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Abstract

Objective: This study aims to evaluate the implications of the Internal Ratings-Based approach on credit risk in comparison to the Standardised Approach among Norwegian banks. The adoption of the IRB approach was initially aimed at offering banks a more flexible tool for credit risk assessment. By including bank-specific factors into the analysis, this study seeks to determine the potential benefits and drawbacks of the approaches. In relation to the proposed revision of the Basel III framework, this study aims to offer insight into the necessity of such revisions in the context of the Norwegian banking sector.

Methods: Various proxies have been used to measure credit risk at the parent bank level. The main variables under observation include Non-Performing Loans, Loan Losses, and Z-Scores. The period under study spans from 2014 to 2022, using quarterly accounting data. High dimensional fixed effects regression, including regional and time fixed effects, have been used to analyse the data. The analysis involved the use of a test variable, the IRB dummy variable, and several bank-specific control variables, including size, regulatory capital, profitability, lending rate, revenue diversification, transferred portfolios to credit subsidiaries, and the corporate loan ratio.

Results: Empirical findings reveal that banks using the IRB approach exhibit significant correlation with the credit risk proxies. Specifically, IRB banks show a 48.1% increase in Non-Performing Loans, a 104% increase in Loan Losses, and a 30.9% decrease in Z-scores compared to the unconditional mean of all banks in the sample. Despite the indications of higher credit risk, IRB banks benefit from favourable treatment in the computation of risk-weighted exposures for credit risk. Furthermore, IRB banks maintain marginally lower equity levels while being nearly twice as exposed to corporate loans. Notably, the study finds that IRB banks outperform their SA counterparts by achieving an average of 50% higher profitability ratios.

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Abbreviations

IRB – Internal Rating Based Approach

SA – Standardised Approach

NPL – Non-performing Loans

RWE – Risk Weighted Exposure

RWs – Risk Weights

FSA – Norwegian Financial Supervisory Authority

EBA – European Banking Authority

PD – Probability of Default

LGD – Loss Given Default

EAD – Exposure at Default

1.0 Introduction

Banks are essential in enabling economic growth as they provide financing to individuals, businesses, and governments. By accepting deposits and extending loans, banks contribute by facilitating the accumulation of deposits, the investment of these savings into assets, and the allocation of these assets for productive activities, which is crucial for economic development. However, banking holds inherent risks, and a bank's failure can have severe consequences for the financial system and the broader economy. To mitigate the risks associated with banking activities, regulatory bodies have implemented various measures to ensure that banks operate in a safe and prudent manner. One essential tool is enforcing minimum capital requirements, which ensures banks' resilience against losses and reduces the risk of insolvency (Financial Supervisory Authority, 2020). It is important to recognise that not all assets or exposures a bank holds carry the same level of credit risk. Credit risk, or the risk of loss when a borrower defaults on a loan, is a significant contributor to the overall risk profile of a bank (Norges Bank, 2022). Banks employ a metric known as the Risk-Weighted Exposure (RWE) to account for these variations in risk among different exposures. This approach assigns different risk weights (RWs) to different categories of exposure based on their associated risk levels.

This thesis analyses the implications of the Internal Ratings-Based (IRB) approach in determining RWE concerning credit risk. The IRB approach allows banks to use their own internal models to measure and estimate credit risk to calculate RWE. This method contrasts with the standardised approach (SA), which relies on a fixed set of predetermined RWs for their different types of exposures. While the IRB approach provides banks with more flexibility, concerns have been raised concerning its ability to accurately reflect the true level of credit risk in a bank's loan portfolio (European parliament, 2016, p.21; Basel committee, 2017, p.1). According to Andersen (2020) and Andersen and Winje (2017), SA banks retain considerably higher RWE than IRB banks for similar exposures to residential mortgages and corporate loans. Such a disadvantage for SA banks could potentially lead to several implications. They may need to maintain a larger equity buffer, charge higher interest rates, limit expansion, and adjust their lending strategy.

Due to the discrepancies between IRB and SA, the research aims to test if Norwegian banks using the IRB approach to calculate RWE have any significant impact on the quality of their loan portfolio in the form of credit risk compared to the banks using the SA. This research could indicate whether the IRB approach has been a more accurate method for managing credit risk between 2014-2022 or if there have been certain shortcomings in the regulations or practices in Norway that have had unintended consequences. Additionally, the research could offer relevant insights into the observed discrepancy between risk weightings and credit risk.

The problem described in this research could have implications for various stakeholders, such as banks, regulators, investors, borrowers, and society. Suppose banks using the IRB model have a higher chance of customers defaulting on their loans while having less capital to cover these potential losses than banks using the SA. If so, they could be more vulnerable to financial stress and insolvency. This could, in turn, lead to negative consequences such as increased difficulty in obtaining funding or higher borrowing costs in society in general. Further, if the SA results in too-high RWE and capital requirements, such banks will be at a disadvantage which could make them have less lending growth, return on equity, increased interest rates, and a lower market share. Borrowers may be affected as this might lead to a decrease in the availability of credit or higher borrowing costs[1]. Furthermore, the overcapitalisation of banks can negatively impact investors' expected return on investment, making the banks less appealing as potential investment opportunities.

This study aims to indicate whether banks that use the IRB approach in Norway have had a significant correlation with credit risk in their parent bank's overall loan portfolios compared to similar banks using the SA, after controlling for other bank-specific factors. A positive correlation between the use of the IRB approach and credit risk could be explained by the complexities and model-related risk of the IRB approach, together with their ability to take on exposures with more favourable RWs. A negative relationship could be explained by better risk management, more regulatory oversight, and the risk-sensitive nature of the method, which can encourage less risk-taking. Further, the study aims to identify and comment on the

[1] Borrowing costs: interest and other costs that an entity incurs in connection with the borrowing of funds. (IAS 23)

potential drawbacks and limitations of the two approaches and look into the bank-specific factors between the two groups.

The definitions of IRB and SA banks used by Behn et al. (2022) are applied for this analysis. Specifically, an IRB bank is defined as a bank that uses the internal ratings-based approach for some or all of its loans during the sample period. On the other hand, an SA bank is defined as a bank that uses the Basel II standard approach for all of its loans during the sample period. The study will use these definitions to distinguish between the two categories of banks being compared. As credit risk cannot be directly observed, the study has utilised various credit risk indicators as proxies. Non-performing loans and loan losses were considered to assess credit risk specifically related to loans. At the same time, the Z-score served as a variable representing the overall default risk of the bank entity. The data used is quarterly accounting data from 2014 to 2022 at the parent bank level gathered from the Norwegian Banks Guarantee Fund. The study uses a test variable, namely the IRB dummy, besides various bank-specific control variables such as size, regulatory capital, profitability, revenue diversification, lending rate, transferred portfolios to credit subsidiaries and corporate loan ratio. This study uses time and regional fixed effects in its regression analysis to answer the research question:

Does being an IRB bank in Norway indicate any significant implications on the parent bank's overall credit risk when compared to banks using the standard approach?

Given the differences between the two methods, the study would ideally have liked to test the credit quality between the two within harmonised portfolios: specifically for mortgages, small and medium enterprises (SME), large corporate & institutions and various industries. However, the data limitations have restricted the analysis to the overall portfolio level, encompassing all exposure classes at the parent bank level. It is to be noted that most Norwegian banks transfer parts of their high-quality portfolios to specialised credit institutions that issue covered bonds (Finans Norge, 2023b). The data used in this analysis include the number of assets transferred to cover such bonds in the credit subsidiary, divided into both business and housing portfolios and the total transferred portfolio. The data does not include loan losses or non-performing loans from these assets, nor does it include any revenues or expenses. As a result of this transfer, the effects related to these loans, including

any associated risks or revenues, are not reflected in the parent bank's balance sheet or income statement. This may potentially distort the perception of the overall bank credit risk and overall financial performance. However, the regression analysis does account for the proportion of loans transferred and the proportion of corporate loans as control variables. Another limitation is the low frequency of IRB banks (eight) versus SA banks (97), which introduce a challenge due to potential limited variation in the primary variable. It is to be mentioned that all Norwegian IRB banks are included, capturing the entire scope of this approach within Norwegian banks.

The study finds indications that IRB banks in Norway have a significant and positive correlation with credit risk. The empirical results suggest that IRB banks have 48.1% higher NPLs, 104% higher loan losses, and a 30.9% lower Z-score compared to the unconditional mean of all Norwegian banks in the sample. For all regression models including time and regional fixed effects, the Corporate Loan Ratio is significant and shows a clear causality with the indicators of credit risk, suggesting that loans made to businesses are riskier than retail loans. IRB banks hold a significantly larger portion of these loans due to their favourable RWE calculation illustrated by their corporate ratio of nearly 48% opposed to 27% for SA banks, all while still maintaining a lower ratio of total RWE. Further the analysis reveals that RWE is insignificant for all test models, which questions its reliability as a measure of credit risk for banks overall, but it is unclear if the RWE is accurately capturing the risk for one approach, either IRB or SA, while failing to do so for the other. On average the IRB banks outperform their SA counterparts by achieving 50% higher profitability ratios.

These results highlight the relevance of the proposed reform to the Basel III framework, and the necessity of the revision for the Norwegian banking sector. Aimed at making the SA approach more risk sensitive and pinning (constraining) the IRB method to the SA in a higher degree, reducing the discrepancy between the two models and the risk of misspecified IRB models (Basel Committee, 2017, p.1.). The study contributes by providing empirical insights into the impact of the two different approaches on banks' risk, capitalisation and performance. It also suggests several interesting avenues for future research, such as harmonised portfolio analysis, a more nuanced exploration of the relationship between lending rates and credit risk within the two bank groups, and a deeper analysis of the consequences of differing risk sensitivities between IRB and SA approaches.

2.0 Conceptual Background

This section provides a theoretical background for the research question. It begins by bringing up some issues that have been raised for the IRB model. Further, it comments on how banks respond to higher regulatory capital. Finally, commenting on existing literature on credit risk and how to measure it.

2.1 The difficulties with the model-based approach

Since the implementation of Basel II, banks have been motivated to create internal models that result in lower RWE in order to reduce the amount of capital required to be held. (European parliament, 2016, p.5). There have been increasing criticisms of the credibility of the IRB approach, as it has been suggested that internal ratings do not accurately reflect the true risk levels of banks (European Parliament, 2016, p.21)

The Basel Committee has conducted empirical analyses that "(...) highlighted a worrying degree of variability in banks' calculation of RWA" (Basel Committee, 2017, p.1). A study by the Basel Committee found that approximately 75% of these variations can be attributed to underlying credit risk, with the remaining 25% being attributed to the differing approaches and practices employed by authorities and banks (Regulatory Consistency Assessment Programme, 2013, p.6). As a response, they have implemented a finalising reform to the Basel III Framework. One of its highlighted objectives is to constrain the use of IRB models (Basel Committee, 2017, p.1.). Further, this framework is being implemented in the EU through Capital Requirement Regulation III (CRR3) and Capital Regulation Directive VI (CRD6). The framework is informally referred to as Basel IV or Basel 3.1, introducing a more risk-sensitive SA and an output floor, restricting the IRB model. (Blogpost PWC, 2021).

There has been a concern that the RWs assigned to SA banks may not accurately reflect the risk of the assets held by these institutions (European Parliament, 2016, p.5). Conversely, the risk weights assigned by IRB banks may be disproportionately lower than those assigned by SA banks, which can lead to potential discrepancies in the overall risk assessment of different banks. Andersen & Winje (2017) outlines that reports from The European Banking Authorities (EBA) show that the IRB approach used by some large banks can result in differing Risk Weights for the

same exposure (Andersen & Winje, 2017, p.8). The following reasoning can be derived: Although the IRB model bases its risk weights on estimates of credit risk parameters, its ability to fully capture underlying credit risk is somewhat limited. Consequently, when comparing SA and IRB, the differences between the two approaches are likely to be even less effective in accurately assessing credit risk.

Based on a consultation document by Eika Gruppen (Alliance of local banks) on behalf of 93 Norwegian banks using SA to the Ministry of Finance responding to the increased systemic buffer requirement, they argue that local savings banks [In Norwegian: Sparebank] using SA have a lower risk profile less present in international markets and a more straightforward and more readily understandable business model. They further argue that their contribution to systemic risk is lower than that of larger banks. According to the consulting document, one of the reasons for this is the lower share of corporate lending compared to larger IRB banks and a more conservative risk measurement with the SA. "It is paradoxical that Standardised Approach (SA) banks, which have the highest risk-weighted and unweighted solvency and the most conservative risk measurement, will be hardest hit by a new regulatory tightening that is calibrated to fit the largest Internal Rating-Based (IRB) banks." (Eika Gruppen, 2019, p.3). On a further note, Andersen et al. (2020) find little support that the IRB model has changed the underlying portfolio quality since the implementation date. It finds statistical evidence that it has not changed the quality of the loan portfolios. (Andersen et. al., 2020, p.21). It should also be mentioned that Eika Gruppen is incentivised to say that SA approaches are more conservative and result in a lower risk profile. On the other hand, support for a lower risk profile and more conservative risk measurement with the SA approach exists. Research from Behn et al. (2022) has shown that IRB banks in Germany underestimate the probability of default and have higher loan losses and non-performing loans when compared with the SA approach.

According to Behn et al. (2022), "(...), complex rules can be exploited to reduce the amount of regulatory requirements imposed by the regulator" (p. 1641). In their article published in The Journal of Finance. The authors look at the potential issues by relying on regulatory models, such as the risk of misspecified models. The researchers discovered that German IRB loans from 2008 to 2012 reported a Probability of Default that significantly underestimated actual default rates relative to the SA control group and in absolute terms. In particular, it has been found that

IRB loans in Germany tend to have significantly lower capital requirements compared to SA loans but also tend to have higher observed loan losses. Additionally, the study found that interest rates for IRB loans are significantly higher than those for SA, suggesting that banks were aware of the higher risk associated with these loans, despite the reported Probability of Default and RWE not reflecting this risk. (Behn et al., 2022.). Andersen et al. (2020) discovered an opposing trend in the Norwegian market, where banks using the IRB approach had lower lending rates compared to those using the SA. Also, we know from Sparebanken Sør that the IRB banks have lower prices on their loans while still achieving higher returns of profitability. (Fristad. B, 2022, p.17).

Previous literature, such as Behn et al., 2022; Rajan et al., 2015; Acharya et al., 2014, have all raised concerns that some banks may use overly optimistic internal models, leading to insufficient capital being set aside to cover potential losses. To address these concerns, the Basel Committee has proposed implementing a "system of floors" (Basel Committee, 2014) to ensure that the internal models utilised by banks are at least as conservative as the SA. Rajan et al. (2015) find that statistical risk models do not reflect changes in the characteristics of loans and non-performing loans. According to Acharya et al. (2014), RWs do not effectively capture changes in actual risk. The authors argue that other measures, such as unweighted core capital ratios, are better indicators of a bank's solidity (i.e., ability to withstand financial stress).

The IRB banks tend to receive significantly more relief than banks using SA in terms of RWE. Residential mortgages are assigned considerably lower RWE by Norwegian IRB banks than by SA banks (Andersen et al., 2020). It is unclear whether this variation accurately reflects the real risk of these assets, as mortgage loans are, to a considerable extent, a standardised product. "All banks in Norway face more or less the same housing market." (Andersen, 2013, p.4)
Further on, there is also a difference in RWE for corporate loans. According to Andersen & Winje (2017), since 2006, the average risk weight for corporate exposures among banks using the IRB approach has, on average, declined by 50%. However, this decrease has not been seen among banks using the SA, where corporate exposures without a credit rating and commercial property mortgages are assigned a risk weight of 100%, the same as under Basel I (Andersen & Winje, 2017).

For instance, one of the largest SA banks, "Sparebanken Sør," says they will increase their CET1 capital ratio by approximately 3,5% if they start using the Foundational IRB approach (Fristad, 2022, p.13). Another SA bank, Sparebanken Øst, mentions that a quick calculation gives that a SA bank needs to hold 80% more CET1 capital than an IRB bank for an identical loan. The prerequisite is that mortgages have 21% RWs and corporate loans have 41% RWs for IRB banks compared to 35% and 88% RWs for a SA bank (Sparebanken Øst, Q4 presentation 2022, p.35).

2.2 How banks respond to higher capital requirements

According to Gropp et al. (2019), when capital requirements are increased, banks tend to reduce their RWE in order to meet these requirements. This can lead to an improvement in regulatory measures of bank solvency. However, cutting assets, such as lending, simultaneously by many banks may have adverse effects, as Hanson et al. (2011) noted. This is consistent with the findings of Julsrud & Getz Wold (2020), who found that Norwegian low-capitalised banks tend to respond to increased capital requirements by adjusting their portfolios towards lower-risk exposures through a process known as portfolio rebalancing. This may lead to a concentration of risk in specific sectors, such as commercial property or households, and a lack of diversification among IRB and non-IRB banks. Julsrud and Getz Wold (2020) found that low-capitalised banks respond to higher capital requirements with decreasing RWE rather than additional equity. Following the lower RWs, 80% can be explained by the observed increase in household lending relative to firm lending.

Further, they argue that reducing credit supply towards firms instead of households can be undesirable for several reasons. Unsustainable price growth in housing and lower firm lending leads to lower employment growth. In total, it can harm the long-term economy. (Julsrud & Getz Wold, 2020).

Further on, Andersen's memorandum for Norges Bank (2020) reports that SA banks have had a significantly lower level of lending to corporate entities after adopting the IRB approach in 2007, which led to higher capital requirements for SA banks compared to IRB banks. This disparity in lending behaviour can be attributed to differences in risk sensitivity between banks employing the SA approach versus those utilising the IRB method with regard to commercial loans. Additionally, drawbacks, except for lower growth in the corporate market, was the ability of IRB

banks to reduce their lending rate compared to SA banks after the IRB method was implemented. Fristad (2022) points out the need to charge a higher lending rate for SA banks in order to get the same return on equity. (Fristad, 2022).

Andersen (2023) refers to the Modigliani-Miller theorem that under certain conditions, financing costs will not depend on the financing structure (Modigliani & Miller, 1958). Further, the author states that results from international studies suggest that the Modigliani-Miller theorem may not hold in practice, implying that a bank's overall financing costs increase as its capital adequacy ratio rises (European Central Bank, 2011). The analyses of (the European Central Bank, 2011) indicate that lower equity return requirements and debt interest rates counterbalance roughly half of the direct cost increase associated with increased equity. It is clear that banks are motivated to somewhat increase their leverage due to this scenario. Investors may price the equity with a higher price to book equity marginally when equity is decreased and vice versa.

2.3 Literature on credit risk indicators

Norges Bank, det norske finanseielle system [the Norwegian financial system] (2022) defines ***credit risk*** as *"The risk of loss due to a borrower not fulfilling their obligations according to the agreement"* (p. 14). This risk cannot be directly observed and has to be estimated. In the instance of the IRB model, through the estimation of probability of default (PD), Exposure at default (EAD), and Loss given default (LGD).

The accuracy of minimum capital requirements for credit risk is essential for banks and regulators. Credit risk is a significant contributor to the overall risk profile of a bank. Therefore, banks are required to hold a minimum level of capital, known as the capital adequacy requirement, to protect against potential losses of assets and insolvency. The capital adequacy requirement intends to ensure that a bank has sufficient financial resources to absorb unexpected losses and meet its obligations to depositors and other creditors. (Norges Bank, 2022)

2.3.1 Non-Performing-Loans

As outlined by European Central Bank (ECB, 2023) on their website, non-performing loans (NPL) are an important factor to look at in conjunction with Credit risk:

"Credit risk is inherent to the banking business: granting loans always entails the risk that they will not be paid back. For the same reason, credit risk is a focus of the ECB's supervisory work, in which we pay particular attention to non-performing loans (NPLs)." Berger and DeYoung (1997) write that it is challenging for managers to alter the NPL figures as loans that have not been paid for at least 90 days are classified as non-performing and must be reported as such.
However, there are downsides to using NPLs as a credit risk measure:

1. While NPLs can accurately reflect the present state of credit risk once defaults begin, they often trail the underlying credit risk, as loans can transition into being risky before borrowers miss payments.
2. NPLs, as a metric, do not fully capture credit risk. They indicate only the current proportion of loans in or near default, not the potential for future defaults or the possible severity of losses if such defaults occur.
3. A notable risk lies in the potential manipulation of NPL ratios.

Banks can manage these ratios by restructuring loans or offloading them to banks specialised in buying NPLs, thus converting potential defaults into realised loan losses. Another method involves offering additional funding to borrowers to settle their loans, thereby preventing the loans from being overdue for more than 90 days and, consequently, becoming non-performing (Berger & DeYoung, 1997). These strategies demonstrate the potential for manipulating the metric. In this study, multiple credit risk indicators and a longitudinal approach using historical data on have been used to mitigate some of these limitations. This methodology reduces the impact of some of the mentioned issues, as it allows us to capture the trends and patterns over an extended period, capturing a more accurate picture of the underlying credit risk for that period. On the positive side, NPLs are simple to understand and calculate, offering an intuitive snapshot of the proportion of a bank's loan portfolio currently in or near default. Moreover, they provide a real-time indicator of credit risk at the same time as borrowers are defaulting on loans and are used by regulatory authorities as a critical measure in their assessments and stress tests.

2.3.2 Loan losses

IAS 39 - superseded in 2018 for listed banks – superseded in 2020 for non-listed banks

Under International Accounting Standard 39 (IAS 39), loan losses were recognised and recorded using the "incurred loss" model. This model delayed recognition of credit losses until there was objective evidence of impairment. A financial asset or a group of financial assets was considered impaired and thus subject to loss accounting only when a loss event had occurred after initial recognition and had an impact on the future cash flows of the financial asset that could be reliably estimated. Loss events could include significant financial difficulty of the borrower, breach of contract, or it becoming probable that the borrower will enter bankruptcy or financial reorganisation. (IAS 39).

This model led to criticism because it recognised losses after there was evidence of a loss event. Consequently, this model often delayed the recognition of loan losses until they were incurred, potentially concealing the build-up of credit risk in the period leading to the impairment event (International Accounting Standards Board (IASB), 2014). One of the recommendations discussed in the basis for the conclusion on IFRS 9 by IASB was to consider a model that would use more forward-looking information (BCIN.11).

IFRS 9 - Implemented in 2018 for publicly listed – 2020 for non-listed banks

Under International Financial Reporting Standards 9 (IFRS 9), loan losses are recognised and recorded using the "expected credit loss" (ECL) model. This approach requires entities to account for anticipated losses from the inception of a loan or other financial instrument, aiming to address the "delayed recognition" issue associated with IAS 39. Upon initial recognition of a financial asset, an entity must recognise a loss allowance equal to the 12-month expected credit losses (Stage 1) unless the credit risk increases significantly, in which case lifetime expected credit losses are recognised (Stage 2). If there is objective evidence of impairment at the reporting date, the financial asset moves to Stage 3, where again, lifetime expected credit losses are recognised. This forward-looking model facilitates earlier recognition of credit losses, allowing stakeholders to assess credit risk more accurately and forward-looking than under the previous standard.

Loan losses as a credit risk proxy

As a credit risk proxy, the loan loss ratio under IAS 39 captures a historical picture of the incurred credit risk of the overall portfolio of the parent bank, as objective evidence of losses was required (stage 3). It cannot precisely predict future credit risk, only historical proportions. Under IFRS 9, however, the proxy also captures

expected credit losses and serves a more forward-looking role by including model-based loss allowances (Stage 1) and model-based impairments (Stage 2). However, the calculation of "expected credit losses" involves substantial judgement and estimation, introducing an element of subjectivity and potential variability in the loan loss provisions. According to a report by PWC, 22 out of 38 banks in Norway experienced either unchanged or reduced loan loss provisions following the transition from IAS 39 to IFRS 9 (PWC, 2018). Looking at section 4.1.1 (***Figure 4)***, in the first quarter of 2018, listed banks started using IFRS 9, and in the first quarter of 2020, non-listed banks implemented it. The data show no clear trends of "delayed or unusual spikes" concerning these two dates between the two groups (IRB and SA), but it is hard to say since Covid-19 coincided at the time of implementation for non-listed banks.

2.3.3 Z-score

The Z-score is an alternative measure of risk that might indicate the distance to default for banks (Gonzalez et al., 2015). The previously mentioned author's research uses the Z-score as a measure and other credit risk proxies like the risk-weighted assets and non-performing loans (NPL) ratio. Their Z-score is constructed out of Return on Assets (ROA%) plus Equity to Assets ratio, which is then divided by the volatility of ROA. The Z-score measures "the distance to insolvency of an entity" (Gonzalez et al., 2015, p.203) and the "(...) distance to default as it is the number of standard deviations ROA would need to fall in order to wipe out book equity." (Hirtle et. al., 2020).

The log Z-score used in this study is defined as:

Equation 1:

$$\log(\mathrm{Z-Score}) = \log\left(\frac{\text{Equity Ratio(Quarterly)} + \text{ ROA(average)}}{\text{3y rolling average Sd(ROA)}}\right)$$

Natural logarithmic transformation is used because the proxy Z-score is highly skewed. The Z-score, utilised as a credit risk parameter, is a metric that considers three crucial aspects of a bank's risk profile: profitability, leverage, and volatility in returns. Its simplicity lies in the fact that despite incorporating these multiple factors, the Z-score is represented as a singular, easily computable number. It provides insights by quantifying the number of standard deviations a bank's returns are from insolvency (where equity is insufficient to offset losses). A lower Z-score

suggests a higher probability of insolvency, translating to increased credit risk and vice versa.

Boyd et al. (1993) highlights several constraints of the Z-score as a measure. Primarily, they note that the median Z-scores calculated from accounting data often produce values so large that, assuming a normal distribution, they indicate tiny chances of failure. This assumption could lead to an underestimation of actual failure risks for several reasons:

1. Real-world financial returns frequently diverge from normal distributions, impairing the Z-score's precision.
2. The definition of bankruptcy as per the Z-score, which requires a single-period loss surpassing consolidated equity, may be excessively limiting, omitting other plausible insolvency scenarios.
3. The authors note the prevalence of earnings smoothing, a common practice that can mask the actual volatility of profits, consequently causing Z-scores to underrate risk.

Boyd et al. (1993) suggest that Z-scores calculated using continually updated market data typically offer more reliable outcomes than those generated with accounting data.

3.0 Institutional Setting

3.1 Regulation of the Norwegian banking sector

The Norwegian Financial Supervisory Authority (FSA) is the regulatory body responsible for overseeing the operations of banks and other financial institutions in Norway. Its primary objective is to maintain the stability and soundness of the financial sector. To accomplish this, the FSA has the power to issue regulations and take enforcement measures against any risks or misconduct within the industry. As stated by Norges Bank (2022), "The financial system plays a vital role in a modern economy. If it becomes impossible to make payments or obtain loans, the effects on the economy will be severe. As a result, the financial system is subject to stricter regulation and oversight by authorities compared to other sectors of the economy" (p.13).

The FSA is an independent agency that reports to the Ministry of Finance and is governed by a board of directors appointed by the Ministry (Norges Bank, 2022). The FSA is responsible for ensuring that institutions in the financial system comply with the laws and regulations. They also have the power to implement new regulations and make recommendations to the financial system. The supervision aims to ensure that the financial system functions well and protects the user's interests (Norges Bank, 2022).

Norwegian authorities regulate the Norwegian banking sector. As a member of the European Economic Area (EEA), Norway is required to adopt and implement EU financial regulations, such as the Basel III capital adequacy standards and the EU's single rulebook for banking supervision. These regulations establish minimum standards that banks, and other financial institutions must meet with regard to capital adequacy, liquidity, and risk management (Norges Bank, 2022). According to Norges Bank (2022), "The framework conditions for the financial system in Norway are determined through the EEA agreement, which regulates our relationship with the EU. Through the EEA agreement, Norway is a part of the EU's internal market for financial services. This means that we largely have the same financial legislation as EU countries."

These bank regulations are based on the international regulatory standards established by the Basel Committee on Banking Supervision (Basel Committee) in the Basel III framework (Norges Bank, 2022). Banks must hold a minimum amount of capital, known as the *"risk-based capital requirement,"* to cover the risks associated with their lending and investment activities. The risk-based capital requirement is calculated based on risk weightings assigned to different assets and activities, with higher-risk exposures and activities requiring higher capital levels (Norges Bank, 2022). In addition to the risk-based capital requirement, banks must also hold a minimum amount of capital, known as the *"capital conservation buffer,"* to cover unexpected losses, a minimum amount of capital, known as the "*countercyclical capital buffer,*" to cover potential losses during times of severe stress and a minimum amount of capital, known as the "*systemic risk buffer,*" based on the current level of structural vulnerability in the financial system (Norges Bank, 2022).

Norwegian banks are also subject to other capital requirements, including a requirement to hold a minimum amount of equity behind their loans with characteristics outlined as Tier 1 capital (Explained further under section 3.4) and a requirement to maintain a minimum capital adequacy ratio (Norges Bank, 2022). These requirements are implemented to ensure that banks in Norway have sufficient financial resources to absorb losses and maintain the confidence of depositors and other creditors (Norges Bank, 2022). Overall, the regulatory environment in Norway, which the FSA leads, ensures the financial system functions well and protects the interests of users while also adhering to international standards set by the EU and the Basel Committee.

3.2 Capital Framework

The Capital Framework offers banks various options for calculating the capital needed for credit risk mitigation. This includes the utilisation of the SA, the FIRB, and the AIRB (Andersen & Winje, 2017). According to the European Parliament (2016), large and well-capitalised financial institutions use the AIRB and FIRB approach to credit risk measurement more frequently. Conversely, smaller banks tend to employ the SA more frequently. According to the FSA's round letter on requirements to be allowed to use the IRB models, *"It is the practice of the Financial Supervisory Authority that new IRB approvals will not be granted if a company's portfolio is less than 30 billion NOK" (FSA, 2021).*

Three main approaches are used to calculate RWE for credit risk: the SA, FIRB, and the AIRB. Both AIRB and FIRB will be defined as IRB for this research paper. The AIRB approach involves the use of a bank's own estimates of risk parameters such as the PD, LGD, EAD, assumed utilisation of framework credit and commitment, as well as calculated maturity (M) and size to calculate RWs for credit risk (FSA, 2021, p.3). FIRB method estimates its own PDs but uses standard supervisory rules for LGD. Definition of FIRB *"Foundation Internal Ratings-Based approach (i.e., approach not using own estimates of loss given default and conversion factors)"* (EBA, 2018, p.3). FIRB is recognised as a simpler and easier method to apply than the AIRB method. The SA is a standardised, formula-based approach that uses prescribed risk weights for different types of assets.

3.2.1 Standard Approach (SA)

SA is a method used by banks to determine RWE for credit risk. The Basel Committee on Banking Supervision promotes it as a consistent set of regulations and inputs for determining the minimum capital needed for a given exposure. The main goal of the SA is to establish a straightforward way of determining capital requirements. It is considered the foundation for more advanced internal models like the AIRB and FIRB. (FSA, 2022).

One of the key aspects of the SA is the use of "look-up" tables to identify the RWs for a specific exposure. These tables are applied with 100% risk weights for corporate exposures if there is no credit rating. There has traditionally been a 35% risk weight for residential real estate exposures with an LTV of less than 80% (FSA, 2022). The risk weights for loans secured by real estate in the SA have remained unchanged since their introduction in 1989 (loans secured by commercial real estate) and 2007 (loans secured by residential real estate) (FSA, 2022).

Credit assessment	AAA to AA-	A+ to A-	BBB+ to BB-	Bellow BB-	Unrated
RW	20%	50%	100%	150%	100%

Table 1: *RWs for corporate claims under Basel II, Source: (Basel Committee, 2006)*

These tables consider factors such as the borrower's credit rating, the type of collateral, and the loan's intended purpose. The SA also incorporates standardised "credit risk mitigants," such as guarantees and collateral, which can decrease the amount of capital required. Due to its straightforwardness and clarity, the SA is considered suitable for smaller banks and those with less complex credit portfolios

(Basel Committee, 2015). Noteworthy is that due to the standardisation, the method is not a good measure of actual credit risk if there is no external credit rating.

3.2.2 Internal Rating Based Approach (IRB)

The AIRB approach involves the use of a bank's own estimates of risk parameters, such as the PD and LGD, to calculate RWE for credit risk (FSA, 2021). FIRB method estimates its own PD ratios but uses standard supervisory rules for LGD. Definition from EBA Report on credit risk Mitigation: "Foundation Internal Ratings-Based approach (i.e., approach not using own estimates of loss given default and conversion factors)" (EBA, 2018). FIRB is recognised as a simpler and easier method to apply than the AIRB method.

FSA needs to approve the IRB method for calculating risk in banking. FSA only gives permission if the bank's own method reflects "a sound measurement of risk at all levels over time" (Capital Requirements Regulation § 3-1(3)). EBA set guidelines for the IRB method, Norway follows this set of guidelines, but FSA uses national adaptation with its own ways of interpretation and implementation. These may differ from other countries.

As evaluated by the FSA, a minimum of 20% of the data must demonstrate an economic recession similar to the bank crisis in the early 1990s. Suppose the bank lacks enough data from a severe economic downturn. In that case, it must calculate an estimation of default rates (LGD) for downturns that are representative of the bank's portfolio, and these rates must be given a weight of at least 20% in the calculation of long-term defaults. (FSA, 2021). From 2007 to 2018, the FSA granted approvals for IRB models to eight banks in Norway. Seven banks received approvals for their AIRB models, while one was granted approval for its FIRB model. Further details regarding the approval of IRB models in Norwegian banks during this period can be found in Appendix 2.

With the AIRB approach, banks use internal data and models to estimate:

- Probability of default (PD) - The probability that an exposure defaults, should reflect the average long-term default probability.
- Loss Given Default (LGD) - An estimate of the potential loss from an exposure in the event of default, should reflect loss ratios during downturn periods.

- Exposure at default (EAD) - A bank's exposure amount in the event of default.
- Effective Maturity (M) - The remaining duration of a particular risk reflects that short maturity can be less risky than a long-term exposure.
- Size (S) - Size of the counterparty (adjustment to correlation parameter).

Note: The overall requirements for the estimation of PD, LGD and M for Norwegian IRB banks are outlined by the Financial Supervisory Authority of Norway (2021).

Calculation of RWE amounts for credit risk as laid out in the Capital Requirements Regulation No 575/2014 in Chapter 3 Article 153-154 by the European Union

PD = 1 (Defaulted Exposures): If the PD is 1 (meaning the borrower has already defaulted), then:

- If the institution applies the Loss Given Default (LGD) values set out in Article 161(1), then the RW is 0.
- If the institution uses its own estimates of LGDs, then the RW is the maximum of 0 or 12.5 times (LGD - ELBE), where ELBE refers to the Expected Loss Best Estimate. This is the institution's best estimate of expected loss for the defaulted exposure.

For non-defaulted exposures with a 0< PD < 1 the RW are derived as:

(i) Exposure to corporates, institutions and central government and central banks

Equation 2:

$$\mathrm{RW} = \left[\mathrm{LGD} \cdot \mathrm{N}\left[\frac{\mathrm{G(PD)}}{\sqrt{(1-\mathrm{R})}} + \sqrt{\frac{\mathrm{R}}{1-\mathrm{R}}} \cdot \mathrm{G}(0.999)\right] - \mathrm{PD} \cdot \mathrm{LGD}\right] \cdot \frac{(1 + (\mathrm{M} - 2.5) \cdot \mathrm{b})}{(1 - 1.5 \cdot \mathrm{b})} \cdot 12.5 \cdot 1.06$$

where:

N(x) = the cumulative distribution function for a standard normal random variable (i.e., the probability that a normal random variable with mean zero and variance of one is less than or equal to x);

G(Z) = denotes the inverse cumulative distribution function for a standard normal random variable (i.e., the value x such that N(x) = z)

b = the maturity adjustment factor, which is defined as

$$b = [\,0.11852 - 0.05478 \cdot \ln(PD)\,]^{2}$$

(ii) Exposures to Retail:

Equation 3:

$$RW = \left[LGD \cdot N\left[\frac{G(PD)}{\sqrt{(1-R)}} + \sqrt{\frac{R}{1-R}} \cdot G(0.999)\right] - PD \cdot LGD\right] \cdot 12.5 \cdot 1.06$$

Where the correlation coefficient R is defined as:

(i) Exposure to corporates, institutions and central government and central banks

Equation 4:

$$R = 0.12 \cdot \frac{(1-e^{-50 \cdot PD})}{(1-e^{-50})} + 0.24 \cdot \left(1 - \frac{(1-e^{-50 \cdot PD})}{(1-e^{-50})}\right)$$

(ii) Exposures to Retail:

Equation 5:

$$R = 0.03 \cdot \frac{(1-e^{-35 \cdot PD})}{(1-e^{-35})} + 0.16 \cdot \left(1 - \frac{(1-e^{-35 \cdot PD})}{(1-e^{-35})}\right)$$

*R = 0.15 for retail exposures secured by immovable property collateral, R= 0.04 for revolving retail exposure

Further, there are different alterations depending on the exposure. Exposures to financial institutions and unregulated financial sector entities have a multiplier of 1.25 to the correlation parameter (Article 153(2)). Exposure to small or medium-sized entities (SMEs) has a firm-size adjustment to the correlation parameter in [***Equation 4***:]: $+\left[-0.04 \cdot \left(1 - \frac{(S-5)}{45}\right)\right]$ where S ranges from €5 to €50 in total annual sales (Article 153(4)). These are some of the most essential, but there are several other alterations and adjustments outlined in sub-section 2 – Article 153-156 of EBAs Capital Requirement Regulation, including RWs for equity exposures (Article 155) and other non credit-obligation assets (Article 156). (European Parliament & Council of the European Union, 2013)

3.3 BASEL

The Basel Committee is considered an important institution within the banking sector. Historically and today, it has made collaborative efforts to supervise the

quality of information between countries and regulatory authorities. The Basel Committee has developed regulations for capital adequacy and other aspects of operations, such as capital instruments and liquidity. (Basel Committee, 2022). In recent decades, the Basel Committee has introduced a series of new regulations, including Basel I, II, III, and the upcoming finalisation of Basel III, informally called "*Basel IV*," which is to be implemented in the EU in 2025. These regulations are designed to promote stability within the financial market.

Basel I, released in 1988, was a framework based on a fixed regulatory RWE. Basel II in 2006 introduced a more risk-sensitive approach known as the IRB method to provide better risk measurement and avoid regulatory arbitrage (Basel Committee, 2013). After the financial crisis (2007-2009), there were several questions about the success of the IRB method (Behn et al., 2022). The Basel III framework is a response to the financial crisis and provides a better foundation for the banking system. This was needed since there was a lot of variability in the calculation of RWE by banks, and the stakeholder's lost faith in the bank's reported RWs. Basel III included:

- increasing the amount of capital banks had to hold,
- enhancing the way risks were captured, and
- adding macroprudential elements such as capital buffers that could be activated in times of stress.

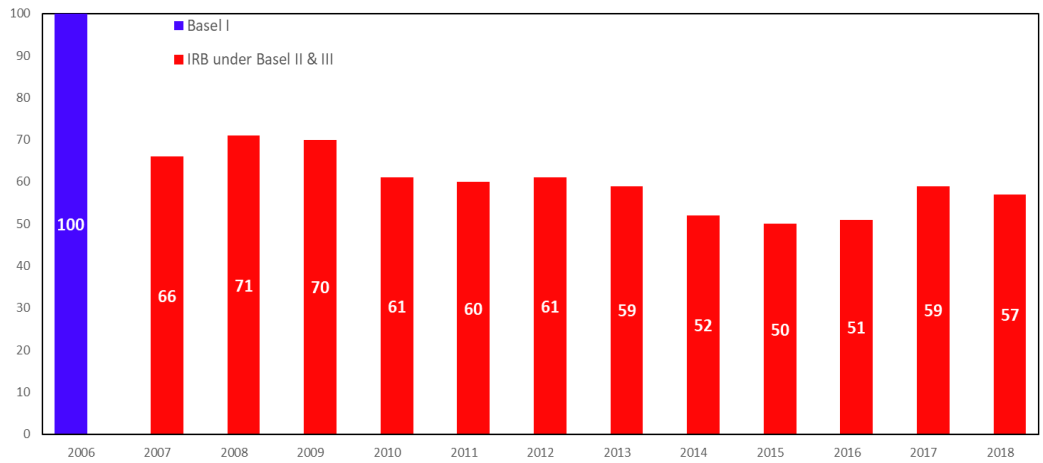
It also included a leverage ratio requirement to constrain excessive leverage in the banking system. These regulations aimed to ensure that banks were better able to withstand losses and maintain financial stability. (Basel Committee, 2011).

Risk weights for Banks with IRB-method

It is widely accepted that a high level of RWE should be associated with a high level of risk. This relationship reflects that banks with higher RWE should be incentivised with higher interest rates on their loans with high RWE, while those with low RWE should be incentivised with lower interest rates. According to Norges Bank, residential mortgages tend to have lower risk and lower interest rates on average compared to loans for businesses and, as such, are given a lower weight (Norges Bank, 2022). This aligns with the principle that higher levels of risk should be compensated with higher interest rates and rates of return, and vice versa. The Basel III regulations have decreased RWs for corporate exposures, from 100%

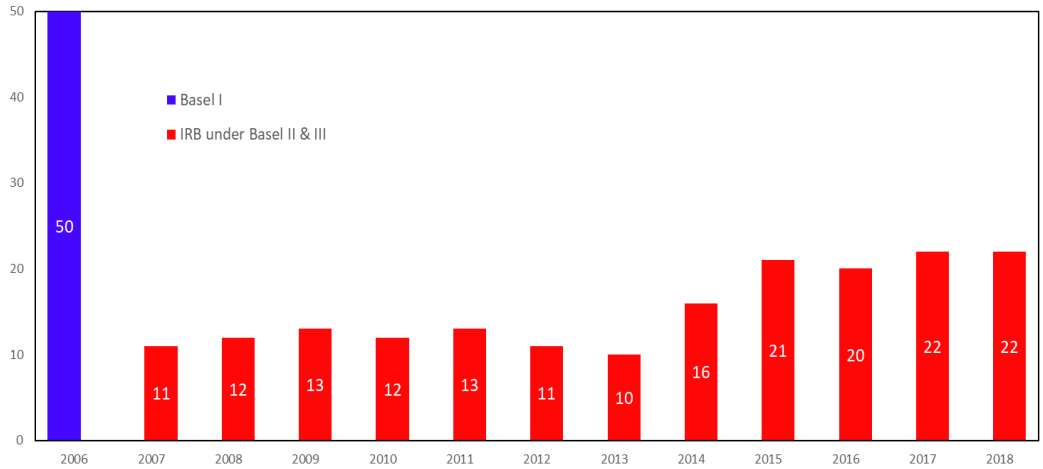
under Basel I to around 57% using the IRB method in 2018. Similarly, risk weights for residential mortgage loans have dropped from 50% under Basel I to 22% using the IRB method in 2018. The two figures below are taken from Norges Bank (2020) and show RWE development from the IRB method's implementation.

Figure 1: Average risk weight on corporate exposures under Basel I and the IRB method. Weighted average of the Norwegian IRB banks. Percentage. 2006 - 2018



Source: Norges Bank (2020); Data derived from banks' Pillar 3 reports.

Figure 2: Average risk weight on residential mortgages under Basel I and the IRB method. Weighted average of the Norwegian IRB banks. Percentage. 2006 - 2018



Source: Norges Bank (2020); Data derived from banks' Pillar 3 reports.

3.3 Basel Framework's Three Pillars and Their Capital Requirements

The Basel Framework comprises three Pillars that act as the core regulatory standards to ensure that financial institutions have adequate capital to absorb risks. These Pillars are:

Pillar 1: Minimum Capital Requirements

Pillar 1 stipulates the minimum capital that a bank must hold to cover its RWE. The risks taken into account are credit, market, operational, and counterparty risks. The capital under Pillar 1 consists of three tiers:

1) **Common Equity Tier 1 (CET1):** This is the purest form of capital and includes common shares and retained earnings. CET1 can absorb losses immediately, making it the most reliable capital source. The minimum CET1 requirement is 4.5% of risk-weighted assets.
2) **Additional Tier 1 (AT1) capital:** This includes instruments such as perpetual hybrid capital and contingent convertible securities. It can absorb losses if CET1 is exhausted and must meet the conditions under Article 52 of the Capital Requirements Regulation (CRR). The minimum AT1 requirement is 1.5% of risk-weighted assets.
3) **Tier 2 capital (T2):** T2 capital includes subordinated debt and can absorb losses if both CET1 and AT1 capitals are depleted. The minimum T2 requirement is 2% of risk-weighted assets.

Pillar 2: Supervisory Review Process

Pillar 2 involves the Internal Capital Adequacy Assessment Process (ICAAP), which requires banks to assess their capital adequacy based on their specific risk profiles. The supervisory authority (in Norway, the Financial Supervisory Authority - FSA) evaluates and monitors the banks' internal capital assessment and can implement measures if the capital is deemed inadequate. Some examples of P2R requirements in Norway: Eika Boligkreditt AS (0.5%), Sparebank 1 SR-Bank (1.6%), Sparebanken Vest (1.5%), DNB Bank ASA (2.1%), Eidsberg Sparebank (2.5%), Åfjord Sparebank (3.3%), Cultura Sparebank (4.5%), Nordic Corporate Bank (6.0%). (FSA, 2023b).

In addition to the Pillar 2 requirements, there is also an individual Pillar 2 Guidance (P2G), which, while not legally binding, recommends additional capital buffers. P2G serves as a supervisory tool that advises banks on maintaining extra capital to effectively manage risks and protect against financial stress scenarios (Finans Norge, 2023).

Pillar 3: Market Discipline

Pillar 3 aims to promote market discipline through transparency and disclosure requirements. Banks are required to publish an annual report, known as the Pillar 3 Report, which provides information on their risk profiles, capitalisation, and risk management practices.

Regulatory Capital Buffers

In addition to the minimum capital requirements stipulated under Pillar 1, banks are also required to maintain additional capital buffers to absorb losses during times of financial stress. These include:

1. **Capital Conservation Buffer (CCoB):** Comprising 2.5% of total risk-weighted assets, this must be held in CET1 capital. (ESRB, 2023)
2. **Systemic Risk Buffer (SyRB):** This varies by jurisdiction and is designed to mitigate systemic risks. It currently covers all domestic exposures in Norway and consists of **4.5%** of CET1 capital or **3%** for non-AIRB or systemically important institutions until 31. December 2023 (FSA, 2023a).
3. **Buffer s for Systemically Important Institutions (G-SIIs/O-SIIs):** Additional capital requirements for institutions that are deemed either global systemically important (G-SIIs) and other systemically important institutions (O-SIIs). In Norway, as of April 2023, four systemically important banks are operating: DNB Bank ASA (2%), Kommunalbanken AS (1%), Nordea Eiendomskreditt AS (1%) and Sparebank 1 SR-bank ASA (1%).
4. **Countercyclical Capital Buffer (CCyB):** This buffer varies and is designed to counteract cyclical systemic risks. When the cyclical systemic risk is judged to be increasing, institutions should accumulate capital to create buffers that strengthen the banking sector's resilience during periods of stress when losses materialise. This will help maintain the supply of credit to the economy and dampen the downswing of the financial cycle. The CCyB can also help dampen excessive credit growth during the upswing of the financial cycle. The requirement is determined quarterly by Norges Bank.

Below is a summary table for Norway:

Criteria	**SA & FIRB**	**AIRB**
Minimum CET1	4.5%	4.5%

Additional Tier 1 capital	1.5%	1.5%
Tier 2 capital	2.0%	2.0%
Capital Conservation Buffer (CCoB)	2.5%	2.5%
Systemic Risk Buffer (SyRB)	3.0%	4.5%
Countercyclical Capital Buffer (CCyB)	1.5%	1.5%
Buffers for Systemically Important Institutions (O-SIIs)	1.0%/2.0%	1.0%/2.0%
Total CET1 (with buffers)	11.5%	13% (+1%/2% if systemically important)
Total Tier 1 (with buffers)	13%	14.5% (+1%/2% if systemically important)
Total Pillar 1 (with buffers)	15%	16.5% (+1%/2% if systemically important)
Pillar 2 requirements (Individual)	Individual	Individual

Table 2: *Minimum capital requirements; Source: Financial Supervisory Authority (FSA), 2023a.*

Equation 6:

$$\text{Total Capital Adequacy Requirement} = \frac{\text{Total Tier 1 capital} + \text{Total Tier 2 capital}}{\text{Risk weighted exposure (RWE)}}$$

3.4 National adoption of EBA on Capital Adequacy

Most European countries have a buffer requirement for banks between 2.5% and 6.5%. However, there are some exceptions to this. For example, Iceland has a buffer requirement that ranges between 4.5% and 9.5%, Bulgaria's buffer requirement is between 6.5% and 7.5%, and Norway has the highest buffer requirement in Europe, ranging from 7% to 10.5%. Additionally, it is worth noting that Norway also has a specific requirement for systemic risk buffer (SyRB) for both IRB and SA banks, which is 3% for SA banks and 4.5% for IRB banks. This requirement for SA banks will remain at 3% until 31. Dec 2023. This is noteworthy as out of 30 European countries, only eight have a specific systemic risk buffer requirement, all lower or equal to that of the Norwegian 3% for SA banks. Several of these have set it to zero for SA banks or differentiated between SA and IRB banks to a higher degree (ESRB, 2023)

Another distinction for Norway is the minimum risk weights for IRB banks of 20% and 35% for mortgages and commercial real estate. (Forskrift om kapitalkrav og nasjonal tilpasning av CRR/CRD IV, 2014, §4). Most other European countries

have RWs much lower than Norway's. European central bank (ECB) banking statistics for the second quarter of 2022 reported an average RWE as low as 13,72% for exposures to retail secured by immovable property. (Supervisory Banking Statistics, 2021).

The CRR requires a minimum LGD of 10% for mass-market loans secured by residential property. Norway is the only country utilising CRR's flexibility to raise the minimum requirement for average LGD on mortgage loans. In 2014, the Norwegian Ministry of Finance increased the minimum requirement to 20%. This measure was justified by rising property prices and increased household debt burden (Finans Norge, 2023a). Banks operating in Norway are required to consider the most severe economic downturn from the past two decades when making their estimations of LGD. According to the Norwegian financial authorities, the last significant economic downturn corresponds to the banking crisis that occurred in the early 1990s.

On the other hand, the European Banking Authority (EBA) stipulates a different requirement for retail exposures. In this context, the EBA requires LGD estimates to be underpinned by a minimum of five years' worth of data (CRR, Article 181). This contrasts with the Norwegian approach, which necessitates the consideration of a longer historical period and specifically focuses on the most severe downturn. In order to address the limitations in data segments that have experienced minimal defaults, it is stipulated that all residential loans in Norway should possess a PD of no less than 0.2%. This requirement is notably higher when compared to the minimum threshold established by the EBA, which sets a lower limit for PD at 0.03% for any given exposure (CRR, Article 160).

Therefore, it is reasonable to conclude that Norway has a significantly different approach to RWE compared to the rest of Europe, at least in terms of RWE for mortgages, regulatory buffers, and to some extent, the lack of differentiation between SA and IRB banks with lower SyRB. If various methodologies undervalue risk, leading to lower risk weights, the calculated capital adequacy ratio may falsely indicate that banks can absorb more losses than they truly possess (Andersen & Winje, 2017). This could also be the opposite for Norwegian banks, which may lead to overvaluing risk, leading to higher RWs.

3.5 The Norwegian local saving bank

The Norwegian banking sector comprises 88 savings banks and 36 savings bank foundations (Sparebankforeningen, 2022). In Norway, there are both savings banks and commercial banks. A savings bank is characterised by being a self-owned institution, either in whole or part. Savings banks without equity shares have community capital that does not belong to specific owners but was added to the bank at its formation and through the annual addition of a portion of the bank's profits. Savings banks with equity shares have capital that consists of both community capital and shareholder equity. In recent years, several savings banks have established savings bank foundations and placed all or part of their community capital in the foundation. On the other hand, a commercial bank is a bank that is organised as a regular corporation with shareholders as owners.
(Sparebankforeningen, 2021.)

4.0 Discussions and Results

4.1 Data and Descriptive Analysis

The principal source used in this research is the parent bank's accounting and balance sheet data compiled and provided by The Norwegian Banks Guarantee Fund. As part of their role, they collect and structure accounting data each quarter of more than 100 banks operating in Norway to be provided to banks and analysts per request. The same data source was also used in the research conducted by Julsrud & Getz Wold (2020), who investigated how banks respond to higher capital requirements in Norway. The data obtained for this study were on a quarterly basis from 31.06.2014 to 31.06.2022. The sample used includes 105 Norwegian banks, eight of which have adopted the IRB method and are referred to as an IRB bank. The eight IRB banks are namely: DNB Bank ASA, Sparebank 1 SR-Bank ASA, Sparebank 1 SMN, Sparebank Vest, Sparebank 1 Nord-Norge, BN Bank ASA, Sparebanken Møre and Sparebank 1 Østlandet. Despite representing a small fraction of the total number of banks, which are largely SA banks, these IRB banks control a significant presence in the market. Precisely, they managed an overwhelming 80.2% (based on own data calculation) of the total assets in the dataset, including the transferred lending portfolio to credit subsidiaries of all Norwegian banks in the analysed period, underscoring their substantial influence within the Norwegian banking landscape. It is important to note that in econometric terms, the inclusion of only eight IRB banks might introduce a challenge due to potential limited variation in the primary variable. Given the low count of IRB banks, this might constrain the variability in the sample, potentially influencing the robustness and generalisability of the findings.

While the dataset does not use weightings according to the size of the banks, the size factor is included in the regression analyses as a control variable.
It should be noted that the data is limited to Norwegian banks and does not include foreign banks operating in Norway. These foreign banks had a market share in Norway of about 22% of private loans and 34% of corporate loans in 2020 (see Appendix 1).

For this research, the data sheets had to be structured and cleaned so that they could be used in a reliable and consistent way together. In order to ensure that all the

quarterly datasets contained common variables, a list including all variables from each was created to cross-check and eliminate variables not common to all. Further, "niche banks" and specialised "consumer credit banks" were removed from the data set; only banks that fit within having both mortgages and corporate loans were included. In the process of checking and cleaning the data for anomalies and errors, it was discovered that several observations of RWE had been incorrectly recorded while appending the data set, giving unreasonable values due to formatting issues. To correct these errors, the values were manually replaced by the correct ones. Further, to be able to use fixed effects panel data analysis, the "xtset" command was used in Stata to declare the panel structure of the dataset, where ID is used as the panel variable (cross-sectional identifier) and date as the time variable (time-series identifier).

4.1.1 Summary statistics

Table 3 presents the summary statistics for Norwegian banks included in the dataset, spanning from June 31, 2014, to June 31, 2022. The data were collected from the Norwegian Guarantee Fund and were limited to the accounting data of the parent banks. Niche and specialised consumer banks were excluded from the dataset to focus on similar banks with mortgage and corporate loan portfolios. Banks included in the table met the criterion of having a minimum of 10% of their portfolio in mortgages and corporate loans. See **Appendix 4** - for the definitions of the below-mentioned metrics.

Table 3: bank summary statistics for all banks (105 Banks)

Bank Descriptives	**N**	**mean**	**sd**	**min**	**p25**	**Median**	**p75**	**max**
BANK ASSETS (Bn NOK)	3196	37.237	217.526	.5369	2.8154	4.491	10.645	2617.93
LOG BANK ASSETS	3196	1.8519	1.3233	-.622	1.0351	1.5021	2.3651	7.8701
CAPITAL ADEQUACY RATIO	3196	.2085	0.0285	.1412	.1909	.2069	.2258	.3792
EQUITY RATIO	3196	.1116	0.0185	.0593	.0988	.1118	.1238	.1739
LEVERAGE RATIO	3196	.1021	0.0144	.056	.0928	.1014	.1107	.1635
CORPORATE RATIO	3196	.2903	0.1169	.1128	.2107	.2685	.3294	.8187
ROA	3196	.0091	0.0043	-.0305	.0067	.0087	.0109	.0604
ROE	3196	.0824	0.0370	-.242	.0617	.08	.0995	.472
REVENUE DIVERSIFICATION	3089	.4061	0.1534	.0377	.3012	.3932	.4945	1.1303
Loan Descriptives	**N**	**mean**	**sd**	**min**	**p25**	**Median**	**p75**	**max**
RISK WEIGHT	3196	.5276	0.0543	.3061	.497	.5249	.5579	.8066
NON-PERFORMING LOANS	3196	.0136	0.0097	0	.0064	.0114	.018	.0794
LOAN LOSSES	3089	.0012	0.0032	-.0137	-.0001	.0006	.0018	.0537
LOG Z-SCORE	3196	4.0476	.5795	1.8010	3.7076	4.0407	4.3422	5.7467
FIXED INCOME SECURITIES RATIO	3195	.0865	0.0491	0	.0556	.0805	.1078	.3452
INTEREST RATE	3195	.0301	0.0082	0	.0265	.0307	.0346	.0773
Adj. INTEREST RATE	3195	.0332	0.0089	0	.0295	.0336	.0379	.0829
NET INTEREST MARGIN	3195	.018	0.0046	0	.0164	.0185	.0204	.0453
TRANSFERRED PORTOFOLIO TO CREDIT COMPANY	3196	.1949	0.0797	0	.1435	.2018	.2486	.4742

Please note: While ROA, ROE, Loan Losses, Interest Rate, and Net Interest Margin are all reported initially on a quarterly basis, the summary table presents these variables on an annualised basis. This is accomplished by multiplying the quarterly figures from the income statement by four before dividing them by the corresponding balance sheet figures, thereby illustrating their yearly average. However, this method has the potential to skew the statistical measures, especially minimum, 25th percentile, median, 75th percentile, and maximum, because it inflates the impact of the highest and lowest quarters. As a result, these calculated extremes may appear larger than they would in reality due to the scaling process.

The Norwegian banking sector, represented by 105 banks, showcases various financial health indicators. As measured by assets, the average bank size is 37.2 billion NOK, with a significant standard deviation of 217.5 billion NOK. This suggests considerable variation in the size of banks, ranging from smaller banks with 0.54 billion NOK in assets to larger banks with 2618 billion NOK. The median bank asset value is around 4.5 billion NOK, which indicates a right-skewed distribution, with the bulk of the banks being smaller and some outliers significantly larger. The log transformation of bank assets provides a clearer picture, with a mean of 1.85, a median of 1.5 and a standard deviation of 1.32, reflecting a more normalised distribution.

The capital adequacy ratio, a key indicator of a bank's financial strength, averages 20.85%, with a standard deviation of 2.85%. The banks have an average equity ratio of 11.16% and a leverage ratio of 10.21%, both metrics indicating the proportion of a bank's total assets financed by shareholders. On the lending side, the average risk weight stands at 52.76%. Additionally, the minimum RWs for IRB banks for retail secured by real estate and commercial real estate in Norway are 20% and 35%, respectively, which is higher than those of most other European countries (Forskrift om kapitalkrav og nasjonal tilpasning av CRR/CRD IV, 2014, §4). European central bank (ECB) Banking statistics for the second quarter of 2022 reported an average RWE as low as 13.72% for exposures to retail secured by real estate (Supervisory Banking Statistics, 2021). Also, compared to other European countries, Norway has one of the highest buffer requirements for banks, ranging from 7% to 10.5%, with a specific requirement for a systemic risk buffer for both IRB and SA banks. Most European countries have a buffer requirement for banks between 2.5% and 6.5%. Therefore, Norway's approach to RWE and regulatory buffers significantly differs from the rest of Europe. The Norwegian banking sector appears to be in good overall health, with higher regulatory buffers and higher floors on risk exposures for property-backed loans. Further, applying the Z-score, on average, Norwegian banks are 68.8 standard deviations of ROA away from insolvency (see Appendix 13).

Most banks demonstrate robust lending activities, evidenced by the relatively low annual NPL ratio, which stands at 1.36%. With a median of 1.14%, the distribution shows a slight right skewness (see Appendix 10). However, two banks, "Blaker Sparebank" and "Vågershei Sparebank," faced difficulties during 2014-2016, with

their NPLs peaking at 7.94% and 7.91%, respectively, coinciding with periods of negative profits. The 75th percentile observations fall within having 1.8% NPLs. The average yearly loan loss ratio is 0.12%, although a high standard deviation of 0.32% reveals notable variation in loan performance among different banks. Most banks report insignificant losses over the studied period. The national adoption with one of the highest regulatory buffer requirements and floors on risk weights in Europe, coupled with virtually negligible loan losses, portrays a reassuring depiction of the resilience and solidity of the Norwegian banking industry during this period. The highest single-quarter loan loss reached 1.34%, while for an entire year, it climbed to a maximum of 2%. Nevertheless, the frequency distribution reveals that such instances are more outliers than common occurrences (see Appendix 11).

The summary statistics provided give an overview of the profitability of a set of banks, as indicated by the ROA and ROE. Both these metrics provide insights into the effectiveness of management in generating profits with the bank's resources. For the ROA, the average is 0.91%, suggesting that for every 100 NOK of assets, the banks generate about 0.91 NOK in profits. However, there is considerable variation, as indicated by the standard deviation of 0.43%. This implies that some banks are more efficient in using their assets to generate profits. The minimum and maximum values further illustrate this variation, ranging from a loss of 3.05% to high profitability of 6.04%. The ROE statistics provide a similar picture but on a larger scale. The average ROE is 8.24%, indicating that the banks generate an average of 8.24 NOK profit per 100 NOK of equity capital. The standard deviation of 3.7% showcases a similar variation as in ROA, with close to being 50% of its mean value. The range is also much broader, from a loss of 24.2% to a substantial return of 47.2%. The 25th, 50th (median), and 75th percentiles provide additional insight into the distribution of profitability. The median is slightly below the mean for both ROA and ROE, indicating a skewed distribution with a long tail on the right. This suggests that while most banks have profitability close to the mean, some exceptionally profitable banks pull the mean upwards. While the average profitability of the banks is positive, there is significant variation across banks. Some banks are much more efficient and profitable, which could reflect differences in management quality, strategy, risk-taking, market conditions, regulatory differences, or other factors.

The mean level of revenue diversification was found to be 40.61%. This suggests a moderate level of diversification in the bank's revenue sources, with commission-based income representing a significant, but not dominating, part of their total revenue. The standard deviation of 15.34% shows variability in how bank's balance interest and commission revenues, with some banks showing significantly higher or lower levels of diversification. This level of diversification is an important indicator of the risk profile of banks. Those with greater diversification may be less vulnerable to fluctuations in a single income source, which can enhance financial stability. However, high diversification might also indicate a strong focus on fee-generating activities, which could be seen as risky if such activities are volatile or cyclical. Less capital-intensive income can be seen as more valuable than more capital-intensive interest revenue since other fee-generating activities can grow faster or demand less capital to grow.

Regarding interest rates, banks charge an average interest rate of 3.01%, which adjusts to 3.32% when excluding the fixed-income securities portfolio from the average interest-bearing asset. The ratio of fixed-income securities, typically safer investments, stands at 8.65% on average. The net interest margin, which represents the difference between interest income and expenses divided by the total interest-bearing asset, averages 1.80%. The average ratio of the portfolio transferred to credit subsidiaries is 19.49%, suggesting that a significant proportion of assets is off-loaded to these entities. Bank's corporate ratio averages 29%, indicating that the loan portfolios mostly consist of low-risk mortgages. When adjusted for the portion of the portfolio that is transferred to the credit company, an average corporate ratio of approximately 23.39% is obtained (See Appendix 4).

Table 4 presents summary statistics divided into Standard Approach (SA) banks and Internal Ratings-Based (IRB) banks. The summary statistics include the number of observations, mean, and standard deviation and a t-test to determine whether the two groups' means are significantly different. The observations span from June 31, 2014, to June 31, 2022. An SA bank is defined as a bank that uses the Basel II Standard Approach for all of its loans during the sample period, while an IRB bank is defined as a bank that employs the Internal Ratings-Based approach for some or all of its loans during the sample period. See **Appendix 4** - for the definitions of the below-mentioned metrics.

Table 4: bank summary statistics for SA & IRB

	SA (97 Banks)			IRB (8 Banks)			t-test
Bank Descriptives	**N(1)**	**mean(2)**	**sd(3)**	**N(4)**	**mean(5)**	**sd(6)**	**(2)-(5)**
BANK ASSETS (Bn NOK)	2932	8.0582	11.8143	264	361.2993	677.0263	-28.2488
LOG BANK ASSETS	2932	1.5769	0.9298	264	4.9066	1.1950	-54.2941
CAPITAL ADEQUACY RATIO	2932	.2072	0.0267	264	.2233	0.0413	-8.9069
EQUITY RATIO	2932	.112	0.0184	264	.1072	0.0193	4.1052
LEVERAGE RATIO	2932	.1021	0.0161	264	.1014	0.0172	2.8866
CORPORATE RATIO	2932	.2734	0.0974	264	.4785	0.1470	-31.1721
ROA	2932	.0087	0.0039	264	.0132	0.0059	-16.7170
ROE	2932	.0788	0.0335	264	.1225	0.0487	-19.4436
REVENUE DIVERSIFICATION	2833	.4001	0.1491	256	.4732	0.1825	-7.3667
Loan Descriptives	**N(1)**	**mean(2)**	**sd(3)**	**N(4)**	**mean(5)**	**sd(6)**	**(2)-(5)**
RISK WEIGHT	2932	.5286	.0496	264	.5166	0.0906	3.4502
NON-PERFORMING LOANS	2932	.0134	.0096	264	.0158	0.0097	-3.9479
LOAN LOSS RATIO	2833	.0011	.0032	256	.002	0.0039	-4.0366
LOG Z-SCORE	2932	4.0927	0.5601	264	3.5464	0.5551	15.1888
FIXED INCOME SECURITIES RATIO	2931	.0811	0.0466	264	.1464	0.0344	-22.2190
INTEREST RATE	2931	.0304	0.0083	264	.0271	0.0073	6.2726
Adj. INTEREST RATE	2931	.0333	0.0089	264	.0323	0.0085	1.7291
NET INTEREST MARGIN	2931	.0182	0.0046	264	.0159	0.0040	8.1103
TRANSFERRED PORTOFOLIO TO CREDIT COMPANY	2932	.1885	0.0779	264	.2664	0.0628	-15.7895

As depicted in **Table *4***, there is a notable difference in size between the average IRB bank and the average SA bank, with IRB banks being approximately 40 times larger in terms of assets. The FSA sets a minimum threshold, restricting smaller banks with less than 30 billion NOK portfolios from adopting the IRB approach (FSA, 2022). This policy highlights the size disparity between the two groups.

The equity ratio can potentially be influenced by loans transferred to subsidiaries. If these transferred portfolios were incorporated into the calculations, the distance in equity ratios might become more considerable. This is particularly the case with IRB banks with substantially higher transfer proportions. These portfolios comprise mostly high-quality mortgages, generally giving lower RWE; consequently, these exposures should result in a lower equity ratio than the parent bank. It is not known with certainty how the inclusion of the transferred portfolios would affect the equity ratios and, consequently, the explanation for the profitability ratios. However, it can be hypothesised that this might be the case. As the transfers for IRB banks are proportionally larger, and they have significantly lower RWE connected to these mortgages (i.e., lower equity ratio in the credit subsidiaries). Based on calculations with some assumptions, it is found that the combined (parent + transfers) equity ratio for the IRB banks on average was 8.92% vs 10.37% for SA, about 13.95% lower (See Appendix 9). The example of the biggest IRB bank in the study DNB also shows a similar tendency in 2020, where the equity ratio is 8.135% in the parent bank vs 5.5% in the credit subsidiary (Annual report & Boligkreditt 2022).

Although the IRB banks, on average, hold a higher total capital adequacy ratio, these banks also have nearly double the exposure to corporate loans, which are generally deemed riskier with higher RWE. Surprisingly, the RWs for SA banks are significant and higher than for IRB banks, although their differences are not vast. By including the transferred portfolio and making an assumption that the Risk-Weighted Exposure (RWE) for the SA on the housing portfolio is 35% and approximately 20% for the IRB approach - based on the average RWE for IRB banks in 2020 reported by Norges Bank, the difference in RWE would noticeably increase. Specifically, it would be 49.52% and 43.20%, respectively (see own calculation - Appendix 4).

This discrepancy may be attributed to the more sensitive RWs employed by IRB banks for corporate loans, which could incentivise them to lend more to such clients while still maintaining lower RWs than their SA counterparts. Andersen et al.

(2020) conducted an analysis that revealed that IRB banks in Norway lowered their lending margins and achieved greater growth in the commercial market than SA banks after the introduction of a new system in 2007 (Andersen et al., 2020, p.13). Additionally, Julsrud & Getz Wold (2020) mentioned that some Norwegian banks would rather adjust their portfolio toward lower RWs than raise additional equity, explained by the substitution from corporate loans to household lending. This strategic adjustment may have been necessary due to SA bank's inability to compete effectively against IRB banks on commercial loans, as well as their desire to decrease their RWs. Further investigation is needed to understand how SA banks' non-risk sensitive approach influences their loan portfolios, particularly if these banks are opting for riskier loans due to the non-risk sensitive weights. There is a possibility that IRB banks outperform in the arena of lower-risk loans. However, the findings present an interesting twist. Despite the competition, SA banks continue to exhibit lower loan losses and fewer non-performing loans. These results might point in another direction and need to be looked at more in-depth.

SA banks charge a higher average interest rate on their loans (3.04% vs. 2.71%). Interestingly, SA banks have considerably fewer corporate loans, which should imply a lower average interest rate, but this is not true for this case. This is also something that shows up on the net interest margin (1.82% vs. 1.59%). The lending rate of IRB banks may be influenced by their larger fixed-income securities portfolio, which is at 14.64% compared to SA banks' 8.11%. The higher share of fixed-income securities, coupled with a higher credit rating, could potentially result in a lower lending rate for IRB banks. However, even after adjusting the interest rate and removing the fixed income portfolio from the denominator, SA banks still exhibit a slightly significantly (one sided test - 5%) higher lending rate (3.32% vs 3.33%). However, it is evident that the fixed income security portofolio explains a larger part of the difference between their interest rates. Assuming the transferred portfolios to credit subsidiaries are incorporated at a combined level, a more notable difference between the lending rates of the SA banks and the IRB banks could be anticipated. This can be linked to the higher proportion of transferred portfolios in IRB banks, which predominantly consist of high-quality mortgages. Consequently, while both lending rates might decrease due to these high-quality, low-interest loans, the rate for IRB would likely reduce more due to their larger share of such loans.

According to Bjørn Fristad, the Director of Risk Management at Sparebanken Sør, "The IRB banks can charge significantly lower prices than the standard banks and still achieve a higher return on equity" (Fristad. B, 2022, p.17). This is potentially a drawback for competition and loan growth. Implementing new regulations could lead to improved competition. Andersen & Johnsen (2023) writes about how the interest rate would decrease for SA banks, with lower CET1 capital of 3.6 percentage points with the new reform regulations: "According to the calculations from the Basel Committee (2021), this could result in a decrease in the standard method banks' average lending rates by 0.2 - 0.3 percentage points." (Andersen & Johnsen, 2023, p. 40). For the descriptive statistics, the average lending rate would change from 3.04% to 2.84% or 2.74% (subtracting 0.2% or 0.3%). This is in close with the IRB bank's average interest rate of 2.71% (**Table *4***). It remains to be seen whether there will be a convergence in interest rates between SA and IRB banks following the implementation of Basel IV in 2025.

Despite having a lower net interest margin, IRB banks still exhibit significantly higher average profitability in terms of both ROA *(1.32% vs 0.87%)*, which indicates higher profitability relative to assets, and ROE *(12.25% vs 7.88%)*, which on average indicates approximately 50% higher earnings relative to equity for IRB banks, which is quite substantial. Other factors that contribute to these higher profitability ratios among IRB banks may extend beyond revenue from lending activities and may include higher efficiency, lower equity ratios, and a higher degree of non-interest income sources such as account-related fees, loan origination fees, credit card fees, provisions, trading, and investment income. IRB has a slightly lower equity ratio of (10.72% vs 11.2%), which results in a higher leverage effect on ROE. The lower equity ratio and higher corporate ratio in IRB banks can be attributed to the fact that they are able to maintain lower RWE than SA banks, particularly with respect to corporate exposures. On average, revenue diversification is greater for IRB banks (*47.32% vs 40.01%*), suggesting a higher proportion of fees and commissions relative to total interest income compared to SA banks. This revenue diversification may further contribute to the higher profitability observed among IRB banks. It is probable that if the transfers to the credit subsidiaries were included in the profitability ratios calculation, the ratios would change – as the revenues from the credit companies come solely from lending out to residential mortgages, which might include lower profitability ratios

compared to their parent bank portfolio, that include corporate lending exposures and other revenue sources. This effect would likely be larger for IRB banks as they have a higher proportion of transfers.

Considering all proxies measuring credit risk, IRB banks exhibit significantly higher risks in terms of Z-score (3.55 vs 4.09), non-performing loans (1.58% vs 1.34%), and loan losses (0.20% vs 0.11%). The data suggest that banks using the IRB approach appear to have a higher credit risk on their parent bank loan portfolio than banks using the SA, based on the provided metrics. However, it is important to put these results into context. A key factor to consider is that IRB banks have nearly double the corporate loan ratio (47.85%) on the parent bank compared to SA banks (27.34%). Corporate loans generally carry a higher risk level than other types of loans, such as personal or mortgage loans, which could contribute to the higher credit risk observed for IRB banks.

Moreover, IRB banks have transferred a significant proportion, about 26.64%, of their assets to subsidiary credit companies. This is substantially higher than the average for SA banks, 18.85%. Most of these transferred assets are mortgages, which are typically lower-risk exposures. When accounting for these transferred assets in a combined view, the corporate loan ratio becomes more comparable but still displays a large difference between the two groups: approximately 35.13% for IRB banks versus 22.19% for SA banks (see Appendix 3). Therefore, while the raw data may suggest a higher credit risk on loans for IRB banks, a closer examination that accounts for the distribution of assets and the nature of the loans suggests a more nuanced picture. The higher risk observed for IRB banks may be partly attributable to their larger corporate loan portfolio and the significant proportion of lower-risk mortgage assets transferred to subsidiary credit companies. Further, in section 4.3, these effects are controlled for with a regression analysis while isolating the effect of being an IRB bank.

4.1.1 Average over time for the Proxies

Figure 3 presents the mean NPL to gross loan ratio in the parent bank, **Figure 4** presents the mean loan loss ratio to gross loans in the parent bank, and **Figure 5** presents the Z-score calculated as Equity ratio + ROA divided by the standard deviation of ROA, by the two groups: Standard Approach (SA) banks and Internal Ratings-Based (IRB) banks. The observations span the period from June 31, 2014, to June 31, 2022, with the quarterly date from June 2014 on the X axis. An SA bank is defined as a bank that uses the Basel II Standard Approach for all of its loans during the sample period, while an IRB bank is defined as a bank that employs the Internal Ratings-Based approach for some or all of its loans during the sample period.

Figure 3: Mean NPL

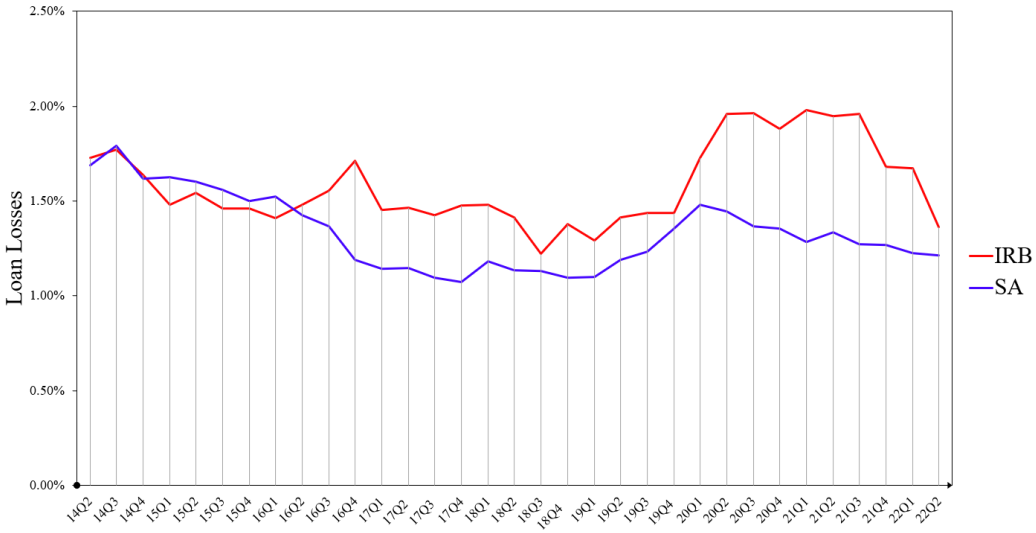


Figure 4: Mean Loan Loss

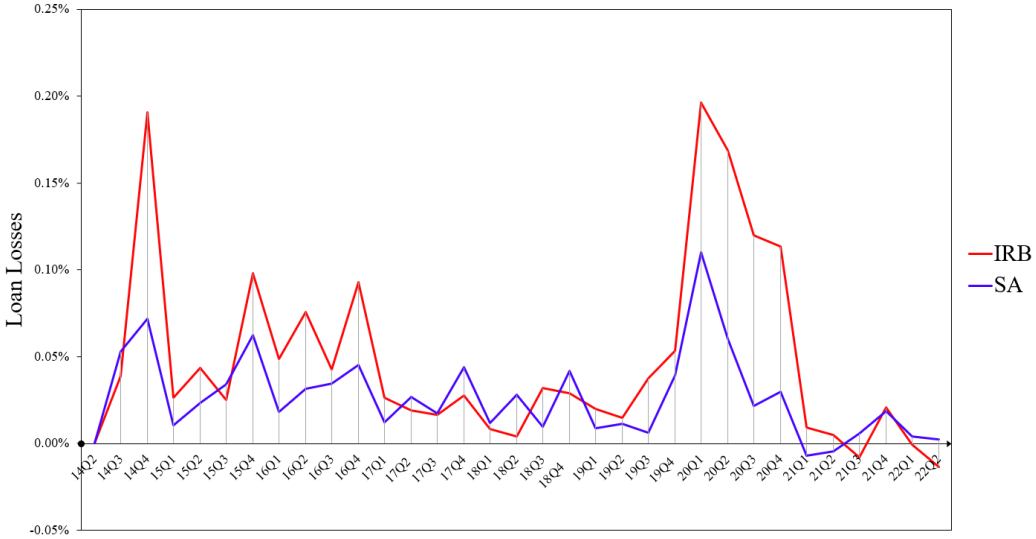
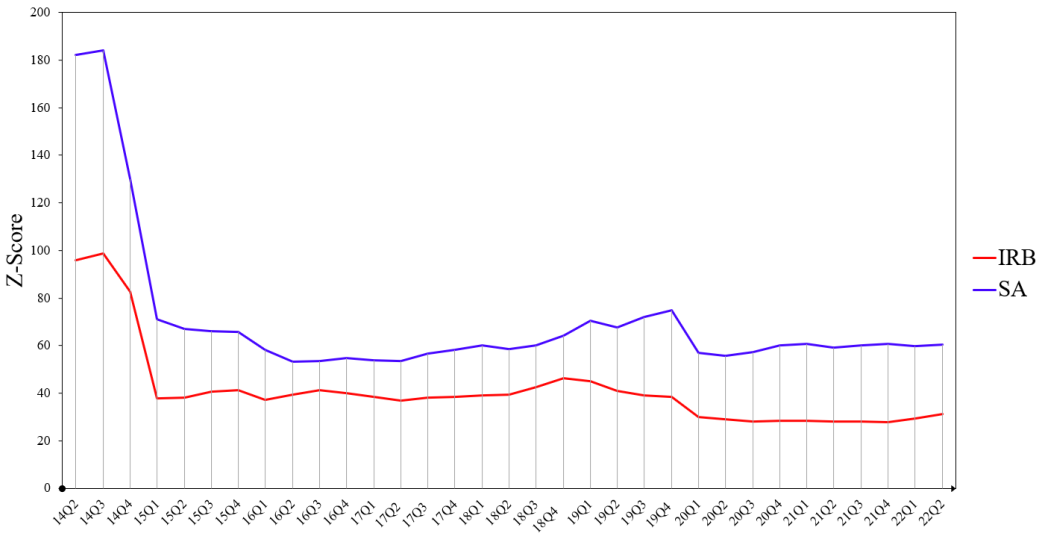


Figure 5: Mean Z-Score



Note: due to three years rolling average sd(ROA) the dates before 2017Q2 will gradually become more representative. At and beyond 2017Q2 all dates will have a three-year rolling SD(ROA).

From the first quarter of 2016 to the fourth quarter of 2016, there was a noticeable surge in NPLs among banks using the IRB approach. This uptick may be connected to the crisis in the oil, offshore, and shipping sectors that began in 2014, followed by an increase in defaults related to these industries. This could imply a heightened sensitivity of IRB banks to downturns in these specific sectors. Moreover, it is evident that the emergence of NPLs typically trails behind the initial detection of loan losses, indicating that banks often preemptively set aside provisions in anticipation of these loan defaults. Corresponding to the period from the fourth quarter of 2019 to the third quarter of 2021, a substantial rise in NPLs and loan losses is observed for both types of banks. However, this surge appears to be more pronounced for banks using the IRB approach. This significant increase in NPLs is likely attributed largely to the COVID-19 pandemic and the associated effects of nationwide lockdowns. Loan losses spiked much faster than NPLs and returned to normal levels within a shorter timeframe for both approaches. This indicates an initial pessimistic outlook that prompted swift action, but the subsequent quicker recovery suggests that the initial provisions were perhaps overly conservative. It could also reflect that the impact of the COVID-19 pandemic on the banks was less severe than initially anticipated.

The Z-score shows that both IRB and SA banks have had stable financial positions over the period. The development of the Equity Ratio has been upward-sloping due to stricter regulatory requirements (see Appendix 6). At the same time, the

variability in ROA has increased (see Appendix 8). These two nearly outweigh each other, forming a flat Z-score development. However, in the aftermath of the COVID-19 crisis, a slight downturn in the Z-score is noticeable for both type of banks. This decline is likely due to increased loan losses, which have negatively affected the ROA, and a decrease in the equity ratio for these banks. See the development of Equity and ROA in Appendix 6 & Appendix 7.

Table 5: Pairwise correlation matrix

This table presents a correlation matrix with 16 variables related to bank performance and risk. The values in the table represent correlation coefficients, which range from -1 to 1. A positive correlation (closer to 1) indicates that the two variables tend to increase or decrease together, while a negative correlation (closer to -1) indicates that one variable tends to increase when the other decreases, and vice versa. A value closer to 0 indicates no significant relationship between the variables. The correlations marked with (*) are statistically significant at the 0.05 level. See **Appendix 4** - for the definitions of the below-mentioned metrics.

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**	**(16)**	**(17)**
(1) *IRB*	1.000																
(2) *BANK ASSETS (Bn NOK)*	0.447*	1.000															
(3) *LOG BANK ASSETS*	0.693*	0.547*	1.000														
(4) *CAPITAL ADEQUACY RATIO*	0.156*	0.082*	0.054*	1.000													
(5) *EQUITY RATIO*	-0.072*	-0.166*	-0.019	0.579*	1.000												
(6) *LEVERAGE RATIO*	-0.015	-0.181*	-0.084*	0.630*	0.789*	1.000											
(7) *CORPORATE RATIO*	0.483*	0.484*	0.683*	-0.039*	-0.072*	-0.035	1.000										
(8) *ROA*	0.284*	0.022	0.337*	-0.026	0.228*	0.092*	0.184*	1.000									
(9) *ROE*	0.325*	0.097*	0.356*	-0.232*	-0.132*	-0.190*	0.198*	0.923*	1.000								
(10) *REVENUE DIVERSIFICATION*	0.131*	0.018	0.057*	0.073*	0.296*	0.019	-0.035	0.244*	0.135*	1.000							
(11) *RISK WEIGHT*	-0.061*	-0.231*	0.063*	-0.427*	0.175*	0.327*	0.209*	0.237*	0.166*	-0.018	1.000						
(12) *NON-PERFORMING LOANS*	0.070*	0.165*	-0.010	-0.016	-0.101*	0.032	0.066*	-0.147*	-0.108*	-0.093*	0.073*	1.000					
(13) *LOAN LOSS RATIO*	0.072*	0.075*	0.056*	-0.048*	-0.085*	-0.020	0.071*	-0.206*	-0.185*	-0.070*	0.046*	0.298*	1.000				
(14) *LOG Z-SCORE*	-0.260*	-0.027	-0.269*	-0.079*	-0.057*	0.078*	-0.080*	-0.181*	-0.136*	-0.240*	0.071*	0.019	-0.094*	1.000			
(15) FIS RATIO	0.366*	0.135*	0.443*	0.197*	-0.015	0.014	0.447*	0.063*	0.059*	0.035	-0.037*	0.069*	-0.013	-0.140*	1.000		
(15) *INTEREST RATE*	-0.110*	-0.127*	-0.218*	-0.190*	-0.128*	-0.007	-0.114*	-0.054*	-0.021	-0.290*	0.200*	0.065*	0.167*	0.023	-0.181*	1.000	
(16) *NET INTEREST MARGIN*	-0.142*	-0.102*	-0.279*	0.052*	0.139*	0.169*	-0.138*	-0.009	-0.079*	0.016	0.103*	0.014	0.089*	-0.091*	-0.178*	0.778*	1.000
(17) *TRANSFERED PORT.*	0.269*	0.090*	0.426*	0.001	0.136*	-0.029	0.279*	0.256*	0.203*	0.343*	0.161*	-0.051*	0.013	-0.184*	0.306*	-0.007	-0.127*

4.2 Methodology

This section presents the methodology employed to address the research question: "*Does being an IRB bank in Norway have any significant implications on credit risk when compared to banks using the standard approach*?". This study use panel data analysis with high-dimensional fixed effects to examine the relationship between being an IRB bank and credit risk while controlling for other bank-specific factors and unobservable characteristics.

The dataset consists of 3,088 observations, capturing bank-level data for Norwegian banks during a period of eight years from June 31. 2014 to June 31. 2022. The different dependent variables, non-performing loans, loan loss ratio, and Z-score, represent the credit risk faced by banks. The primary independent variable of interest is a dummy variable for IRB banks. The study also control for other factors such as bank size, capital adequacy ratio, profitability ratios, revenue diversification (RD), RWE relative to total assets, corporate loan ratio, the proportion of transferred portfolio and the interest rate measured as a percentage of what bank's charge on their loans.

To assess the relationship between being an IRB bank and credit risk, the study employs a panel data regression model with high-dimensional fixed effects [Stata command: "*reghdfe*"] for time (τ_t) and region (α_i). Further, the study uses the cluster-robust variance estimator to obtain robust standard errors by clustering at the bank level ($\varepsilon_i t$). The model specification is as follows:

Equation 7:

$$\begin{aligned}\text{CreditRisk}_i t = \beta^0 + \beta^1 \cdot \text{IRB}_i t + \beta^2 \cdot \text{SIZE}_i t + \beta^3 \cdot \text{CAR}_i t + \beta^4 \cdot \text{Profitability}_i t + \beta^5 \cdot \text{RD}_i t + \beta^6 \cdot \%\text{RWE}_i t \\ + \beta^7 \cdot \text{CorporateRatio} + \beta^8 \cdot \text{InterestRate}_i t + \beta^9 \cdot \text{Transfers}_i t + \alpha_i + \tau_t + \varepsilon_i t\end{aligned}$$

To ensure the validity, unobserved heterogeneity is controlled for by including high-dimensional fixed effects for time and region, which is the regional affiliation of the bank, divided into the 11 large regions in Norway. Time-fixed effects capture macroeconomic factors and other time-varying influences on credit risk, while region-fixed effects capture regional factors that may influence credit risk. Fixed effects are the default option "(...) because they yield unbiased estimates in the presence of correlation between the individual effects for the subject and the regressors included in the model." (Beck et al., 2022, p. 1723)

4.3 Main results

Table 6: NPL Regression

Table 6 shows regression results with non-performing loans as the dependent variable. The primary test variable is IRB, which is a binary indicator representing the risk-based capital frameworks used by banks. It is set to 0 for all SA banks and 1 for all banks using either the FIRB approach or the AIRB approach for any or all of their exposures. In parentheses we have clustered robust t-statistics, i.e., t-statistics adjusted for clustering at the bank level. See **Appendix 4** - for the definitions of the below-mentioned metrics.

VARIABLES	**(1)** **NPL Ratio**	**(2)** **NPL Ratio**	**(3)** **NPL Ratio**
IRB	0.0050 (2.15)	0.0059 (2.27)	0.0065 (2.57)
LOG BANK ASSETS	-0.0002 (-0.19)	-0.0004 (-0.51)	-0.0001 (-0.06)
CAPITAL ADEQUACY RATIO	0.0234 (1.18)	0.0264 (1.50)	0.0306 (1.39)
ROA	-0.4512 (-4.14)	-0.4493 (-3.89)	-0.5195 (-3.48)
REVENUE DIVERSIFICATION	-0.0003 (-0.07)	-0.0006 (-0.16)	-0.0042 (-1.00)
RISK WEIGHTS	0.0174 (1.25)	-0.0043 (-0.30)	-0.0039 (-0.24)
CORPORATE RATIO	0.0057 (0.69)	0.0174 (2.33)	0.0170 (2.36)
INTEREST RATE	0.2396 (2.99)	0.3128 (3.76)	0.7136 (3.11)
TRANSFERRED PORTOFOLIO	-0.0045 (-0.43)	-0.0049 (-0.52)	-0.0038 (-0.42)
CONSTANT	-0.0024 (0.016)	0.0070 (0.015)	-0.0107 (0.017)
Observations	3,089	3,089	3,089
Adjusted R-squared	0.074	0.121	0.155
Time FE	No	No	Yes
Region FE	No	Yes	Yes

According to the findings in ***Table 6*** column (3), when controlling for time and regional fixed effects being an IRB bank is significantly associated with a positive relationship to NPLs close to the 1% significance level. This indicates that being an IRB bank is linked to an increase of 0.65% in NPLs. To determine the magnitude of this effect, the economic significance is calculated as the ratio of the estimated coefficient for IRB ($\hat{\beta}_{IRB}$) divided by the mean NPL ($\bar{Y}_{NPL}$), resulting in 0.0065/0.0135 = 48.1%. This implies that, on average, an IRB bank has an NPL ratio of 48.1% higher compared to the unconditional mean. These findings are consistent with Behn et al. (2022), who also reported higher NPLs and loan losses for IRB banks compared to SA banks in Germany.

The model underscores a considerable positive correlation between the proportion of corporate loans and NPL at the 5% significance level. Following the regression in the third column of ***Table 6***, the economic significance of a 10-percentage point increase in the corporate ratio is computed as follows: 0.0170 ($\hat{\beta}_{CR}$) · 10% / 0.0135($\bar{Y}_{NPL}$). This means that for every 10% points increase in corporate loans from the unconditional mean, there is an associated 12.6% increase in the NPLs. The corporate loan ratio appears to exhibit a causal relationship with credit risk, particularly when excluding banks with low asset quality on household loans, such as consumer credit banks, and focus on banks primarily lending mortgages to consumers. In contrast, the interest rate coefficient may be more of a symptom of credit risk, as banks with higher loan risk tend to charge higher interest rates to compensate for the increased risk.

The regression analysis reveals a significant negative relationship between the bank performance indicator, ROA, and NPLs. In interpreting causality, it is feasible that an increase in NPLs and subsequent loan losses could lead to diminishing returns in proportion to the assets, assuming other factors remain constant, which would reduce ROA. However, this does not automatically signify that banks with higher ROA will exhibit lower NPLs; it is rather the other way around. This is exemplified by the summary statistics in **Table *4***, which demonstrate that banks using the IRB approach tend to have higher average ROA yet experience higher loan losses and NPLs. It is worth noting that in the overall dataset, banks with higher ROA might be performing well and, hence, could potentially have lower NPLs. If this is indeed the case, it might suggest that the adverse effects of increased losses surpass any potential benefits that could be gained from undertaking additional risk.

Table 7: Loan Losses Regression

Table 7 shows regression results with loan loss ratio as the dependent variable. The primary test variable here is IRB, which is a binary indicator representing the risk-based capital frameworks used by banks. It is set to 0 for all SA banks and 1 for all banks using either the FIRB approach or the AIRB approach for any or all of their exposures. In parentheses we have clustered robust t-statistics, i.e., t-statistics adjusted for clustering at the bank level. See **Appendix 4** - for the definitions of the below-mentioned metrics.

VARIABLES	**(1)** **Loan Loss Ratio**	**(2)** **Loan Loss Ratio**	**(3)** **Loan Loss Ratio**
IRB	0.0001 (1.19)	0.0002 (1.68)	0.0003 (1.97)
LOG BANK ASSETS	0.0001 (4.16)	0.0001 (3.54)	0.0001 (3.05)
CAPITAL ADEQUACY RATIO	0.0008 (1.02)	0.0011 (1.48)	-0.0002 (-0.19)
ROA	-0.0568 (-4.34)	-0.0584 (-4.20)	-0.0601 (-3.58)
REVENUE DIVERSIFICATION	0.0003 (1.95)	0.0002 (1.24)	0.0002 (0.87)
RISK WEIGHTS	0.0007 (1.25)	-0.0004 (-0.63)	0.0001 (0.08)
CORPORATE RATIO	-0.0000 (-0.13)	0.0006 (2.32)	0.0005 (2.00)
INTEREST RATE	0.0326 (7.54)	0.0342 (8.53)	0.0430 (4.00)
TRANSFERRED PORTOFOLIO	-0.0000 (-0.11)	-0.0000 (-0.04)	-0.0001 (-0.45)
CONSTANT	-0.0028 (-4.05)	-0.0022 (-3.52)	-0.0023 (-2.81)
Observations	3,089	3,089	3,089
Adjusted R-squared	0.114	0.126	0.184
Time FE	No	No	Yes
Region FE	No	Yes	Yes

Table 7 shows that the IRB dummy is significant at the 5% level only when controlling for both time and region fixed effects. In column (3), IRB has a positive relationship with loan losses with a coefficient of 0.03%; the model suggests a 0.00031($\hat{\beta}_{IRB}$) /0.000299($\bar{Y}_{LL}$), $\approx$ 104% increase in the loan-loss ratio if being an IRB bank compared to the unconditional mean. With this increase in loan losses, the average bank would see [0.03%($\hat{\beta}_{IRB}$) /11.16% (average equity ratio)] $\approx$ 0.027% more of their equity being lost in a quarter if there were no earnings. That being said, the loan losses were almost non-existent for both IRB and SA banks during the observed period. In summary, the fixed effects regression analysis reveals that factors such as IRB (5% significance), bank size (1%), ROA (0.1%), corporate ratio (5%), and interest rate (0.1%) all have a significant relationship with the loan loss ratio. Including time and regional fixed effects improve the model's explanatory power. This is similar to ***Table 6*** column (3), except that size is insignificant. It is also important to note that the proportion of transferred portfolios has no significant influence, and thus its impact on the loan loss ratio can essentially be treated as negligible. However, it is impossible to control the credit risk within the transferred portfolios considering the available data. The regression analysis results indicate that adopting the IRB approach is associated with higher credit risk for the loans measured by historical loan losses, compared to banks using the SA. This finding contradicts the notion that IRB banks are better equipped to manage credit risk due to their more in-depth risk modelling techniques. One possible explanation for this result is that IRB banks may be more exposed to riskier borrowers and asset classes, as reflected in the higher corporate ratio and lower RWs observed for IRB banks in the summary statistics.

The result indicates that larger banks have higher loan losses; this could be attributed to several potential reasons. Key among these is the fact that larger banks typically have more exposure to various lending sectors, including offshore, oil, and shipping industries. These sectors have displayed heightened volatility during the observed period, contributing to higher loan losses. For example, the largest banks in the dataset (all IRB) - DNB ASA, Sparebank 1 SR Bank, Sparebanken 1 SMN, and Sparebanken Vest - have all held exposures to these sectors. In addition, the broad geographical footprint of larger banks may also play a role. These banks often operate across multiple regions, which exposes them to diverse economic

conditions. This diversity in operational areas could inherently lead to greater risks and, subsequently, higher loan losses.

To measure the economic impact of a 10 percentage point increase in the corporate ratio on loan losses, the calculation is derived from ***Table 7*** column (3) as follows: 0.0005 ($\hat{\beta}_{IRB}$) · 10% / 0.0003($\bar{Y}_{LL}$). This means that for every 10 percentage points increase in corporate loans, there is an associated 16.7% increase in the loan loss ratio. This demonstrates that corporate loans tend to carry a greater risk than retail loans. As anticipated, the RWE does not appear to correspond with loan losses. This might be due to the SA banks using a non-risk-sensitive method. If examine the IRB banks separately, the results might indeed show a different pattern due to the higher risk sensitivity. The coefficient for ROA is significant and negative, indicating a strong correlation, but it does not necessarily suggest causality. Loan losses are more likely to influence ROA rather than the reverse. In other words, an increase in loan losses tends to decrease ROA rather than ROA influencing loan losses. Observing the interest rate coefficient in ***Table 7***, which is positive and statistically significant at the 0.1% level in all three models, column (3) reveals that an increase in interest rate by 0.10% is associated with a 14.3% rise in loan losses (4.3% ($\hat{\beta}_{IR}$) · 0.10%/3% ($\bar{Y}_{LL}$)).

Table 8: Log Z-Score Regression

Table 8 presents regression models where the dependent variable is the Log Z-score, which is calculated as (Equity Ratio + ROA)/SD ROA. Z-Score is winzorised (i.e., trimmed 2% at the top) and logarithmically transformed. The standard deviation of ROA is three quarter rolling average. The primary test variable here is IRB, which is a binary indicator representing the risk-based capital frameworks used by banks. It is set to 0 for all SA banks and 1 for all banks using either the FIRB approach or the AIRB approach for any or all of their exposures. In parentheses we have clustered robust t-statistics, i.e., t-statistics adjusted for clustering at the bank level. See **Appendix 4** - for the definitions of the below-mentioned metrics.

VARIABLES	**(1)** **Z-Score**	**(2)** **Z-Score**	**(3)** **Z-Score**
IRB	-0.4227 (-2.40)	-0.4746 (-2.65)	-0.4114 (-2.37)
LOG BANK ASSETS	-0.0205 (-0.46)	0.0221 (-0.50)	-0.0369 (-0.80)
CAPITAL ADEQUACY RATIO	2.0740 (1.49)	2.3344 (1.68)	2.2405 (1.49)
ROE	-1.2697 (-1.56)	-0.7222 (-0.91)	-1.7368 (-1.94)
REVENUE DIVERSIFICATION	-0.3492 (-1.56)	-0.1603 (-0.74)	-0.3083 (-1.34)
RISK WEIGHTS	-0.1618 (-0.24)	0.1945 (0.26)	0.3001 (0.40)
CORPORATE RATIO	0.5597 (1.44)	0.6059 (1.20)	0.5247 (1.05)
INTEREST RATE	26.9279 (6.47)	28.4377 (7.35)	12.1810 (1.55)
TRANSFERRED PORTOFOLIO	-0.3385 (-0.69)	-0.6183 (-1.17)	-0.3700 (-0.76)
CONSTANT	3.3344 (4.18)	2.9950 (3.72)	3.8106 (4.41)
Observations	3,089	3,089	3,089
Adjusted R-squared	0.195	0.238	0.334
Time FE	No	No	Yes
Region FE	No	Yes	Yes

Table 8 column (3) suggests that banks using the IRB approach exhibit a lower log Z-score, evidenced by a coefficient of -0.41. This implies a shorter distance to default. The economic significance of this observation equates to approximately 100 * [exp (-0.41($\hat{\beta}_{IRB}$)) - 1], or a reduction of roughly 34% in the Z-score. Therefore, the model suggests that being an IRB bank corresponds to a 34% decrease in Z-score, compared to the unconditional mean. The critical p-values across all three models fall below the 5% significance level, suggesting that the IRB dummy variable is indeed statistically significant. Therefore, it can be concluded that IRB exhibits a significant and negative correlation with Z-Scores.

To understand the difference in Z-scores between IRB and SA banks, it is necessary to examine the variables contributing to the Z-score calculation: Equity ratio, average ROA, and the standard deviation of ROA, which represents the volatility of returns. Considering first the combined measure of solidity (Equity ratio + average ROA), a marginal difference is observed. On average, Standard Approach (SA) banks have an Equity ratio of 11.2% and a ROA of 0.874%, leading to a total solidity of 12.074%. On the other hand, IRB banks, with an average Equity ratio of 10.7% and a ROA of 1.315%, exhibit a total solidity of 12.015%. Although slight, the SA banks are somewhat more solid, by about 0.06%. However, the most notable difference, and the key factor behind the Z-score difference, lies in the volatility of returns. IRB banks demonstrate nearly double the volatility of SA banks, with an average for the group sd(ROA) at 0.41% versus 0.24% (see Appendix 13). This increased volatility in returns among the IRB group likely contributes as the main factor to their lower observed Z-score. See Appendix 6, Appendix 7 & Appendix 8 for the development through time of the average equity, ROA and sd(ROA) for the two groups.

Although IRB banks have significantly lower Z-Score, both banks have extremely low probabilities of insolvency, which signifies the high stability of Norwegian banks during the observed period. **Table *4*** shows that the average SA bank has a higher solvency than the average IRB bank, with a log Z-score of 4.09 vs 3.55, which translates to an average of 71.3 and 41.3 standard deviations away from default (see Appendix 13).

The interest rate being very significant in ***Table 8*** column (1) and (2) might be highly explained by the high correlation with the central bank's policy rate; when

the time fixed effect is accounted for, most of this significance disappears, and interest rates are no longer independently significant in column (3).

If looking at the profitability indicator ROE, it becomes evident that an increase in profitability is associated with a slightly significant (p-value: 5.5%) decrease in the Z-Score. The profitability ratio ROE is highly correlated with ROA, which is a factor in the Z-Score and hence will naturally explain some of the variations in the Z-Score. Looking at Appendix 7, we can see the average ROA development between the two banks; although IRB banks have more volatile returns, their average ROA has not been observed below the SA group in a single quarter. This might point in the direction that the increased returns gained do not outweigh the increased volatility of these higher returns. According to the third column in ***Table 8***, the economic implications of a one standard deviation change in Return on Equity (ROE), which is equivalent to 3.7% as indicated in ***Table 3***, indicate a corresponding decrease of 3.05% in the Z-Score (calculated as 3.7% * [exp(-1.74 ($\hat{\beta}_{ROE}$)) - 1]).

5.0 Conclusion

Using data from the Norwegian bank's guarantee fund, the study investigates whether IRB banks have any implications on credit risk when compared to SA banks. Based on the empirical findings of this master thesis, it is evident that being an IRB bank in Norway indeed indicates significant positive implications on the overall credit risk proxies, measured for the parent bank when compared to the SA bank group. The time and regional fixed effects regressions indicate that the average IRB bank has **48.1%** higher NPLs, **104%** higher loan losses and **30.9%** lower Z-score, all significant below the 5% threshold compared to the unconditional mean of all Norwegian banks in the sample. Please note that these findings are specific to the period studied, from the second quarter of 2014 to the second quarter of 2022, a period characterised by relative stability, economic growth, rising house prices and lower incidences of loan defaults and losses.

Further, the results interestingly also show that for all the three test models, the proportion of RWE is not a significant predictor of the credit risk proxies. Underscoring the relevance of the new Basel reforms. However, it is unclear whether RWE is correctly assuming credit risk for one of the groups or not for both; further analysis is required to conclude on this matter. The regression results suggest that the proportion of corporate loans is statistically significant and related to higher levels of NPLs and loan losses. A 10%-point increase in the ratio of corporate loans is associated with a 12.6% increase in NPLs and a 16.7% in loan losses. Corporate loans indeed are riskier than retail loans, as demonstrated by the data; however, it is not known whether the corporate loan portfolio for IRB banks exhibits more or less risk than the same portfolios of SA banks. The test models show a significant positive relationship between increased lending rates and two proxy indicators, the NPL ratio and the loan loss ratio.

The results from the Z-Score model in ***Table 8*** show that when the time-fixed effect in the third column is included, the significance level of the interest rate disappears, similarly it is observed for NPLs and loan losses models that the significance is reduced when accounting for the time-fixed effects compared to only regional-fixed effects.

Further, the interest rate variable may illustrate that banks with higher loan risk charge a higher interest rate to compensate for the additional risk. Notably, it is

observed that SA banks generally have higher lending rates before and after controlling for fixed-income securities compared to IRB banks. However, this discrepancy may not necessarily indicate a risk difference between the two groups when looking at lending rates. It is plausible that SA banks are elevating their lending rates to counterbalance the higher RWE requirements, aiming not only to meet their cost of equity but also to ensure they yield competitive returns on equity. The relationship between interest rates and risk may be more accurately depicted within the two groups, where increased levels within the same group indicate increased risk. This claim warrants further exploration and could form the basis for future research.

Interestingly, it has been found that IRB banks exhibit approximately a 50% higher return on assets and equity compared to SA banks. A small portion of this difference, around 4.5% (own calculations), can be ascribed to the higher leverage effects brought by maintaining a lower equity ratio in the parent bank. When including the combined effects at the parent bank and credit subsidiary, this difference in profitability ratios likely decreases to some extent, and the leverage effects with the assumption of a lower ROA and equity ratio in the credit subsidiary could then describe more of the differences in the profitability ratios. However, only looking at the parent bank, the ROA and ROE would likely mostly be explained by higher efficiency (e.g., scale advantages, lower costs) and a greater extent of other revenue sources such as commissions, fixed income, and fees for the IRB banks.

Based on the empirical findings, it presents a paradox that IRB banks, despite exhibiting higher levels of credit risk proxies, are given such favourable treatment in their RWE computation. This situation may incentivise IRB banks to extend more credit to the corporate market at lower RWE, consequently holding less capital for the same exposure. On the flip side, this arrangement potentially hampers the competitiveness of SA banks in the corporate market. This especially becomes problematic when considering that these local SA banks, equipped with localised knowledge and insights into the local business environment, may not be as incentivised to lend to local businesses. For the SA group's current level of risk weights to be justifiable, these banks would essentially need to manifest a significantly higher level of credit risk compared to their IRB counterparts. As it is limitations to the credit risk proxies, SA banks may have higher levels of underlying credit risk that have not manifested themselves during the observed period. The

discrepancies and implications revealed in the investigation warrant a more comprehensive review of the current risk weighting methodology and its potential impact on competitive balance in the banking sector.

For a deeper understanding of the credit risk between IRB and SA banks, future research should utilise harmonised loan portfolios, including both parent and credit subsidiary. This analysis would examine credit risk proxies within the same categories of loans, such as loans to SMEs, large corporate institutions, various industries, and retail. Future studies should concentrate on understanding the motivations of IRB and SA banks when it comes to lending in either less risky or more risky loan segments. This becomes particularly important given their marked differences in risk sensitivity. There is a hypothesis that IRB banks tend to favour less risky loans due to their heightened sensitivity to risk. SA banks might not be as incentivised to extend loans to businesses. However, when they do decide to lend, they may favour riskier corporate borrowers due to their consistent RWs. This also extends to the retail loan sector, albeit less significantly, due to the uniformity of mortgage products.

Writing tools (disclaimer)

Throughout the development of this document, the language capabilities of OpenAI ChatGPT have been used to enhance the clarity of some of the sentences and optimise the overall structure of the writing. It is important to note that ChatGPT is only used as a language tool and not for empirical sources, knowledge, new content or ideas. It has been taken great care to ensure that ChatGPT does not change the core concepts of primary sources. This AI-powered tool has been instrumental in refining language usage and suggesting more precise phrasings to convey ideas more effectively. In addition, Grammarly has helped improve the quality of the writing further.

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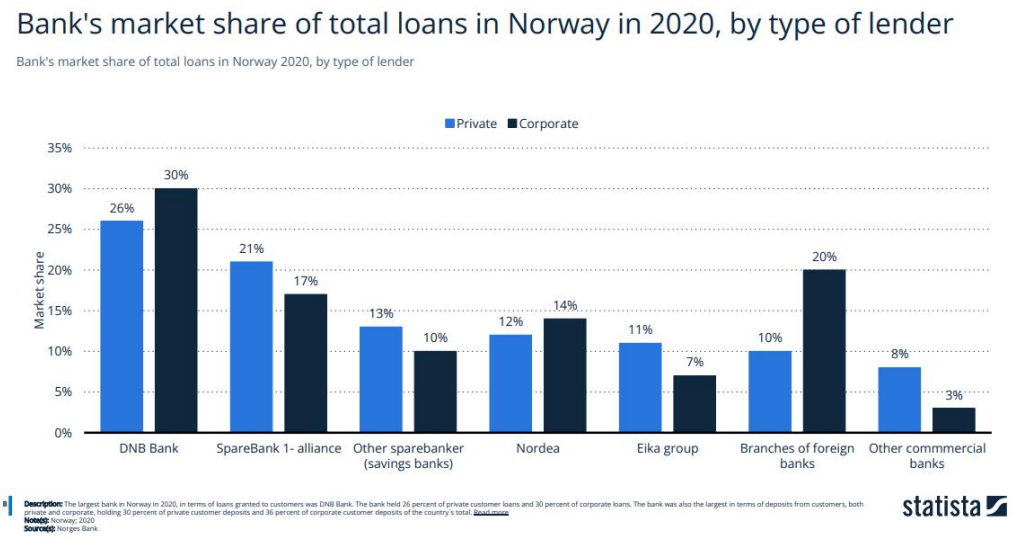
6.0 Appendices

Appendix 1: Banks market share of total loans in Norway in 2020, by type of lender



Source: Statista

Appendix 2: Approvals of IRB models in Norwegian banks. Between 2007 and 2018.

	DNB	**SPB. SR Bank**	**SPB. 1 SMN**	**SPB. Vest**	**SPB. 1 Nord Norge**	**SPB. Møre**	**SPB. 1 Østlandet***	**BN Bank**	**Bank 1 Oslo Akershus ***
2007	FIRB + IRB Housing	FIRB+ IRB (Housing)	FIRB+ IRB (Housing)	FIRB+ IRB (Housing)	FIRB+ IRB (Housing)				
2008									FIRB+ IRB (Housing)
2009	AIRB (Enterprises)	IRB (Housing)	IRB (Housing)	IRB (Housing)	IRB (Housing)				IRB (Housing)
2010	AIRB (Enterprises)								
2011									
2012	AIRB (Enterprises, banks & institutions)						FIRB + IRB (Housing)		
2013									
2014						FIRB		AIRB	
2015	AIRB (Enterprises)	AIRB (Enterprises)	AIRB (Enterprises)		AIRB (Enterprises)	IRB (Housing)	AIRB (Enterprises)	IRB (Housing)	AIRB (enterprises)
2016									
2017				AIRB (Enterprises)					
2018									

Source: Norges Bank, Staff memo, Effekter av IRB-metoden på bankenes utlån til norske foretak, (2020)

**Note: SPB.1 Østlandet and Bank 1 Oslo akershus merged in 2017.*

Appendix 3: Calculation Corporate Ration Combined

Description	**Value**
Percentage Transferred	19.49%
Corporate Loans Ratio in transferred portfolio	0.042%
Percentage Not Transferred	80.51%
Existing Corporate Loans Ratio	29.03%
Entire sample - Corporate ratio Combined	**23.39%**
SA Percentage Transferred	18.85%
SA Corporate Loans Ratio in transferred portfolio	0.006%
SA Percentage Not Transferred	81.15%
SA Existing Corporate Loans Ratio	27.34%
SA banks - Corporate Ratio Combined	**22.19%**
IRB Percentage Transferred	26.64%
IRB Corporate Loans Ratio in transferred portfolio	0.049%
IRB Percentage Not Transferred	73.46%
IRB Existing Corporate Loans Ratio	47.85%
IRB banks - Corporate Ratio Combined	**35.13%**

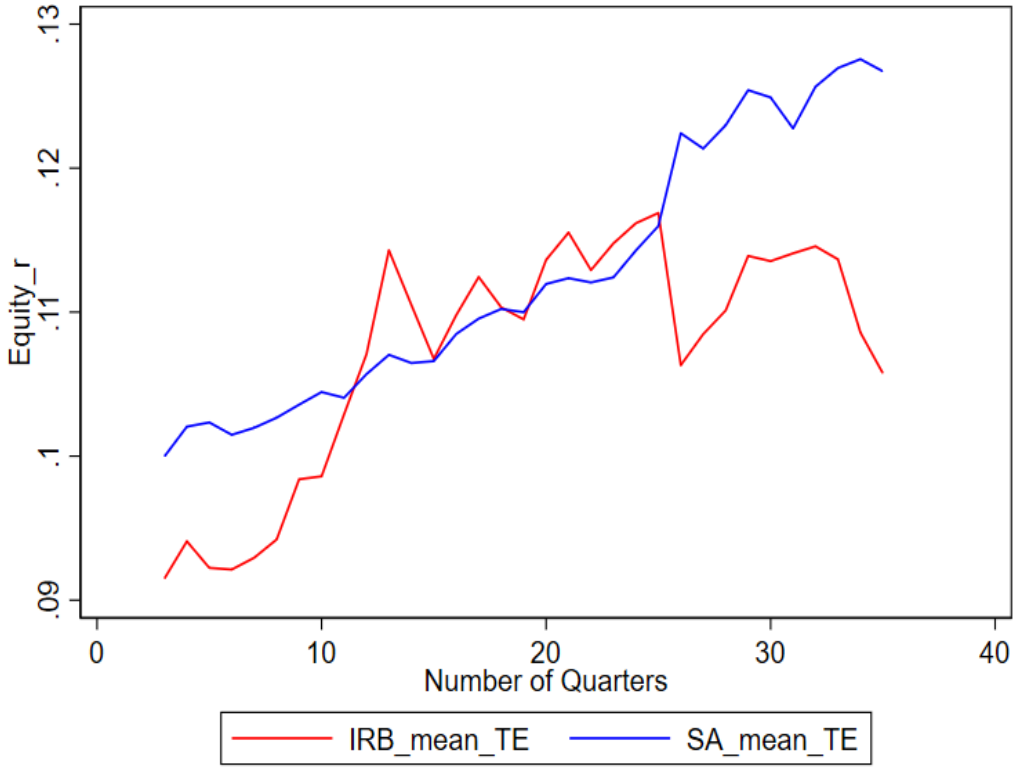
Appendix 4: Calculation example

Lending Type	SA	IRB
Transferred portfolio (RWE %) [Assumptions]	35%	20%
Share of transferred portfolio	18.85%	26.64%
Total RWA Calculation		
Transferred housing portfolio (RWE*Share %)	35% * 18.85%	20% * 26.64%
Parent bank (RWE %)	52.86% * 81.15%	51.66% * 73.36%
RWA (Parent Bank + Transferred portfolio) (%)	6.598% + 42.92% = **49.52%**	5.328% + 37.87% = **43.20%**

Appendix 5: Definition of metrics

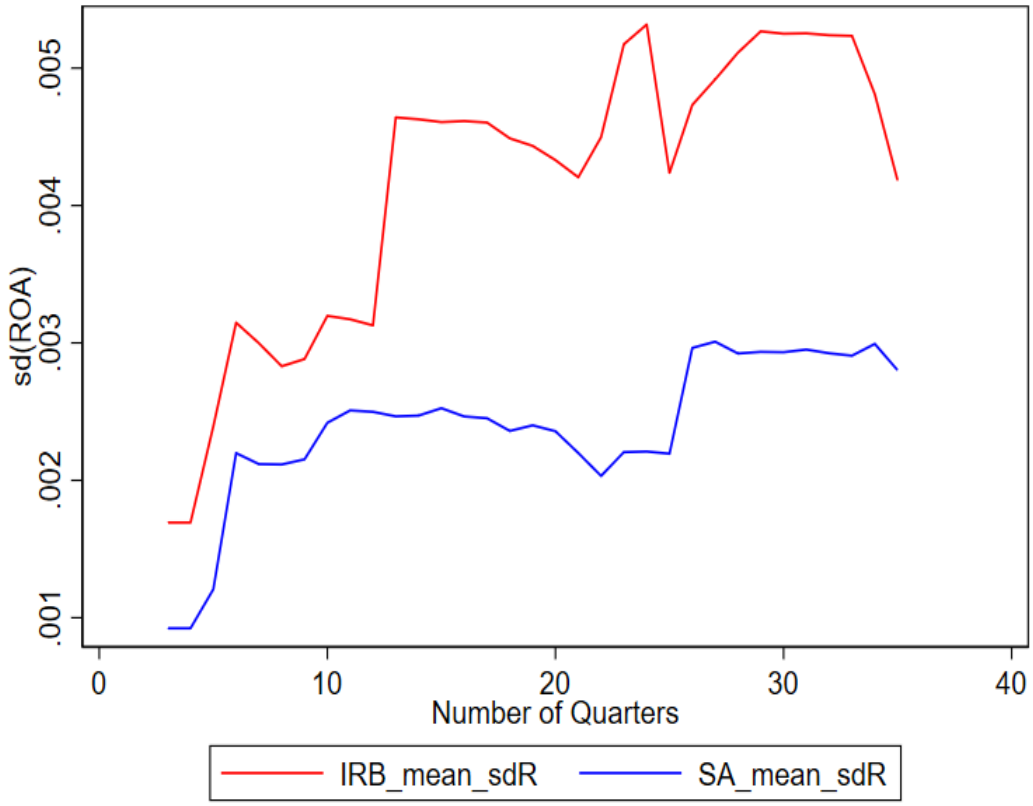
Metric	**Formula/Calculation Method**
Bank Assets	Sum of all assets owned by the bank (in Bn NOK)
Log Bank Assets	Natural logarithm (ln) of Bank Assets
Capital Adequacy Ratio (%)	(Tier 1 Capital + Tier 2 Capital) / Risk Weighted Assets
Equity Ratio (%)	Total Equity / Total Assets
Leverage Ratio (%)	(Total Tier 1 Capital% * RWE) / Total Assets
Corporate Ratio (%)	Business Loans / (Business Loans + Retail Loans + Public Loans)
Return on Assets (ROA) (%)	ROE * Equity Ratio
Return on Equity (ROE)	Annualised Result Before Other Revenues and Costs / Average Equity over (n+1) periods
Revenue Diversification	Total Commissions And Fees (quarterly) / Interest Revenue (quarterly)
Risk Weight	RWA / Total Assets
Non-Performing Loans	[Stage 3] Non-performing (90 days past due) and loss prone commitments / Gross Loans
Loan Losses	Total amount of loans written off and provisioned for quarterly / Gross Loans (multiplied four quarters in summary statistics)
Log Z-Score	Natural logarithm (ln) of Z-Score
Fixed Income Securities Ratio	Fixed Income Securities / Total Assets
Interest Rate	Interest Revenue quarterly / Total Interest Bearing Assets (multiplied four quarters)
Adjusted Interest Rate	Interest Revenue quarterly / Interest Bearing Assets ex. Fixed Income Securities
Net Interest Margin	(Interest Income - Interest Expense) / Total Interest Bearing Assets (multiplied four quarters)

Appendix 6: Development of the Equity Ratio



Appendix 7: Development of the ROA

Appendix 8: Development of the sd(ROA)



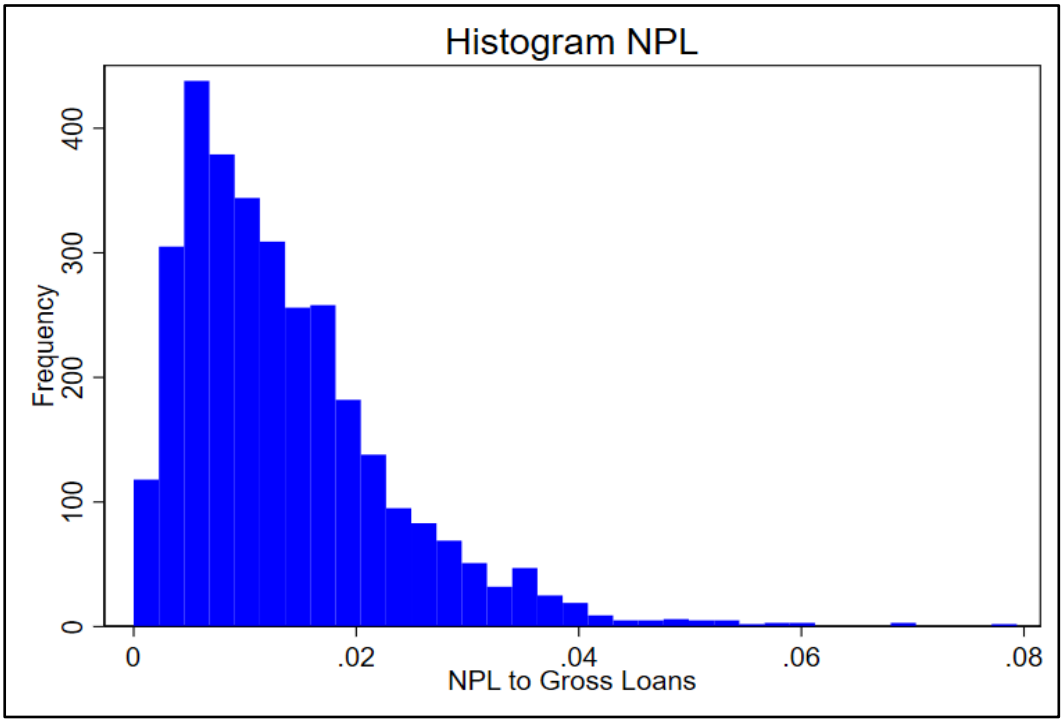
Note: due to three year rolling average sd(ROA) the dates before 2017Q2 (date 15) will gradually become more representative. At and beyond 2017Q2 (date 15) all dates will have a three-year rolling SD(ROA).

Appendix 9: Calculations combined equity ratio

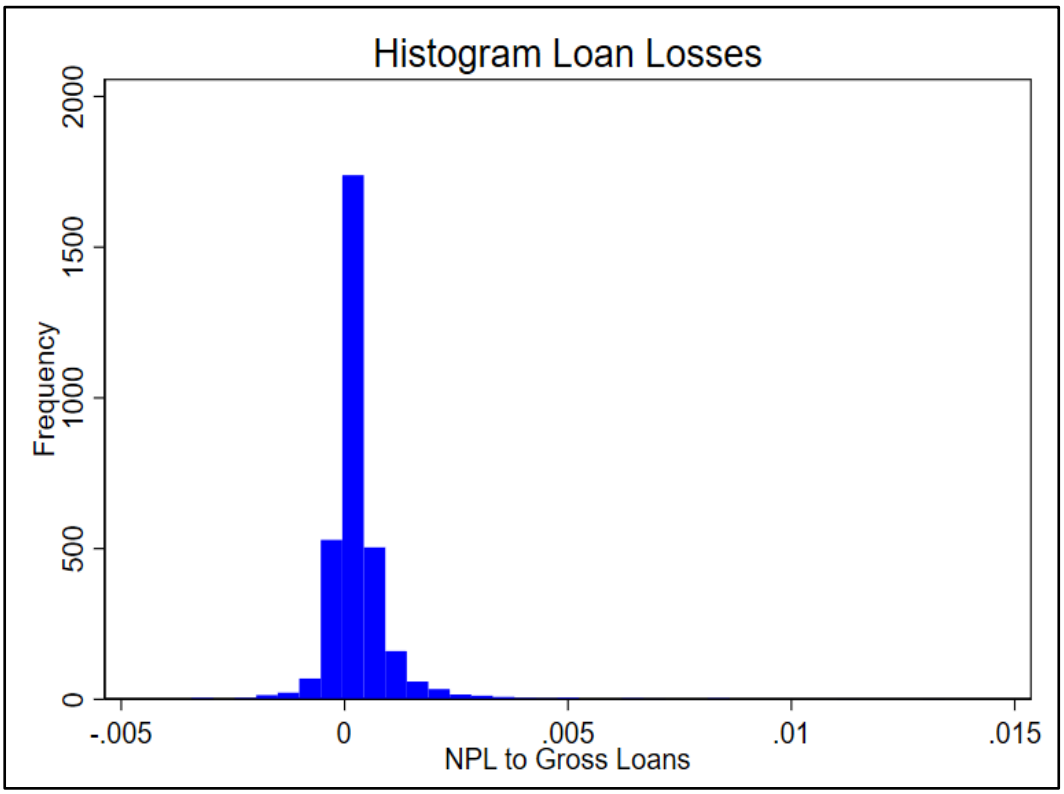
	SA credit + subsidiary	**IRB Banks + credit subsidiary**
Assumption for TT1 (average from data)	19.4%	19.97%
Assumption for RWE%	35%	20%
Total Mortgages Transferred %	18.85%	26.64%
(1) Contribution to equity ratio from parent bank portofolio	11.2% * (1-18.85%) = 9.09%	10.72% * (1-26.64%) = 7.86%
(2) Contribution to equity ratio from transferred portofolio	(35% * 19.4%) * 18.85% = 1.28%	(20% * 19.97%) * 26.64% = 1.064%
Total Equity Ratio Combined (Parent + Credit subsidiary) (1) + (2)	**9.09% + 1.28% = 10.37%**	**7.86% + 1.064% = 8.924%**

Assumptions: TT1 1 is the average Total tier 1% for the parent bank used for the credit subsidiary. Assumption for RWA% is the minimum floors for mortgages both for IRB and SA, and it is assumed that it would be close to the floors due the requirement of high-quality mortgages transfers.

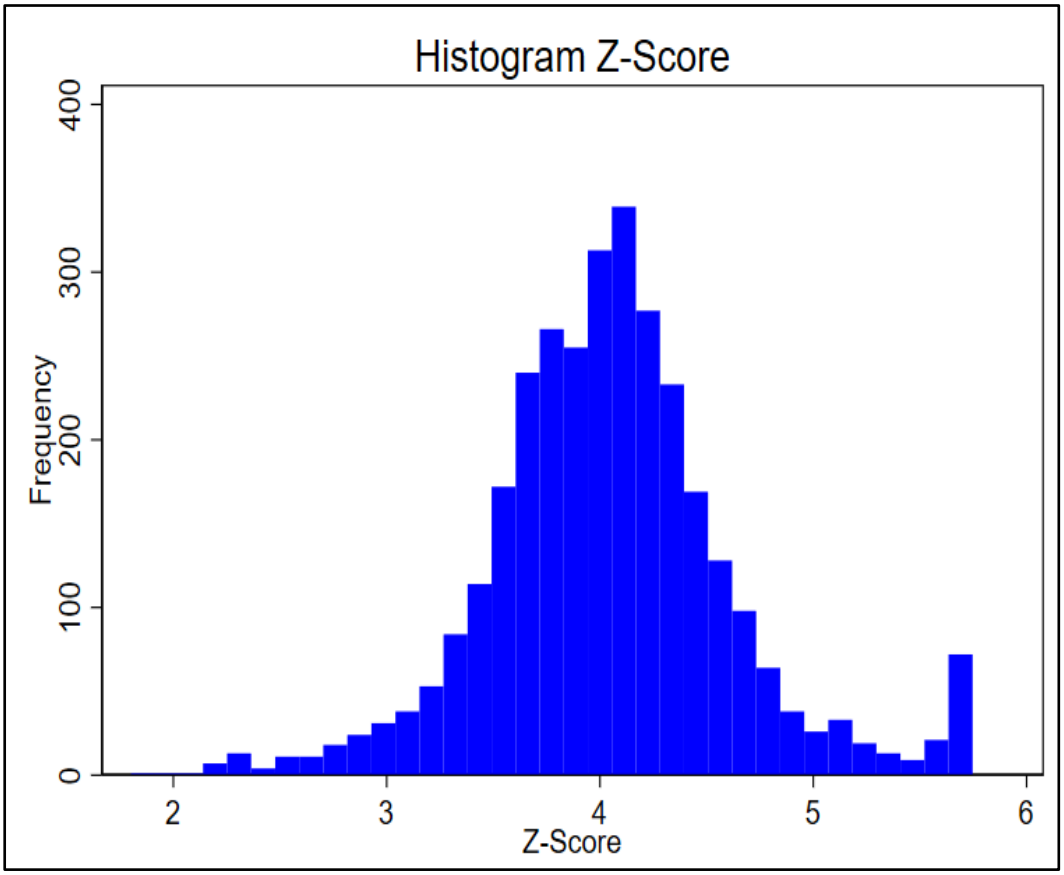
Appendix 10: Frequency distribution NPLs



Appendix 11: Frequency distribution Loan Losses



Appendix 12: Frequency distribution Z-Score



Appendix 13: Summary statistics other factors

Summary statistics: SA

	N	mean	sd	min	p25	Median	p75	max
Z-Score	2932	71.2547	52.3356	6.0561	43.3459	58.4693	79.0261	313.1733
sd(ROA)	2932	.0024	0.0016	0	.0015	.002	.0028	.0183
Transfered Corporate ratio	2932	.0006	0.0029	0	0	0	0	.0257
Transfered housing ratio	2932	.1879	0.0776	0	.1373	.1949	.2438	.4742
CET1	2932	18.2742	3.0757	11.16	16.08	17.88	20.15	29.79
TT1	2932	19.4099	2.7050	12.55	17.6	19.11	20.995	29.79
CAR	2932	20.7217	2.6683	14.12	19.07	20.61	22.36	31.58

Summary statistics: IRB

Z-Score	264	41.3143	35.0650	8.6741	27.9923	34.7573	44.0762	313.1733

sd(ROA)	264	.0041	0.0030	.0002	.0025	.0036	.0043	.0159
Transfered Corporate ratio	264	.0049	0.0110	0	0	0	.0071	.0776
Transfered housing ratio	264	.2615	0.0640	.1271	.2221	.2407	.2921	.463
CET1	264	18.3936	3.8731	11.3	15.68	18.085	20.45	31.57
TT1	264	19.9722	3.8196	12.6	17.36	19.87	21.735	31.57
CAR	264	22.3345	4.1347	14.7	19.315	22.295	24.245	37.92

Summary statistics: Entire sample

	N	**mean**	**sd**	**min**	**p25**	**Median**	**p75**	**max**
Z-Score	3196	68.7815	51.7867	6.0561	40.7566	56.865	76.8787	313.1733
sd(ROA)	3196	.0025	0.0018	0	.0015	.0021	.003	.0183
Transfered Corporate ratio	3196	.0009	0.0043	0	0	0	0	.0776
Transfered housing ratio	3196	.194	0.0792	0	.1435	.2008	.2468	.4742
CET1	3196	18.2841	3.1487	11.16	16.055	17.9	20.15	31.57
TT1	3196	19.4563	2.8173	12.55	17.565	19.13	21.05	31.57
CAR	3196	.2085	0.0285	.1412	.1909	.2069	.2258	.3792