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Master's Thesis:

Too Big to Fail or Too Small to Compete?

The Impact of Basel III on Risk Taking of Large and Small Banks

Author: Maria Plotnikova (s4455487)

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Supervisor: Dr. Jianying Qiu

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1. INTRODUCTION

The aftermath of the financial crisis of 2007-2008 demonstrated that the risk-adjusted capital requirements of the Basel II regulatory framework were inadequate in preventing banks from excessive risk taking. The main response of the regulators to this problem was to strengthen the pre-existing capital requirements by introducing the new Basel III framework (Basel Committee on Banking Supervision, 2017). Similar to its predecessor, Basel III predominantly focuses on capital adequacy ratios. Namely, the framework requires banks to hold at least a minimum amount of capital relative to their risk-weighted assets (RWAs), which is assumed to increase bank's probability of solvency during times of financial distress.

However, while Basel III strengthens the regulatory requirements concerning the quality of capital held by banks, its changes to the RWA methodology used in calculating the risk-adjusted capital ratios have been modest (Leslé & Avramova, 2012; Pakravan, 2014). Previous literature dedicated to banks' risk taking has raised numerous criticism regarding the actual risk sensitivity of RWAs, thus questioning the ability of the Basel II and III frameworks to effectively limit the risk-taking behavior of banks (e.g. Leslé & Avramova, 2012; Mariathasan & Merrouche, 2014; Pakravan, 2014; Slovik, 2012; Vallascas & Hagendorff, 2013). A common consensus among previous research is that the RWA methodology leads to an asymmetric treatment of banks. Namely, banks approved to use the Internal Ratings-based (IRB) approach to estimate RWAs can "game" the regulatory system and underreport their portfolio risk, allowing them to hold less capital than required (e.g. Hakenes & Schnabel, 2011; Mariathasan & Merrouche, 2014; Vallascas & Hagendorff, 2013).

What remains less clear, however, is which banks are more likely to take relatively higher risk in the presence of the existing regulation asymmetries. As argued by VanHoose (2007), bank characteristics play an important role in determining the effect of capital regulation on risk taking. One of such characteristics that is particularly important for the national and global macroeconomic stability is bank size. Interestingly, previous literature on banks' risk taking has predominantly focused on large banks due to their high systemic importance and their "too-big-to-fail" attitude as a result of the deposit insurance schemes provided by the government (Laeven et al., 2014; Lindquist, 2004; Vallascas & Hagendorff, 2013). However, Hakenes and Schnabel (2011) show that the asymmetries inherent in the RWA methodology can result in higher risk-taking particularly for smaller banks, as they may otherwise be too small to compete with large banks that use the IRB approach. To the extent that the current regulation can induce a large number of small banks to engage in more risk taking, their collective importance for the financial sector can be comparable to that of larger banks (Haan & Poghosyan, 2011).

To this point, no research has provided an in-depth analysis of how a bank's size can determine its risk-taking behavior in the current regulatory environment. In addition, previous literature has not paid much attention to the fact that this regulatory environment also varies on the national level, with banks from some countries having more room to exhaust the existing asymmetries, and some less. This

thesis aims to fill in these gaps and shed more light on the consequences of the Basel III framework on banks' risk taking by tackling the following research question: "*How does Basel III affect risk taking of banks of different sizes?*" Examining this question is of particular importance for the on-going debate regarding the strengthening of capital requirements and the RWA methodology. At the moment of writing, the Basel Committee has already started to design a new framework, Basel IV, in which changes are being proposed with regard to limiting flexibility of the internal models (Deutsche Bank, 2018). If the RWA methodology under Basel III fails to substantially mitigate banks' risk taking, this calls for a revision of the existing regulatory framework in Basel IV. Furthermore, if the current Basel III regulations affect banks of different sizes differently, with a particular group of banks having more room to circumvent the regulatory requirements, this can lead to economically important implications in terms of competitiveness of the banking sector. Last but not least, knowing the exact mechanisms and channels through which increases in risk taking can occur can aid policymakers across the globe in fine-tuning or designing bank regulations.

This research adds to the existing empirical literature on risk-adjusted capital requirements and banks' risk taking on three counts. Firstly, this thesis is first to explicitly analyze the opportunities and incentives of banks of different sizes to engage in risk taking, while contrasting several alternative risk-taking measures as opposed to the regulatory RWA-based measure. Secondly, in line with Matejašák et al. (2009), this thesis acknowledges the differences in the implementation of Basel III in different regulatory environments and aims to account for them by testing its predictions on a sample of banks of different sizes from the EU and the US. Finally, this thesis will focus on the post-crisis period that is marked by the implementation of the new Basel III regulations, whereas previous literature mostly analyzed the periods prior to the 2007-2008 financial crisis.

The results of the mediation model constructed in this thesis revealed that the IRB approach serves as a mediator in the relationship between bank size and risk taking as large banks are more likely to adopt IRB. Consequently, while small banks in the sample were found hold riskier portfolios than large banks, the IRB approach allows large banks to underreport their RWAs and engage in higher risk taking. These findings thus highlight the shortcomings of RWAs as an indicator of risk taking and show that the current Basel III framework leads to an increase in risk taking of both large and small banks.

The thesis is structured as follows. Chapter 2 will provide a concise literature review, formulate the theoretical framework, and introduce the hypotheses. Chapter 3 will elaborate upon the data and methods used for analysis. Chapter 4 will exhibit and discuss the main results as well as robustness check. Finally, Chapter 5 will summarize the results, discuss the directions for further research, and provide advice for policymakers.

2. THEORETICAL FRAMEWORK & HYPOTHESES DEVELOPMENT

2.1 Literature review

The theoretical underpinning behind the introduction of risk-adjusted bank capital regulation is unambiguous: in the absence of minimum capital requirements, value-maximizing bank shareholders may have incentives to take on higher risks, while holding insufficient equity to absorb potential losses. Hence, imposing minimum capital requirements that are tied to the bank's portfolio risk is assumed to limit banks' ex-ante risk taking by increasing shareholders' exposure to the risks associated with their investments (Vallascas & Hagendorff, 2013). In practice, these considerations have inspired global regulators to design the RWA methodology, which is currently implemented in the calculations of all Basel II and III capital ratios. This methodology is expected to encourage banks to limit their risk taking in order to avoid the costs of having to accumulate more capital (VanHoose, 2007).¹

However, in the presence of asymmetric information between bank managers and regulators, the ability of such capital regulation to constrain banks' risk taking can be questioned (Tanda, 2015).² Firstly, regulators have to rely on the ex-ante information regarding banks' portfolio risk provided by the bank managers themselves. As managers realize that reporting higher levels of risk results in having to accumulate more capital, they have an incentive to initially underreport their portfolio risk, creating the problem of adverse selection (Blum, 2008). Secondly, the problem of moral hazard is also present in banks' behavior and largely pertains to the existing government deposit insurance schemes which banks have incentives to exploit (Jokipii & Milne, 2011; Tanda, 2015). This problem also translates into the "too-big-to-fail" attitude adopted by large systemically important banks, which are inclined to take on excessive risks in the anticipation of government bailouts (Farhi & Tirole, 2012; Laeven et al., 2014). Furthermore, assuming that risk-adjusted capital requirements can have an effect on the banks' portfolio risk choice, these requirements also need to be highly calibrated to the actual riskiness of bank assets (Vallascas & Hagendorff, 2013). Alternatively, low risk sensitivity of capital requirements can encourage banks to engage in capital arbitrage, especially since the costs of holding additional capital can be high. Consequently, discrepancies between the regulatory measure of risk and the actual bank portfolio risk can lead to a riskier banking sector and undermine the credibility of the capital regulation (Vallascas & Hagendorff, 2013).

While there exist multiple theoretical models for studying banks' risk-taking behavior under the risk-adjusted capital regulations (e.g. Besanko & Kanatas, 1996; Hakenes & Schnabel, 2011; Repullo, 2004; Rime, 2005), VanHoose (2007) notes that the overall outcomes of these models are ambiguous. It thus remains unclear on the theoretical level whether imposing risk-adjusted capital requirements necessarily constrains the risk-taking behavior of banks. According to VanHoose, the

¹ The RWA methodology will be discussed in detail in Section 2.2 of this chapter.

² For more detailed discussion of the problem of information asymmetry in the bank capital regulation literature, see VanHoose (2007).

majority of the respective models focus on a single supposedly representative bank and its response to capital regulation, which has little resemblance to the actual banking system in which there are heterogeneous institutions that may face different capital regulation exposures (VanHoose, 2007). For instance, in their imperfect information model, Besanko and Kanatas (1996) show that the effect of capital regulation on banks' risk taking is not monotonic and thus depends on bank's particular characteristics, such as bank size or bank capitalization.

In contrast to these theories, however, recent empirical research dedicated to the effect of the risk-adjusted bank capital requirements on risk taking has paid more attention to banks' characteristics. One of the characteristics that is most frequently used in the research on banks' risk taking as a control variable or considered when selecting a sample is bank size (e.g. (Camara et al., 2013; Jokipii & Milne, 2011; Lindquist, 2004; Mariathasan & Merrouche, 2014; Matejašák et al., 2009; Teixeira et al., 2014; Vallascas & Hagendorff, 2013)). However, most of the literature that discusses bank size and its effect on a bank's risk taking focuses on large banks (e.g. Laeven et al., 2014; Lindquist, 2004; Vallascas & Hagendorff, 2013)). This focus is not surprising, considering the overall importance of large banks to the financial system. Due to market deregulation, large banks have significantly grown in size as well as increased in their complexity and are now considerably more involved in market-based activities as opposed to smaller banks (Laeven et al., 2014). Berger et al. (2001) also note that due to the recent M&A wave the proportion of small banks and the assets controlled by them in the overall banking industry has decreased. Consequently, a failure of a large bank is considered to be more troublesome to the financial system relative to smaller banks. The systemic importance of large banks for the financial system also makes it particularly advantageous for them to engage in risk taking in order to maximize the benefits provided by the government safety net (Lindquist, 2004; Vallascas & Hagendorff, 2013).

Nevertheless, Haan and Poghosyan (2011) argue that the importance of smaller banks should not be underestimated: if they behave similarly, smaller banks can collectively become too important to fail. Small banks perform different economic functions than large banks. For instance, they constitute an important source of financing for small businesses and firms (Haan & Poghosyan, 2011). Small banks were also found to be more perceptive to the "soft" type of information which requires closer relationship with the borrowers that large banks usually lack (Berger et al., 2001; Haan & Poghosyan, 2011). Relative to larger banks, however, small banks lack the ability to diversify their portfolio and thus may bear more risk than large banks (Haan & Poghosyan, 2011; Stever, 2007; Tanda, 2015).

There is thus no clear-cut evidence on whether large or small banks are more likely to take larger risks under the current risk-adjusted capital regulation. Furthermore, there has not been conducted any empirical study that explicitly focuses on the differences in risk taking between banks of different sizes. Most of the research dedicated to banks' risk taking was conducted using a sample of large banks (Laeven & Levine, 2009; Lindquist, 2004; Vallascas & Hagendorff, 2013), which provides limited inference with regard to the behavior of small banks. This thesis aims to fill this research gap by exploring the relationship between risk taking and bank size under the current Basel III regulatory

framework. It considers the regulatory circumstances in which both large and small banks operate and argues that the mechanism through which bank size affects a bank's risk taking is directly related to the RWA methodology under which banks currently calculate their Basel III capital requirements. Section 2.2 of this chapter will discuss the RWA methodology and its implications for banks' risk taking, while Sections 2.3 and 2.4 will establish a potential mechanism through which bank size may affect risk taking under Basel III.

2.2 Basel III and the RWA methodology

In order to establish the mechanism through which bank size can affect risk taking under Basel III, it is important to first discuss the implications of the Basel III framework for banks' risk taking. The Basel III framework was designed by the Bank for International Settlements (BIS) as a response to the aftermath of the global financial crisis of 2007-2008. More specifically, the crisis revealed the shortcomings of the previously adopted Basel II regulatory framework which overlooked the presence of systemic risk in the banking sector, despite banks accumulating sufficient capital under the required ratios (Basel Committee on Banking Supervision, 2017). The newly introduced Basel III reforms thus aim to strengthen the micro-prudential regulations during stressful periods, and ensure the macro-prudential approach in regulation in order to circumvent procyclicality in the banking sector (Walker, 2011).³

However, despite the global implementation of the Basel III capital standards, the academic community has raised numerous questions regarding the ability of both Basel II and III to effectively limit the risk-taking behavior of banks (e.g. Pakravan, 2014; Slovik, 2012; VanHoose, 2007). This criticism particularly refers to the risk sensitivity of the RWA methodology, which had been originally adopted by Basel II and was later incorporated in Basel III without substantial changes (Leslé & Avramova, 2012). The importance of the RWA methodology in the current regulatory environment is significant: RWAs serve as a denominator in the majority of the capital ratios and thus determine whether a bank meets the capital requirements, i.e.:

$$CAR = \frac{\text{Regulatory capital}}{\text{Total RWAs}}$$

The RWAs are calculated by weighting banks' assets according to the "bucket system" developed by the BIS, in which riskless assets (e.g. cash) receive a weight of 0%, with the weighting increasing in accordance with the credit risk of a particular asset class. The original RWA approach was meant to create a common risk measure, while effectively matching the capital invested in assets with their riskiness and timely identifying the occurrence of destabilizing bubbles (Leslé & Avramova, 2012). However, as argued by Pakravan (2014), the consequences of the recent financial crisis revealed that the RWA approach failed on all three counts, with the problem being not only structural but also

³ For more information on the novelties introduced in Basel III, see the summary published by the BIS (2017) and the reviewing article by Allen et al. (2012).

concerning the fact that banks could easily game the system by, for instance, manipulating the risk weights. According to Slovik (2012), using RWAs results in shifting banks' focus from more conventional lending methods towards more unconventional and riskier activities that are not openly observable to the regulators. This critique against the RWA methodology introduced in Basel II can be fully extended to Basel III since the latter is "essentially a modified and augmented Basel II", with no changes made in the RWA methodology (Pakravan, 2014, p. 213).

Indeed, research (e.g. Behn et al., 2016; Mariathasan & Merrouche, 2014; Vallascas & Hagendorff, 2013) has found that the risk-adjusted capital ratios reported by banks often are not correlated with the ex-post riskiness of their portfolios, providing evidence that the RWA methodology leaves room for manipulation. More specifically, such opportunities to game the system arise from the fact that the RWA methodology can generate asymmetries between banks by allowing them to choose between two alternative approaches to calculating RWAs: the Standardized Approach (SA) and the Internal Ratings-based approach (IRB) (e.g. Antão & Lacerda, 2011; Hakenes & Schnabel, 2011; Rime, 2005; Vallascas & Hagendorff, 2013). Under the SA, banks have to rely on external risk assessments provided by the credit rating agencies, with the risk weights being set by the Basel Committee and taking only discrete values. Alternatively, banks that use the IRB approach can use their own internal models with internally generated risk parameters which can be inserted into the risk weight function provided by the Basel Committee (Antão & Lacerda, 2011). Since the business activities of banks are, by their nature, highly opaque, the introduction of the IRB approach was assumed to make banks' risk assessments more credible as banks themselves are more aware of the underlying risks of their assets. However, Blum (2008) notes that delegating risk assessments to banks using the IRB approach is contradictory to why the RWA methodology was introduced in the first place, namely because banks often have incentives to behave in a socially inefficient manner. Therefore, expecting banks to truthfully report their portfolio risk is not entirely feasible as risky banks have a strong incentive to underreport their RWAs in order to avoid accumulating costly capital (Blum, 2008).

Recent empirical studies (e.g. Behn et al., 2016; Mariathasan & Merrouche, 2014; Vallascas & Hagendorff, 2013) provide evidence that the IRB approach indeed leaves ample room for banks to manipulate their RWAs, potentially allowing them to take higher risks unobserved by the regulators. For instance, Mariathasan and Merrouche (2014) show that weakly capitalized banks report lower RWAs when approved for the IRB, whereas these banks are more likely to engage in capital arbitrage. Moreover, Vallascas and Hagendorff (2013) argue that the IRB approach led to a reduction in RWAs of banks with low-risk portfolios without appropriately penalizing banks with high-risk portfolios which also experienced a decrease in RWAs. Behn et al. (2016) also find that there is a surprisingly low correlation between banks' probabilities of default (calculated under IRB) and the actual default rates of the IRB banks. These findings thus substantially compromise the actual risk sensitivity of RWAs as a reflection of banks' risk taking.

This thesis thus argues that, under Basel III, IRB banks will exhibit relatively higher levels of risk taking than SA banks due to their ability to manipulate RWAs. More specifically, due to the high opaqueness of their activities and incentives to maximize their profits, IRB banks may underreport their RWAs while engaging in higher risk taking than observed by the supervisors. This is in contrast with the SA banks, the credit ratings of which are assessed by external parties, and are thus less likely to be manipulated. However, it is important to account for the measure of risk taking, i.e. the regulatory measure of risk taking (based on RWAs) and alternative measures of risk taking. As showed by previous research (e.g. Turk-Ariss, 2017; Vallascas & Hagendorff, 2013), measures based on RWAs may lack risk sensitivity precisely due to the opportunity of IRB banks to underreport their portfolio risk. Therefore, this thesis proposes two hypotheses:

H1a: Banks that use the IRB approach will take less risk measured in terms of RWAs than banks that use the SA.

H1b: Banks that use the IRB approach will take more risk measured by non-regulatory risk-taking measures than banks that use the SA.

While the magnitude of this manipulation by the IRB banks may differ per country or regulatory environment (as explored in Section 2.4), it can be expected that there will be significant differences between IRB and SA banks with regard to risk taking. More importantly, this thesis contrasts the regulatory measure of risk taking (based on RWAs) with alternative measures of risk taking (namely, non-performing loans and bank z-scores) and argues that these alternative measures will reflect different patterns of risk taking than RWAs. A full discussion of the risk-taking measures used in the banking literature can be found in Section 3.3.1.

2.3 Basel III asymmetries and bank size

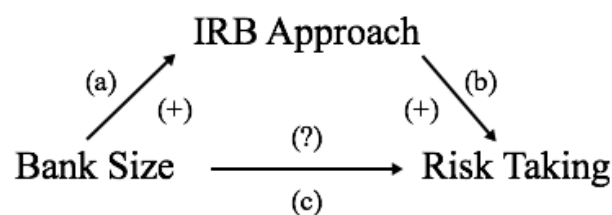
As follows from the discussion, adopting the IRB approach provides more opportunities for banks to manipulate their RWAs. If banks know that choosing the IRB approach allows them to engage in riskier activities without being “punished” accordingly through increased capital requirements, all banks would prefer IRB over SA. However, in order to use the IRB approach banks first need to receive a supervisory approval of their internal models (Brouillard, 2017). Hakenes and Schnabel (2011) mention that there are high fixed costs associated with the development of internal risk models, such as installing a sophisticated risk management system or complying with a long list of requirements set by the Basel Committee. Consequently, this may deter certain groups of banks that are not able to meet the approval requirements from adopting the IRB approach. Importantly, Hakenes and Schnabel (2011) and Behn et al. (2016) argue that large banks are more likely than small banks to adopt IRB due because of high fixed costs associated with its adoption. This leads to an asymmetric treatment of large and

small banks under Basel III, where the former tend to use IRB approach and the latter are obliged to use SA under Basel III.

What does this imply for the risk-taking behavior of large and small banks? Considering that only large banks can afford adopting IRB, the asymmetries arising from the banks' right to choose the IRB approach under Basel III can create competitive distortions particularly among large and small banks (Behn et al., 2016; Hakenes & Schnabel, 2011). In particular, as IRB allows large banks to profit from the reduction in capital requirements for safe loans, the less flexible SA approach used by smaller banks leaves them at a disadvantage. This can fiercen the competition for deposits in the banking sector, and thus induce small banks to engage in riskier projects in order to stay competitive (Hakenes & Schnabel, 2011). However, as discussed earlier, the IRB banks may face more opportunities to effectively manipulate their RWAs, allowing them to engage in more risk taking than is observable to the regulators. If larger banks are the ones which are more likely to be approved for the IRB, one can anticipate that large banks are more likely to increase their risk taking under Basel III relative to smaller banks. This implies that one would observe relatively higher portfolio risk held by large banks as opposed to small banks.

There are thus two potential scenarios to which the existing asymmetric treatment of large and small banks under Basel III can lead. On the one hand, the small banks that cannot adopt IRB can be more inclined to take higher risks as they are simply too small to compete with larger banks in the playing field shaped under Basel III. On the other hand, large banks that are too big to fail may become more induced to engage in riskier projects due to their opportunities to underestimate RWAs under IRB. Due to these two opposite scenarios, it is not feasible to predict the direction of the relationship between bank size and risk taking under Basel III. What follows from the discussion, however, is that there is high correlation between higher bank size and the usage of the IRB approach. Furthermore, as proposed under Hypothesis 1, IRB banks may indeed exhibit higher risk taking than SA banks. Therefore, it appears that under Basel III the IRB approach can serve as a mechanism through which bank size affects risk taking. A variable that can explain how the relationship between dependent and independent variables can occur is called a mediator (Baron & Kenny, 1986). Consequently, the relationship between bank size and risk taking would look as follows:

Figure 1 - The relationship between bank size and risk taking mediated by IRB



More specifically, the relationship between bank size and risk taking (*c*) can be mediated via the variable indicating whether or not a bank uses IRB. In order for that to hold, relationships (*a*) and (*b*) need to hold, too.⁴ Consequently, this thesis proposes the following hypothesis:

H2: The IRB approach serves as a mediator in the relationship between bank size and risk taking.

However, two remarks need to be made with regard to the mediation hypothesis. Firstly, Zhao et al. (2010) note that there can be several types of mediation. Traditionally, mediation is assumed to be complementary, i.e. the effect of the mediator reinforces the relationship between the two variables. It is also possible, however, that mediator suppresses this relationship, i.e. the effect of mediation is competitive. While Hypothesis 1 predicts that IRB should have a positive effect on risk taking, the ultimate mediation effect depends on whether bank size positively or negatively affects risk taking. Therefore, no prediction can be made yet with regard to the mediation type. Secondly, another way in which a third variable can determine the relationship between the other two is moderation (Baron & Kenny, 1986). Moderation implies that the effect of the independent variable depends on the level of the moderator. However, if the two variables are highly correlated, mediation effect is a more likely to occur between the variables than moderation (Baron & Kenny, 1986). While the possibility of moderation was taken into account and tested in Section 4.1, this thesis argues that mediation of the IRB approach is the mechanism that can explain the relationship between bank size and risk taking under Basel III.

2.4 Differences in national capital regulations

The main focus of this thesis is on the Basel III capital requirements and their implications for banks of different sizes. However, it is important to note that, in reality, Basel III provides a *voluntary* regulatory framework, meaning that these requirements are not applied uniformly on a global scale. For instance, while both the EU and the US follow the Basel III rules closely, there exist substantial differences in their implementation (Reynolds et al., 2013). More specifically, in the US, the bank capital requirements are modulated according to the bank size. This means that the standard Basel capital ratios represent a floor for regulatory ratios that must be met by all banks, while banks of larger sizes and higher complexity have to meet additional requirements, i.e. higher capital ratios (Masera, 2013). This, however, is not the case for the EU, where banks are treated equally regardless of their size as the regulators aim to avoid competition-distorting effects of a differential treatment. Furthermore, in the EU, IRB and SA approaches serve as alternatives, with banks having a *choice* to apply for the IRB approval. In contrast, according to the US regulations, the SA serves as a floor capital requirement, while large internationally active banks are *obliged* to use the IRB approach (U.S. Federal Reserve

⁴ The relationship between the IRB approach and risk taking is tested under hypothesis H1.

System, 2017).⁵ In addition, when evaluating capital adequacy, the US banks must calculate their RWAs under both IRB and SA approaches and apply the more stringent of the two calculations (Kini et al., 2013).

In terms of the above-held discussion, it appears that the US implementation of Basel III is relatively more responsive to the differences in bank sizes when compared to the EU. Hakenes and Schnabel (2011) argue that the competitive distortions between small and large banks, arising from the ability of banks to choose between the two RWA approaches, is one of the main setbacks of the Basel III regulation. However, higher risk sensitivity of capital requirements for smaller banks, as in the US, can mitigate these distortions (Hakenes & Schnabel, 2011). This leads to the third hypothesis of this thesis, namely:

H3: The mediation effect of the IRB approach is less strong for the US banks than for the EU banks.

As mentioned by VanHoose (2007), most of the earlier studies do not take into account the apparent differences in the capital regulation exposure that different groups of banks face. Therefore, this thesis aims to address this concern and to see how the regulatory environment large and small banks operate in can influence their risk taking.

⁵ In the US, the IRB approach is known as Advanced Approach.

3. DATA AND METHODOLOGY

3.1 Models and specifications

In order to explore the relationship between bank size, IRB and risk taking under Basel III, this thesis used several techniques. Firstly, to analyze the effect of using the IRB approach on risk taking (see Hypotheses 1a and 1b), a panel data analysis was conducted using a random effects model.⁶ Such analysis allows to observe the behavior of banks through time and is well-suited to estimate the effect of the independent variables while controlling for heterogeneity across banks. The baseline specifications for testing Hypothesis 1 are as follows:

$$Risk_{it} = \alpha_{10} + \alpha_{11}IRB_i + \alpha_{12}Size_{it} + \alpha'_{13}Controls_{it} + \epsilon_{it} \quad (1)$$

$$Risk_{it} = \alpha_{20} + \alpha_{21}IRB_i + \alpha_{22}Size_{it} + \alpha_{23}IRB_i * Size_{it} + \alpha'_{24}Controls_{it} + \epsilon_{it} \quad (2),$$

where $Risk_{it}$ is a variable reflecting risk taking of a bank i at time t , IRB_i is a time-invariant dummy variable denoting whether or not the bank was approved for using IRB, and $Size_{it}$ is a variable indicating bank size. Adding an interaction term between IRB and bank size ($IRB_i * Size_{it}$) allows to compare the effect of bank size on risk taking for the IRB banks (estimated by $\alpha_{22} + \alpha_{23}$) and the SA banks (estimated by α_{22}). Moreover, the sum of the coefficients $\alpha_{21} + \alpha_{23} * Size_{it}$ shows the effect of using the IRB approach for a bank of a given size. Consequently, these two specifications allow to explore the direct effect of the IRB approach on bank's risk taking as discussed in Hypotheses 1a and 1b, and shed more light on the potential moderation effect of the IRB approach on risk taking of banks of different sizes.

However, due to the ambiguous predictions regarding the risk-taking behavior of small and big banks under Basel III, it is also vital to examine whether using the IRB approach can mediate the relationship between bank size and risk taking. In order to test whether such an effect is present (see Hypothesis 2 and Figure 1), this thesis departed from a standard approach to testing mediation popularized by Baron and Kenny (1986). Their approach involves estimating three separate regressions: one where the mediating variable (MV) is regressed on the independent variable (IV), one where the dependent variable (DV) is regressed on the IV, and one where DV is regressed on both IV and MV. To establish mediation, the first two regressions should yield significant results. If the mediating effect does exist, in the third equation, MV must significantly affect DV, while the effect of the IV must be less than in the second equation and have a reduced predictive power. According to the model developed in this thesis (see Figure 1), $RISK_{it}$ takes on the role of the DV, while $SIZE_{it}$ and IRB_i are the IV and the MV respectively. However, Kenny (2018) and VanderWeele (2016) warn that having binary (or dichotomous) variables in the mediation analysis requires a different approach, e.g. a logistic or a probit

⁶ A fixed effects model commonly used in estimating panel data would omit the time-invariant independent variable of interest, i.e. the IRB dummy. See Section 4.1 for further discussion of the random effects model choice.

regression. Consequently, the following three equations were estimated in order to test the mediation hypothesis:

$$\text{logit}\{P(\text{IRB}_i = 1)\} = \beta_{10} + \beta_{11}\text{Size}_i + \beta'_{12}\text{Controls}_i + \epsilon_i \quad (3)$$

$$\text{Risk}_i = \beta_{20} + \beta_{21}\text{Size}_i + \beta'_{22}\text{Controls}_i + \epsilon_i \quad (4)$$

$$\text{Risk}_i = \beta_{30} + \beta_{31}\text{Size}_i + \beta_{32}\text{IRB}_i + \beta'_{33}\text{Controls}_i + \epsilon_i \quad (5)$$

In his guide on mediation analysis for social sciences, VanderWeele (2016) refers to the approach of Baron and Kenny (1986) as the product method, where the product $\beta_{11} * \beta_{32}$ would capture the indirect effect of bank size on risk taking through using IRB (i.e. the effect of the IV on the MV multiplied by the effect of MV on IV). Following this logic, the direct effect of size on risk taking would be measured by β_{31} .⁷ A common approach to testing the significance of both effects is to use the Sobel test (Sobel, 1986). However, Kenny (2018) argues that with binary MVs (such as the IRB dummy variable) the Sobel test is problematic, as there can exist difficulties with standardizing the coefficients to calculate the indirect effect. To deal with this problem as well as to overcome the drawbacks of the Sobel test, a bias-corrected bootstrap test (using 500 replications) suggested by Zhao et al. (2010) was used to test the significance of the three effects (i.e. direct, indirect, and total). Furthermore, an interaction effect between IRB and bank size ($\text{IRB}_i * \text{Size}_{it}$) was also included in additional tests as a second MV in order to test for moderated mediation (Baron & Kenny, 1986; Kenny, 2018; VanderWeele, 2016). Last but not least, Hypothesis 3 was tested using specifications (3)-(5) for two separate samples: the EU banks and the US banks.

To confirm the robustness of the main results, two methods were used. Firstly, the analysis was replicated using an alternative measure of bank size (logarithm of total revenues). Secondly, a probit regression was used instead of logistic regression for mediation analysis in order to compare the results. All results are presented in discussed in Chapter 4.

3.2 Sample

The bank-level data for the panel dataset used in this research was retrieved from the Orbis Bank Focus database. In addition, the information regarding the use of IRB was hand-collected from the individual annual reports and Pillar III disclosures of banks.⁸ The data on the IRB approval was recorded only if a bank explicitly indicated whether or not it was approved for the use of the IRB approach to calculate

⁷ VanderWeele (2016) warns that in order to infer the direct and the indirect effects from these equations, four fairly strong assumptions must be made regarding the absence of confounders affecting the relationships between the three variables involved in mediation. In addition, the mediation model assumes no measurement error and no causal effect of DV on IV (Baron & Kenny, 1986).

⁸ An exception was a list of the IRB-approved banks provided by the central bank of Germany (Bundesbank) on its website, and the guidelines regarding the use of the advanced (IRB) approaches implemented by the Federal Reserve Bank of America.

RWAs (see Section 3.3 for more information). The data regarding country macroeconomic variables was retrieved from the World Bank and the OECD databases. The analyzed time period spans from 2012 until 2016. The year 2012 was chosen as a starting point for two reasons. Firstly, most of the research agrees that by 2012, the world economy had already sufficiently recovered from the 2007-2008 financial crisis, and thus the effect of the crisis on banks' behavior should be minimal in this sample. Secondly, by 2012, the Basel Committee on Banking Supervision has already announced the start of implementation of the Basel III capital requirements in the consecutive years, meaning that by that time banks were already aware of the new requirements and were preparing to meet them. Therefore, there are no expected extreme events in this time period that could substantially impact banks' risk taking.

The dataset covers in total 546 banks from several countries, namely the 15 EU member states and the US in order to compare the effect of the differences in the Basel III application on bank's risk taking.⁹ Only banks with consolidated balance sheets (i.e. codes C1 and C2 as categorized in the Orbis Bank Focus database) were used. Furthermore, following the procedure suggested by Vallascas and Hagendorff (2013) for sample selection, certain types of banks were excluded from the sample. Namely, cooperative banks, government-owned institutions, and Islamic banks were omitted as their risk choice decisions are less likely to be affected by the shareholder value considerations. Last but not least, only those banks that are categorized by Orbis Bank Focus as ultimate owners were selected to account for the possibility that the risk choices made by subsidiaries were initiated by the holding bank.

3.3 Variables

3.3.1 Dependent variable

The main DV in this analysis is risk taking, defined as an overall portfolio risk of a particular bank in a specific year. The measure of a bank's risk taking used by the regulators is RWA/TA, which is the ratio of risk-weighted assets relative to the total assets of a bank. Starting from Basel II and III, RWAs are assumed to capture the overall risk of the bank, as they account for credit, market, and operational risks (Antão & Lacerda, 2011; Tanda, 2015). However, when treating RWAs as a measure of a bank's risk taking, it is important to bear in mind that this measure of bank's portfolio risk remains contested and needs to be treated with caution.¹⁰ As indicated earlier, there is evidence that banks can manipulate and underreport their RWAs in order to increase their capital ratios, which undermines the validity of the reported numbers (e.g. Mariathan & Merrouche, 2014; Vallascas & Hagendorff, 2013). Furthermore, the arbitrary risk weights assigned to the asset buckets were designed by the regulators and are thus not exempt from error. Therefore, for the purpose of this thesis, several alternative

⁹ Due to the data constraints for the other EU countries, only the 15 largest member states were selected.

¹⁰ For instance, Mariathan and Merrouche (2014) refer to RWA/TA as "reported riskiness" in order to highlight the difference between the actual risk taking and the risk taking measured under the Basel regulations.

measures of risk taking will be used to contrast them with the regulatory measure of risk (RWA/TA) and to capture the actual risk exposure of a bank's portfolio.

Tanda (2015) mentions that studies examining banks' risk taking tend to rely on two other alternative measures of risk: one based on standard deviation of the market value of equity, and another one based on non-performing loans. However, as this study aims to analyze a wide sample of banks of different sizes, many of which are not publicly listed, it appears to be unreasonable to use measures based on the market value of equity. Consequently, this thesis will use the ratio of non-performing loans to total assets as a second measure of banks' risk taking. Jokipii and Milne (2011) mention that while RWA/TA is an ex-ante measure of risk, a measure based on the non-performing loans can reflect bank's risk ex post. However, Tanda (2015) warns that this measure captures only bank's credit risk, and is more representative for those banks that follow a traditional lending model of business. As an alternative, this thesis considers a third measure of risk taking, namely a bank's z-score. In line with Laeven and Levine (2009), a natural logarithm of the z-score of a bank (defined as the return on assets plus the capital asset ratio divided by the standard deviation of asset returns) indicates an inverse probability of a bank's default and can serve as another proxy for risk taking. Therefore, the higher the z-score, the more stable the bank is. These two measures will thus serve as alternatives to the regulatory measure of risk, RWA/TA, and are expected to reflect different patterns of risk taking than RWA/TA as the latter were found to be often manipulated by banks.

3.3.2 Independent variable

The main IV that is hypothesized to affect both IRB and risk taking is bank size. Traditionally, bank size is measured as a logarithm of total assets (TA) of a bank. While Schildbach (2017) notes that there are other measures of bank size that are less ambiguous than total assets, this thesis will predominantly rely on the TA approach to measuring bank size. This measure of bank size is consistent with previous literature (e.g. Laeven & Levine, 2009; Mariathasan & Merrouche, 2014; Matejašák et al., 2009; Teixeira et al., 2014; Vallascas & Hagendorff, 2013) and thus allows to compare the results of this thesis to earlier findings.

For the robustness purposes, a logarithm of total revenues was used as an alternative proxy for bank size. Schildbach (2017) finds measuring bank size based on revenues is more advantageous and straightforward than the alternatives. Total revenues were calculated as a sum of net interest income, net fee and commissions income, net trading and other income, as proposed by Schildbach (2017). Another possibility could be to examine the mediation effect of IRB on the two separate groups of banks (i.e. large banks and small banks). The sample would thus be split based on the median bank size in the sample. However, since bank size is highly correlated with the use of the IRB approach, this technique would not show any variation in the IRB dummy for both groups (it would simply be equal to 1 for large banks, and 0 for small banks). Therefore, this analysis could not be implemented.

3.3.3 Mediator

As argued in this thesis, the relationship between bank size and risk taking may not be moderated, but rather mediated through the variable indicating whether or not a bank implemented (i.e. was approved for the use of) IRB to calculating its RWAs. The IRB variable is usually proxied by a dummy variable that takes a value of 1 if a bank was approved to implement IRB, and 0 if otherwise (e.g. Mariathasan & Merrouche, 2014). Currently, there exist two types of the IRB approach: Foundation IRB (F-IRB) and Advanced IRB (A-IRB) (Basel Committee on Banking Supervision, 2017). Under both approaches, banks are allowed to use their internal models for estimating probability of default. However, unlike those banks that use F-RIB, A-IRB banks are also allowed to estimate loss given default, life-to-maturity, and exposure at default based on their internal models. In this thesis, the IRB variable will take a value of 1 if a bank was approved to use both A-IRB or F-IRB approaches to calculating its RWAs. It is thus assumed that any type of the IRB approach in which a bank receives autonomy to calculate its own RWAs can lead to opportunistic behavior. Accordingly, if a bank uses SA, the IRB dummy will take a value of 0.

The data was hand-collected from annual reports and Pillar III disclosures of banks, and was recorded only if a bank explicitly reported which approach it uses. While most of the banks did indicate in what year they were approved for the use of the IRB, an overwhelming majority received the approval before the start of the examined time period (i.e. before 2012). More specifically, out of 60 IRB-approved banks in the sample, only 5 EU banks received this approval shortly after 2012 (see Appendix 1 for the frequency of IRB and SA banks in the sample per country). In addition, while all the US IRB-approved banks (15 banks out of 60) officially received the regulatory approval in 2014,¹¹ these banks had already completed their parallel run before this date, i.e. they had already conducted a satisfactory trial using the A-IRB models before 2014. It can thus be argued that even those banks that officially received their approval after 2012 are likely to have had similar characteristics as other IRB banks in the sample, since their internal models were approved for the use shortly after. Consequently, the IRB dummy variable is treated as a time-invariant variable in this analysis, creating two bank categories with potentially different inherent characteristics and preferences for risk-taking: IRB banks and SA banks.

3.3.4 Control variables

In order to rule out spurious relationships and disentangle the effects of the IRB approval and bank size on risk taking from other factors that affect a bank's portfolio risk, this thesis will include several control variables that were found to be significantly correlated with risk taking in previous literature. Table 1

¹¹ For more information, see the Joint Press Release of the Federal Reserve System from February 21, 2014 (can be accessed via <https://www.federalreserve.gov/newsevents/pressreleases/bcreg20140221a.htm>).

provides an overview of all the variables used in the analysis, indicating how they were measured and what effect they are expected to have on risk taking.

Firstly, several bank-specific control variables were considered. In previous studies, bank capitalization was found to be a significant determinant of bank's risk taking (e.g. Camara et al., 2013; Mariathasan & Merrouche, 2014; Matejašák et al., 2009; Vallascas & Hagendorff, 2013). However, the evidence on the effect of capitalization on risk taking is mixed, as some find that weakly capitalized banks are more likely to accrue more risk when closer to the regulatory capital threshold (Mariathasan & Merrouche, 2014; Matejašák et al., 2009), while others argue that highly capitalized banks have more opportunities to engage in risk taking as they are less scrutinized by the regulators (Vallascas & Hagendorff, 2013). While the direction of the effect is unclear, Camara et al. (2013) find that banks react differently in terms of risk taking to capital changes, highlighting the importance of controlling for bank's ex-ante capitalization. Similar to Vallascas and Hagendorff (2013), bank capitalization is measured as the percentage difference between bank's Tier 1 capital and the regulatory minimum (i.e. 6%). Profitability can also affect a bank's incentives for risk taking. Vallascas and Hagendorff (2013) argue that profitable banks are less inclined to engage in capital arbitrage and are negatively associated with RWA/TA. Consequently, more profitable banks can be expected to engage in less risk taking, and thus a negative effect can be anticipated. Profitability is measured as ROA, defined as net income over average TA in that year. Furthermore, bank liquidity can have an impact on risk taking as banks with more liquid assets may hold lower capital buffers. In addition, when required, such banks can easily sell their liquid assets in order to increase their capitalization (Jokipii & Milne, 2011). It can thus be expected that banks with more liquid assets (as a percentage of total assets) can engage in more risk taking, as they are able to convert their assets relatively quickly to cash during a fire sale. Moreover, Matejašák et al. (2009) point out that loan loss provisions relative to gross loans represent funds that are set aside by banks to cover bad loans, and can thus proxy for asset quality. Consequently, banks with lower asset quality (more loan loss provisions to gross loans) are expected to engage in higher risk taking. Last but not least, Vallascas and Hagendorff (2013) find that non-interest income relative to operating revenues can proxy for bank's off-balance sheet activities, which can positively affect a bank's risk taking.

Furthermore, this thesis also includes country-specific control variables to account for changes in the macroeconomic conditions of countries as well as difference in regulatory conditions in which banks from different countries operate in. In line with Mariathasan and Merrouche (2014) and Vallascas and Hagendorff (2013), this thesis includes annual GDP growth, debt-to-GDP ratio, and short-term interest rate as country-level control variables. As argued by Vallascas and Hagendorff (2013), the procyclicality of Basel capital requirements implies that during worse economic conditions the requirements may become stricter, potentially limiting banks' opportunity to seize risks. Last but not least, previous literature argues that country-specific regulatory scrutiny also plays an important role in determining banks' opportunities available for risk taking. Consequently, this thesis will control for the

strength of banking supervision by using the an index of overall bank activity and ownership restrictiveness based on the results of a survey conducted by Barth et al., (2001), commonly used in previous studies (e.g. Laeven & Levine, 2009; Mariathasan & Merrouche, 2014; Matejašák et al., 2009; Vallascas & Hagedorff, 2013). As noted by Schaeck and Cihák (2012), the overall institutional and regulatory environment in which banks operate in does not change quickly, and thus the absence of time variation in this variable does not pose a problem for statistical inference.

Table 1 - List of variables, their measures, and hypothesized effects

<i>Main variables</i>	<i>Measure</i>	<i>Expected effect on risk taking</i>
<i>Dependent variable</i>	RWA/TA (+)	
Risk taking (<i>Risk_{it}</i>)	Non-performing loans/TA (NPL/TA) (+) Ln of a bank's z-score (Z-score) (-)	
<i>Independent variable</i>	Ln of total assets	
Bank size (<i>Size_{it}</i>)	Ln of total revenues	+/-?
<i>Mediator</i>		
IRB approval (<i>IRB_i</i>)	Dummy variable (0/1)	+/-?
Bank-level control variables		
Capitalization	Tier 1 capital ratio minus regulatory minimum (6%)	+/-?
Profitability	ROA (Net income/TA)	-
Liquidity	Liquid assets/Deposits & ST funding	+
Loan loss provisions	Loan loss provisions/Gross loans	+
Off-balance sheet activities	Non-interest income/operating revenues	+
Country-level control variables		
GDP growth	Annual GDP growth (%)	
Debt-to-GDP	Debt-to-GDP ratio (%)	
Interest rate	Short-term interest rate	
Banks' restrictiveness	Index of overall bank activity and ownership restrictiveness	

3.4 Summary statistics

Table 2 illustrates the summary statistics of all variables included in the analysis. The number of observations per variables varies as some observations may be missing, but the overall dataset is highly balanced. All variables (except for the interest rate), that represent percentages are expressed in terms of decimals instead of absolute percentages (see Table 1 for more information on the measures used). IRB is a dummy variable that take a value of 1 if a bank received a regulatory approval to use IRB to calculate its RWAs, and 0 otherwise. Z-scores are calculated as a ratio of the sum of a bank's ROA and its capital-to-assets ratio (total equity relative to total assets), divided by the standard deviation of ROA calculated over the sample period (in this case, 2012 and 2016). Whenever there was a missing observation per bank, z-score was not computed. In addition, whenever this thesis refers to z-score, a natural logarithm of z-score is implied. According to Laeven and Levine (2009), the distribution of bank z-scores tends to be highly skewed, and a logarithm is needed to normalize the distribution of z-scores. It has to be noted, however, that unlike RWA/TA and NPL/TA, z-scores are an inverse measure of risk taking with higher z-scores indicating lower portfolio risk. Bank size is also measured in terms of logarithms of the absolute value of total assets or total revenues. Last but not least, bank restrictiveness is measured using the index developed by Barth et al. (2011).

Table 2 - Summary statistics (winsorized at 1% and 99%)

<i>Variables</i>	<i>(1)</i> <i>N</i>	<i>(2)</i> <i>Mean</i>	<i>(3)</i> <i>S.D.</i>	<i>(4)</i> <i>Min</i>	<i>(5)</i> <i>Max</i>
<i>RISK</i>					
RWA/TA	2,100	0.65	0.19	0.12	0.97
NPL/TA	2,300	0.02	0.03	0	0.20
Z-score	2,163	6.26	1.05	3.06	8.32
<i>SIZE</i>					
Ln(TA)	2,638	15.70	1.96	9.29	21.58
Ln(TR)	2,270	12.80	1.82	9.00	18.32
<i>Other variables</i>					
IRB	2,735	0.11	0.31	0	1
Capitalization	2,121	0.09	0.05	0.01	0.36
ROA	2,631	0.01	0.02	-0.09	0.17
Liquidity	2,500	0.21	0.42	0.01	4
Loan loss provisions	2,375	0.01	0.03	0	0.22
Off-balance sheet activities	2,632	0.37	0.29	-0.15	1.10
GDP growth	2,960	0.02	0.01	-0.04	0.05
Debt-to-GDP	2,960	1.16	0.21	0.52	1.57
Interest rate	2,960	0.29	0.27	-0.66	1.25
Bank restrictiveness	2,960	2.48	0.70	1.3	3

As suggested by previous literature (e.g. Mariathasan and Merrouche, 2014), all variables (except for IRB) were winsorized at 1% and 99% level to diminish the influence of potential outliers.

Consequently, the distribution of the variables is in line with those of previous studies (e.g. Laeven & Levine, 2009; Mariathasan & Merrouche, 2014; Vallascas & Hagendorff, 2013).

Table 3 shows the correlation matrix of the main variables and the bank-level control variables. Relatively strong negative correlation can be observed between RWA/TA and IRB, and between RWA/TA and capitalization (*Capital*). This is not surprising, considering that capital ratios are directly related to banks' RWAs, while banks that adopt the IRB approach tend to experience a decrease in RWA/TA (Mariathasan & Merrouche, 2014; Vallascas & Hagendorff, 2013). Furthermore, NPL/TA appears to be strongly and positively correlated with loan loss provisions as both are related to bank's asset quality. Interestingly, the two alternative risk-taking measures (NPL/TA and Z-score) show a rather weak correlation with RWA/TA. Nevertheless, the variance inflator factor (VIF) test conducted using all variables (including the country-level control variables) showed that there is no multicollinearity between the variables (see Appendix 2).

Table 3 - Correlation matrix of the main variables and bank-level control variables

	<i>RWA/TA</i>	<i>NPL/TA</i>	<i>Z-score</i>	<i>IRB</i>	<i>Size</i>	<i>Capital</i>	<i>ROA</i>	<i>Liquidity</i>	<i>Loan loss</i>	<i>Off balance</i>
<i>RWA/TA</i>	1.000									
<i>NPL/TA</i>	-0.067*	1.000								
<i>Z-score</i>	0.176*	-0.363*	1.000							
<i>IRB</i>	-0.482*	0.153*	-0.147*	1.000						
<i>Size</i>	-0.327*	0.091*	-0.078*	0.654*	1.000					
<i>Capital</i>	-0.508*	-0.048*	0.056*	0.018	-0.085*	1.000				
<i>ROA</i>	0.139*	-0.221*	0.076*	-0.123*	-0.159*	0.207*	1.000			
<i>Liquidity</i>	-0.329*	0.083*	-0.198*	0.177*	0.142*	0.278*	0.314*	1.000		
<i>Loan loss</i>	-0.147	0.687*	-0.387*	0.189*	0.107*	0.048*	0.166*	0.206*	1.000	
<i>Off balance</i>	-0.305*	0.037	-0.230*	0.138*	0.016*	0.219*	0.328*	0.516*	0.239*	1.000

Standard errors in parentheses

** p<0.05*

4. RESULTS

4.1 The effect of the IRB approach on risk taking

Following the structure of this thesis, the first step to analyze the relationship between bank size and risk taking in the presence of the Basel III capital requirements is to examine the effect of using IRB on banks' risk taking. To do so, several regression models were tested using specification (1) and (2) from Section 3.1 using three different measures of risk taking: RWA/TA (regulatory measure), NPLs (non-performing loans to total assets), and bank's z-score. The results are presented in Table 4. Since all main variables are measured in different units, this makes the interpretation of the observed coefficients very challenging and non-intuitive. Therefore, for the purposes of clarity, all coefficients are simply interpreted in terms of small and large banks (for low and high values of bank size) and low and high risk taking.¹²

The Breusch-Pagan Lagrangian multiplier test conducted for all regressions revealed that there is a significant difference across units, and thus a random effects model would produce better estimates than a pooled OLS model. Unlike fixed effects, random effects allow to include time-invariant variables in the analysis, such as the main variable of interest in this analysis (i.e. IRB approval). In addition, as the main hypothesis of this thesis is that differences between banks (namely, their size and the usage of IRB approach) have an effect on risk taking, this model is more appropriate than fixed effects. A crucial assumption behind the random effects, however, is the absence of omitted variables, i.e. there must be no correlation between the unobserved characteristics of a bank and other variables. Although it is practically impossible to achieve zero correlation between the variables and unobserved bank characteristics, one way to minimize this is to include as many available control variables as possible. Consequently, each model includes specialization dummies to account for the influence of bank specialization on its risk-taking decisions, as well as bank-specific and country-specific control variables as discussed earlier in Chapter 3. Since the sample is restricted to the period of 2012-2016, which takes place after the financial crisis of 2007-2008 and the start of implementation of Basel III, it can be expected that there were no major events occurring during that period, and thus the models do not control for year fixed effects, increasing degrees of freedom.

To avoid the presence of other statistical problems biasing the results, the data was carefully examined with the help of commonly used diagnostic techniques and tests. Firstly, plotting the residuals of the explanatory variables against the fitted values for all variables showed that there might be heteroscedasticity present. A Breusch-Pagan/Cook-Weisberg test for heteroscedasticity showed that the variance of residuals is indeed not constant, and thus further measures need to be taken to control for heteroscedasticity. Furthermore, although autocorrelation is considered to be unlikely in panel datasets with a small number of time periods and many individual units, the data was examined using the

¹² Low values of RWA/TA and NPL/TA and high values of z-score imply low risk taking, while the opposite holds for high risk taking.

Wooldridge test for autocorrelation in panel data. The test confirmed that there is indeed autocorrelation present in the data. A common approach to tackling both heteroscedasticity and autocorrelation in panel data is to use robust (or clustered) standard errors in estimating coefficients (e.g. see Gropp & Heider, 2009). Consequently, this thesis will implement robust standard errors clustered at the bank level. Last but not least, the VIF test showed that there is no problem of multicollinearity between the variables (see Appendix 2). All VIFs are below the cut-off value of 10 (with an exception of the interaction term between size and the IRB dummy, which can safely be ignored (Allison, 2012)).

Table 4 shows the main results regarding Hypotheses 1a and 1b. Models 1-3 are based on specification (1) and show the effect of using IRB on bank's risk taking, using three different measures (RWA/TA, NPL/TA, and Z-score). In addition, including bank size as a control variable also allows to make inferences about its effect on risk taking, whereas excluding it could result in an omitted variable bias. Alternatively, Models 4-6 using specification (2) test potential moderating effect of IRB on the relationship between bank size and risk taking, providing evidence on how the IRB dummy can alter the relationship between the two. The R-squared statistics show that models using the RWA/TA and NPL/TA explain a modest proportion of the total variance in the data, while models using z-scores suffer from a relatively low explanatory power.

The results of all six models differ significantly depending on the measure of risk taking. The results of Model 1 show that the IRB banks have significantly lower RWA/TA relative to the SA banks. This is consistent with previous evidence showing that banks adopting IRB exhibit lower values of RWA/TAs upon receiving a regulatory approval (Mariathasan & Merrouche, 2014; Turk-Ariss, 2017), and confirms Hypothesis 1a. However, in this regression bank size appears to have no effect on bank's risk taking, which can be attributed to the potentially high correlation between bank size and IRB and the potential mediation effect of IRB on risk taking (as tested later in Section 4.2). Interestingly, when measuring risk taking as NPL/TA (Model 2), the model produces strikingly different results: using IRB increases risk taking (confirming Hypothesis 1b), whereas smaller banks take relatively more risk than larger banks (as reflected in the negative coefficient of bank size). When measuring risk taking in terms of z-scores (Model 3), however, no significant results were obtained for either of the variables. As for control variables, liquidity, and loan loss provisions have the expected effects, whereas higher profitability leads to higher risk taking in terms of RWA/TA, but lower risk taking in terms of NPL/TA and z-scores. Bank capitalization, however, appears to decrease bank's risk taking, confirming the view that higher capital buffers can have a positive impact on bank stability.

Table 4 - Main results for Hypothesis 1 (Models 1-3) and the moderation effect of IRB (Models 4-6)

<i>Dep. var.</i>	(1) <i>RWA/TA</i>	(2) <i>NPL/TA</i>	(3) <i>Z-score</i>	(4) <i>RWA/TA</i>	(5) <i>NPL/TA</i>	(6) <i>Z-score</i>
IRB	-0.144*** (0.031)	0.011** (0.005)	-0.106 (0.197)	0.105 (0.227)	-0.044** (0.021)	3.276*** (1.143)
IRB*Size				-0.013 (0.012)	0.003** (0.001)	-0.177*** (0.061)
Size	-0.004 (0.006)	-0.002*** (0.001)	0.020 (0.028)	-0.002 (0.006)	-0.003*** (0.001)	0.031 (0.029)
Capitalization	-1.094*** (0.091)	-0.004 (0.014)	2.187*** (0.230)	-1.093*** (0.091)	-0.040 (0.014)	2.193*** (0.230)
Profitability	0.986*** (0.300)	-0.332*** (0.110)	6.808*** (0.969)	0.981*** (0.299)	-0.332*** (0.110)	6.719*** (0.967)
Liquidity	-0.057 (0.049)	0.000 (0.004)	-0.227** (0.096)	-0.053 (0.050)	-0.001 (0.004)	-0.201** (0.098)
Loan loss provisions	0.478*** (0.160)	0.634*** (0.208)	0.452 (0.622)	0.476*** (0.160)	0.634*** (0.208)	0.458 (0.625)
Off-balance sheet activities	-0.027 (0.029)	-0.001 (0.004)	-0.101 (0.096)	-0.027 (0.029)	0.000 (0.004)	-0.093 (0.100)
GDP growth	1.345*** (0.227)	-0.158*** (0.048)	2.145*** (0.608)	1.325*** (0.229)	-0.154*** (0.048)	2.010*** (0.588)
Debt-to-GDP	-0.061 (0.038)	0.004 (0.009)	-0.097 (0.144)	-0.060 (0.039)	0.003 (0.009)	-0.126 (0.144)
Interest rate	0.060*** (0.009)	-0.004*** (0.001)	0.041* (0.023)	0.060*** (0.009)	-0.004*** (0.001)	0.044** (0.022)
Bank restrictiveness	0.113*** (0.018)	0.000 (0.004)	0.291* (0.161)	0.113*** (0.019)	0.000 (0.004)	0.300* (0.164)
Constant	0.573*** (0.104)	0.047** (0.019)	5.218*** (0.642)	0.541*** (0.110)	0.055*** (0.020)	5.057*** (0.654)
Observations	1,996	1,974	1,876	1,996	1,974	1,876
Number of banks	461	457	403	461	457	403
Specialization FE	Yes	Yes	Yes	Yes	Yes	Yes
Within R ²	0.25	0.32	0.24	0.25	0.32	0.25
Between R ²	0.63	0.61	0.15	0.63	0.61	0.14
Overall R ²	0.62	0.58	0.14	0.62	0.58	0.13

Robust standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Including an interaction term between IRB and bank size provides more insight into bank's risk-taking behavior and tests whether IRB can serve as a moderator. In Model 4, where risk taking is measured using RWA/TA, the interaction term has no significant impact on risk taking, with none of the three coefficients having a p-value below the 0.05 threshold. The results change slightly in Models

5 and 6, when NPL/TA and z-scores are used. The effect of IRB on risk taking, calculated by adding two coefficients, becomes more positive as bank size increases.¹³ However, although both the interaction term and bank size are significant, adding the two coefficients to see the moderation effect of IRB on the relationship between bank size and risk taking shows that the total effect is effectively zero.¹⁴ For the SA banks (i.e. IRB dummy = 0), risk taking increases with lower bank size, as reflected in the negative coefficient of size on NPL/TA. Model 6 with z-scores as an inverse measure of risk taking (higher z-scores indicate more stable banks) provides additional evidence of the moderation effect of IRB. Using IRB results in relatively higher risk taking when bank size is sufficiently large (i.e. the z-score decreases).¹⁵ The effect of bank size, however, is not significant in this model.

These preliminary results highlight several crucial aspects that deserve further attention. Firstly, the different outcomes of all models, depending on which risk-taking measure was used, provide additional evidence that the risk sensitivity of the regulatory RWA/TA measure may indeed be lower when compared with alternative measures, such as NPL/TA or bank's z-score. Secondly, the insignificance of the bank size variable in models using RWA/TA and z-scores as well as effectively no effect of IRB moderation in Model 5 hint that IRB may serve as a mediator rather than a moderator in the relationship between bank size and risk taking. As argued by Baron and Kenny (1986), mediators can be often confused for moderators, while mediation is more likely to occur when there is a strong correlation between IV and MV. The direct effect of bank size on risk taking and the potential mediation effect of IRB is explored in Section 4.2. Subsequently, while there is evidence in the support of Hypothesis 1b provided by models using NPL/TA and z-scores (i.e. banks that use IRB tend to exhibit higher risk taking), the findings show that a mediation model indeed needs to be considered to shed more light on the research question.

4.2 Mediation analysis

4.2.1 Mediation analysis using the full sample

Table 5 shows the results of the mediation analysis for the three different measures of risk taking. Model 1 shows the results of the logistic regression as specified by equation (3) in Section 3.1, i.e. the effect of bank size on the probability of using IRB. Models 2, 4, and 6 are based on the specification (4) and Models 3, 5, and 7 on the specification (5) from Section 3.1. Regressions in these specifications are

¹³ For an average bank in the sample (i.e. $\ln(\text{TA}) = 15.70$, see Table 2), using IRB results in higher risk taking. When measured using NPL/TA, the total effect is $-0.044 + 0.003 \cdot 15.70 = 0.0031$ (see Table 4, Model 5 for coefficients), indicating a very modest positive effect of bank size on risk taking. However, as bank size of an IRB bank increases, its effect on NPL/TA will tend to be more positive.

¹⁴ When a bank uses IRB (i.e. IRB dummy = 0), the effect of an increase in its size on NPL/TA is captured by the sum of two coefficients (see Table 4, Model 5): Size (-0.003) and IRB*Size (0.003). Adding the two coefficients results in the total effect being zero

¹⁵ Although average IRB banks in the sample tend to take on less risks and exhibit a higher z-score ($3.276 - 0.177 \cdot 15.70 = 0.4971$, see Table 4, Model 6 for coefficients), starting from banks with $\ln(\text{TA}) = 18.51$, using IRB results in more risk taking.

performed using pooled OLS model, which is a standard model used in the mediation research. The control variables remained the same as in Models 1-6 in Table 3, with an exception for industry dummies (which were left out to increase the degrees of freedom).

Table 5 – Main results for the mediation effect of IRB (Hypothesis 2)

<i>Dep. var.</i>	(1) IRB	(2) RWA/TA	(3) RWA/TA	(4) NPL/TA	(5) NPL/TA	(6) Z-score	(7) Z-score
IRB			-0.131*** (0.012)		0.003 (0.002)		-0.252** (0.101)
Size	2.149*** (0.173)	-0.022*** (0.002)	-0.006*** (0.002)	0.000 (0.000)	0.000 (0.000)	0.060*** (0.014)	0.089*** (0.018)
Capitalization	6.997** (2.827)	-1.839*** (0.060)	-1.807*** (0.058)	-0.027*** (0.009)	-0.028*** (0.009)	2.097*** (0.513)	2.157*** (0.513)
Profitability	-7.712 (16.598)	3.580*** (0.319)	3.326*** (0.310)	-0.186*** (0.045)	-0.181*** (0.046)	7.268** (3.268)	6.845** (3.268)
Liquidity	-0.512 (0.608)	-0.042*** (0.014)	-0.030** (0.013)	-0.003 (0.002)	-0.003 (0.002)	-0.431*** (0.130)	-0.390*** (0.131)
Loan loss provisions	-2.145 (3.705)	1.322*** (0.113)	1.190*** (0.110)	0.815*** (0.021)	0.818*** (0.021)	-11.083*** (0.994)	-11.367*** (0.999)
Off-balance sheet activities	1.875*** (0.682)	-0.043*** (0.015)	-0.042*** (0.015)	-0.014*** (0.002)	-0.014*** (0.002)	-0.442*** (0.132)	-0.452*** (0.132)
GDP growth	-34.043*** (11.977)	1.951*** (0.325)	1.595*** (0.316)	-0.203*** (0.048)	-0.195*** (0.048)	3.560 (2.784)	2.988 (2.789)
Debt-to-GDP	-3.570*** (0.727)	-0.064*** (0.017)	-0.086*** (0.016)	-0.002 (0.003)	-0.002 (0.003)	-0.761*** (0.150)	-0.784*** (0.150)
Interest rate	-1.190** (0.531)	0.069** (0.012)	0.056*** (0.117)	-0.004** (0.002)	-0.004** (0.002)	-0.022 (0.102)	-0.044 (0.103)
Bank restrictiveness	-2.079*** (0.285)	0.150*** (0.006)	0.136*** (0.006)	0.001 (0.001)	0.001 (0.001)	0.403*** (0.058)	0.365*** (0.060)
Constant	-30.401*** (2.544)	0.755*** (0.034)	0.592*** (0.037)	0.021*** (0.005)	0.024*** (0.006)	5.180*** (0.301)	4.892*** (0.322)
Observations	2,019	1,996	1,996	1,974	1,974	1,876	1,876
Direct Effect			-0.060***		-0.018		0.160***
Indirect Effect			-0.220***		0.034		-0.079**
Total Effect			-0.280***		0.017		0.082***
Model	Logit	OLS	OLS	OLS	OLS	OLS	OLS

Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

An important remark needs to be made regarding the coefficients, however. The coefficients reported in Table 5 (and the subsequent tables showing the results of mediation tests) are not standardized. Therefore, no exact inference can be made with regard to the magnitude of the observed effects or their

significance. Calculating the bias-corrected bootstrapped standard errors, however, allows to compute standardized coefficients and confidence intervals for the direct, indirect, and total effects. These coefficients are thus the main coefficients of interest in these models. The results of the bootstrap test (using 500 replications) for the significance of the direct, indirect, and total effects are reported in the end of Models 3, 5, and 7.

Model 1 shows the results of the logistic regression and provides evidence on high and significant positive correlation between using IRB and bank size. More specifically, it shows that a one-unit increase in bank size (measured using the logarithm of total assets) results in substantially higher odds of using IRB.¹⁶ This confirms a common conception in the literature on Basel III that larger banks are more likely to be approved for and use IRB (e.g. see Behn et al., 2016; Hakenes & Schnabel, 2011). The next step in the mediation analysis is to examine the relationship between IV and DV, as specified in the equation (4). This regression shows the direct effect that bank size has on risk taking, without taking into account potential mediation via IRB. The results in Models 2 and 6 using RWA/TA and z-scores as measures of risk taking indicate that there is a significant negative relationship between bank size and risk taking. Namely, larger banks tend to have lower RWA/TA (shown by the negative coefficient of size in Model 2) and higher z-scores (shown by the positive coefficient of size in Model 6). The results for Model 4 using NPL/TA, however, appeared to be insignificant.

The last and the most important step in the mediation analysis is testing specification (5), in which both DV is regressed on both IV and MV. Similar to the results observed in Section 4.1 for Hypotheses 1a and 1b, the outcomes differ significantly depending on the measure of risk taking. In Model 3 using RWA/TA, both the IRB dummy and bank size exhibit a negative effect on risk taking. The bootstrap test provides supporting evidence for the sign and the significance of both direct and indirect effects. Following Zhao et al. (2010), when both direct and indirect effect have the same sign, the mediation is called complementary since the MV reinforces the effect of the IV on DV. Therefore, using IRB appears to reinforce the negative effect of bank size on risk taking, i.e. large banks on average are less risk taking than small banks, and adopting IRB reinforces this effect. However, Model 7 using z-scores shows different results: while bank size has a negative effect on risk taking (i.e. larger bank size increases the z-score), using IRB leads to higher risk taking as indicated by the negative coefficient of the IRB dummy on z-score. Moreover, the bootstrap test confirms the significance of these opposite effects, indicating not complementary but competitive mediation of the IRB dummy (see Zhao et al., 2010). Mackinnon et al. (2007) also classify this type of mediation as inconsistent mediation, where the direct effect of the IV on DV is being suppressed by the MV. Consequently, while large banks tend to take less risk than small banks, using IRB increases their risk taking. However, no inference can be

¹⁶ The output in Model 1 is given in terms of log odds. To translate the coefficient of bank size into odds, one needs to use exponentiation, i.e. $e^{2.149} = 8.576$. This means that a one-unit increase in bank size in terms of $\ln(\text{TA})$ leads to 7.576 higher chance (odds) that this bank uses IRB.

made with regard to Model 5 using NPL/TA, as the coefficients of both bank size and IRB remain insignificant.

Testing the indirect (mediation) effect of IRB on bank size and risk taking partly confirms Hypothesis 2, under which using IRB mediates the relationship between bank size and risk taking.¹⁷ The difference between the results of models using RWA/TA and z-scores also highlights potentially low risk sensitivity of RWA/TA as a measure of risk taking, as tested earlier under Hypotheses 1a and 1b. As for the evidence on the relationship between bank size and risk taking, it appears that without controlling for whether a bank uses IRB or SA, larger banks tend to be more stable and have relatively lower portfolio risk than smaller banks (reflected in higher z-scores). However, once the usage of IRB by larger banks is taken into account, IRB banks tend to be more risk-taking than SA banks (Model 7). These findings thus support previous evidence that IRB can create competitive distortions between large and small banks as it creates barriers-to-entry for smaller banks while subsidizes larger banks that could afford the costs of adopting IRB (Behn et al., 2016; Hakenes & Schnabel, 2011). Therefore, adopting the IRB does not appear to make banks safer as IRB has a negative effect on risk taking when measured in terms of z-scores.

4.2.2 Moderated mediation

So far, the results of the mediation model in Table 5 provide some support for the IRB mediation hypothesis. However, the results of the moderation effect in Models 4-6 in Table 4 also provided some indication that the effect of bank size on risk taking may depend on its environment, i.e. whether or not it uses IRB (reflected in the significant coefficient of the interaction term in Table 4, Model 5). Baron & Kenny (1986) state that it is indeed possible to confuse both effects with each other, whereas the ultimate choice of the model depends on the correlation between IV and the moderator/mediator. While this thesis argues that IRB is a mediator rather than a moderator due to its high correlation with bank size, VanderWeele (2016) proposes to include an interaction term between IV and MV (i.e. $IRB_i * Size_{it}$) to see if the effect of IRB can differ for different bank sizes. Table 6 thus shows the results for specification (5) with an addition of the interaction term between IRB and bank size. The coefficients of IRB and its interaction with bank size appear to be insignificant in all models. However, the bootstrap test indicates that the combined indirect effects of IRB and its interaction with bank size are significant in Models 1 and 3, with mediation being complementary when risk taking is measured as RWA/TA, and competitive when risk taking is measured as NPL/TA. Comparing these results to Models 4-6 testing exclusively the moderation effect in Table 4, there seems to be no strong evidence in favor of moderation or moderated mediation, which can be explained by the fact that large banks are the ones

¹⁷ Since Models 4 and 5 using NPL/TA showed no significant results, they cannot provide evidence on Hypothesis 2.

who are more likely to use IRB, and thus the effect of IRB on the risk taking of small banks is difficult to detect.

Table 6 – Main results for moderated mediation of IRB

<i>Dep. var.</i>	(1) <i>RWA/TA</i>	(2) <i>NPL/TA</i>	(3) <i>Z-score</i>
IRB	-0.115 (0.093)	-0.008 (0.014)	-1.086 (0.826)
IRB*Size	-0.001 (0.005)	0.001 (0.001)	0.045 (0.044)
Size	-0.006** (0.002)	0.000 (0.000)	0.081*** (0.020)
Capitalization	-1.809*** (0.059)	-0.027*** (0.009)	2.204*** (0.515)
Profitability	3.326*** (0.310)	-0.181*** (0.046)	6.773** (3.269)
Liquidity	-0.029** (0.014)	-0.003 (0.002)	-0.443*** (0.141)
Loan loss provisions	1.190*** (0.110)	0.816*** (0.021)	-11.386*** (1.000)
Off-balance sheet activities	-0.043*** (0.015)	-0.142*** (0.002)	-0.432*** (0.133)
GDP growth	1.598*** (0.317)	-0.198*** (0.048)	2.826 (2.794)
Debt-to-GDP	-0.085*** (0.016)	-0.002 (0.003)	-0.802*** (0.151)
Interest rate	0.056*** (0.012)	-0.004** (0.002)	-0.044 1.103
Bank restrictiveness	0.136*** (0.006)	0.001 (0.001)	0.361*** (0.060)
Constant	0.588*** (0.041)	0.026*** (0.006)	5.064*** (0.364)
Observations	1,996	1,974	1,876
Direct Effect	-0.058**	-0.027	0.144***
Indirect Effect	-0.214***	0.003	-0.148**
Total Effect	-0.273***	-0.024	-0.004
Model	OLS	OLS	OLS

Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

4.3.3 Mediation analysis for the EU and the US banks

According to Hypothesis 3, the mediation effect should be more profound for the EU banks relative to the US banks, as the latter operate under stricter guidelines with regard to the adoption of the advanced

(IRB) approaches (e.g. see Hakenes & Schnabel, 2011; Masera, 2013). To test this hypothesis, the mediation test was run for two separate samples: the EU banks (including 15 EU member states) and the US banks.

Table 7 - Main results of the mediation model for the EU banks (Hypothesis 3)

<i>Dep. var.</i>	(1) IRB	(2) RWA/TA	(3) RWA/TA	(4) NPL/TA	(5) NPL/TA	(6) Z-score	(7) Z-score
IRB			-0.092*** (0.020)		0.006* (0.004)		-0.385*** (0.122)
Size	1.942*** (0.199)	-0.036*** (0.003)	-0.020*** (0.004)	-0.001* (0.001)	-0.003** (0.001)	0.065*** (0.020)	0.137*** (0.030)
Capitalization	6.603* (3.728)	-1.778*** (0.119)	-1.687*** (0.118)	-0.171*** (0.022)	-0.179*** (0.022)	3.372*** (0.750)	3.753*** (0.751)
Profitability	-15.311 (20.709)	4.026*** (0.567)	3.937*** (0.556)	0.231** (0.109)	0.236** (0.109)	7.058 (4.671)	7.008 (4.619)
Liquidity	-5.736*** (1.328)	-0.009 (0.031)	-0.038 (0.031)	-0.022*** (0.006)	-0.020*** (0.006)	-0.582** (0.236)	-0.814*** (0.244)
Loan loss provisions	-8.848** (4.303)	1.629*** (0.148)	1.543*** (0.146)	0.772*** (0.034)	0.775*** (0.034)	-7.476*** (0.948)	-7.835*** (0.944)
Off-balance sheet activities	2.000** (0.858)	-0.046 (0.029)	-0.037 (0.029)	-0.033*** (0.005)	-0.035*** (0.005)	0.325 (0.205)	0.404** (0.205)
GDP growth	12.311 (14.487)	-1.055** (0.520)	-1.079** (0.509)	-0.031 (0.098)	-0.032 (0.098)	-1.847 (3.206)	-1.790 (3.170)
Debt-to-GDP	-4.633*** (0.883)	-0.060*** (0.022)	-0.090*** (0.022)	-0.008** (0.004)	-0.006 (0.004)	-0.846*** (0.147)	-1.000*** (0.153)
Interest rate	0.433 (0.655)	-0.030 (0.021)	-0.031 (0.020)	0.004 (0.004)	0.004 (0.004)	-0.220* (0.127)	-0.210* (0.125)
Bank restrictiveness	0.886* (0.526)	-0.006 (0.016)	-0.002 (0.016)	0.013*** (0.003)	0.012*** (0.003)	-0.128 (0.101)	-0.101 (0.100)
Constant	-30.176*** (3.348)	1.272*** (0.064)	1.070*** (0.076)	0.049*** (0.012)	0.062*** (0.015)	5.608*** (0.437)	4.678*** (0.523)
Observations	505	504	504	460	460	410	410
Direct Effect			-0.237***		-0.121**		0.350***
Indirect Effect			-0.210***		0.072*		-0.196***
Total Effect			-0.448***		-0.049*		0.153***
Model							

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 7 shows the results for the sample of the EU banks only. The results for Models 1-3 are similar to the results obtained from the overall sample (see Table 5). Furthermore, the mediation observed in Model 3 is also complementary (as both direct and indirect effects are negative), with the total effect

being stronger for the EU banks than for the overall sample (-0.448 as compared to -0.28 in Table 5). Interestingly, the results of Models 4-7 using alternative measures of risk taking (NPL/TA and z-score) confirm the findings observed for the overall sample: while larger EU banks tend to be less risky than smaller EU banks, using IRB by larger banks leads to higher risk taking for these banks (as indicated by the significant coefficient of the indirect effect for both NPL/TA and z-score). Similarly, the mediation observed through IRB is competitive rather than complementary. In contrast with the full sample (Table 5), the mediation effect in Models 4 and 5 using NPL/TA for the EU banks is significant.

Table 8 - Main results of the mediation model for the US banks

<i>Dep. var.</i>	(1) <i>IRB</i>	(2) <i>RWA/TA</i>	(3) <i>RWA/TA</i>	(4) <i>NPL/TA</i>	(5) <i>NPL/TA</i>	(6) <i>Z-score</i>	(7) <i>Z-score</i>
IRB			-0.088*** (0.017)		-0.003 (0.002)		0.225 (0.176)
Size	13.42** (5.635)	-0.006*** (0.002)	0.001 (0.002)	0.000 (0.000)	0.000 (0.000)	0.124*** (0.019)	0.108*** (0.023)
Capitalization	-104.60* (63.300)	-1.785*** (0.063)	-1.807*** (0.062)	0.033*** (0.007)	0.032*** (0.007)	1.488** (0.635)	1.528** (0.636)
Profitability	-101.762 (135.216)	2.645*** (0.371)	2.643*** (0.368)	-0.356*** (0.041)	-0.356*** (0.041)	2.035 (4.187)	1.691 (4.195)
Liquidity	13.636** (7.201)	-0.041*** (0.013)	-0.019 (0.014)	-0.002 (0.002)	-0.002 (0.059)	-0.313** (0.151)	-0.396** (0.164)
Loan loss provisions	123.462 (132.381)	3.099*** (0.528)	3.170*** (0.524)	1.116*** (0.059)	1.118*** (0.059)	-49.649*** (5.899)	-50.216*** (5.914)
Off-balance sheet activities	17.651*** (6.378)	-0.091*** (0.017)	-0.082*** (0.017)	-0.002 (0.002)	-0.002 (0.002)	-0.902*** (0.169)	-0.913*** (5.914)
GDP growth	-132.182 (133.273)	1.429** (0.619)	1.352** (0.614)	-0.220*** (0.071)	-0.223*** (0.071)	-0.787 (6.088)	-0.635 (6.088)
Debt-to-GDP	-32.489 (190.474)	3.285*** (0.876)	3.195*** (0.869)	-0.272*** (0.101)	-0.274*** (0.101)	-13.120 (8.630)	-12.971 (8.629)
Interest rate	-3.338 (11.020)	-0.110** (0.053)	-0.111** (0.052)	0.005 (0.006)	0.005 (0.006)	0.669 (0.518)	0.672 (0.518)
Bank restrictiveness	-	-	-	-	-	-	-
Constant	-215.259 (247.179)	-3.155*** (1.076)	-3.141*** (1.067)	0.352*** (0.124)	0.353*** (0.123)	21.071** (10.601)	21.124** (10.599)
Observations	1,514	1,492	1,492	1,514	1,514	1,466	1,466
Direct Effect			0.007		0.013		0.166***
Indirect Effect			-0.141***		-0.039		0.048*
Total Effect			-0.134***		-0.026		0.214***
Model							

Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

For comparison, the results were also run for the sample of the US banks only. However, it has to be noted that due to a small number of the IRB banks (13 banks only as opposed to 348 SA banks) in the US sample, this analysis was statistically difficult to execute.¹⁸ This can also explain extremely high coefficients for certain control variables. Furthermore, bank restrictiveness was omitted as this is a time-invariant variable calculated at the country-level.

Table 8 illustrates the results using a sample of the US banks. The bootstrap significance test showed that, in line with the predictions regarding more stringent US bank regulations, using IRB leads to less risk taking when measured in terms of RWA/TA and z-scores. As both indirect and direct effects in Models 3 and 7 have the same sign, the observed mediation effect is complementary, meaning that IRB reinforces the positive correlation between bank size and risk taking. Furthermore, Models 4 and 5 indicate that the mediation effect of IRB disappears when NPL/TA is used as a risk-taking proxy. This may explain why the results of Models 4 and 5 were insignificant for the overall sample (see Table 5). Overall, these results are supportive of Hypothesis 3 as the mediation effect of IRB is weaker for the US banks than for the EU banks. Moreover, it appears that risk sensitivity of RWA/TA may depend on the settings in which banks operate, such as different regulatory environment. More specifically, in the settings where banks do not independently choose which RWA/TA methodology to use (i.e. IRB or SA), IRB appears to decrease the risk taking of large banks (as showed by the positive indirect effect of IRB on z-scores in Model 7). Last but not least, the results regarding the direct effect of bank size on risk taking (Model 7) are in line with previous findings that smaller banks take more risk than larger banks.

4.3 Robustness check

To confirm that the main results are robust and do not depend on the measures or approaches used in the analysis, this thesis conducted two robustness checks. Firstly, an alternative measure of bank size was used to test Hypothesis 1 and 2. Secondly, a probit regression was applied instead of logistic regression in the mediation tests. The following sections of this sub-chapter will discuss the results.

4.3.1 Alternative measure of bank size

The main measure of bank size used in this thesis is logarithm of total assets. While this measure is commonly used by other researchers (e.g. by Laeven & Levine, 2009; Mariathan & Merrouche, 2014; Matejašák et al., 2009; Vallascas & Hagendorff, 2013), an alternative proxy for bank size can be logarithm of total revenues (Schildbach, 2017). Consequently, to ensure that the main results are independent of the choice of the proxy, the results for Hypotheses 1a, 1b, and 2 were replicated measuring bank size as a logarithm of total revenues. Tables 9 and 10 show the respective results.

¹⁸ For instance, the bootstrap test could not generate all 500 replications for all models. In Model 1, only 479 replications were generated, while in Model 2 and 3 only 478 and 483 replications were generated, respectively.

Table 9 – Main results for Hypothesis 1 (Models 1-3) and the moderation effect of IRB (Models 4-6)
using an alternative measure of bank size ($\ln(TR)$)

<i>Dep. var.</i>	(1) <i>RWA/TA</i>	(2) <i>NPL/TA</i>	(3) <i>Z-score</i>	(4) <i>RWA/TA</i>	(5) <i>NPL/TA</i>	(6) <i>Z-score</i>
IRB	-0.208*** (0.0303)	0.00627 (0.00398)	-0.369* (0.193)	-0.138 (0.183)	-0.00334 (0.0165)	-0.359 (0.808)
IRB*Size				-0.00454 (0.0122)	0.000624 (0.00100)	-0.000655 (0.0513)
Size	0.0159*** (0.00477)	-0.00101 (0.000621)	0.0657** (0.0304)	0.0166*** (0.00529)	-0.00111* (0.000668)	0.0657** (0.0321)
Capitalization	-1.059*** (0.0934)	0.00713 (0.0128)	2.276*** (0.240)	-1.060*** (0.0932)	0.00732 (0.0128)	2.276*** (0.240)
Profitability	0.794*** (0.307)	-0.357*** (0.108)	6.880*** (0.979)	0.792*** (0.307)	-0.357*** (0.108)	6.880*** (0.981)
Liquidity	-0.0725 (0.0542)	-0.00163 (0.00349)	-0.229** (0.102)	-0.0711 (0.0559)	-0.00185 (0.00351)	-0.229** (0.102)
Loan loss provisions	0.447*** (0.166)	0.696*** (0.186)	0.621 (0.615)	0.445*** (0.167)	0.696*** (0.186)	0.621 (0.616)
Off-balance sheet activities	-0.0437 (0.0320)	0.00143 (0.00416)	-0.149 (0.105)	-0.0438 (0.0322)	0.00150 (0.00418)	-0.149 (0.105)
GDP growth	1.326*** (0.223)	-0.173*** (0.0455)	2.097*** (0.568)	1.319*** (0.224)	-0.173*** (0.0458)	2.096*** (0.571)
Debt-to-GDP	-0.0961** (0.0387)	0.00518 (0.00814)	-0.126 (0.145)	-0.0943** (0.0399)	0.00489 (0.00829)	-0.127 (0.146)
Interest rate	0.0546*** (0.00870)	-0.00500*** (0.00124)	0.0270 (0.0233)	0.0544*** (0.00867)	-0.00497*** (0.00125)	0.0270 (0.0234)
Bank restrictiveness	0.131*** (0.0180)	0.00244 (0.00324)	0.175 (0.149)	0.130*** (0.0181)	0.00249 (0.00324)	0.176 (0.150)
Constant	0.310*** (0.0854)	0.0137 (0.0123)	5.108*** (0.577)	0.300*** (0.0924)	0.0151 (0.0131)	5.107*** (0.593)
Observations	1,930	1,914	1,840	1,930	1,914	1,840
Number of banks	443	439	397	443	439	397
Specialization FE	YES	YES	YES	YES	YES	YES
Within R ²	0.26	0.35	0.26	0.26	0.35	0.26
Between R ²	0.65	0.66	0.14	0.65	0.66	0.14

Robust standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 10 – Main results for the mediation effect of IRB (Hypothesis 2) using an alternative measure of bank size ($\ln(\text{TR})$)

<i>Dep. var.</i>	IRB (1)	RWA/TA (2)	NPL/TA (3)	NPL/TA (4)	NPL/TA (5)	Z-score (6)	Z-score (7)
IRB			-0.168*** (0.011)		0.000 (0.002)		-0.233** (0.100)
Size	2.058*** (0.161)	-0.016*** (0.002)	0.004* (0.002)	0.000* (0.000)	0.000 (0.000)	0.064*** (0.015)	0.091*** (0.018)
Capitalization	9.527*** (2.717)	-1.776*** (0.062)	-1.744*** (0.059)	-0.397*** (0.047)	0.003 (0.008)	1.868*** (0.524)	1.912*** (0.524)
Profitability	-56.141*** (15.523)	3.592*** (0.369)	2.937*** (0.353)	-0.005*** (0.002)	-0.396*** (0.048)	9.386*** (3.484)	8.601** (3.496)
Liquidity	-0.367 (0.476)	-0.068*** (0.014)	-0.047*** (0.014)	0.866*** (0.021)	-0.005*** (0.002)	-0.397*** (0.131)	-0.351*** (0.132)
Loan loss provisions	-8.125** (3.825)	1.422*** (0.122)	1.181*** (0.117)	-0.010*** (0.002)	0.866*** (0.021)	-11.989*** (1.036)	-12.349*** (1.047)
Off-balance sheet activities	-1.169* (0.660)	-0.019 (0.017)	-0.048*** (0.016)	-0.021*** (0.045)	-0.010*** (0.002)	-0.673*** (0.139)	-0.724*** (0.140)
GDP growth	-53.811*** (12.761)	2.263*** (0.337)	1.680*** (0.322)	-0.004 (0.002)	-0.212*** (0.045)	5.018* (2.880)	4.337 (2.891)
Debt-to-GDP	-3.840*** (0.694)	-0.0877 (0.017)	-0.113*** (0.017)	-0.005*** (0.002)	-0.004 (0.002)	-0.648*** (0.155)	-0.666 (0.155)
Interest rate	-2.099*** (0.562)	0.074*** (0.0126)	0.052*** (0.012)	0.003*** (0.001)	-0.005*** (0.002)	-0.005 (0.106)	-0.030 (0.106)
Bank restrictiveness	-2.199*** (0.287)	0.166*** (0.007)	0.139*** (0.007)	0.009** (0.004)	0.003*** (0.001)	0.275*** (0.064)	0.230*** (0.067)
Constant	-19.857*** (1.733)	0.577*** (0.032)	0.475*** (0.031)	0.009** (0.004)	0.009** (0.004)	5.572*** (0.268)	5.446*** (0.273)
Observations	1,953	1,930	1,930	1,914	1,914	1,840	1,840
Direct Effect			0.039		0.025		0.162***
Indirect Effect			-0.028***		0.003		-0.071**
Total Effect			-0.245***		0.028		0.090***
Model	Logit	OLS	OLS	OLS	OLS	OLS	OLS

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Models 1-3 in Table 9 are in line with the respective models in Table 4 and indicate different effects of IRB on risk taking depending on the measure used. However, bank size does have a significant effect on risk taking, with larger banks being riskier than smaller banks in terms of RWA/TA but less risky in terms of z-scores (since higher z-scores imply higher bank stability). Models 1 and 3 confirm Hypotheses 1a and 1b, respectively. When a moderation effect is added in Models 4-6, the coefficients of IRB and the interaction term appear to be insignificant, opposite to what was observed in Table 4.

Interestingly, the coefficients of bank size are significant, and show that an increase in the logarithm of total revenues leads to higher risk taking in terms of RWA/TA, but lower risk taking in terms of NPL/TA or z-scores. It thus appears that IRB does not have a moderating effect on the relationship between bank size and risk taking, while the risk sensitivity of RWA/TA can be compromised. Furthermore, Models 3, 5, and 6 confirm that smaller banks have riskier portfolios than larger banks in terms of non-regulatory measures of risk taking under Basel III.

As for the mediation analysis, Model 1 in Table 10 supports positive correlation between the IRB dummy and bank size. The results of the bootstrap test in Model 3 also partly confirm that IRB has a negative moderating effect on the relationship between bank size and risk taking (as the direct effect of bank size appears to be insignificant). While Model 5 does not show significant results for mediation (similar to Model 5 in Table 5), the bootstrapped coefficients of Model 7 confirm that bank size has a direct positive effect on risk taking, while using IRB suppresses this effect and serves as a competitive mediator.

4.3.2 Estimating mediation models with probit regression

While both logit and probit regressions allow to estimate models with binary dependent variables, the difference between the two is that the former assumes logistic distribution of the error term, whereas the latter assumes that the error term is normally distributed (Wooldridge, 2002). While both approaches tend to produce similar results, for the robustness purposes the mediation model was tested using the probit regression instead of logit. The results observed in Table 11 show that Model 1 is closely in line with the results reported in Table 5. Furthermore, the coefficients obtained in Models 2-7 are absolutely identical to those of the respective models in Table 5. It can thus be concluded that the choice of the logit model did not affect the main results.

Table 11 – Main results for the mediation effect of IRB (Hypothesis 2) using a probit regression

<i>Dep. var.</i>	(1) <i>IRB</i>	(2) <i>RWA/TA</i>	(3) <i>RWA/TA</i>	(4) <i>NPL/TA</i>	(5) <i>NPL/TA</i>	(6) <i>Z-score</i>	(7) <i>Z-score</i>
IRB			-0.131*** (0.012)		0.003 (0.002)		-0.252** (0.101)
Size	1.177*** (0.091)	-0.022*** (0.002)	-0.006*** (0.002)	0.000 (0.000)	0.000 (0.000)	0.060*** (0.014)	0.089*** (0.018)
Capitalization	4.046** (1.614)	-1.839*** (0.060)	-1.807*** (0.058)	-0.027*** (0.009)	-0.028*** (0.009)	2.097*** (0.513)	2.157*** (0.513)
Profitability	-5.393 (9.550)	3.580*** (0.319)	3.326*** (0.310)	-0.186*** (0.045)	-0.181*** (0.046)	7.268** (3.268)	6.845** (3.268)
Liquidity	-0.243 (0.326)	-0.042*** (0.014)	-0.030** (0.013)	-0.003 (0.002)	-0.003 (0.002)	-0.431*** (0.130)	-0.390*** (0.131)
Loan loss provisions	-1.663 (2.116)	1.322*** (0.113)	1.190*** (0.110)	0.815*** (0.021)	0.818*** (0.021)	-11.083*** (0.994)	-11.367*** (0.999)
Off-balance sheet activities	0.912** (0.375)	-0.043*** (0.015)	-0.042*** (0.015)	-0.014*** (0.002)	-0.014*** (0.002)	-0.442*** (0.132)	-0.452*** (0.132)
GDP growth	-18.966*** (6.745)	1.951*** (0.325)	1.595*** (0.316)	-0.203*** (0.048)	-0.195*** (0.048)	3.560 (2.784)	2.988 (2.789)
Debt-to-GDP	-1.951*** (0.398)	-0.064*** (0.017)	-0.086*** (0.016)	-0.002 (0.003)	-0.002 (0.003)	-0.761*** (0.150)	-0.784*** (0.150)
Interest rate	-0.642** (0.289)	0.069** (0.012)	0.056*** (0.117)	-0.004** (0.002)	-0.004** (0.002)	-0.022 (0.102)	-0.044 (0.103)
Bank restrictiveness	-1.140*** (0.156)	0.150*** (0.006)	0.136*** (0.006)	0.001 (0.001)	0.001 (0.001)	0.403*** (0.058)	0.365*** (0.060)
Constant	-16.590*** (1.329)	0.755*** (0.034)	0.592*** (0.037)	0.021*** (0.005)	0.024*** (0.006)	5.180*** (0.301)	4.892*** (0.322)
Observations	2,019	1,996	1,996	1,974	1,974	1,876	1,876
Direct Effect			-0.060***		-0.018		0.160***
Indirect Effect			-0.220***		0.034		-0.079**
Total Effect			-0.280***		0.017		0.082***
Model	Probit	OLS	OLS	OLS	OLS	OLS	OLS

Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

5. CONCLUSIONS

The main goal of this thesis was to explore the relationship between bank size and risk taking, the specifics of which have been largely ignored in previous literature on banking. Considering the increasing importance and stringency of bank capital regulation, it is also important to acknowledge the regulatory environment in which banks operate and make their risk decisions. Therefore, this study also aims to shed more light on the influence of the Basel III capital requirements imposed on large and small banks. The findings show that the existence of two approaches (IRB and SA) to calculating RWAs can negatively affect the prudence and stability of both groups of banks. More specifically, the asymmetric treatment of small and large banks under Basel III implies that only large banks can adopt the IRB approach, which allows them to underreport their RWAs and take higher risks than observed by the regulators. As small banks cannot afford the costs of adopting IRB, they are less flexible with regard to their RWA reporting and are forced to compete with more profitable and efficient larger banks. Therefore, under Basel III large banks consider themselves as “too big to fail” and accumulate higher portfolio risks, while small banks are engaging in higher risk taking as they are too small to compete with larger banks. This problem, however, is less pronounced in the US, where the decision behind the choice of the IRB approach is dependent on the regulators, which can thus mitigate opportunistic behavior of banks.

This study is not without its limitations, however. Endogeneity is a common concern in empirical research, and this study cannot reject the possibility that the causality of the variables goes the other way. It is possible that banks with high risk appetite are more likely to choose IRB approach in order to underreport their capital ratios, and banks that tend to have low-risk portfolios are more inclined to adhere SA. Furthermore, it is possible that banks that take more risk are also increasing in size. However, using random effects model and panel data is assumed to be an efficient way to mitigate the issue of potential endogeneity. Furthermore, the mediating variable in this analysis is a time-invariant IRB dummy. This is due to the fact that the majority of banks in the sample did not change their RWA approach during the analyzed period (2012-2016). Future research could consider extending the time period to capture more changes in the approaches used by banks. In addition, due to the novelty of the mediation model introduced in this thesis, the models were tested using pooled OLS. However, it is possible that OLS may not have sufficiently captured the dynamic nature of the data. Consequently, a suggestion for further research could be to calculate the direct and indirect effects separately for each year. Moreover, while this thesis focuses on the mediation effect of the IRB approach, there may exist other mechanisms that influence the risk-taking decisions of large and small banks. The choice behind adopting the IRB approach may also depend on other considerations rather than opportunistic behavior of value-maximizing banks. This thesis thus encourages further research in this direction.

The analysis conducted in this thesis has both scientific and practical relevance. To the knowledge of the author, this is the first empirical study in the banking literature which explicitly

analyzes the risk-taking behavior of large and small banks. Furthermore, the findings of this thesis support and add to the previous studies (e.g. Behn et al., 2016; Hakenes & Schnabel, 2011; Mariathasan & Merrouche, 2014; Vallascas & Hagendorff, 2013) that analyzed the consequences of the RWA methodology on banks' risk taking. It demonstrates that imposing stricter risk-adjusted capital requirements may compromise the overall stability and health of the banking sector as it provides opportunities and incentives to engage in higher risk taking for both large and small banks. This may call for a revision of the RWA methodology in the future, for instance, in Basel IV. The recent news regarding the reforms of Basel IV shows that regulators are beginning to acknowledge the problems arising from the voluntary implementation of the IRB approach. Namely, restrictions on the parameters used by banks in their internal models as well as more comparison of the results provided under both IRB and SA are being considered for the IRB banks (Deutsche Bank, 2018). However, while these are steps in the right direction, more changes can be considered. For instance, the results show that adjusting capital requirements according to bank size and strictly regulating the usage of the IRB approach (as done in the US) may affect and constrain bank's risk taking. It may thus be of interest for the EU regulators to consider adopting size-calibrated capital requirements in order to strengthen the stability of the EU banking sector.

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APPENDIX

Appendix 1 - Frequency of IRB and SA banks per country

<i>Country</i>	<i>Number of IRB banks</i>	<i>Number of SA banks</i>
Austria	4	3
Belgium	1	2
Germany	5	22
Denmark	3	17
Spain	6	8
Finland	2	4
France	2	4
United Kingdom	9	47
Greece	2	2
Ireland	1	1
Italy	4	15
Luxembourg	0	1
Netherlands	1	3
Portugal	1	2
Sweden	6	7
United States	13	348
Total	60	486

Appendix 2 - VIFs for the main regressions

<i>Variables</i>	<i>VIF (1)</i>	<i>VIF (2)</i>	<i>VIF (3)</i>	<i>VIF (4)</i>
IRB	2.61	165.12	2.49	105.68
IRB*Size		179.46		
IRB*Size2				114.68
Size (ln(TA))	2.38	2.96		
Size2 (ln(TR))			2.42	2.89
Capitalization	1.15	1.16	1.16	1.18
Profitability	1.14	1.14	1.24	1.24
Liquidity	1.69	1.89	1.73	1.96
Loan loss provisions	1.53	1.53		1.65
Off-balance sheet activities	1.51	1.52		1.68
GDP ratio	1.52	1.53		1.62
Debt-to-GDP	1.69	1.71	1.69	1.78
Interest rate	1.32	1.32	1.34	
Bank restrictiveness	1.98	1.99	2.13	2.13