 0.001$), indicating that the model as a whole is statistically meaningful.

To conclude, while this study provides strong empirical evidence on the complexity of the relationship between leverage, risk, and size, future research should continue to refine these relationships in the context of evolving regulatory standards, market dynamics, and other bank-specific characteristics.

7. Conclusion and Recommendations

This master's thesis has examined the relationship between bank size, leverage (i.e., proxied by equity ratio), and risk-taking behaviour, with a particular emphasis on how size moderates the leverage-risk relationship. Drawing on a panel dataset comprising financial metrics from over 600 Austrian and German banks over the period 2014 to 2023, the study provides new empirical insights with relevance for both academic research and regulatory policy.

This research was driven by the observation that capital structure remains a key determinant of bank risk in the modern financial system. Regulatory frameworks, most notably Basel III and the forthcoming Basel IV, continue to underscore the importance of robust capital structures in ensuring financial stability among intermediaries, with leverage and other capital ratios playing a central role. However, the theoretical literature offers divergent views regarding the influence of bank size, both in isolation and in its interaction with leverage, on risk-taking behaviour. So, did this research manage to answer how does bank size influence the relationship between leverage and risk-taking behaviour?

Three econometric models were estimated to analyse the relationship using Generalized Least Squares (GLS) and panel data regression techniques. The analysis began with a baseline GLS model, which was then extended by incorporating quadratic terms for equity ratio and size, followed by a fully saturated panel data model with fixed effects to control for unobserved heterogeneity and time-variant shocks.

Across all models, leverage consistently yielded statistically significant results, confirming that it is a key determinant of bank risk in these model specifications, as inversely measured by the Z-score. Higher leverage was robustly associated with lower Z-scores in the second and third models, indicating greater risk exposure. This finding supports the theoretical view that excessive debt financing heightens moral hazard and increases the likelihood of financial instability. Furthermore, the coefficients for the quadratic equity ratio term were positive and statistically significant in both Model 2 and Model 3, suggesting a non-linear relationship where risk initially rises with leverage but may level off or reverse at very high leverage levels. This non-linear dynamic requires further investigation. The results align with theoretical expectations, particularly those outlined by Dell'Ariccia et al. (2014), who argue that leverage exacerbates bank risk.

Most notably, the interaction term in Model 3 demonstrates strong statistical significance, indicating that bank size significantly moderates the relationship between leverage and risk. Specifically, the results suggest that the adverse effect of leverage on bank stability diminishes as bank size increases. This implies that smaller banks are more vulnerable to increases in leverage, while larger institutions exhibit a less pronounced risk response, likely attributable to better diversification, stronger governance structures, or their perceived systemic relevance.

This study contributes to the existing literature by empirically confirming the non-linearity of the leverage–risk relationship, a pattern that has not been consistently established in prior research. Furthermore, it underscores the moderating effect of bank size on this relationship, offering robust empirical support for differentiated regulatory approaches based on institutional size. By focusing on post-crisis data from a uniform regulatory context, namely, Austria and Germany, the study ensures contextual consistency and provides insights that are highly relevant to ongoing policy debates within the Eurozone.

The findings of this study yield several policy implications. Capital regulation should account for bank size, as smaller institutions are more vulnerable to leverage-related risk. Regulators may therefore consider stricter leverage limits or higher capital buffers for these banks. Moreover, supervisory frameworks should reflect individual bank characteristics such as size, business model, and capital strategy, rather than relying on uniform rules. Enhancing the transparency and comparability of risk disclosures could further strengthen market discipline and discourage excessive risk-taking, particularly among large banks.

Future research should explore the underlying causes of the observed upward-sloping leverage–risk relationship, especially the elevated Z-Scores seen among extreme leverage (i.e., lowest equity ratios) outliers. Expanding the analysis to include banks from other EU countries may offer valuable insights into the impact of institutional differences. Furthermore, the use of dynamic econometric methods such as GMM or SVAR is recommended to better address endogeneity concerns.

In conclusion, this thesis provides strong empirical evidence that leverage is a key driver of bank risk, with bank size acting as a significant moderating factor. These insights are relevant for both academic research and the refinement of regulatory approaches in a complex financial environment.

8. References

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