

Approximating Capital Requirement Due to Name Credit Concentration Risk

- A Comparison of Two Methodologies, the Standardised Approach
and A Selected IRB Approach; A Granularity Adjustment.

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June 3, 2014

Abbreviations and Notations

AHI	Adjusted Herfindahl Index
APD	Adjusted Weighted Average Probability of Default, for a Portfolio
BCBS	Basel Committee on Banking Supervision
CAR	Capital Adequacy Ratio
EAD_i	Exposure At Default, for an Exposure
EL	Expected Loss
GA	Granularity Adjustment
HI	Herfindahl Index
ICAAP	Internal Capital Adequacy Assessment Process
IRB (Approach)	Internal Ratings-Based (Approach)
K	Regulatory Capital for Credit Risk, as a share of total EAD
LGD_i	Loss Given Default, for an Exposure
M_i	Maturity, for an Exposure
N	Number of Exposures in a Portfolio
PD_i	Probability of Default, for an Exposure
PD	Weighted Average Probability of Default, for a Portfolio
RWA	Risk-Weighted Assets
s_i	EAD_i for an exposure as a share of total EAD, for a portfolio
UL	Unexpected Loss

Executive Summary

- Title:* Approximating Capital Requirement Due to Name Credit Concentration Risk - A Comparison of Two Methodologies, the Standardised Approach and A Selected IRB Approach, A Granularity Adjustment
- Seminar date:* 2014-05-13
- Course:* TMA820, FEKP02 TM-examensarbete
- Authors:* Christian Green, Pauline Lidberg
- Supervisors:* Erik Lindström, Jonas Ljungqvist, Birger Nilsson
- Key words:* Credit risk, Name Concentration Risk, Capital Requirement, Granularity Adjustment, Standardised Approach, Basel agreements.
- Purposes:* The main objective is to compare two methodologies proposed by FI for approximating capital requirements for name concentration risk, by examining how the methodologies' resulting capital requirement differ.
- Another purpose is to map the large number of laws, regulations and notations within the field, as well as sort out their interrelationships.
- An additional purpose is to provide a derivation of FI's proposed IRB Approach, i.e. the Granularity Adjustment methodology, adding to the existing derivation in the article "*Granularity Adjustment for Regulatory Capital Assessment*" by Gordy & Lütkebohmert (2013).
- Methodology:* The thesis is performed through a quantitative study of generated realistic portfolios and of Ikano Bank's leasing portfolio, where two methodologies for approximating capital requirement for name concentration risk are applied on the portfolios.
- Theory:* The Standardised Approach and an IRB Approach, i.e. the Granularity Adjustment according to Michael Gordy and Eva Lütkebohmert, proposed by FI.
- Conclusion:* The relationship between a portfolio's large and small exposures in terms of assigned PD_i is of great importance for how the two methodologies' resulting capital requirements differ.

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1 Introduction

1.1 Background

The core business of banks is to receive deposits and to provide various forms of credit, e.g. loans (Swedish Banker's Association, 2013:a). This implies that banks, like most financial institutions, expose the business to risks through their own lending operations. Since banks play an important and well-integrated role in society, by allocating capital between lenders and borrowers, a consequence is that also society is exposed to risks at the same time. The societal risk is a result of the major negative effects on a bank's environment, following the default of a bank. This has led to considerable pressures from society and, consequently, banking regulations have existed for a long time with the aim to ensure that banks keep enough capital for the risks they are taking (Hull, 2012, p. 257).

As a result of the recent years' major global financial crises there has, however, been an intensification in efforts to strengthen the regulations. The previous regulations have apparently been insufficient and stricter unifying universal frameworks have been developed to reflect the growing global financial world that affect society today. In these stricter banking regulations emphasis is laid on tougher capital adequacy requirements. (Sveriges Riksbank, 2011:b) Capital adequacy requirements involves requirements that a certain amount of capital should be put aside in relation to the risks a bank is taking on. This capital is known as regulatory capital and for this there is a legal minimum level. (BCBS, 2006, p. 12) The capital adequacy requirement exists to secure that the bank can live up to its commitments.

The Basel Committee on Banking Supervision, henceforth BCBS, is an international organisation with the mandate to establish a majority of the standards for the supervision of banks. BCBS's overall objective is to improve the quality of banking regulations, supervision and practices worldwide, while striving for an improved financial stability. Furthermore, they have devised three major global unifying agreements, known as Basel I, Basel II and Basel III. (Bank for International Settlements , 2013:a)

Current eligible Approaches for calculating the capital adequacy requirement of a bank is conducted in accordance with what was published in the Basel II framework from 2007, with a marginal correction in the Basel III framework that partly came into force in 2013. These new rules will be gradually implemented until 2019. (BCBS, 2011, p. 57, 60 & 69) The rules from the Basel agreements are normative, not binding, but most countries have incorporated them into their national legislation. At EU level the framework is incorporated into EU law through regulations and directives, thereby making the framework binding for Swedish banks. (Sveriges Riksbank, 2011:a) Finansinspektionen (henceforth called FI) is the regulatory body in Sweden that assess the financial health of the financial market. Supervision conducted by FI ensures that the Basel regulations

are complied with, and they can also issue their own provisions, regulations and general guidelines for compliance. (Finansinspektionen, 2014:b) The Basel rules are structured in the shape of three pillars. The section called Pillar 1 specifies the minimum regulatory capital requirement for the risks of a financial institution. Pillar 2 indicates that for these institutions there are requirements for internal supervision in order to prove that the overall risk assessment is satisfactory (covering additional risks than those required within Pillar 1). Finally, Pillar 3 covers the disclosure requirements for institutions. (BCBS, 2006, p. 2)

The risks for which banks are exposed to, and thus should cover with regulatory capital, are broken down into three types of risk; credit risks, market risks and operational risks. (BCBS, 2006, p. 12). The thesis addresses the risk type of credit risk, and it is for the thesis specially important to understand the difference between credit risk and credit concentration risk as well as how they are related. Credit risk is defined as the potential event that one of the bank's borrowers or counterparties does not fulfill its obligations in accordance with agreed terms. (BCBS, 1999, p. 1) This may result from a drop in the counterparty's credit rating or if the counterparty defaults, which in worst case could mean that the bank's claim from the other party becomes worthless. Credit risk can also exist on a portfolio¹ level, and is the summarised credit risk of all individual exposures. Credit concentration risk, on the other hand, arise when the credits in a portfolio have a skew distribution across different segments. These credits are typically referred to as exposures. The segments may for instance consist of certain industries, regions or correspond to individual counterparties. (BCBS, 2006, p. 214) In the regulatory framework Basel II it is stated that concentration risk² in general is arguably the single greatest cause of problems in banks, as it is difficult to quantify the risk that the concentration generates. (BCBS, 2006, p. 214) To further demonstrate its importance, concentration risks in mortgage banks was one relevant cause of the most recent financial crisis. (Hibbeln, 2010, p. v) Moreover, by taking a brief historical look back, thirteen banking crises are analysed by the BCBS, where they concluded that nine had been affected by risk concentrations. This further indicates its importance for the stability of the whole banking system. (Hibbeln, 2010, p. 1) Since lending is the main activity of most banks, risk arising from credit concentration is often the most significant concentration risk (BCBS, 2006, p. 214).

Risks arising from credits, credit risk, is treated under Pillar 1 of the Basel rules (BCBS, 2006, p. 12). The two Approaches devised by BCBS to calculate capital requirements for credit risk are simplified based on some fundamental assumptions. The simplification is conducted in order to, among other reasons, enable supervision from supervisory authorities. The supervision requires a certain degree of standardisation, ease of use and traceability. It is furthermore worth mentioning that the BCBS's minimum capital

¹Note that the term portfolio is aimed only to describe a bank's credit portfolio, and this notation will be applicable throughout the thesis.

²It is important for the thesis to distinguish concentration risk from credit concentration risk as credit concentration risk is a subset of concentration risk.

requirement for credit risk is expressed as a percentage of a bank's risky assets. (BCBS, 2006, p. 12) For treating credit risk the two Approaches developed by the Basel Committee applies in Sweden. (Finansinspektionen, 2013:a, 9-11) There are guidelines from FI that at least a Standardised Approach shall be followed for such management, which is based on external credit ratings. Institutions may also seek permission from FI for an internal ratings-based (IRB) Approach instead of using the Standardised Approach. This permission gives banks some possibility to develop internal methodologies for estimating credit risk, allowing for greater risk sensitivity and adaptation to the bank's particular circumstances. (BCBS, 2006, p. 4) In cases where a bank's credit portfolio deviates from what is stated in the fundamental assumptions, an additional management of the subsequent concentration risk that the portfolio generates is required. (Lütkebohmert, 2009, p. 101) This add-on to the capital requirement for credit risk is managed under Pillar 2.

Within the second Pillar in the Basel rules it is described that institutions should perform an Internal Capital Adequacy Assessment Process (ICAAP) (BCBS, 2006, p. 204) that contains internal processes to identify, measure, monitor and control all risks (BCBS, 2006, p. 214, §773); including credit concentration risk. (BCBS, 2006, p. 204) Regarding practical methodologies for the quantification of credit concentration risk within each of the two Approaches, there are none specifically designed and proposed by the BCBS. Nor is it clear how such methodologies should be implemented in a way that is consistent with the Basel framework. (Hibbeln, 2010, p. 2)

Although no methodologies are provided by BCBS, however, guidance from FI on how the credit concentration risk could be approximated within each Approach exists in Sweden, for Swedish banks and financial institutions. Thereby, they must at least follow a given methodology within the Standardised Approach. In cases where a bank is authorised by FI for an IRB Approach, there is however a possibility to independently devise a methodology if not following one that is proposed. To further complicate things there are different types of credit concentration risks and it is only for name concentration risk³ that FI's proposed methodologies within each Approach differ. For name concentration risk alone, FI propose a particular methodology within the IRB Approach for the banks entrusted with the permission. This is called "Granularity Adjustment" or "GA" and is the same methodology used by FI for assessing whether institutions, through their internal IRB Approach, conducts a reasonable assessment of capital adequacy requirement to cover all the name concentration risk arising from their credits.

FI states that an institution's credit-related concentration risks are only possible to quantify approximately, i.e. a theoretical correct methodology does not exist. (Finansinspektionen, 2009:c, p. 1) FI furthermore urges Swedish banks to devise internal methodologies

³Name concentration risk arise when the exposures of a portfolio are unequally distribution between individual counterparties. Note that the term name concentration risk is aimed only to describe name concentration within credits, i.e. name credit concentration risk. This notation will be applicable throughout the thesis.

for the approximation of name concentration risks, but still proposes a particular methodology within the IRB Approach. As this is the same methodology used by FI for assessing the institutions, it implies a higher burden of proof should the banks pursue a different methodology. The proposed methodology, even though unintentionally, after all indicates a certain ranking of all methodologies available within the IRB Approach for Swedish banks. At the same time it also indicates a ranking between the Approaches for banks in Sweden. These underlying reasons raises an interest to compare how FI's proposed methodologies for approximating regulatory capital requirement for name concentration risk within each Approach, i.e. within the Standardised Approach and within the IRB Approach, differ for portfolios with different characteristics.

There exists at least two public studies that demonstrate the relationship between Granularity Adjustment's resulting capital requirement and HHI⁴ for portfolios, but none of how the Standardised Approach's resulting capital requirement relates to HHI. A comparison between the resulting capital requirements for FI's two proposed methodologies do not publicly exist. Furthermore, there is no indication that the previous studies take a third dimension into account, namely the distribution of PD_i for the portfolios' exposures. This is believed to be an interesting parameter that contributes to such a comparison, in order to allow for further conclusions. Finally, performing such a comparison for portfolios with different characteristics, including the third parameter, would add to previous research. The comparison would also provide Swedish banks and institutions with additional knowledge of the differences in resulting capital requirements when applying FI's two proposed methodologies on their portfolios. The purpose and research question of this master thesis is thereby:

1.2 Purpose

The main objective is to compare the two methodologies proposed by FI for approximating capital requirements for name concentration risk, by examining how the methodologies' resulting capital requirements differ.

As the introductory text indicates, there is a large number of laws, regulations and notations within the field. An overall, comprehensive but simplified compilation of these is missing and such a compilation is considered essential for a complete understanding of the comparison. Another purpose of this thesis is therefore to map those laws, regulations and notations as well as sort out their interrelationships in the Empirical Input section.

⁴HHI is a measure to specify concentration, similar to the measure FI uses in their methodology within the Standardised Approach.

An additional purpose is to provide a derivation of FI's proposed IRB Approach, i.e. the Granularity Adjustment methodology, adding to the existing derivation in the article "*Granularity Adjustment for Regulatory Capital Assessment*" by Gordy & Lütkebohmert (2013). This derivation is positioned in Appendix A.

1.3 Research Question

What patterns or features can be established when applying the Standardised Approach and the proposed IRB Approach, i.e. a Granularity Adjustment, for name concentration risk on a variety of portfolios with diverse characteristics?

1.4 Limitations

There exist many different methodologies that strive to quantify the capital requirement for name concentration risk. In accordance with the main objective, a limitation is that only the two methodologies that FI is proposing will be compared. Thus, all other available methodologies are disregarded. This limitation falls out naturally as the aim is to compare the methodologies proposed by the supervisory authority in Sweden, i.e. applicable for Swedish banks.

In light of the fact that it is two proposed methodologies being compared, the same assumptions made by the supervisory authority when applying the Granularity Adjustment is also made in the conducted comparison. These assumptions mainly concerns existing parameter estimations of two input parameters to the methodology as well as dependency on one systematic risk factor. These assumptions are further explained in Appendix A as well as in the original article by Gordy & Lütkebohmert (2007).

An additional limitation is that all possible portfolio combinations are not aimed to be compared, but the strive is an adequate sample of portfolios to establish patterns or features when conducting the comparison between the two methodologies. The amount of portfolios compared is limited to 10 000, each with the size of 10 000 exposures. Furthermore, the comparison is conducted with two sets of axes that are insufficient to describe all the variations of a bank's portfolio. Thereby it limits the conclusions possible to draw.

Reality-based data from one company, the case company Ikano Bank, is provided for the authors. For this data the methodologies are applied and the results compared to a variation of portfolios. The limitation to apply the methodologies on only one reality-based portfolio results in restricted generalisability.

Finally, the thesis is performed during a period of 20 weeks in the spring of 2014, which implies a limitation in time and scope.

2 Method

In this chapter the quantitative approach and deductive method is presented mainly theoretical. This presentation is followed by a review of the literature examined by the authors within the field. The chapter furthermore includes a thorough description of how the thesis is conducted. Finally, shortcomings of the method and the outline of the thesis is explained.

2.1 Quantitative Approach

The thesis is performed through a quantitative approach, i.e. based on the assumption of an objectively given and measurable reality. (Backman, 2009, p. 53) The followed methodology is also distinctly of a quantitative nature. An explanation is thereby formulated by statistical and quantifiable results from replicable trials. (Backman, 2009, p. 33) From a more specific perspective, the quantitative approach implies that credit concentration risk is assumed to be measurable and that statistical data allows for comparisons between different approximation methodologies for the resulting capital requirement.

However, it should be made clear that a quantitative approach not only implies that the processing of numbers comprise a major part of a study. In fact, a quantitative research strategy includes significantly more. (Bryman & Bell, 2013, p. 162) Furthermore, measurements allow for explanations through achieving a certain degree of causality, which often leads to a possibility to generalise and replicate. (Bryman & Bell, 2013, p. 176-181)

2.2 Deductive Method

Furthermore, the thesis is conducted with a deductive method as the starting point is conceptual formulations in the shape of regulations and proposals from supervisory authorities. (Backman, 2009, p. 54) Thus, the proposed methodologies by FI can be seen as mathematical theories that will be tested on a variety of portfolios with diverse characteristics. The different proposed methodologies will thereby be compared in order to attain an answer to how they differ, which is typical for a deductive method. (Bryman & Bell, 2013, p. 31-32) The ambition is not to state whether one of the methodologies quantifies credit concentration risk in a more satisfying way than the other. The ambition is only to give an easily understandable explanation to how the results from the two methodologies differ, and if patterns or features can be established for a variety of different portfolios.

2.3 Literature Review

Prior to, and during, the initiation of the actual research work presented in the thesis, a significant portion of time was spent on taking note of existing documentation within the selected field. This, to consult and imbibe the available knowledge, is commonly conducted to create an overview of the previously collective knowledge within the field. This overview, in turn, is required in order to formulate a meaningful research question. (Backman, 2009, p. 28-29) Based on the following literature review, a historical perspective is obtained and the currently used and established methodologies are identified. The literature review also provides insights regarding how terms and notations within the field are defined, specified and used. More importantly, previous shortcomings in the knowledge base are identified, and especially the absence of the comparison performed by the authors in the thesis. Moreover, this is in line with the contribution that a literature review should result in for a thesis. (Backman, 2009, p. 29 & 57)

The empirical, as well as the theoretical, basis of the thesis is retrieved from various sources of literature, such as international frameworks, scientific articles and books on the topic covered in the thesis. Overall, it is possible to make a distinction between legal and regulatory documents on the one hand, and scientific articles and books on the other hand. The articles and books dealt with are all forced to relate to the regulations.

Presented below is an overview of current knowledge within the field of approximating the capital requirement for credit concentration risk. To present it in its proper and understandable context, certain parts of current knowledge concerning calculation of capital requirements for credit risk is also accounted for. To clarify, emphasis of this literature review is placed on describing current knowledge and not just reciting an overview of the treated literature, which is in accordance with what is proposed by Backman (2009, p. 73).

The authors' coverage of the Basel agreements consists of several final regulatory documents as well as preparatory documents. All other literature, and thus knowledge within the field, are forced to take these into account, i.e. adapt to and comply with the regulatory framework. This applies primarily within the field of calculating credit risk, as the BCBS define the methodologies used. It also applies within the field of approximating credit concentration risk, as an overarching guideline. The authors obtained knowledge of credit concentration risk from BCBS's "*International convergence of capital measurement and capital standards*" (BCBS, 1998), "*International convergence of capital measurement and capital standards - A revised framework comprehensive version*" (BCBS, 2006), "*Basel III: A global regulatory framework for more resilient banks and banking systems*" (BCBS, 2011), "*Working Paper No. 15: Studies on credit risk concentration*" (BCBS, 2006) and the superseded consultative paper "*The New Basel Capital Accord*" (BCBS, 2001) together with its supporting documents, which were all published prior to the Basel II Accord. Focus is placed on the sections covering credit concentration risk. As the Basel

agreements are incorporated into EU law, the two documents currently in force are read to obtain additional knowledge about how credit concentration risk could be managed. These documents are “*Regulation (EU) No 575/2013 of the European Parliament and of the Council*” and “*Directive 2013/36/EU of the European Parliament and of the Council*”. Usually these legislations are jointly referred to as “CRD IV”. The consultancy report “*CRD IV: Single Rule Book for EU Banking Regulations*” from KPMG as well as the European Commission’s “*CRD IV/CRR – Frequently Asked Questions*” is also studied, since they provide a description of the most recent changes and what the reason for these additions are.

Furthermore, the EU legislations is incorporated into Swedish law through a number of documents from Swedish legislative authorities, one of which is FI. As a supervisory authority, FI holds the permission to propose certain methodologies for Swedish bank’s approximation of credit concentration risk. These methodologies must of course be in line with the regulations in the Basel agreements. With respect to the main objective of the thesis, it is these documents that contains the most significant and useful knowledge. Several documents made available through FI is studied, and these include memorandums, instructions, provisions as well as reports. Special attention is given to the two memoranda on “*Kreditrelaterade koncentrationsrisker*”, i.e. dealing with credit-related concentration risks, as well as the memorandum “*Bedömning av kapitalbehov för koncentrationsrisker*” where the resulting capital requirements corresponding to certain measurement values, according to FI, are determined.

Regarding approximation of capital requirement for name concentration risk, FI refers to three scientific articles. These articles comprise parts of the knowledge within the field of approximating capital requirement for name concentration risk. However, FI particularly propose that Swedish IRB approved banks should comply with one out of these articles, named “*Granularity adjustment for regulatory capital assessment*” by Gordy & Lütkebohmert (2013). FI also uses this methodology to verify whether the IRB approved institutions approximate their capital requirement for name concentration risk adequately. Consequently, this article is thoroughly studied and it contains a comprehensive description with derivations of the original version of the proposed Approach of quantifying capital requirement for name concentration risk according to FI. To further summarise and integrate empirical research, the research synthesis is enhanced (Backman, 2009, p. 72) by covering additional literature, such as the books “*Concentration Risk in Credit Portfolios*” by Eva Lütkebohmert, “*Risk Management in Credit Portfolios*” by Martin Hibbeln and “*Risk Management and Financial Institutions*” by John C. Hull. These books present and discuss methodologies for approximating capital requirement for credit concentration risk. Furthermore, a Master thesis by Björn Torell named “*Name Concentration Risk and Pillar 2 Compliance*” covers the difficulties that banks may encounter when the add-on from name concentration risk should be approximated.

In the search for knowledge, it is however not possible to find a public comparison between the methodology that Swedish IRB approved banks are suggested to comply with and the Standardised Approach methodology that bigger Swedish non-IRB-approved banks must comply with. In this search experts at FI are consulted, while tools such as google scholar and the library databases Lovisa and LIBRIS also are used. However, two particularly interesting sources are found, each consisting of a previously conducted study that demonstrates the relationship between the Granularity Adjustment's resulting capital requirement and HHI. This implies that they resemble the comparison conducted by the authors. Interestingly, one of the studies carried out is based on data from the German credit register, leading to realistic portfolios that are modified due to confidentiality. The second interesting source is the article "*Measuring Concentration Risk in Bank Credit Portfolios Using Granularity adjustment: practical aspects*" published by SEB in Lithuania. It includes a similar study, based on data from an Eastern Europe bank. (Beivydas et al, 2009, p. 55) However, a public comparison between FI's two proposed methodologies' resulting capital requirements, that also includes a third parameter, is missing within the field.

2.4 Course of Action

The main target audience of the thesis is individuals with an interest, but limited knowledge, within the field. The thesis therefore contains additional basic and detailed explanations. However, a basic prior knowledge in mathematical statistics is assumed. For further mathematical explanations, see Appendix B. Remaining stakeholders are regarded as a secondary target audience. These can therefore skip certain parts, such as the simplified mapping of laws, regulations and notations. Furthermore, this secondary target audience is regarded as for example people with prior knowledge at the financial institutions that may be interested in the result. The ambition is to explain the course of action so that it is possible to repeat by someone else under exactly identical conditions, in accordance with what is highlighted by Backman (2009, p. 40).

To facilitate the reader's understanding regarding the comparison between the two methodologies, i.e. FI's Standardised Approach and their proposed IRB Approach, a Granularity Adjustment, the empirical chapter thoroughly maps how the current Basel framework are devised and what historical circumstances that underlies its existence. To give an understanding of notations and applicability, the empirical chapter also describes the first and second Pillar of the Basel framework. The latter is described in a more detailed manner. With notations and recommended implementation from the Basel framework in place, the incorporation of the Basel agreements in the EU is described.

Furthermore, the impact on Swedish banks today is described in order to create an awareness of what underlies the guidelines from FI. The interrelationships within the regulations is also explained in detail, prior to a presentation of the case company Ikano Bank and its credit portfolio of interest. The presentation is intended to provide an

improved understanding of where the empirical portfolio data origins from. All the compiled empirical input in section 3 Empirical Input consist of secondary data, which also applies to the empirical data from Ikano. Additionally, the data from Ikano is of a quantitative nature.

The theory chapter deals with mathematical explanations of the two methodologies proposed by FI, as well as describes the most common notations for approximating credit risk. Basic mathematical theories necessary for understanding the two methodologies are treated in Appendix B.

In performing the comparison between the two methodologies, a large amount of portfolios with different characteristics are generated. All of these generated portfolios are varied for two parameters. Initially, however, a couple of example portfolios are presented in order to provide an intuitive understanding of how the resulting capital requirement is affected when varying the portfolios. The starting point is a reference portfolio where all exposures are considered homogeneous, i.e. identical in size. Subsequently, the consequences of violating this assumption is illustrated.

After the presented example portfolios, the computational course of action for generating the 10 000 realistic portfolios is described. This is followed by describing the application of the two methodologies for all generated portfolios. After explaining how the resulting capital requirement for both methodologies is approximated for each portfolio, the results are graphically illustrated in 3-dimensional graphs, more specifically scatter plots. In the first resulting graph, all portfolios are illustrated with measured values of the two variables being based on the entire portfolio, the first set of axes. Thereafter, in the second resulting plot, the same portfolios are illustrated with measured values based only on the 30 biggest exposures' characteristic, the second set of axes. Due to the 3-dimensional shape of the graphs, they are illustrated in four different angles. The reason that the resulting capital requirements are graphically illustrated in these two different 3-dimensional graphs, is that different conclusions can be drawn from each set of axes.

In order to somewhat validate that the generated portfolios are realistic, a case company is included in the comparison of the methodologies. The resulting capital requirement of the case company's portfolio is positioned in relation to the generated realistic portfolios. Thereby, Ikano Bank's portfolio acts as a benchmark in whether the generated portfolios results in reasonable values in the two set of axes. Thereafter, the graphical illustrations are again presented, with the only difference that the two data points corresponding to Ikano Bank's portfolio is included.

The next step in the analysis is to graphically illustrate the difference in resulting capital requirement for the two methodologies, for each of the generated portfolios. This also results in two additional graphs, but illustrates instead only the difference of the two methodologies' resulting capital requirement for each portfolio. The conclusions re-

garding patterns and features on how the two methodologies relate to one another are thereafter drawn. The presented conclusions are followed by a discussion regarding the results and if the conclusions in the analysis are reliable and generalisable.

Finally, when generating portfolios and implementing the two methodologies a certain computer software is used, i.e. the numerical computing environment Matlab. An exception is when calculating resulting capital requirements for Ikano Bank's portfolio where Microsoft Excel is used. Furthermore, Latex is used when generating the report.

2.5 Shortcomings of the Method

A shortcoming of the quantitative approach is, as adversaries argue, that measurement processes often imply an artificial and somewhat untrue feeling of precision. (Bryman & Bell, 2013, p. 182) However, the authors awareness of this for the conducted analysis allows for it to be regarded as a non-substantial shortcoming. Furthermore, there are also difficulties in how portfolios are generated, in the decision of which portfolios are realistic and how this is underpinned.

The processing of data is conducted by Ikano Bank, prior to the handover of the leasing portfolio. It affects the approximation, since Ikano Bank marginally modifies the data for secrecy reasons. Thus, the resulting capital requirement for their portfolio is most likely affected. A reliance on that the handed over data is realistic is necessary, i.e. that it mimics their real portfolio without any large deviations.

2.6 Outline of the Thesis

The thesis will follow a linear outline, which is typical for research papers. It implies a logical organisation of the thesis in accordance with the following sequence: introduction, description of the problem, research question, method, analysis, result, conclusion and lastly discussion. (Backman, 2009, p. 67) The current chapter theoretically explains quantitative approach and deductive method, while thereafter describing the review of literature within the field, the steps for how the thesis is conducted and shortcomings from using the quantitative approach. This chapter will be followed by 3 Empirical input, which consist of an explanatory mapping of the laws and regulations currently in force as well as the notations within the field, in order to give the target audience a chance to better understand the conducted comparison.

In chapter 4, a short introduction of common notations for portfolio characteristics is presented along with the theoretical explanations of FI's two proposed methodologies. In chapter 5, it is described how portfolios are generated, how the two methodologies are applied to the portfolios and it is presented how the resulting capital requirements are

graphically illustrated. In chapter 6, the actual difference between the two methodologies' resulting capital requirements are illustrated for different portfolios. In chapter 7 the authors' major conclusions from the analysis and the results are presented. These are mainly focused on the actual difference between the methodologies. Thus, they include conclusions regarding observed patterns and features of the two compared methodologies. In chapter 8 the main conclusion is presented along with the authors' reasoning concerning the generalisability, plausibility and reliability of the conducted comparison and its observed results. In the latter chapter, suggestions for further research are also proposed. Parts considered too fundamental for anyone who is somewhat familiar within the field and holds a basic prior knowledge in mathematical statistics are added to Appendix B.

3 Empirical Input

In order to attain an enhanced understanding regarding the field within which the comparison is conducted, this chapter presents an explanatory mapping of laws and regulations as well as notations within the field. To provide a holistic picture the mapping starts out with presenting the historical background and laws being developed, to finally end up in the laws currently in force. New regulations modifies the previous, while the approaches used usually are preserved. Therefore it is necessary to understand the historical developments in order to understand the current regulatory environment (Hull, 2012, p. 257). Additionally, the mapping begins with what applies globally and thereafter treats what is specifically applicable for Swedish banks, being relevant due to the comparison of FI's two proposed methodologies.

3.1 History Behind Global Banking Regulations

Banking regulations have existed for a long time, with the purpose of ensuring that banks keep enough capital for the risks they are taking. (Hull, 2012, p. 257) However, during the last 10-20 years significantly stricter and unifying requirements have been devised. (Hibbeln, 2010, p. 5) The reason for these emerging regulations are recent years' major global financial crises. The world is becoming more and more connected, resulting in financial institutions and national markets being dependant on what happens in other parts of the world. This phenomena further reinforces the fact that problems in one bank rapidly spreads to other banks. Today, this domino effect goes far beyond national borders and poses a threat to the financial stability worldwide. Potentially, the effect can even lead to a collapse of the entire banking system. (Hibbeln, 2010, p. 5)

The major negative effects on a bank's environment is largely dependant on interbank loans, i.e. the lending among banks, which can cause problems to spread onto other banks. (Hibbeln, 2010, p. 59) After having occurred several times, the observed effects of financial crises are that the whole world economy is hit hard and the consequence is a period of difficulty for the entire society. Only a few eludes the consequences, and the victims range from private individuals to the largest multinational corporations. The negative effects, for example, consists of higher unemployment rates, fewer investments, lower interest rates and dim future expectations.

Banks have always had a relevance for the entire economy, but due to the globalisation and further integration into society their relevance today is becoming enormous. This leads to the "too big to fail" phenomenon. In order to clarify, this implies that states acts as a "lender of last resort", i.e. they hold an implicit obligation to save the bank from default since the wake of it would hit the country's economy just too hard. (Hibbeln, 2010, p. 5) The support loans and rescue packages, from tax payers, that states are forced to give to both banks and other countries are thus performed to prevent a com-

plete collapse of the world as we know it, as observed in the wake after the most recent crisis.

Based on the awareness of today's global environment, it is not difficult to explain why there is a need for organisations that are responsible for maintaining global financial stability. However, the world has not always looked like today and it is historically quite recently that this type of organisations are founded. One of these established organisations today hold the mandate to devise, suggest and recommend global banking regulations regarding capital requirements and the supervision of banks. An understanding of this particular organisation is of great importance to the thesis, therefore its role and purpose is described hereinafter.

3.1.1 The Role and Purpose of the Basel Committee on Banking Supervision

The BCBS was founded in 1974 and since holds the mandate to establish a majority of the global standards for supervision of banks. BCBS's overall purpose is to improve the quality of banking regulations, supervision and practices worldwide, while striving for an improved financial stability. (Bank for International Settlements , 2013:b) A subsidiary purpose is also to close gaps in international supervisory coverage and thereby ensure global convergence. BCBS ensures the local supervisory cooperation through regional committees and offers training in the field of prudential supervision. The global standards established by BCBS is normative for most national regulatory and supervisory authorities. (Finansinspektionen, 2013:c)

The BCBS has devised three major global agreements that all led to international regulatory frameworks, known as the Basel I Accord, Basel II Accord and Basel III Accord respectively. In the context of overall global banking regulations this frameworks, commonly referred to as the Basel agreements, is usually the first mentioned since it is one of the most significant frameworks. The Basel Accords are all devised as a response to financial crises or financial problems causing societal problems. Hereinafter, the crises and problems underlying the Basel agreements will be briefly addressed, along with their implications for banking regulations. Furthermore, consequences from the banking regulations will be touched upon.

3.1.2 Financial Crises And Problems as Well as Following Responses From the BCBS

Regarding the financial crises and problems, especially three sequences of events made the decision-makers come to realise that previous regulatory frameworks clearly were inadequate; leading to stricter and tougher requirements.

3.1.2.1 The Default of Herstatt Bank: Basel I

Back in 1974, a financial crisis occurred that was the very reason why BCBS even was founded later that year. The default of the German Herstatt Bank led to a financial crisis that spread all the way across the Atlantic sea, affecting several foreign banks including a number of US banks. (Hibbeln, 2010, p. 6) At this time many countries had some sort of bank regulations, but the definitions and levels of required capital varied from country to country (Hull, 2012, p. 258). Many countries thus realised that they had to unite and devise shared regulations to prevent history from repeating itself. Yet, even though the founding of BCBS, it took 14 years of hard cooperative work before the first globally unifying framework at last was established. (Hibbeln, 2010, p. 6) Consequently, the 1988 Basel Accord was published, also known as the Basel I Accord (Hull, 2012, p. 257). This framework was the first time an attempt was made to set international risk-based standards for capital adequacy and two requirements were defined, both specifically treating credit risk (Hull, 2012, p. 259). Furthermore, these international standards thereby led to a major harmonisation of international banking regulations and a minimum capital adequacy requirement for banks (Hibbeln, 2010, p. 6).

The system for approximating risks was, however, very simplistic in its design and exhibited several shortcomings, such as the limited consideration of risk-sensitivity (Hibbeln, 2010, p. 6). Due to its weaknesses, it was therefore subject to much criticism. (Hull, 2012, p. 259 & 268) As the approximation system was designed to be generally applicable, this resulted in that the same capital requirements applied to all exposures; no matter their credit rating nor the type of counterparty (Hibbeln, 2010, p. 6). But the mere fact that the Basel I Accord induced banks to follow the same regulation, regarding the minimum level of capital required to set aside, was a great progress (Hull, 2012, p. 259). Parts of the proposed regulations were nevertheless left to interpretation, which led to differences in the incorporation of national regulatory authorities and national supervision.

3.1.2.2 Regulatory Capital Arbitrage And Competitive Inequality: Basel II

After some time it was recognised that many banks took advantage of shortcomings in the Basel I Accord through so called “regulatory capital arbitrage”. (Hibbeln, 2010, p. 6) The main reason that this became possible was that all loans to corporations were treated in the same way, i.e. the credit rating was disregarded when calculating capital requirement (Hull, 2012, p. 268). Banks thus had the possibility to bundle their low-risk assets in asset backed securities and then sell them to investors. This type of transaction results in excess free capital for almost the same degree of risk. Capital that moreover could be invested in additional, risky projects. The risk-taking behaviour of banks was thus not effectively inhibited. (Hibbeln, 2010, p. 6-7) Furthermore, the increased globalisation had resulted in a growing number of major banks establishing abroad and it became of great importance to prevent injustice when banks increasingly began to compete with

each other on a global scale. (BCBS, 2006, p. 2) The reason was that some states in fact incorporated the Basel I Accord through looser regulations, whereas some banks got comparative advantages.

In order to put an end to the injustices and cover the gaps, a revision of the previous regulations was drafted by BCBS to reflect the altered financial environment. (BCBS, 2006, p. 2) The first draft was published already in 1999, however, there were many improvements and alterations needed to be done after identifying the financial problems that emerged from the Basel I accord. The finalised agreement, known as the Basel II Accord, was therefore not released until June 26 2004. (Hibbeln, 2010, p. 6) (Lütkebohmert, 2009, p. 31)

In the revised regulatory framework some key elements were retained but, as a revision implies, the majority of the elements were substituted or updated while at the same time new elements were added (BCBS, 2006, p. 2, §5-6). This meant that most of Basel I lost normative legal force, even if a few unaltered elements still remained in effect (BCBS, 2006, p. 5, §19). The revision consisted of significantly more advanced capital adequacy regulations, and it sophisticatedly incorporated risk-sensitivity (Hibbeln, 2010, p. 5-6)(BCBS, 2006, p. 3, §10). It introduced a system to match different exposures with capital requirements corresponding to their specific risk. Additionally, it provided a range of options for determining the capital requirement for risks to allow both banks and supervisors to select the most appropriate Approaches for their operations and their financial market infrastructure. (BCBS, 2006, p. 2, §7) The revised framework was also based on three, so called, Pillars, introduced in order to simplify understanding as well as treatment of various risks (BCBS, 2006, p. 2, §4)(Hull, 2012, p. 268). The overall objective of the Basel II framework is to implement methodologies within each Approach whose capital requirements complies more closely to the underlying risk, thus strengthening the financial stability and soundness of the international banking system (Hibbeln, 2010, p. 1). But also, as described, to address the competitive inequality among internationally active banks (BCBS, 2006, p. 2, §4).

3.1.2.3 The Financial Crisis 2007-2008: Basel III

As most of us remember, these new regulations were again inadequate to maintain global financial stability. In 2007-2008, a severe financial crisis paralysed the world. Considered by many top economists as the worst financial crisis since the Great Depression of the 1930s. (Reuters, 2009) One of the main reasons for the crisis was that the banking sector had built up excessive on- and off-balance sheet leverage. (BCBS, 2011, p. 1) The event that finally worsened the crisis and really started the domino-effect was the default of the American investment bank Lehman Brothers in 2008. At the time it was the fourth-largest bank in the US, with debts and liabilities at 613 billion dollars, indicating the magnitude of its significance. A main reason for the rapid spread of the crisis was the difficulty for banks to assess the credit quality of other banks. There had in fact been a

gradual erosion of the level and quality of the regulatory capital base. (BCBS, 2011, p. 1) Shortcomings of the then current regulatory framework thus contributed to the domino-effect, and the BCBS came to realise that the framework needed to be complemented.

Fundamental reforms were drafted to address the various failures of the previous framework, which were revealed by the crisis, and strengthen the global capital framework (BCBS, 2011, p. 2). The result of this most recently devised framework was another Basel agreement finally published in December 2010, the Basel III Accord. Its main purpose is to inhibit the probability of financial bubbles, i.e. there should be fewer, and make crises occur more scarce. Focus is put on improved liquidity, increased quantity and quality of the regulatory capital as well as efforts to take into account and reduce cyclicity. (BCBS, 2011, p. 2-8) Briefly, it consists of capitals reforms and liquidity standards (KPMG, 2013, p. 1). The capital reforms is expressed as three extra capital buffers during periods outside of stress to inhibit breaches of the minimum capital adequacy requirement (BCBS, 2011, p. 6 & 54), whereas global liquidity standards are introduced to improve the measurement of accessibility to regulatory capital (BCBS, 2011, p. 8). The implementation of Basel III implies a huge effect on banks, increasing their costs and capital adequacy requirements (Swedish Banker's Association, 2010) (Sveriges Riksbank, 2011:b), but will also inhibitory affect the global economy. Interestingly, OECD predicts that a medium-term yearly decrease of GDP of -0,05% to -0,15% will occur from the implementation of the tough Basel III Accord alone. (Slovik & Courneade, 2011, p. 2) The latest addition to the Basel agreements is yet another part of the Basel III Accord, namely "Basel III: The Liquidity Coverage Ratio and liquidity risk monitoring tools", published in January 2013. However, this part deals only with liquidity risk (BCBS, 2013, p. 1, §1) whereby it is not of relevance to the thesis.

3.1.3 The Basel Agreements Primarily Treats Capital Adequacy Requirements

The Basel agreements aim to address several issues, which at an overall level all are leading to a reasonable capital adequacy level for the risks a bank is exposed to (BCBS, 2006, p. 1, §1). For the thesis it is of importance to fully understand the term capital adequacy requirement and how it can be measured by the capital adequacy ratio. This term and measure is explained in Appendix B.1, for those who find it unfamiliar. Furthermore, the essential parts of the content in current global bank regulations with respect to capital adequacy requirements for risks will be mapped in the subsequent section. The scope of the thesis determines what is briefly mentioned as well as what is explained in a more detailed manner.

3.2 Today's Global Bank Regulations Regarding Capital Adequacy Requirements

The current regulatory framework of capital adequacy requirements for risks applies both from the Basel II and Basel III Accords, i.e. the currently applicable Basel agreements. As already mentioned, Basel II introduced the notion of three Pillars. These Pillars remain valid today and are illustrated in Figure 1. In fact, the Basel III framework builds on the three Pillars of the Basel II framework. (BCBS, 2011, p. 2) Large sections of the first and second Pillars are highly relevant for the thesis and will thus be explained and treated extensively. The third and last Pillar concerns the disclosure requirements for institutions (BCBS, 2006, p. 2). Since it does not affect the appointment of standards, it will not be given any further treatment.

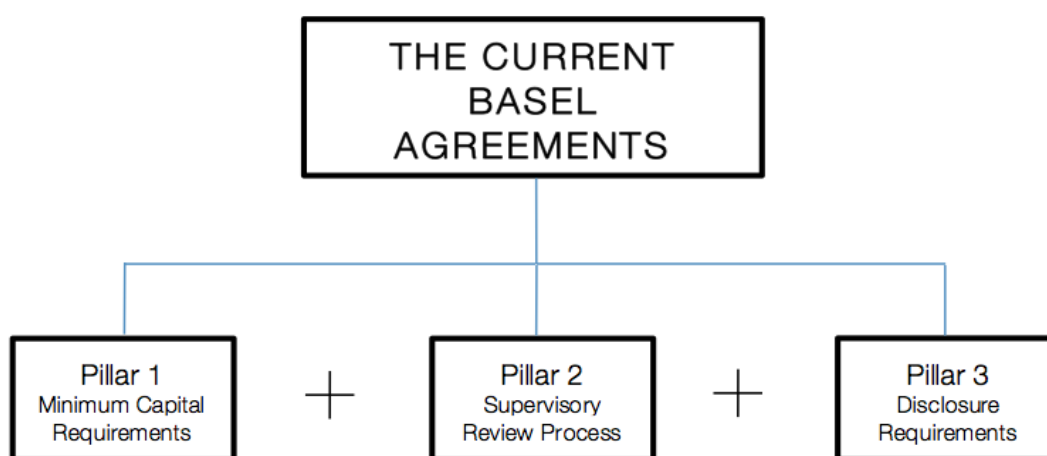


Figure 1: The current Basel agreements are based on the three so-called Pillars.

3.2.1 The First Pillar

The first Pillar, also referred to as Pillar 1, specifies the minimum capital requirement for risks of financial institutions (BCBS, 2006, p. 2) and the minimum capital adequacy ratio is set to 8% of risk-weighted assets (BCBS, 2006, p. 12). However, national authorities are free to define higher levels of minimum capital in their specific states (BCBS, 2006, p. 3). The risks are separated into three diverse risk types; credit risk, market risk and operational risk. Each type of risk independently generates capital requirements, which is then added to result in the total capital requirement under Pillar 1. (BCBS, 2006, p. 12) This corresponds to a computational bottom-up approach, which is illustrated in Figure 2.

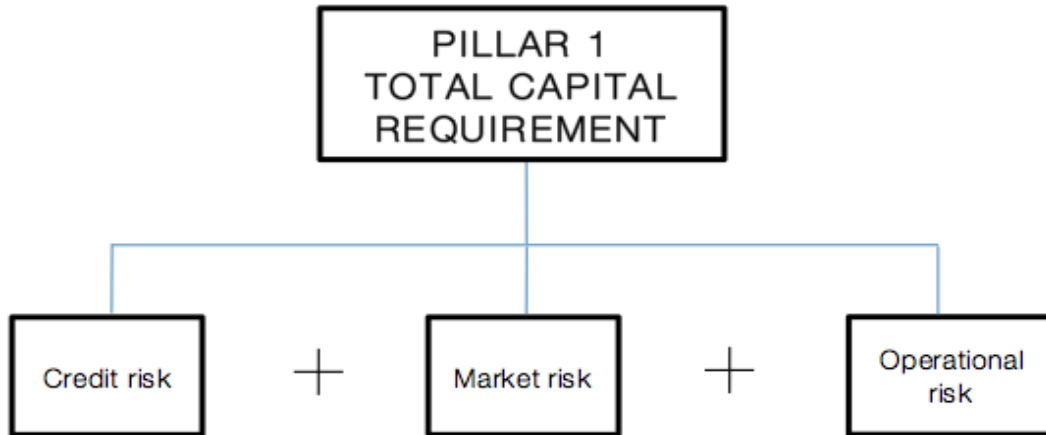


Figure 2: Total capital requirement in the first Pillar is equal to the sum of the capital requirement that each of the three risk types generate, independently.

With the three types of risk presented, from now on only credit risk is treated due to the scope of the thesis. The regulatory framework of capital requirements for credit risks are, for the majority, contained in Basel II and can be found in Pillar 1 and partially in Pillar 2. The Basel III Accord acts mainly supplementary for credit risk, but also includes marginal adjustments within the standards for calculating the regulatory capital for credit risks. (BCBS, 2011, p. 30 & 39) A brief explanation of consequences from these minor alterations will be treated in Appendix C.

The calculation methodologies for credit risk that are presented in Pillar 1 are simplified based on fundamental assumptions, in order to enable a certain degree of generalisation in terms of the implementation in banks. They need to be both easy to use and traceable. Another reason for the simplification is for making it possible for supervisory authorities to accomplish their supervision. For this purpose it is required that the methodologies are standardised and descaled. The negative consequence is that this reduction of methodology complexity leads to several limitations. To begin with, for approximating the capital requirement for credit risk the portfolio is assumed to be perfectly fine grained, or in other words perfectly diversified. (CEBS, 2010, p. 2)(Gordy & Lütkebohmert, 2013, p. 34) Another assumption is that there is only a single systematic source of risk, i.e. one risk factor. This is a consequence from basing formulas on the so-called Asymptotic Single Risk Factor (ASRF) model developed by the BCBS. (Lütkebohmert, 2009, p. 31) These reductions of methodology complexity was constructed to ensure that capital required for any risky exposure should not depend on the composition of the portfolio it is added to. In other words, each exposure does not claim any additional diversification effect (Hibbeln, 2010, p. 38). This characteristic is known as portfolio invariance and is regarded as necessary for achieving the generalised applicability, i.e. making compu-

tations possible as well as easily manageable for all banks (Lütkebohmert, 2009, p. 32). The notion of portfolio invariance further corresponds to a computational bottom-up approach, illustrated in Figure 3.

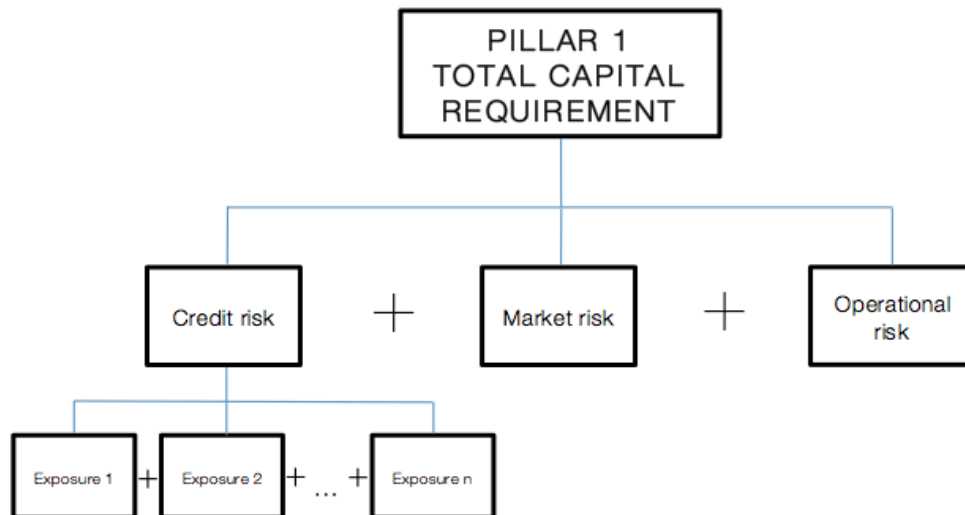


Figure 3: Capital requirement for credit risk is the sum of the capital requirement for each exposure, independently of the other exposures.

Calculations of capital requirement for credit risk for a single exposure depends only on the characteristics of the exposure and its obligor, e.g. type of loan, default probability and maturity. The identity of the counterparty is immaterial, i.e. the risk of two exposures connected to the same counterparty can be calculated separately. (Gordy & Lütkebohmert, 2007, p. 2) As a result of the assumptions of portfolio invariance and a perfectly fine grained portfolio, approximations within Pillar 1 only accounts for systematic (undiversifiable) risk, and thereby ignores idiosyncratic (diversifiable) risk since there should not be any in the assumed portfolio.

The current Basel agreements permit banks a choice between two Approaches for calculating capital requirements for credit risk under Pillar 1. The first alternative, the Standardised Approach, implies measuring credit risk with a standardised methodology, which is supported by external credit assessments. The second alternative, known as the Internal Ratings-based (IRB) Approach, is comprised of different methodologies and is subject to explicit approval of the bank's supervisor. It allows banks to use their internal rating system for credit risk or to simply conduct a more advanced methodology. (BCBS, 2006, p. 19) This enables banks to customise the approximations according to their specific situation and circumstances, allowing for greater risk sensitivity. (BCBS, 2006, p. 4)

3.2.1.1 The Standardised Approach for Credit Risk Under Pillar 1

The Standardised Approach involves a methodology where a reliance on external credit assessments is significant (BCBS, 2006, p. 19). These ratings can only be collected from an approved external credit assessment institution, abbreviated ECAI (BCBS, 2006, p. 27). An example of such an approved ECAI is Standard & Poor's, whose notation for credit ratings is the one used as an example in the Basel II framework (BCBS, 2006, p. 19).

In spite of its computational simplicity, the methodology is comprehensive to learn since a categorisation of exposures is made between many different types of counterparties. Depending on the type of counterparty, i.e. for instance a corporate, a bank or a sovereign, the same credit rating may result in different risk weights. The Approach therefore covers a whole section in the Basel II Accord, in order to explain all categories and all specific cases. (BCBS, 2006, p. 19-51)

3.2.1.2 The IRB Approach for Credit Risk Under Pillar 1

Although it is convenient to use external credit assessments, the negative aspect is that they are not always completely reliable nor the most suitable with respect to each institution's situation and unique portfolio. In order to give banks the opportunity to approximate the credit risk capital requirement for a given exposure, in a way that is more closely aligned with the bank's particular circumstances, the IRB Approach is designed as an alternative to the Standardised Approach. (BCBS, 2006, p. 52) But, as mentioned, a bank needs supervisory approval before using the IRB Approach (BCBS, 2006, p. 52). The minimum requirements that a bank needs to fulfill in order to be eligible for the IRB Approach are described in detail in the Basel II Accord (BCBS, 2006, p. 88).

The IRB Approach is based on the existence of both expected loss (EL) and unexpected loss (UL). Without going into thorough details of the calculations, the result of the mathematical functions is that they measure and return the capital requirement for credit risk based on the UL portion. (BCBS, 2006, p. 52) Figure 4 illustrates the underlying model for which the IRB Approach is based (Hull, 2012, p. 272). The reason why the capital requirement for credit risk only corresponds to UL in this model is that EL already is assumed to be covered by how financial institutions price their products (Hull, 2012, p. 271). In order to attain capital required the risk measure Value at Risk (VaR) is used, see B.12. The VaR is based on a one-year horizon and a 99.9% confidence level. Furthermore, VaR is thus the total loss unlikely to be exceeded, i.e. calculated so that the bank is 99.9% certain it will not be exceeded next year. For an intuitive understanding it can also be seen as the worst-case scenario out of 1 000 years. (Hull, 2012, p. 272)

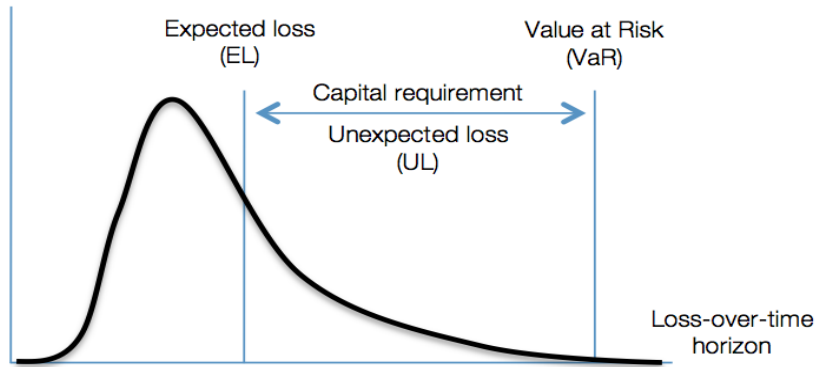


Figure 4: The loss probability density function and the capital required for credit risk by a financial institution.

Due to the above description and figure, the following notations are applicable:

$$\begin{aligned} \text{VaR}_{99.9\%}(L) &= \text{VaR}_{99.9\%}(L) - \text{EL} + \text{EL} \\ &= \text{UL} + \text{EL} \end{aligned} \quad (1)$$

Within the IRB Approach, several risk components are approximated for every exposure in a portfolio. These consist of probability of default (PD), loss given default (LGD), exposure at default (EAD) and effective maturity (M). (BCBS, 2006, p. 52) For further explanation of these risk components, please see §285-325 in the Basel II Accord. (BCBS, 2006, p. 67-76) Furthermore the BCBS has made available two broad methodologies, also referred to as Approaches, namely a foundation IRB (FIRB) and an advanced IRB (AIRB). What distinguishes them from each other is that banks, as a general rule, only provide their own estimates of PD for the FIRB Approach, while providing more of their own estimates for all the risk components for the AIRB Approach. (BCBS, 2006, p. 59) Apart from this deviation the methodologies are equivalent and they even use identical formulas, referred to as the risk-weight functions, for deriving capital requirements (BCBS, 2006, p. 59). These formulas can be found in the Basel II Accord, for the interested reader please see §271-284 (BCBS, 2006, p. 63-66). To finally clarify, all these formulas hold only under the assumption of an asymptotically fine grained portfolio (Beivydas et al, 2009, p. 46).

3.2.2 The Second Pillar

Pillar 2 specifies the key principles of internal supervisory review to ensure that the overall banking risk assessment is satisfactory (BCBS, 2006, p. 2, 204). The second Pillar therefore includes guidance to treatment of additional risks, as an add-on or supplement to those risks required within Pillar 1 (BCBS, 2006, p. 204). The first key principle simply states that there should be a process in order to assess overall capital adequacy in relation to the risk profile of a bank (BCBS, 2006, p. 205). The management of each bank is responsible for developing such an internal capital adequacy assessment process (BCBS, 2006, p. 204, §721), which is often referred to with the abbreviation ICAAP. Furthermore, the BCBS literally states that “All material risks faced by the bank should be addressed in the capital assessment process. While the Committee recognises that not all risks can be measured precisely, a process should be developed to estimate risks”. (BCBS, 2006, p. 206, §732) The BCBS is obviously aware of the drawbacks associated with simplifications in Pillar 1, and therefore Pillar 2 is instituted as a means to prevent banks from actually disregarding the risks that are overlooked or neglected in Pillar 1.

Additionally, the assessment of compliance with the minimum capital requirements associated with the methodologies in Pillar 1 is likewise an important aspect of Pillar 2. This particularly applies for banks using one of the more advanced methodologies within the IRB Approach. (BCBS, 2006, p. 204) The purpose of the second Pillar is to ensure that banks hold adequate capital to support all the possible risks in the business, but also to reassure a development and usage of improved risk management techniques. Emphasis is given to the importance of a well functioning internal supervisory review process, and it is made clear that extra regulatory capital is not regarded as a substitute for addressing fundamentally inadequate control or risk management processes. (BCBS, 2006, p. 204) Finally, there exists no proposed methodology for how this process should be performed, only overall guidance is available in the Basel agreements (BCBS, 2006, p. 206-208).

There are three main areas of risks⁵ that are suggested as particularly suited for treatment within the second Pillar, see Figure 5. The capital requirement from each of these risk-areas therefore constitute a part of the total capital requirement under Pillar 2. (BCBS, 2006, p. 204) One such area is stated as “risks considered under Pillar 1 that are not fully captured by the Pillar 1 process”. The example set out for this type of risks is credit concentration risk (BCBS, 2006, p. 204, §724), which is furthermore treated as one of the specific issues that should be addressed under the supervisory review process. It is specifically stated in the Basel II Accord that “banks should have in place effective internal policies, systems and controls to identify, measure, monitor, and control their credit risk concentrations. Banks should explicitly consider the extent of their credit risk concentrations in their assessment of capital adequacy under Pillar 2”. (BCBS, 2006, p. 214)

⁵Note that this is not the three risk types of credit, market and operational risk.

From now on, a distinction is made to only treat the credit concentration risk out of all the material risks that should be managed according to Pillar 2 (BCBS, 2006, p. 206), due to the scope of the thesis.

3.2.2.1 Credit Concentration Risk Under Pillar 2

The arising of credit concentration risk is a result of credits having a skew distribution across different segments. The segments may for instance consist of certain industries, regions or correspond to individual counterparties. (BCBS, 2006, p. 214, §773)(Lütkebohmert, 2009, p. 65)

Credit concentration risk can more specifically be divided into three main types, i.e. name concentration, sector concentration and credit contagion, see Figure 5 (Hibbeln, 2010, p. 57). Firstly, name concentration can occur either on an individual or on a portfolio level. Individual name concentration risk arises when one individual counterparty's exposure is extremely large compared to the remaining exposures in the portfolio. Portfolio name concentration, in turn, arises when a portfolio contains few firms, each with large exposures. (Hibbeln, 2010, p. 58) Secondly, sector concentration in a portfolio exists when groups of counterparties that correlates to each other because of common underlying factors, e.g. same industry or geographical location, are associated with large exposures (Hibbeln, 2010, p. 58). In the Basel agreements, the BCBS additionally divides sector concentration into concentrations in the same geographic region as well as in the same industry. (BCBS, 2006, p. 214, §773) It is important to understand how these notations are related and the breakdown is illustrated in Figure 5. Lastly, credit contagion refers to the increased dependence or correlation of two firms' probability of default, resulting from their shared business connections. Many banks also demonstrate this joint dependence due to the large market of interbank loans, which is one of the underlying reasons that financial crises can spread, already been touched upon. (Hibbeln, 2010, p. 59) Many scientific articles treats different methodologies for quantifying name concentration risk, while the other two concentration types are sparsely treated due to the difficulties and burden in practically dividing individual exposures into their corresponding sectors.

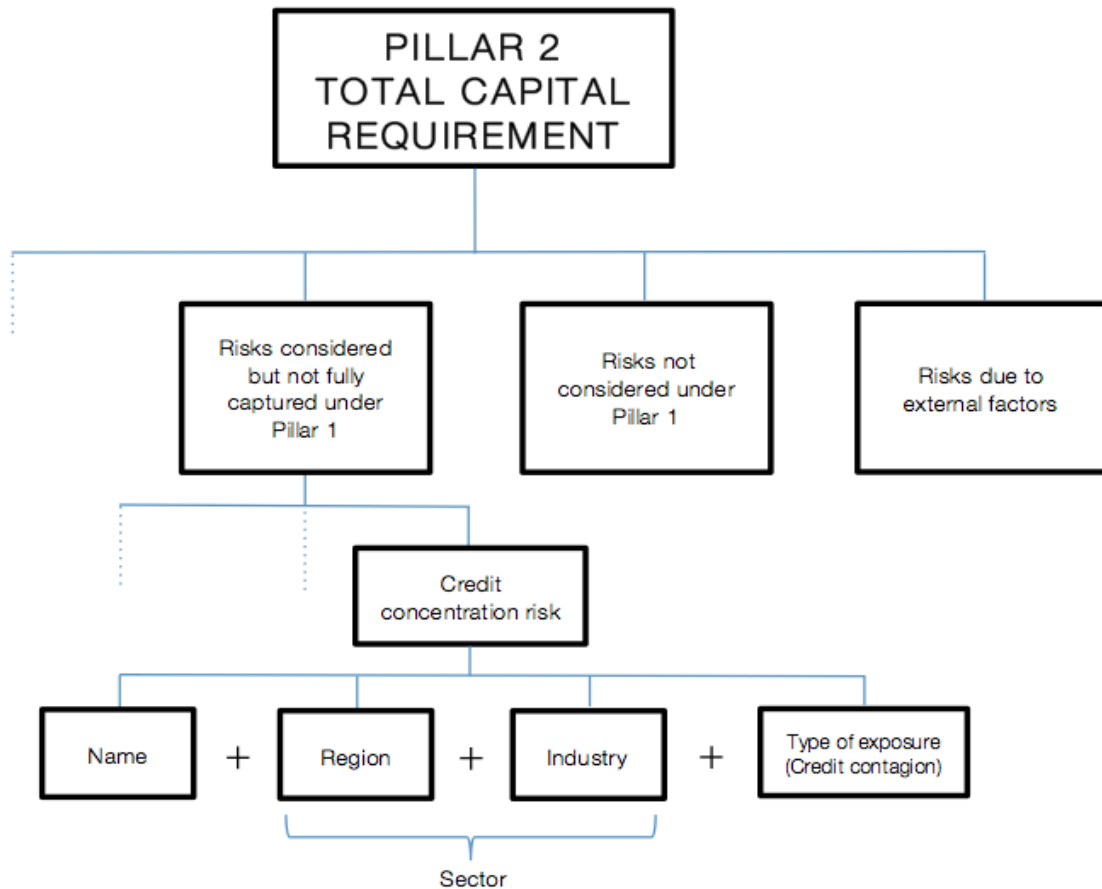


Figure 5: Total capital requirement under Pillar 2 is based on several risks, where credit concentration risk is considered as a significant risk.

According to assumptions of portfolio invariance and perfectly fine grained portfolios in Pillar 1, the notion of credit concentration risk is not fully captured by the Pillar 1 process. As previously mentioned, the reduction of methodology complexity, i.e. the bottom-up approach, leads to several limitations; one of which is just that credit concentration risk is not captured. (Lütkebohmert, 2009, p. 32) The risk-weight formulas in Pillar 1 simply omits the contribution of undiversified idiosyncratic risk, which can be seen as a residual, to required economic capital (Gordy & Lütkebohmert, 2013, p. 34). However, such a residual of credit concentration risk exists in most real portfolios. This is due to that these portfolios do not fulfill the assumptions, and thus the idiosyncratic risk is not completely diversified (Lütkebohmert, 2009, p. 32). The only portfolios where the asymptotic assumption might be approximately valid is for the absolute largest banks, whereas the portfolios of smaller and more specialised institutions definitely contains a residual (Gordy & Lütkebohmert, 2013, p. 34). Since most banks fail to fulfil this asymptotic assumption due to their characteristics, regulations states that all but the

very smallest banks are expected to account for this actual existence of concentration risks under Pillar 2 (Lütkebohmert, 2009, p. 32).

Regarding credit concentration risk, all that the Basel agreements state is that banks should have methodologies or processes that considers and approximates that risk. These processes should also enable banks to identify potential weaknesses of their portfolios due to the risk. (BCBS, 2006, p. 206) The credit concentration risk should therefore be monitored and managed through these processes, but the BCBS does not, however, give any concrete recommendations nor proposals on how such a process should or could be designed. Finally, the most recently devised Basel III Accord includes minor alterations for credit risk, implying indirect consequences for credit concentration risk. For the interested reader these consequences are described in Appendix C.1.

3.3 Consequences for Swedish Banks

Furthermore, it is important for the thesis to understand how currently applicable global bank regulations affect Swedish banks, particularly the regulations concerning credit concentration risk described above. Although these regulations are not binding, most countries have incorporated them into their national legislation. Sweden is one of those countries. However, being a member state of the European Union (EU) implies that the incorporation into Swedish legislation as a first step passes through implementation at EU level. This is the case for all EU member states, since the European Parliament incorporates the Basel agreements into legislation at EU level. (Sveriges Riksbank, 2011:a) Subsequently, as a second step, the EU legislation is incorporated into Swedish legislation through application of the documents published by the European Parliament. These provisions, consisting of complementary rules, are published by FI (Finansinspektionen, 2013:b, p. 1), being the responsible supervisory authority within the field in Sweden (Finansinspektionen, 2014:b). The relationship between legislative acts treating credit risk and credit concentration risk on different levels is illustrated in Figure 6.

The legislative acts currently in force

Level	Legislative act
Global	Basel agreements, by BCBS
EU	CRD IV, by European Commission
Sweden	Provisions and regulations, by FI

Figure 6: The legislative acts treating credit risk and credit concentration risk on different levels.

When incorporating at an European level, the goal is to adopt a regulation that establishes uniform rules, applicable in all Member States (European Commission, 2013:b, p. 2, §11). After the addition of the Basel III Accord in 2010, the European Parliament accordingly revised the EU regulatory framework. They then chose to implement it by publishing both a regulation and a directive; a legislative package commonly referred to as ‘CRD IV’. (KPMG, 2013, p. 1) The final legislative acts, the Capital Requirements Regulation (CRR) and the Capital Requirements Directive (CRD) (KPMG, 2013, p. 1), was published on June 26 2013 (European Commission, 2013:b, p. 1). Together, they currently form the legal framework on EU level (European Commission, 2013:b, p. 2, §5) corresponding to the Basel II and III frameworks (European Commission, 2013:b, p. 5, §41).

When one of the EU institutions agree on new EU laws, Swedish legislators together with their opposites in other Member States are obliged to comply (EU-upplysningen, 2013). However, there is a certain difference between a regulation and a directive. Regulations apply directly in the form in which they are enacted, while directives only set targets to be reached and therefore must be incorporated into national law before they gain definite legal force. (EU-upplysningen, 2013)(European Commission, 2013:b, p. 6)

Before the implementation of ‘CRD IV’, the EU legislation consisted of two directives, published in 2006. These were intended to implement the Basel II Accord, but due to their legislative form they left room for certain differences when incorporated into national legislation. (European Commission, 2013:b, p. 2) A consequence were slightly different computational methodologies in accordance to the national legal frameworks, although based on the same calculation technique by BCBS. The injustices that arose was one of the underlying reasons that a regulation was instead devised (European Com-

mission, 2013:b, p. 6), with the aim to accomplish a “single rule book for banking regulation”. (KPMG, 2013, p. 1) Uniform rules applicable in all Member States of the EU also strengthens the trust in the stability of the institutions, especially in times of crisis (European Commission, 2013:b, p. 2)(Finansinspektionen, 2013:b, p. 21). The current legislative package replaces the two previous directives (European Commission, 2013:b, p. 5, §41) and currently applicable capital adequacy requirements for credit risk can be found in the CRR (Finansinspektionen, 2013:b, p. 29), where it is treated in detailed and prescriptive regulations (European Commission, 2013:b, p. 6). Thus, these current rules removes the major source of national divergences (European Commission, 2013:b, p. 6) and gains direct legal force for Swedish banks (Sveriges Riksbank, 2011:a). Concentration risk, on the other hand, is briefly treated on a general level in both the regulations and the directive (European Commission, 2013:a, p. 382, a81)(European Commission, 2013:b, p. 6). It is stated that “having a large number of relatively small exposures should be reflected in the requirements” (European Commission, 2013:b, p. 6, §43), but just as in the Basel agreements there are no suggested methodologies for how to specifically treat credit concentration risk (European Commission, 2013:a, p. 382, a81).

FI is the proprietor of the supervisory function in Sweden and is for example providing general advice to Swedish financial institutions regarding their management and control (Finansinspektionen, 2005, p. 1). In particular, FI performs the supervision of Swedish banks’ and financial institutions’ credit risk assessments, which also includes the supervision of the ICAAP under Pillar 2. (Finansinspektionen, 2010)(Finansinspektionen, 2014:a)

3.3.1 FI’s Proposed Methodologies for Credit and Credit Concentration Risk

Concerning Pillar 1, FI complements the CRR with provisions on prudential requirements for credit institutions and investment firms (Finansinspektionen, 2013:b, p. 1). In this respect they practically comply with the currently applicable Basel agreements described in 3.2.1. Furthermore, FI performs a so-called SKB (Samlad kapitalbedömning; i.e. a comprehensive capital assessment) for supervised institutions, where the supervision according to law shall include large exposures and concentration risk (Finansinspektionen, 2009:c, p. 1). However, in terms of Pillar 2 FI differ from Basel and EU to the extent that they publish methodologies for credit concentration risks that Swedish banks could choose between to follow in order to manage their risks under their ICAAP. There exists methodologies within the Standardised Approach for the different types of credit concentration risks, as minimum requirements. It also exist proposed methodologies within the IRB Approach. The proposals of the IRB Approach is done by expressing what specific methodologies FI conducts for the approximation of credit concentration risks and for assessing institutions, which thus can be seen as guidance from FI and an indication of approved methodologies. (Finansinspektionen, 2009:a, p. 1)(Finansinspektionen, 2009:b, p. 1)

FI furthermore chooses to segment parts of credit concentration risks in their conducted methodologies, namely into name concentration, regional concentration and industry concentration. (Finansinspektionen, 2009:b, p. 1) In other words a proposed computational methodology for credit contagion is omitted, although it still needs to be taken into account since a segmentation of parts of the risks provides space to take into account more than the three segments. Moreover, FI propose methodologies both for banks using the Standardised Approach as well as for IRB approved banks using an IRB Approach⁶. The banks or banking groups that used an internal model for credit risk at the end of 2013 are Handelsbanken, Nordea, SEB, Swedbank, Svensk Exportkredit, Landshypotek, Länsförsäkringar Bank, Volvo Finans and SBAB. (Finansinspektionen, 2013:a, p. 4) Owing to the proposed methodologies within the two Approaches, the only computational difference between the Approaches is for name concentration risk, as illustrated in Figure 7 (Finansinspektionen, 2009:c, p. 2-5). Thus, the two proposed methodologies for name concentration risk receives additional focus, i.e. one methodology within each Approach.

The methodologies within the two Approaches proposed by FI for credit concentration risk

	Standardised Approach	Proposed IRB Approach
Name concentration	AHI	GA
Region concentration	HHI	HHI
Industry concentration	HHI	HHI

Figure 7: The methodologies within the two Approaches proposed by FI implies that the Approaches only differ for the two proposed methodologies for name concentration risk.

⁶To clarify, it is the IRB authorisation valid for credit risk which applies to credit concentration risk as well.

3.3.1.1 FI's Methodologies for Name Concentration Risk

Regarding the capital requirement for name concentrations, FI proposes one methodology within each Approach. Furthermore, institutions must at least comply with the Standardised Approach. It is for both methodologies important to be able to aggregate all exposures to a single counterparty. (Finansinspektionen, 2009:a, p. 4)(Finansinspektionen, 2009:b, p. 4) The methodology in line with the Standardised Approach includes the use of a Share Adjusted Herfindahl index (AHI), resulting in simplified approximations. For a mathematical explanation please see section 4.2 (Finansinspektionen, 2009:a, p. 4-5). The methodology is computationally very simple and is a minimum requirement for banks as long as they are not very small, implying that they are not covered by FI's requirement and thus allowed to disregard name concentration risk (Finansinspektionen, 2009:a, p. 1).

For financial institutions authorised to use the IRB Approach, FI propose a specific methodology that institutions should use for name concentrations. FI thus refers to the article "*Granularity Adjustment for Basel II*" and presents a simplified analytical expression with a brief description. (Finansinspektionen, 2009:b, p. 4-5) The referenced article is written by Michael Gordy and Eva Lütkebohmert in 2007 and in this article they present the more advanced and detailed methodology that FI actually propose, which is based on the risk model CreditRisk⁺ (Gordy & Lütkebohmert, 2007). This proposed methodology for IRB approved banks is described in section 4.3 and derived in Appendix A.1. Generally, the methodology known as Granularity Adjustment can be used to assess the impact of undiversified idiosyncratic risk on portfolio capital requirements (Gordy & Lütkebohmert, 2013, p. 34). In this manner, the methodology can be used to quantify the additional risk from name concentration. An important aspect being emphasised is that when measuring the granularity adjustment borrower identity can not be ignored, i.e. all exposures to the same counterparty must be aggregated. (Gordy & Lütkebohmert, 2007, p. 2)

FI furthermore states that the retail portfolio currently can be excluded when IRB banks implement the granularity adjustment, since there is no significant concentration risk in the retail portfolio (Finansinspektionen, 2009:b, p. 4). This implies that they do not see the need to account for exposures towards private customers, but instead only account for exposures towards counterparties consisting of institutions and companies (Finansinspektionen, 2009:c, p. 4). FI's statement of excluding the retail portfolio is in line with a proposal that was once published by the BCBS, in a consultative paper later being superseded (BCBS, 2001, p. 90,§427). A brief explanation to why BCBS even made a statement on this in such a previous stage is that a granularity adjustment at first was considered for inclusion in the formal minimum capital requirement of the Basel II Accord, but then removed in the finally published Basel II Accord (Gordy & Lütkebohmert, 2013, p. 37). BCBS's reasoning was that the retail portfolio is, by its very nature, highly unlikely to worsen the granularity adjustment of a portfolio, whereby it is neither likely to

greatly reduce the approximated granularity adjustment. Most likely the inclusion of all retail exposures would marginally reduce the granularity adjustment, but the negligible difference is why the retail portfolio can be excluded. Thus, such a excluding treatment of the retail portfolio is a conservative approach that allows the capital requirement to be marginally higher. (BCBS, 2001, p. 90, §427)

What might also be important to understand in this context is that ever since the drafting of the Basel II framework, several analytical methodologies have been devised for approximating the supplementary capital requirement for name concentration risk. (Finansinspektionen, 2009:b, p. 4) There is, for example, at least three Approaches for how the granularity adjustment representing name concentrations could be estimated, i.e. Approaches by Vasicek (2002), by Emmer & Tasche (2005) and by Gordy & Lütkebohmert (2007). A performed analysis of these three approaches concluded that the third approach proposed by Gordy and Lütkebohmert is most applicable in practice and furthermore holds fewer drawbacks than the other two approaches. (Beivydas et al, 2009, p. 58) Thereafter, at least one additional approach for granularity adjustment for name concentration has been devised by Gordy & Marrone (2010), having further developed the work by Wilde (2001). (Gordy & Marrone, 2010) The basis for the choice of compared methodologies is, however, only the proposals by FI since the application of these methodologies are closer at hand for Swedish banks.

3.4 The Case Ikano Bank

In order to validate the resulting capital requirements for the generated portfolios presented in chapter 5, the two methodologies are also applied on a Swedish bank's portfolio, namely Ikano Bank's leasing portfolio. The following section is therefore dedicated to a presentation of this Swedish bank.

3.4.1 History And Information of Ikano Bank

Ikano Bank is historically linked with the globally well-known home furnishing company IKEA. This background is a consequence of Ikano Bank being a part of Ikano Group (Annual Report 2013, 2014, p. 3 & 14), which in 1988 were separated from IKEA and became an independent group of companies owned by the Kamprad Family (Ikano Group, 2014). Ikano Bank was founded in 1995 and in accordance to their background the roots are in Älmhult, while the headquarter is placed in Lund (Annual Report 2013, 2014, p. 14). Today, Ikano Bank is represented in six geographical markets, namely Sweden, Denmark, Norway, Finland, the Netherlands and the UK (Annual Report 2013, 2014, p. 14). Meanwhile, their business to business operations currently exists in Sweden, Denmark and Norway. The business area "Corporate" offers financing solutions to corporate clients and organisations in the form of rental and lease agreements, object financing, invoice purchasing as well as factoring. (Annual Report 2013, 2014, p. 14)

3.4.1.1 Current Situation

The total assets of the bank at the end of last year amounted to 23 783 mSEK (Annual Report 2013, 2014, p. 14) and on the same date they had about 2 million active customers (Annual Report 2013, 2014, p. 2). Total lending amounted to around 20 000 mSEK (Annual Report 2013, 2014, p. 2) and with roughly 700 employees, whereof around 30% of them in Sweden (Annual Report 2013, 2014, p. 10), the bank can be regarded as a smaller player within the Swedish banking sector, dominated by four major banks (Swedish Banker's Association, 2013:a). The Swedish Bankers' Association categorises Ikano Bank as a niche bank (Swedish Banker's Association, 2013:c), and resulting from their IKEA-background they hold a unique situation with respect to knowledge of financial solutions and loyalty programs for companies similar to IKEA. (Annual Report 2013, 2014, p. 10)

3.4.2 Compliance With the Basel Agreements and Guidelines from FI

Needless to say, Ikano Bank complies with the capital adequacy requirements in the Basel framework as well as with the guidelines from FI. However, due to the scope of the thesis only compliance with regards to credit risk will be further addressed. Credit risk is regarded as the Bank's greatest risk, and Ikano defines it as the risk that a counterparty fails to meet its obligations (Annual Report 2013, 2014, p. 16)(Capital adequacy and risk management 2013, 2014, p. 3).

3.4.2.1 Current Methodology for the Capital Adequacy Requirements for Credit Risk

When approximating capital requirements for credit risk, i.e. under Pillar 1, Ikano Bank uses the Standardised Approach by FI. Overall, their capital adequacy exceeds the minimum capital requirements by a wide margin. (Capital adequacy and risk management 2013, 2014, p. 8) The capital adequacy ratio (CAR, see Appendix B.1) at last year-end was 16,7%, implying that the regulatory capital in relation to the minimum capital requirements, i.e. the capital adequacy quotient, receives a ratio of 2,09. (Annual Report 2013, 2014, p. 64) The Bank's internal goal is that the CAR should at least exceed 14% (Annual Report 2013, 2014, p. 63) This buffer represents an additional margin suited for the risk profile of the bank. (Capital adequacy and risk management 2013, 2014, p. 9)

In order to make sure that the CAR is sufficient, Ikano annually performs an ICAAP in accordance with Pillar 2. Accordingly, an assessment of possible additional capital requirements are made for all identified risks under Pillar 2. The high CAR implies that Ikano Bank complies with the minimum requirements under Pillar 1, as well as by a wide margin satisfies the internally assessed capital requirement under Pillar 2. (Capital adequacy and risk management 2013, 2014, p. 9) Subsequently, within the ICAAP one of

the risks Ikano Bank takes into consideration is credit concentration risk, for which the Standardised Approach by FI is applied. (Capital adequacy and risk management 2013, 2014, p. 9) However, the risk department at Ikano Bank is interested in more advanced methodologies in order to quantify and take into account skew distribution of exposures in their portfolios.

3.4.3 A Leasing Portfolio at Ikano Bank

It is for a leasing portfolio at Ikano Bank that reality-based data is processed and used when applying the two methodologies on Ikano Bank. This leasing portfolio consists of around 34 000 individual exposures. Each exposure is a lease agreement concerning leased assets of primarily office equipment, vehicles and cleaning equipment, all being recognised as operational leases. (Annual Report 2013, 2014, p. 55) The amount of individual exposures moreover correspond to roughly 16 000 exposures when aggregated to individual counterparties, as well as after elimination of the exposures with a value equal to 0. Around two-thirds of the portfolio's number of exposures correspond to a credit rating of A or better, which indicates that the portfolio is composed of mostly low-risk lease agreements. The total value of the lease agreements in the portfolio, or in other words the total EAD of the exposures in the portfolio, amount to nearly 2 700 mSEK.

The data set is slightly modified by Ikano Bank prior to the handover, but without compromising the appearance and characteristics of the portfolio. A part of the modification is also the anonymisation of data. This, however, does not affect the portfolio's validating contribution to the thesis, since the actual counterparties of the individual exposures are not of any interest. However, it is of interest to note that all the counterparties in the data set consists of corporates and sovereigns, whereas all lease agreements to retail customers are disregarded.

4 Theory

In this chapter a short introduction of common notations for portfolio characteristics is presented along with explanations of the mathematical theory forming FI's two proposed methodologies for name concentration risk.

4.1 Common Notation for Credit Risk Calculations

A portfolio consists of several exposures to different counterparties. Each exposure is assigned a value of EAD , PD , LGD , and M , which are usually noted EAD_i , PD_i , LGD_i and M_i for the i :th exposure. One counterparty may correspond to multiple exposures. For calculation of name concentration risk it is, however, required that these exposures are aggregated with respect to the counterparty, which means that all EAD_i for the same counterparty are added together. To get a joint PD_i , LGD_i and M_i for the aggregated exposures, different techniques are used where weighted averages are commonly used.

4.2 Standardised Approach by FI

Swedish banks must at least comply with FI's proposed methodology within the Standardised Approach, as long as they are not very small (Finansinspektionen, 2009:a, p. 1). It is for this methodology important that an institute is able to aggregate their risk exposures corresponding to the same obligor, and particularly for their biggest risk exposures. FI furthermore gives institutes an opportunity to reduce their computational burden. Instead of aggregating all their risk exposures, it is sufficient to only aggregate their 30 biggest risk exposures in the portfolio. (Finansinspektionen, 2009:a)

Herfindahl index, or HI, is a commonly accepted measure of concentration and it is defined according to Appendix B.7. (U.S. Department of Justice, 2014) For the Standardised Approach of approximating name concentration risk, the HI is approximated with the use of a share adjusted Herfindahl index (AHI). The AHI uses a HI_{30} which is calculated based only on the 30 biggest aggregated exposures according to Equation 4. (Finansinspektionen, 2009:a, p. 5) Consequently the AHI is calculated according to Equation 3, which then corresponds to an interval in Table 1 and consequently a percentage of capital requirement also shown in Table 1. For a simple example on how this additional capital requirement is calculated, see Equation 2.

$$Capital\ Requirement_{\text{Pillar 2}} = X\% \cdot Capital\ Requirement_{\text{Pillar 1}} \quad (2)$$

where the percentage, X , is assigned according to Table 1.

4.2.1 Share Adjusted Herfindahl Index or AHI

$$AHI = HI_{30} \cdot \frac{\sum_{i=1}^{30} EAD_i}{\sum_{i=1}^n EAD_i} \quad (3)$$

where n denotes the total number of exposures in the portfolio and

$$HI_{30} = \sum_{i=1}^{30} \sigma_i^2 \quad \text{where} \quad \sigma_i = \frac{EAD_i}{\sum_{i=1}^{30} EAD_i}. \quad (4)$$

Regarding FI's notation σ_i , it is more commonly accepted to use s_i . Consequently, FI's notation is the one used in Equation 4.

Table 1: Table on capital requirements based on AHI for name concentration (Finansinspektionen, 2009:c, p. 2).

AHI	Capital requirement as a share of the Pillar 1 capital requirement for credit risk
$AHI < 0.01$	0%
$0.01 \leq AHI < 0.02$	2%
$0.02 \leq AHI < 0.04$	4%
$0.04 \leq AHI < 0.08$	6%
$0.08 \leq AHI$	8%

4.3 IRB Approach by FI; A Granularity Adjustment

An explanation and derivation regarding construction of the methodology Granularity Adjustment (GA) proposed by FI is presented in Appendix A.1. Thus, only a brief explanation of the methodology follows in this section.

Granularity Adjustment is a methodology for calculating additional capital requirement associated with name concentration risk. The necessity of approximating this additional risk owes to it being overlooked in calculations of Pillar 1 capital requirement, due to the assumption of portfolio invariance. There exists several GA methodologies devised by different authors. FI propose Swedish IRB-approved banks to use the Granularity Adjustment in accordance with a certain article (Finansinspektionen, 2009:b, p. 4). This article was published in 2007 (Gordy & Lütkebohmert, 2007) and updated by the same authors in 2013 under the name *Granularity Adjustment for Regulatory Capital Assessment* (Gordy & Lütkebohmert, 2013). This article states a recommended formula of

the add-on as follows below. Unless otherwise stated, all subsequent explanations are retrieved from the latter article. The capital requirement according to the methodology Granularity Adjustment is expressed as:

$$GA = \frac{1}{2K} \sum_{i=1}^n s_i^2 C_i (\delta(K_i + R_i) - K_i). \quad (5)$$

where the parameter K corresponds to the total capital requirement for the portfolio, i.e. a weighted average calculated as $K = \sum_{i=1}^n s_i K_i$ where the parameter s_i is each exposures share of the total portfolio and $K_i = \frac{UL_i}{EAD_i}$ is the asymptotic unexpected capital requirement as a share of EAD_i . Furthermore, the parameter C_i is defined as

$$C_i = \frac{V[LGDI_i] + E[LGDI_i]^2}{E[LGDI_i]} \quad (6)$$

where the variance of $LGDI$ for each exposure, $V[LGDI_i]$, needs to be estimated. The variance of $LGDI$ can be described as $V[LGDI_i] = \gamma \cdot E[LGDI_i] \cdot (1 - E[LGDI_i])$. The parameter R_i corresponds to the capital requirements for credit losses as a percentage of EAD and K_i corresponds to the capital requirement for unexpected loss, UL , as a percentage of EAD , that is:

$$s_i = \frac{EAD_i}{EAD_{tot}}$$

$$K_i = \frac{UL_i}{EAD_i}$$

$$K = \frac{\sum_{i=1}^n UL_i}{\sum_{i=1}^n EAD_i} = \sum_{i=1}^n s_i K_i$$

$$V[LGDI_i] = \gamma \cdot E[LGDI_i] \cdot (1 - E[LGDI_i])$$

$$C_i = \frac{V[LGDI_i] + E[LGDI_i]^2}{E[LGDI_i]}$$

$$R_i = \frac{EL_i}{EAD_i} = \frac{PD_i \cdot LGDI_i \cdot EAD_i}{EAD_i} = PD_i \cdot LGDI_i$$

(Finansinspektionen, 2009:b, p. 4-5)(Gordy & Lütkebohmert, 2013, p. 58)

FI makes assumptions regarding the two input parameters of the methodology Granularity Adjustment as the ones in the article *Granularity Adjustment for Regulatory Capital Assessment*, i.e. $\gamma = 0,25$ and $\delta = 4,83$ (Finansinspektionen, 2009:b, p. 4). These estimations are described as a precision parameter and a recovery risk parameter $\gamma[0, 1]$ (Gordy & Lütkebohmert, 2013, p. 43 & 47), which are more thoroughly described and examined by Beivydas et al (2009, p. 51).

The resulting capital requirement under Pillar 2 is by FI transformed to be expressed as a percentage of the capital requirement under Pillar 1. This is done by dividing the expression 5 with the portfolio specific weighted average K . By the conversion from

the original article, the resulting capital requirement for the Granularity Adjustment is comparable with FI's Standardised Approach. With the square of the portfolio specific weighted average K as well as the values of γ and δ inserted into Equation 5, the expression now takes the form:

$$GA = \frac{1}{2K^2} \sum_{i=1}^n s_i^2 \cdot (0,25 + 0,75LGD_i)(4,83 \cdot (K_i + R_i) - K_i). \quad (7)$$

(Finansinspektionen, 2009:b)

Note that the article chooses to express the add-on as a share of a portfolio's total *EAD* (Gordy & Lütkebohmert, 2013, p. 58), while FI's memorandum instead express the add-on as a share of the Pillar 1 capital requirement (Finansinspektionen, 2009:b, p. 4).

Also note that a factor of 100 is removed from FI's formula, since it only serves to express the add-on in percentage points.

5 Analysis

To fulfill the main objective of the thesis, the performed comparison between the two methodologies proposed by FI is explained in the following chapter. The chapter presents how portfolios are generated and how the methodologies are applied for these portfolios, as well as for the portfolio of the case company Ikano Bank. Important to note is that both the methodologies are marginally modified to enable the comparison, whereas this joint modification is presented. Throughout the analysis, the computational calculation programme Matlab is used for performing calculations. One exception is when applying the methodologies for the portfolio of the case company Ikano Bank, whereas Microsoft Excel is used.

5.1 Generating Portfolios

A variation of portfolios are generated, which includes both examples portfolios and realistic portfolios. Thus, the following presentation of these are organised in two sections. Firstly, the example portfolios will be treated and consequently the generation of realistic portfolios follows thereafter.

5.1.1 Generating Example Portfolios

To provide an understanding about appearance and terms regarding portfolios, a few example portfolios are constructed and illustratively presented. One of the example portfolios is the so-called reference portfolio, where the portfolio is homogeneous regarding both *EAD* and *PD*. The other examples consist of portfolios with a high concentration, but with a reduced skewness for each subsequent portfolio. The portfolios are concentrated when a few obligors represent a large share of the portfolios total *EAD*.

Important to note is that all the illustrated example portfolios are extreme cases compared to realistic portfolios. Furthermore, note that their corresponding figures only show the 50 biggest exposures of the example portfolio, i.e. the horizontal axis is not comprehensive. The reason for this omission is for the illustrations to be readable. The example portfolios all consist of $N = 10\,000$ number of exposures each. The first example portfolio, the reference portfolio P1, is illustrated in Figure 8. For a portfolio with these characteristics the capital requirement for name concentration risk is negligibly low.

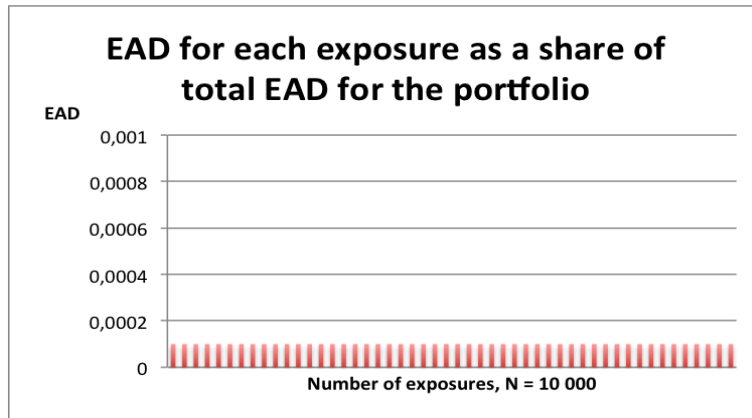
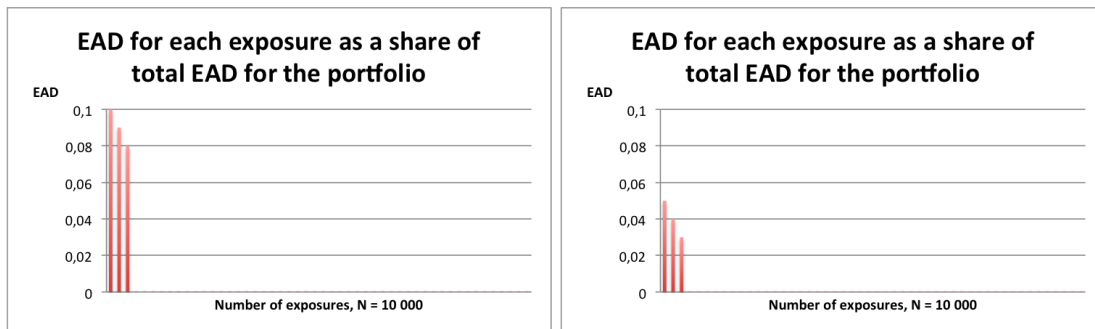


Figure 8: First example portfolio, P1. The reference portfolio with homogeneous distribution of *EAD* and *PD*.

The second example portfolio, P2, is illustrated in Figure 9a. This portfolio is highly concentrated and holds an extremely skewed *EAD*-distribution, as the first three exposures represent 10, 9 and 8 percent of total portfolio *EAD*. The remaining 9 997 exposures equally share 73 percent of the portfolio *EAD*. Consequently, for portfolios being this concentrated the capital requirement for name concentration risk is high.

The third example portfolio, P3, is also highly concentrated and holds an extremely skewed *EAD*-distribution, illustrated in Figure 9b. However, the first three exposures does not represent as much of *EAD* as in the previous portfolio P2. They represent 5, 4 and 3 percent. Thus, the remaining 9 997 exposures equally share 88 percent of the portfolio *EAD*. All else being equal, P3 therefore corresponds to a lower capital requirement for name concentration risk compared to P2.

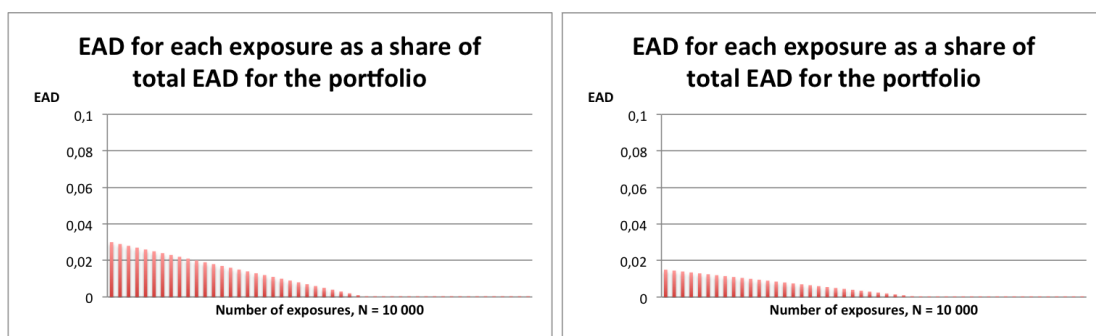


(a) Second example portfolio, P2. A portfolio with an extremely skewed *EAD*-distribution. (b) Third example portfolio, P3. A portfolio with an extremely skewed *EAD*-concentration, but lower than the foregoing example portfolio.

Figure 9: Illustration of *EAD*-distribution of the example portfolios P2 and P3.

Example portfolio number four, P4, is likewise highly concentrated. However, the *EAD*-distribution of the biggest exposures is rather gradually decreasing, in contrast to the radical reduction in the foregoing example portfolios, see Figure 10a. The absolutely biggest exposure represents 3 percent, while the 30 succeeding decrease by steps of 0,1 percent. Thus, 9 970 exposures equally share 53,5 percent of the portfolio *EAD*. A portfolio with similar *EAD*-characteristics corresponds to a high capital requirement for name concentration risk.

The fifth example portfolio P5, see Figure 10b, is similar to the P4. The 30 biggest exposures, however, does not represent as much of total *EAD* as the previous portfolio P4. In fact, they represent half the value. All else being equal, P5 therefore corresponds to a lower capital requirement for name concentration risk compared to P4.



(a) Fourth example portfolio, P4. A portfolio where the *EAD*-distribution decreases more gradually than for P2 and P3. (b) Fifth example portfolio, P5. A portfolio where the decreasing *EAD*-distribution is lower than for P4.

Figure 10: Illustration of *EAD*-distribution of the example portfolios P4 and P5.

After illustrating and describing these five generated example portfolios, the following section will present how a large amount of realistic portfolios are generated. Consequently, it is for these generated realistic portfolios that FI's two methodologies for name concentration risk later are applied.

5.1.2 Generating Realistic Portfolios

Portfolios are now generated in order to illustrate how the two methodologies capital requirements differ. The total number of generated portfolios amounts to 10 000. Since both methodologies require a portfolio to be aggregated on a counterparty level, all portfolios will be generated on this level, i.e. as if the aggregation had already occurred. Out of all portfolios possible to generate, there are some that are more realistic than others. Only such realistic portfolios are of interest for the comparison, whereas it is among these that the selection of generated portfolios is made. Therefore, the sample of generated

realistic portfolios is a subset of all realistic portfolios, as well as of all possible portfolios, see Figure 11. The selection aims to provide an adequate sample to conduct the comparison between the two methodologies. Thus, in order to mimic realistic portfolios, the portfolios are generated based on assumptions for what is regarded reasonable for realistic portfolios. This is done in order to attain somewhat generalisable conclusions of the comparison's result. The assumptions are explained below.

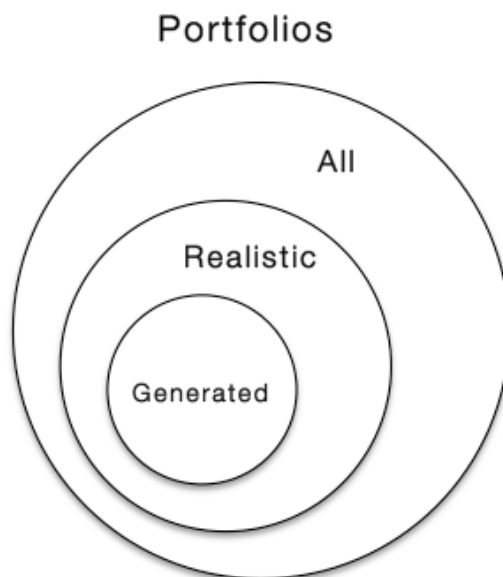


Figure 11: The generated realistic portfolios represent a subset of all realistic portfolios as well as of all possible portfolios.

Firstly, the generated realistic portfolios consist of $N = 10\,000$ exposures. This portfolio size may be considered lower than the size of many actual portfolios, but sufficiently large to illustrate the resulting capital requirements for the two methodologies. As a benchmark, the case company Ikano Bank's leasing portfolio contains around 16 000 aggregated exposures. Furthermore, each of these exposures are assigned values of M_i and LGD_i , whereas these values are assumed to be homogeneous for all exposures. LGD is assumed to be $LGD_i = 0,45$ for all exposures in the generated realistic portfolios, which is reasonable and conservative according to BCBS (2006, p. 67, §287). M_i is assumed to have a value of 2,5 years for all exposures, which also is reasonable according to BCBS (2006, p. 74, §318).

Secondly, the distribution of EAD_i in the portfolios is explained. The realistic portfolios are generated with anything from 1 up to 2 000 number of big exposures, i.e. the first generated portfolio contains one big exposure while the two-thousandth generated

portfolio contains 2 000 big exposures. The remaining exposures in every portfolio, which thus amounts to between 9 999 and 8 000, are treated as small exposures. This process is repeated five times in order to attain the total number of 10 000 portfolios, out of which five portfolios contains one big exposure, five portfolios contains two big exposures etc. up to five portfolios with 2 000 big exposures. The big exposures are assigned random EAD_i -values in intervals, with respect to how many exposures are considered to be big exposures. These intervals are described in Table 2, with a fixed EAD_i -interval when portfolios consist of only up to a handful of big exposures. Furthermore, the remaining small exposures that represent up to and including 90 percent of portfolios' exposures are randomly assigned values around an approximate value. The approximate assigned value is based on the value if equally sharing the remaining total EAD . Finally, the 10 last percent of the exposures are assigned values so that they adjust the portfolio's total EAD to become equal to 1.

Table 2: Table of intervals for assignment of EAD_i and PD_i -values for each exposure. Note that when the number of big exposures (k) is less than 2 000, the $k+1$:th exposure is assigned values according to intervals in the third row of the table.

Exposure number (i) (k is the number of big exposures which is fixed for one portfolio but varies between generated portfolios)	EAD_i-intervall (as a share of portfolio total EAD)	PD_i-intervall
1 - 5	[0.01 , 0.07]	[0 , 0.01%]
6 - 2 000	$\left[\frac{0.3}{k} - \frac{0.3}{2k}, \frac{0.3}{k} + \frac{0.3}{2k} \right]$	[0 , 0.1%]
($k+1$) - 5 000	$\left[\frac{1 - \sum_{j=1}^k EAD_j}{N-k} - \frac{1}{N \cdot 10}, \frac{1 - \sum_{j=1}^k EAD_j}{N-k} + \frac{1}{N \cdot 10} \right]$	[0 , 0.2%]
5 001 - 8 700	$\left[\frac{1 - \sum_{j=1}^k EAD_j}{N-k} - \frac{1}{N \cdot 10}, \frac{1 - \sum_{j=1}^k EAD_j}{N-k} + \frac{1}{N \cdot 10} \right]$	[0.2 , 2%]
8 701 - 9 000	$\left[\frac{1 - \sum_{j=1}^k EAD_j}{N-k} - \frac{1}{N \cdot 10}, \frac{1 - \sum_{j=1}^k EAD_j}{N-k} + \frac{1}{N \cdot 10} \right]$	[3.5 , 4.5%]
9 001 - 10 000	$\frac{1 - \sum_{k=1}^{9000} EAD_i}{0.1 \cdot N}$	[0 , 0.1%]

Thirdly, the distribution of PD_i in the portfolios is explained. Standard and Poor's publishes information about how many companies that exist within each given rating in a certain geographical area, see Standard and Poor's (2011). It is assumed that a bank's portfolio should consist of a similar composition with respect to PD_i , regarding its exposures. I.e., if there exist about 50% companies that are A-rated, a general portfolio should consist of approximately 50% exposures with an A-rating. When determining the PD_i intervals illustrated in Table 2, it is assumed reasonable that the big exposures in a portfolio are assigned the lowest values of PD_i , relatively speaking. This is a consequence of that it is unreasonable that a bank allows large credits to be exposed towards

a risky counterparty. Furthermore, the approximate share of exposures that are assigned a specific PD_i in the generated realistic portfolios are listed in Table 3, which are in line with the proportions published by Standard and Poor's. These ratings are thereafter assigned an interval based on the values of PD_i that Ikano Bank assigns the different ratings, see Table 4.

Table 3: Table for assigned ratings in the generating of portfolios and their corresponding possible values of PD_i .

Rating	Number of exposures assigned	Intervals for assigning PD_i for each rating
A	50%	[0% , 0.1%]
B	45%	[0.2% , 2%]
C	5%	[3.5% , 4.5%]

Table 4: Corresponding PD_i for each rating according to Ikano Bank, slightly modified due to secrecy.

Rating	PD_i corresponding to each rating
Gov (Government)	0.00%
AAA	0.11%
AA	0.10%
A	0.15%
B	1.47%
C	4.16%
NR (Non-Rated)	0.43%

According to Table 2, exposures are assigned values of PD between 0 to 4,5%. Corporate exposures' minimum PD level is 0,03% (Basel II, p. 67, §285), whereas exposures to sovereigns most often are considered a PD of 0%. Thus, the interval of 0 to 4,5% implies that the generated realistic portfolios are allowed to include both sovereign and corporate exposures, ranging from AAA- to C-rated. The reason for this implementation is that the portfolios then mimics reasonable realistic portfolios.

When banks assign values of PD_i to their exposures, each rating normally corresponds to a certain value, as in Table 4 for Ikano Bank. For the generated realistic portfolios, note that the values of PD_i are randomly generated uniformly over the intervals and not discrete. The reasons for assigning PD_i to the exposures from a continuous interval is to increase the variations and to avoid dependence in what the corresponding value of PD_i is given for each rating.

To summarise, for each and every exposure values of EAD_i , PD_i , LGD_i and M_i is assigned. Every combination of 10 000 such exposures then represents one generated realistic portfolio. Furthermore, the total number of generated realistic portfolios amounts to 10 000. In the following section the two methodologies are applied on these generated portfolios.

5.2 Applying the Methodologies Standardised Approach and Granularity Adjustment on All Generated Portfolios

After generating the example portfolios as well as the realistic portfolios, the two methodologies, i.e. the one within the Standardised Approach, see section 4.2, and FI's proposed Granularity Adjustment, see section 4.3, are now applied on each of these portfolios. First, however, a description of how the methodologies are implemented is provided in the following section. This is thereafter followed by a description of how the two methodologies are applied for all the generated portfolios, which results in two capital requirements for each portfolio, produced by the two methodologies respectively.

In FI's versions of the two methodologies, their resulting capital requirements are given as a percentage of the Pillar 1 capital requirement. Since all generated portfolios corresponds to a different Pillar 1 capital requirement, it complicates the interpretation of a comparison. However, all generated portfolios have the same total EAD . Therefore it is possible to compare the resulting capital requirement of the different portfolios if it is instead expressed as a percentage of the portfolios total EAD . The results from the two methodologies are therefore converted into that form for the comparison. The conversion is conducted by multiplying FI's expressions for the two methodologies with a portfolio specific value, i.e. the weighted average K , whereas the expression as a percentage of EAD is attained.

In the application the variables γ and δ used in Granularity Adjustment, see Equation 7 and its preceding section, are set to $\delta = 0.25$ and $\gamma = 4.83$. This is in line with both the article *Granularity Adjustment for Regulatory Capital Assessment* and what FI states in their proposal, see Gordy & Lütkebohmert (2013, p. 46) and Finansinspektionen (2009:b, p. 4).

5.3 Illustrating Capital Requirement when Applying the Two Methodologies

In order to illustrate patterns and features of the two methodologies, the resulting capital requirements for the generated portfolios are graphically illustrated. This is done firstly for the example portfolios and secondly for the selected sample of generated realistic portfolios with diverse characteristics. In the following section all illustrations are

presented with two different sets of measurements on the axes. The usage of two set of measurements allows for a wider range of conclusions. The illustrations are presented in 2-dimensional scatter plots for the example portfolios and 3-dimensional scatter plots for the generated realistic portfolios. Consequently, these 3-dimensional figures are shown in four different angles to give the reader an enhanced understanding of the 3-dimensional appearances. These four angles are presented as subfigures in a joint figure.

The resulting capital requirement from the Standardised Approach for each portfolio corresponds to blue circles in all upcoming illustrations. The resulting capital requirement from the Granularity Adjustment is, on the other hand, represented by red crosses.

The first set of axes consist of HI , weighted average PD and *Capital Requirement*, where HI is calculated according to B.7 and PD according to the definition in Equation 8. These dimensions indicate the entire portfolio's features, but not specifically how the large exposures relate to the others. In order to draw conclusions about how the large exposures relate to the other exposures for the various portfolios, the resulting capital requirements are also illustrated with the measurements AHI , APD and *Capital Requirement* on the axes. AHI is an adjusted Herfindal Index, see Equation 3, while APD is an adjusted measure of the weighted average PD , see Equation 9. Both these measured values determine how the 30 biggest exposures relate to the other exposures for the various generated portfolios.

The variation of measurements on the axes is repeated for the example portfolios' resulting capital requirements and also for the generated portfolios' capital requirements. Later on this variation is also repeated when applying the methodologies on Ikano Bank's leasing portfolio, see section 5.4.1.

In order to understand forthcoming illustrations resulting from applying the methodologies on the generated portfolios, an improved understanding of measurements on the axes is required. Consequently, these measurements are presented hereinafter.

5.3.1 Measurements for Comparing Appearances of Different Portfolios

In this section the two created measurements are explained. These are weighted average PD and APD , which are both used to demonstrate the appearance of different portfolios and thus allow for the comparison.

PD is a weighted average value of probability of default for a portfolio, that takes the whole portfolios appearance into account.

$$PD = \sum_{i=1}^n s_i \cdot PD_i \quad \text{where} \quad s_i = \frac{EAD_i}{\sum_{i=1}^n EAD_i} \quad (8)$$

APD is a weighted average value of probability of default for the 30 biggest exposures in a portfolio. Thus, it is an equivalent measure to the weighted average PD , adjusted in order to correspond to the AHI measure proposed by FI.

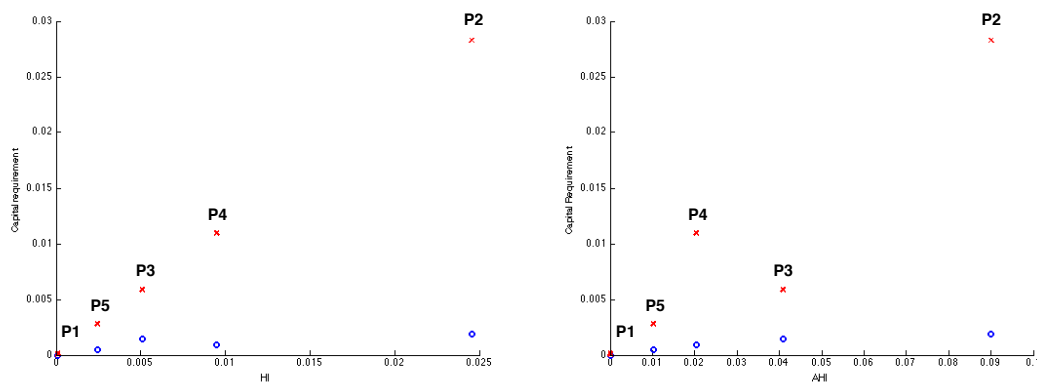
$$APD = \sum_{i=1}^{30} s_i \cdot PD_i \quad \text{where} \quad s_i = \frac{EAD_i}{\sum_{i=1}^{30} EAD_i}. \quad (9)$$

5.3.2 Illustrating Resulting Capital Requirement for the Example Portfolios

All example portfolios are homogeneous with regard to the values of PD_i for each exposure. The portfolios therefore have the same value assigned to each exposure, i.e. $PD_i = 0.001$ regardless of i . As a consequence, the weighted average PD for these portfolios are identical. Therefore, the example portfolios are presented in two dimensions instead of all three when illustrating capital requirement for the two methodologies. This means excluding the axis with weighted average PD , i.e. the used axes are $HI, Capital Requirement$ and $AHI, Capital Requirement$ respectively. Figure 12a illustrates the example portfolios resulting capital requirement with the axes HI and $Capital Requirement$. The reference portfolio, P1, is located on low values of both HI and $Capital Requirement$, i.e. close to origo in Figure 12a. In the same Figure, example portfolio P2 and P3 corresponds to high values of $Capital Requirement$, whereof P2 receives the highest. Furthermore, example portfolios P4 and P5 also results in high values of $Capital Requirement$, although somewhat lower. Comparing P4 and P5, P4 receives the highest capital requirement. Example portfolio P4 implies a higher HI than P3, whereby it is important to clarify that the illustration mainly aims to compare the difference in capital requirement from P3 with P2 and P4 with P5 respectively.

Figure 12b on the other hand illustrates the results from the two methodologies with axes AHI and $Capital Requirement$, instead of using HI . Once more the reference portfolio, P1 is located close to origo, i.e. with low values of both AHI and $Capital Requirement$. The other four example portfolios are located on higher values of both AHI and $Capital Requirement$ and in descending order regarding the sequence they are

presented, i.e. P5 is located closest to the reference portfolio. The reason for the graph's appearance, i.e. with a non-linear relation regarding the difference between the methodologies, is that in both P2 and P3 there is a high concentration among the 30 biggest exposures which thus results in a higher *AHI*. P4 is, however, treated as more concentrated in terms of the overall portfolio and thereof results in a higher capital requirement. That a non-linear relation is possible is an important insight. As will be illustrated later on, this relation also applies when portfolios' resulting capital requirements are observed in relation to HI.



(a) First set of axes, regarding the appearance of all exposures. (b) Second set of axes, regarding the appearance of the 30 biggest exposures.

Figure 12: Illustrations of the example portfolios' resulting capital requirement for name concentration risk in two dimensions. Red crosses correspond to capital requirements from Granularity Adjustment while blue circles correspond to capital requirements from the Standardised Approach.

After illustrating the capital requirement for the five generated example portfolios, the following section will present resulting capital requirement for the generated realistic portfolios.

5.3.3 Illustrating Resulting Capital Requirement for the Realistic Portfolios

The methodologies are applied on each of the 10 000 generated portfolios and the resulting capital requirements when using the first set of axes are illustrated in Figure 13. The resulting capital requirements with the second set of axes are then illustrated in 14.

5.3.3.1 The first set of axes

Starting with the first set of axes it can be seen that the capital requirement from Granularity Adjustment in most cases exceed the capital requirements from the Standardised Approach, see Figure 13. On the contrary, for generated portfolios with a relatively high weighted average PD, it can be seen that those of these with a slightly higher HI most often results in a lower required capital from the Granularity Adjustment than the Standardised Approach. This relationship is specifically clarified in Figure 13c and Figure 13d.

The generated portfolios' HI-value varies between 0.0001 and 0.017, see Figure 13b. This is desirable in order to cover several variations of realistic portfolios. A general tendency among the generated and illustrated portfolios is that for portfolios with a higher HI, the portfolios also result in a higher capital requirement. Accordingly, both methodologies' resulting capital requirement increases for increasing HI, but the Granularity Adjustment implies a much steeper increasing slope. This steeper slope consequently generates an increasing difference between the two methodologies. For the methodology within the Standardised Approach it is furthermore possible to observe a staircase-like increase in capital requirement for generated portfolios with higher HI. The increase in resulting capital requirement from the Granularity Adjustment, on the other hand, seems to imply somewhat linear relationship to HI, at least for the majority of the generated portfolios.

However, there exists portfolios over large parts of the range of generated HI values where the Granularity Adjustment result in lower capital requirement than the methodology within the Standardised Approach, see Figure 13b. This shows that the outcome is possible, even though it only occurs for a small fraction of the generated portfolios.

Moreover, a majority of the generated portfolios results in a value of weighted average PD in the range of 0.004 to 0.005, see Figure 13d. The reason for why some portfolios deviate is most likely that the assigned PD_i for several exposures are simultaneously randomised high or low in the interval of PD_i for the exposures.

Finally, Figure 13a shows that there is a large accumulation of portfolios with very low HI relative to other generated portfolios, and thus low capital requirement. For these portfolios, there exists a spread in weighted average PD and their capital requirements are very low relative to the other generated portfolios.

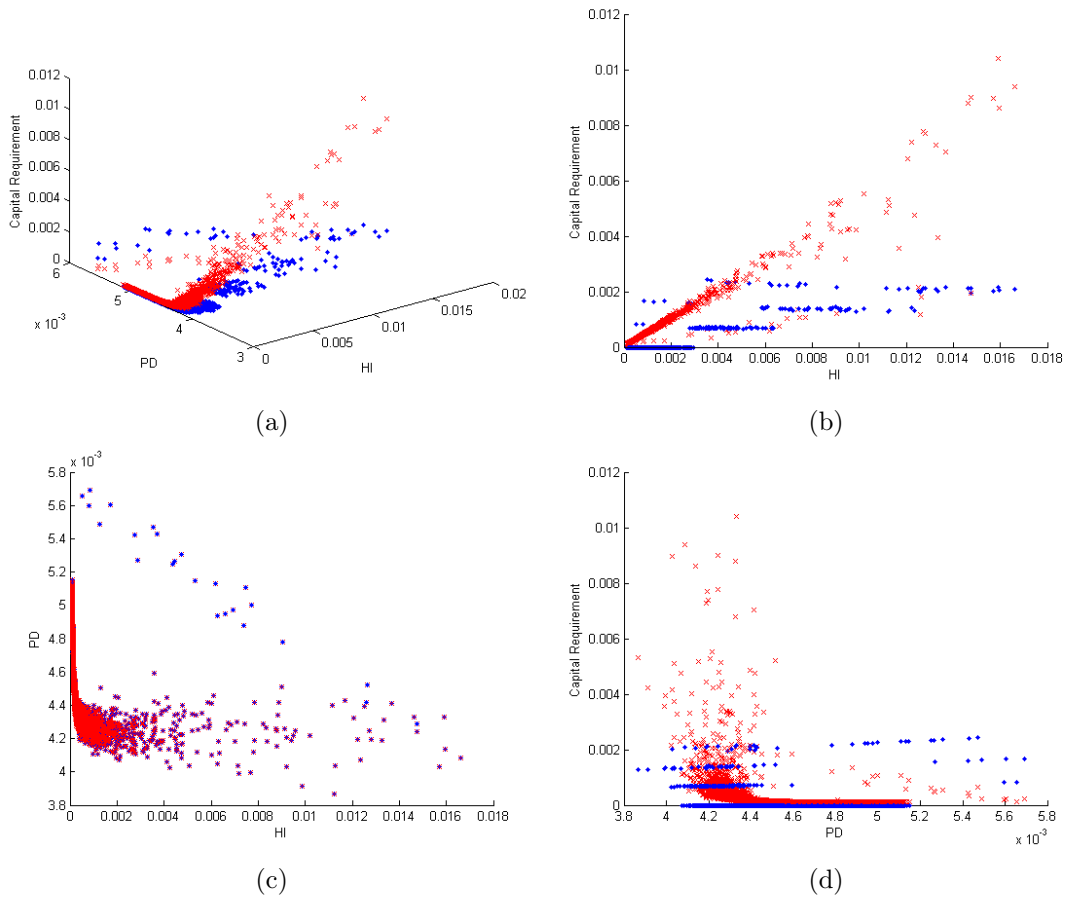


Figure 13: Different angles of resulting capital requirements for name concentration risk for the 10 000 generated realistic portfolios with the first set of axes. Red crosses correspond to capital requirements from Granularity Adjustment while blue circles correspond to capital requirements from the Standardised Approach.

5.3.3.2 The second set of axes

Concerning the second set of axes, the overall observation that the *GA* methodology results in a higher capital requirement than the methodology within the Standardised Approach is of course also noted. However, the step-like tendency for the portfolios' Standardised Approach will be even more prominent, and this is in accordance with what is expected given the definition of the methodology and that the portfolios are illustrated with respect to *AHI*.

Furthermore, the generated portfolios result in much lower weighted average of *APD*, i.e. when it is measured only for the 30 biggest exposures with respect to *EAD_i* instead

of the whole portfolio. This observation is a result of the lower interval that is set in the generation of portfolios for the biggest exposure. This lower range is set similar to all generated portfolios and therefore the results are accumulated around weighted average $PD = 0.0005$. This accumulation can be seen in Figure 14 and very clear in Figure 14c. This can be considered as a low value, but realistic given that the 30 biggest exposures in real portfolios most likely consist of a combination of Government and A-rated corporate exposures.

The small accumulation of generated portfolios with relatively low weighted average APD values and high values of AHI , is interesting, see Figure 14a and Figure 14c. The generated portfolios with these characteristics, in a majority of the outcomes, result in lower values of Granularity Adjustment than the Standardised Approach, see Figure 14b and 14d. To better understand the appearance of these portfolios, they are portfolios in which the 30 biggest exposures exhibit skewness and are given a large portion of the portfolio total EAD . Simultaneously, these big exposures are assigned low values of PD_i , thus reducing the weighted average APD .

Furthermore, it is interesting that in the generated range of AHI , it seems possible that the Granularity Adjustment methodology result in lower capital requirement regardless of low or high values of the portfolios' AHI . It is also observed that the generated portfolios can result in lower required capital from Granularity Adjustment than the Standardised Approach in the generated APD interval, as is clearly shown in 14d, i.e. both relatively high and low APD can result in Granularity Adjustment giving a lower value than the methodology within the Standardised Approach.

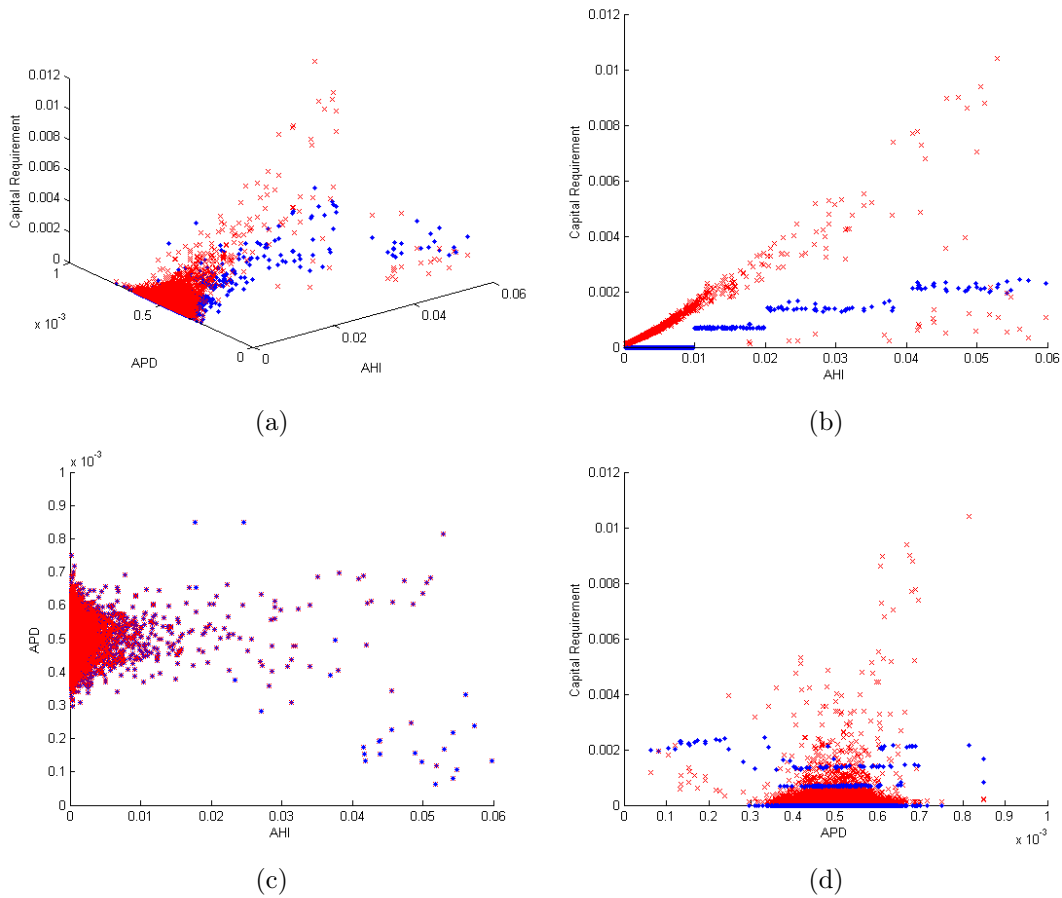


Figure 14: Different angles of resulting capital requirements for name concentration risk for the 10 000 generated realistic portfolios with the second set of axes. Red crosses correspond to capital requirements from Granularity Adjustment while blue circles correspond to capital requirements from the Standardised Approach.

5.4 Applying and Illustrating the Methodologies on Ikano Bank's Portfolio

In the following section, the two methodologies Standardised Approach and Granularity Adjustment are applied on the leasing portfolio of Ikano Bank. For this application the converted methodologies are applied, i.e. when multiplying FI's proposed methodologies with the portfolio specific weighted average K . This is done in accordance with the previously explained application on all generated portfolios. Likewise, the assumptions made by FI are regarded as valid also for this application. To repeat, the assumptions are thus $\gamma=0,25$ and $\delta=4,83$ for the portfolio, while $LGD_i=0,45$ and $M_i=2,5$ is assigned to every exposure. Both the use of the converted methodologies and the use of the same

underlying assumptions is chosen in order to attain resulting capital requirements comparable with the generated realistic portfolios.

Based on the raw data presented from Ikano, some processing of the data set is made. It is controlled that metrics exist on all relevant parameters. Furthermore, the data set is controlled regarding whether there are any outliers or missing values. Moreover, since all exposures are expressed on an individual level, they are all aggregated to counterparty level since this is a requirement for application of both methodologies. Finally, all aggregated exposures for which the EAD_i amounts to 0 are excluded from the data set. Subsequently, the remaining data is then used when applying the two methodologies, whose capital requirements for name concentration risk is illustrated in the forthcoming section.

5.4.1 Illustrating Resulting Capital Requirement for Ikano Bank's Portfolio

The resulting capital requirements when applying the two methodologies for Ikano Bank's portfolio are presented by adding them to the previously illustrated Figures 13 and 14 of all generated portfolios. The resulting capital requirement for Ikano Bank's leasing portfolio is therefore illustrated as two additional data points in Figures 15 and 16, in the shape of a green cross and a green circle. This is done in order to clarify where Ikano Bank's portfolio is positioned in respect to the generated realistic portfolios. Once more the variation of measurements on the axes is performed. Thus, the first illustration consist of HI , PD , *Capital Requirement* while the second illustration consist of AHI , APD , *Capital Requirement*.

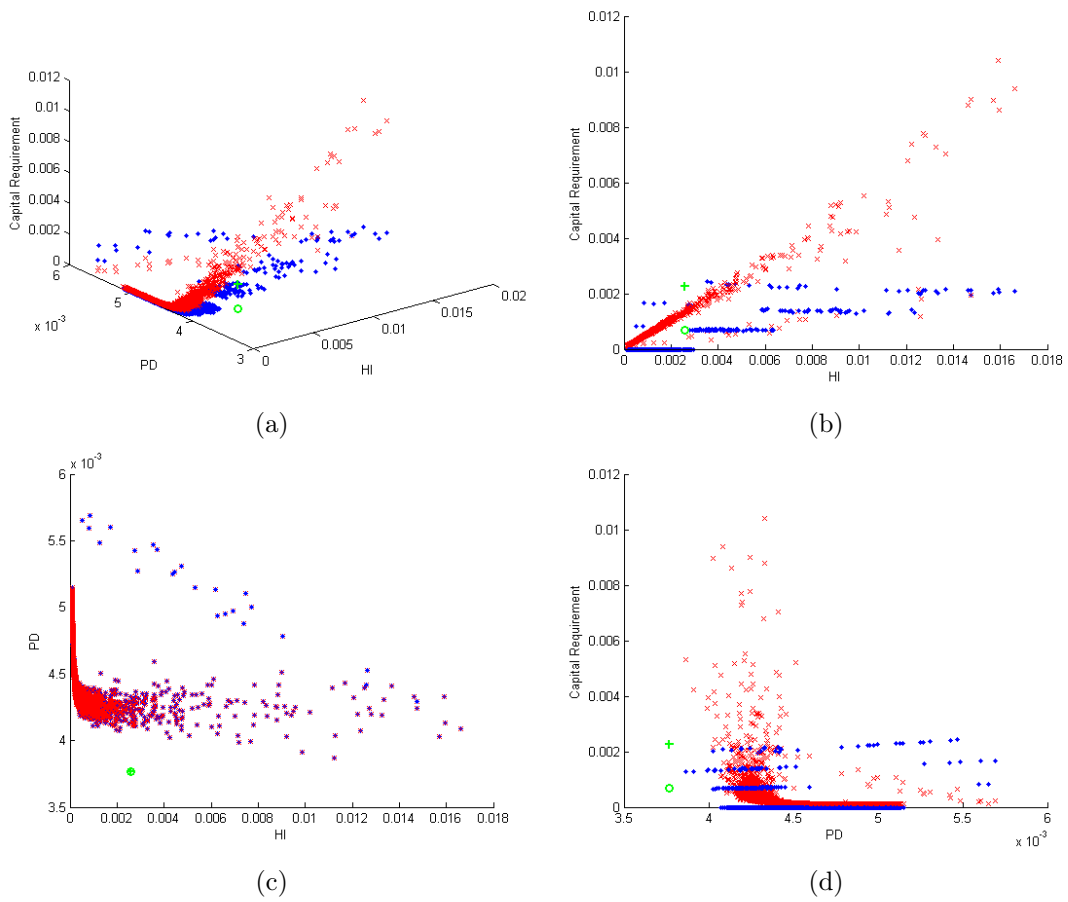


Figure 15: Different angles of resulting capital requirements for name concentration risk for the 10 000 generated portfolios and Ikano Bank's portfolio, with the first set of axes. Red crosses correspond to capital requirements from Granularity Adjustment while blue circles correspond to capital requirements from the Standardised Approach. The green markings represent Ikano Bank's portfolio.

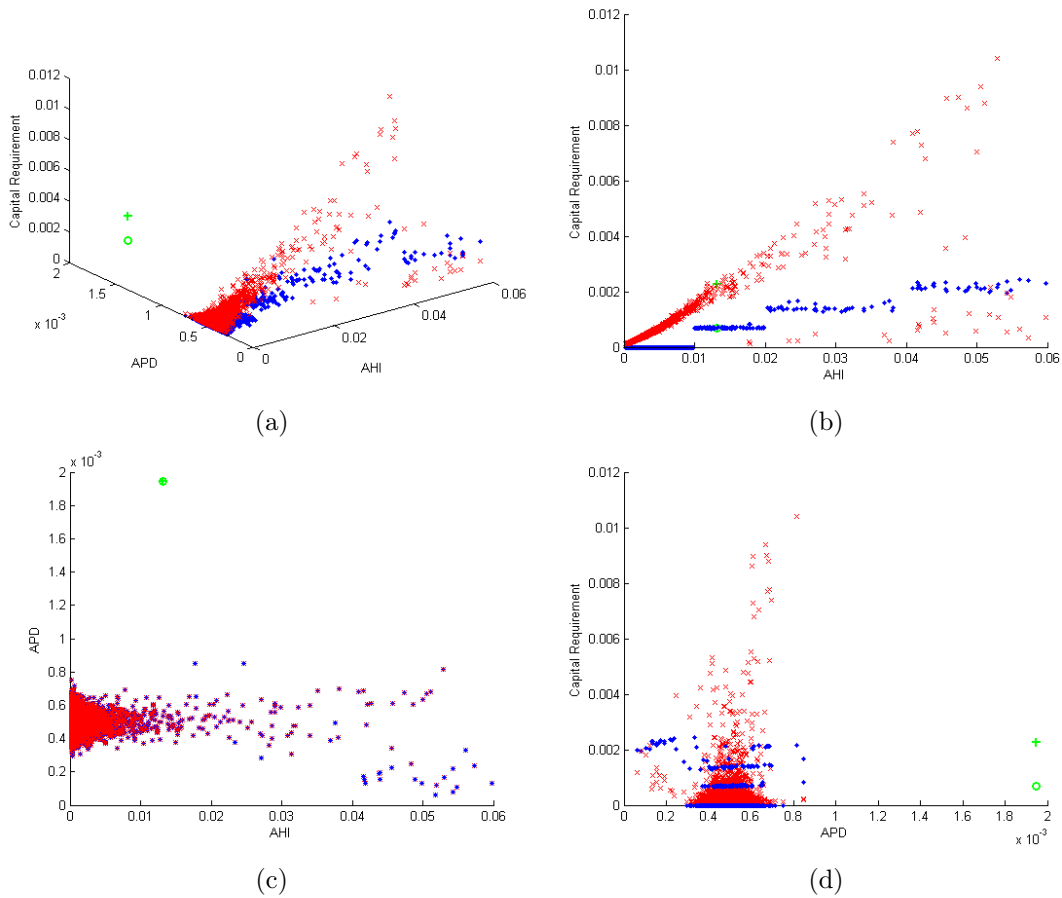


Figure 16: Different angles of resulting capital requirements for name concentration risk for the 10 000 generated portfolios and Ikano Bank's portfolio, with the second set of axes. Red crosses correspond to capital requirements from Granularity Adjustment while blue circles correspond to capital requirements from the Standardised Approach. The green markings represent Ikano Bank's portfolio.

5.4.1.1 The two set of axes

As can be seen in Figures 15b and 16b, the resulting value from the methodology within the Standardised Approach is positioned in the "second step of the stair". Furthermore, the resulting value from the Granularity Adjustment is slightly above the generated portfolios with respect to HI , but on an equal level with respect to AHI . Ikano Bank's portfolio results in a slightly lower weighted average PD than the generated portfolios and at the same time higher weighted average APD , see Figure 15c and 16c. This can be explained by that the portfolio of Ikano Bank contains slightly higher PD_i values on its 30 biggest exposures, in comparison to the generated portfolios. Furthermore,

Ikano Bank's portfolio's lower value of weighted average PD is explained by that a larger proportion of their portfolios total EAD probably consist of exposures corresponding to lower PD_i , compared with the generated portfolios.

The deviation in PD and APD axes are after all understandable. Additionally, with respect to the level of resulting capital requirements, it is possible to say that Ikano Bank's portfolio somewhat validates the generated portfolios plausibility.

The resulting capital requirements for name concentration risk when applying the two methodologies on Ikano's modified leasing portfolio are also presented in Table 5. As previously mentioned, note that the percentages are expressed as a share of total portfolio EAD . The total EAD of Ikano Bank's leasing portfolio is 2 699 261 275 SEK. The resulting capital requirements are also expressed in SEK in order to more clearly illustrate their actual monetary value.

Table 5: Resulting capital requirements for Ikano Bank's leasing portfolio.

Methodology	As a percentage of total portfolio EAD	In SEK
Standardised Approach	0.068874%	1 859 083
Granularity Adjustment	0.226513%	6 114 190

Furthermore, most important for the thesis is the differences in resulting capital requirements between the two methodologies. Therefore, these differences are especially clarified for the generated portfolios as well as for Ikano Bank's portfolio. With the purpose of clarification, chapter 6 will illustrate Figures 15 and 16 again, but instead with the difference in capital requirement between the methodologies on the vertical axis.

6 Differences in Resulting Capital Requirements Between the Two Methodologies

In order to more clearly present how the methodologies resulting capital requirements differ for each portfolio, scatter plots of the difference in capital requirement are generated, see Figures 17 and 18. These scatter plots include all generated portfolios as well as Ikano Bank's portfolio. They provide further opportunity to discover for which of the different portfolios, i.e. for different values of HI and PD or AHI and APD , that the methodologies differ regarding resulting capital requirement. Furthermore, they also facilitate the identification of patterns as the two methodologies are applied.

In both sets of axes, some already described patterns are again illustrated. An example is that among the generated portfolios it is for those with a higher HI that most often result in a higher difference in capital requirement between the methodologies. What can also be noted is that among the generated portfolios, the spread of the difference between the methodologies is greater for portfolios with high values on HI .

Moreover, in the first set of axes it is more clearly illustrated that there exists portfolios with negative differences, i.e. where the Granularity Adjustment results in a lower value of resulting capital requirement than the methodology within Standardised Approach, as well as where they are located. These portfolios can easily be found in Figures 17b and 17d where they are positioned below zero. These portfolios are spread over different values of HI and with relatively high values of PD . Consequently, the portfolios are visible as a streak of points with high values of PD , illustrated in Figures 17c and 17d.

Furthermore, it is illustrated that the same portfolios with negative differences are presented as points scattered across AHI , but with an emphasis on relatively high values, see Figure 18b. In terms of the weighted average APD for these particular portfolios, they can be found at low values of APD , see Figure 18c. Thus, the portfolios that generate lower values for Granularity Adjustment than the Standardised Approach are those whose 30 biggest exposures are assigned low values of PD_i and is relatively undiversified in terms of EAD_i , i.e. where a concentration exists among the 30 biggest exposures. They are simultaneously such portfolios, in accordance with the previously conducted argument on the first set of axes, that result in relatively high weighted average PD and which constitute a part of the lower values for generated HI . Thus, these portfolios result in low PD_i for their 30 biggest exposures in relation to the remaining smaller exposures, as these are assigned relatively high PD_i .

It is thus the generated portfolios with very different PD_i for the large and small exposures that generate lower capital requirement when applying the Granularity Adjustment than when applying the methodology within the Standardised Approach.

Regarding the relationship between capital requirements from Ikano Bank's leasing portfolio and the generated portfolios, nothing can be added to the reasoning already presented. However, Figures 17 and 18 illustrate a validation that the size of the differences in capital requirements are reasonable for the generated portfolios.

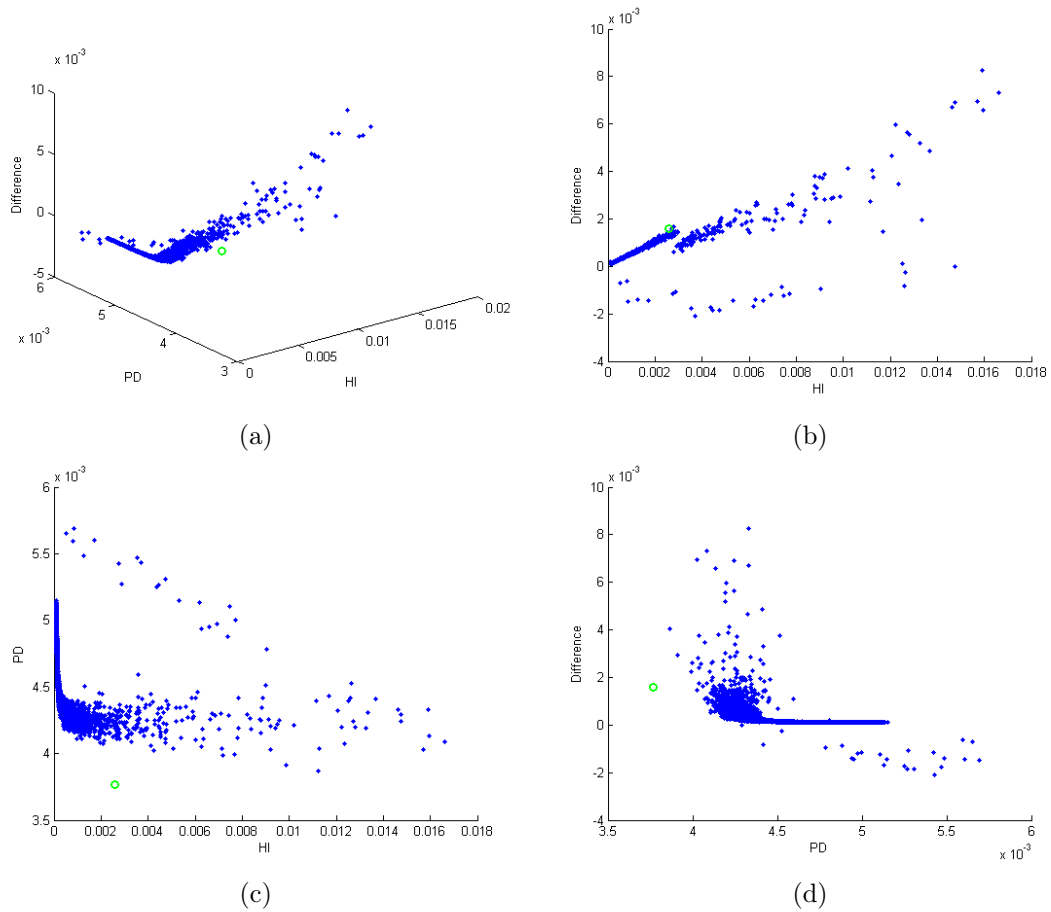


Figure 17: With the first set of axes, four angles of the difference in resulting capital requirements for name concentration risk between the two methodologies, for each of the 10 000 generated portfolios and Ikano Bank's portfolio. Note that the difference is calculated as capital requirement from Granularity Adjustment minus capital requirement from the Standardised Approach. The green markings represent Ikano Bank's portfolio.

The difference in capital requirement between the two methodologies are now presented with the second set of axes, see Figure 18.

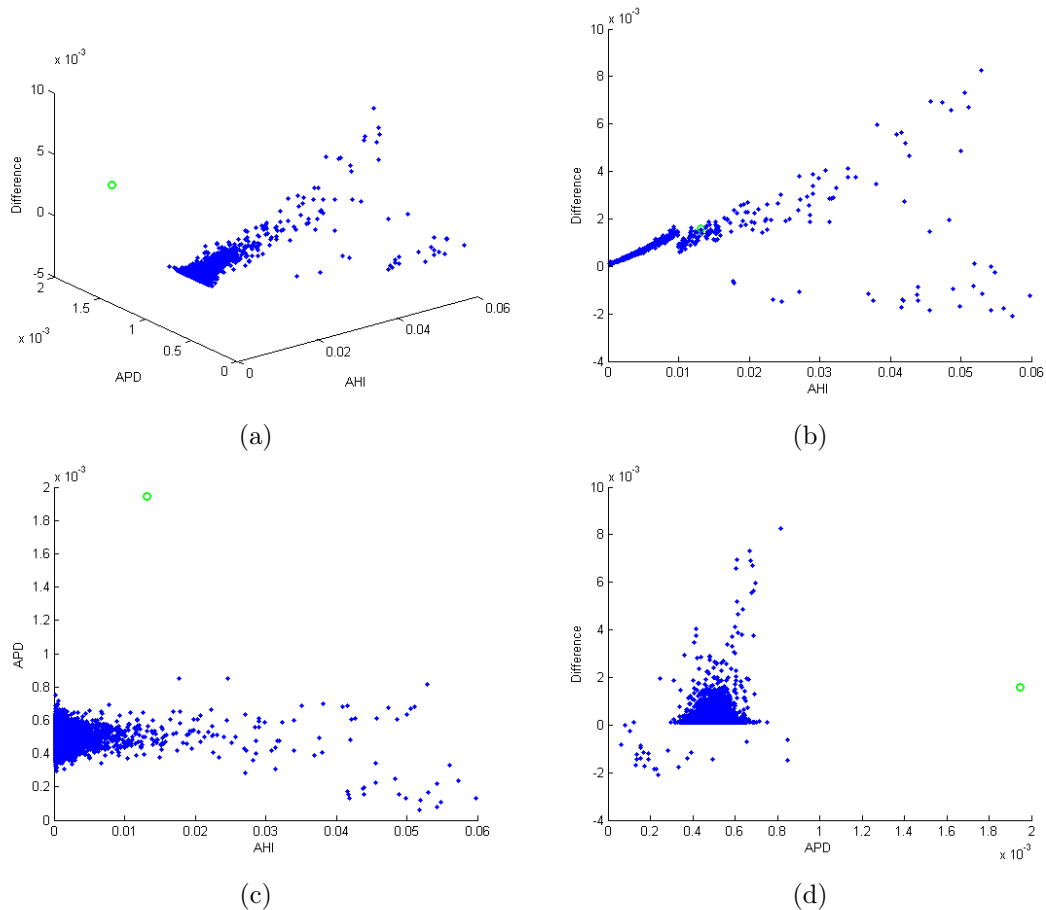


Figure 18: With the second set of axes, four angles of the difference in resulting capital requirements for name concentration risk between the two methodologies, for each of the 10 000 generated portfolios and Ikano Bank's portfolio. Note that the difference is calculated as capital requirement from Granularity Adjustment minus capital requirement from the Standardised Approach. The green markings represent Ikano Bank's portfolio.

Based on the reasoning and illustrations presented in chapter 5 and chapter 6, the resulting conclusions will be presented hereinafter.

7 Conclusion

For a majority of the generated realistic portfolios, the Granularity Adjustment methodology results in a higher capital requirement than the Standardised Approach. An observed feature of both methodologies is that they both typically result in higher capital requirements when applied on generated portfolios with comparatively high HI and AHI . This conclusion is intuitively reasonable considering that the methodologies are intended to approximate the additional risk of a concentration, while HI and AHI are measurements that demonstrate concentration.

Another observed pattern is that the difference in capital requirement between the methodologies typically tends to increase as the distribution of EAD_i in the portfolios is more concentrated, implying high HI and AHI . The pattern of larger deviation therefore indicates greater uncertainty for the portfolios with more concentrated distribution of EAD_i . For the interval of HI and AHI formed by the generated portfolios, the Granularity Adjustment seems to imply somewhat linear relationship with HI and AHI . This relationship applies for far from all generated portfolios, but since the Standardised Approach does not imply the same tendency of a steep slope it is anyhow a reason for the pattern of increasing difference in capital requirement.

Moreover, some of the generated realistic portfolios display a relation contrary to the majority, i.e. where the Granularity Adjustment methodology results in a relatively lower capital requirement than the Standardised Approach. These portfolios are illustrated in the figures and the most interesting ones are explained in chapter 5 and chapter 6. A common characteristic of the explained portfolios is that the 30 biggest exposures correspond to a low PD_i in relation to the remaining exposures. As an example, consider two portfolios A and B with the same distribution of EAD_i , and accordingly equal HI as well as AHI . If portfolio B contains a lower PD_i for the 30 biggest exposures, portfolio B results in a relatively lower capital requirement from both methodologies. This result is fully consistent with what is intuitive.

However, an interesting insight is drawn for the same two portfolios A and B, but when portfolio B instead contains a higher PD_i for several of the small exposures. In this case, portfolio B may in fact also result in a relatively lower capital requirement from Granularity Adjustment. But for these characteristics, portfolio B will simultaneously result in a slightly higher capital requirement from the Standardised Approach since it indirectly depends on the Pillar 1 capital requirement. The difference between portfolio A and B implies a reduced result for one of the methodologies and an increased result for the other, when comparing A and B's resulting capital requirements. This implies that the methodologies move in an opposite direction, which is counterintuitive. The described phenomenon is one reason for why the difference between the two methodologies for some portfolios is negative, but also for why the Granularity Adjustment appears more scattered. The summarised conclusion from this observed phenomenon is that the rela-

tionship between the large and small exposures' assigned PD_i is of great importance for how the two methodologies' resulting capital requirements differ. Furthermore, it seems that in order for the outcome to occur, i.e. that the Standardised Approach exceeds the Granularity Adjustment, the 30 biggest exposures need to be assigned low PD_i since they are required to be low in relation to the PD_i of the smaller exposures. Finally, the relationship between PD_i for a portfolio's large and small exposures leads to the large deviation between the methodologies' differences, which as mentioned is most prominent for portfolios with high HI and AHI .

The implied relation that an increased EAD_i -concentration in most cases results in a high capital requirement, is a conclusion that is more difficult than expected to draw. This is a conclusion by itself, which depends on the significant impact of the PD_i -distribution. However, it can be stated that for two portfolios with the same PD_i on the exposures, a higher concentration leads to a higher capital requirement for both the compared methodologies.

When differences between the methodologies are illustrated in Figures 17 and 18, a large proportion of the portfolios where the methodology within the Standardised Approach exceeds the Granularity Adjustment share the characteristics of high weighted average PD , low APD , low HI and high AHI in relative terms. For these generated portfolios the negative difference occurs in a majority of the portfolios. A conclusion is thus that for portfolios sharing these characteristics, it is highly probable that the two methodologies can result in capital requirements with the same relationship, namely where the Standardised Approach exceeds Granularity Adjustment.

A final conclusion is that the inclusion of Ikano Bank's leasing portfolio to the comparison validates that the size of the capital requirements as well as the size of the differences are reasonable for the generated portfolios. Particularly, it confirms the validity of the closest positioned portfolios, for which the patterns and features of interest are demonstrated.

8 Discussion

First of all, our main conclusion is that the relationship between a portfolio's large and small exposures in terms of assigned PD_i is of great importance for how the two methodologies' resulting capital requirements differ. To further clarify, it is this relationship that affects the difference in capital requirements between the two methodologies, rather than the actual levels of PD_i for the big and small exposures.

It should be noted that it is not possible to draw generalised conclusions based on one or very few generated realistic portfolios' resulting capital requirements. A pattern of several generated realistic portfolios with similar characteristics, that gives similar results, is needed. This is due to that the generated portfolios only constitute a subset of the possible and realistic portfolios. Consequently, the observed patterns in resulting capital requirement results from outcomes of our generated portfolios. Thus, portfolios with identical HI , PD or AHI , APD as the ones generated, but with slightly different appearance, may result in different resulting capital requirements. This is due to that these measurements does not cover all types of variations in characteristics of the portfolios. Thus, a randomness of resulting capital requirement for a certain combination of the two measurements occurs. Furthermore, a sufficient amount of realistic portfolios is not generated to be able to say how the resulting capital requirement ought to look for one portfolio with a particular combination of HI , PD or AHI , APD . The only conclusions that can be drawn regarding portfolios with a certain combination of HI , PD or AHI , APD is that they may give rise to the obtained resulting capital requirements. Thus, it should be noted that these are not the actual capital requirements that apply to all portfolios with identical set of values for HI , PD or AHI , APD .

Note that, as previously mentioned, the generated portfolios are not the only ones possible to generate since they represent a subset of all possible portfolios. Thus, it is debatable why we choose to generate precisely the portfolios selected. We believe the assumptions to be well-founded and that the portfolios thus represent characteristics of reasonable portfolios. Simultaneously, the results do not deviate significantly from Ikano Bank's leasing portfolio and the deviation that arises is understandable. According to the authors this can be viewed upon as a validating indication of the generated portfolios' realism.

Furthermore, we stick to our reasoning that the biggest exposures in real portfolios most often are assigned low values of PD_i . A bank would more likely lend a big share of their money to relatively safe obligors, instead of risky ones. The generated distribution of PD_i is therefore considered to reflect the distribution in actual realistic portfolios. The fact that Ikano Bank somewhat deviates is understandable, and given the explanation for the deviation it has no limiting effect of the comparison of the thesis.

Additionally, some of the generated realistic portfolios may be considered as extreme cases of realistic portfolios. The most easily definable such extreme cases are the generated realistic portfolios with one or a few really big exposures, and where the remaining exposures are extremely small in comparison. These are still interesting to generate in order to present the two methodologies' resulting capital requirement for a variety of portfolios.

When generating portfolios, PD_i for each exposure is assigned randomly within intervals, not discrete as for exposures in real portfolios. This is done in order to avoid limiting the generated portfolios to depend on particular values assigned to each rating. Since the aim is to generate a variation of portfolios with diverse characteristics, we consider this to be an advantage as it results in a greater variety.

For assigning the amount of a portfolio's exposures included within each rating, a distribution of rated companies published by Standard and Poor's is used. This might be an assumption that leads to differences with realistic portfolios, since all portfolio does not necessarily corresponds to a cross section of existing companies.

Prior to the conducted comparison, our understanding was that the methodology within the Standardised Approach was a conservative methodology, i.e. that it would result in higher resulting capital requirements for a majority of the portfolios. However, the observed result of the comparison shows the opposite. This may provide a basis for questioning whether the methodologies work as they are intended. A possible reason why the two methodologies do not work as intended, may be that the assumed values of the parameters γ and δ are not adapted to the present conditions. These parameters are not updated since 2007, when the article *Granularity Adjustment for Regulatory Capital Assessment* is written, see Gordy & Lütkebohmert (2007). Thus, they were not changed when the article was updated in 2013, see Gordy & Lütkebohmert (2013). Perhaps, these parameters are estimated for a whole other economical climate than the current climate.

The counterintuitive tendency implying that the two methodologies can move in opposite directions, when changing a portfolio, might provide a basis for questioning whether the two methodologies that FI propose goes in line with each other. Furthermore, the distribution of PD_i should intuitively not have such a significant influence as observed, since it is already incorporated when calculating the capital requirement for credit risk under Pillar 1. But as demonstrated, the distribution of PD_i significantly influences the results. This is especially the case for the Granularity Adjustment methodology, since it directly takes the PD_i -distribution into account. The methodology within the Standardised Approach only indirectly takes the PD_i -distribution into account, and is therefore only marginally affected. The methodologies' diverse dependence on PD_i -distribution also adds to the questioning to what extent the proposed methodologies are working in line with each other.

The methodologies proposed by FI remains firm, but credit concentration risk is meanwhile a field where new methodologies evidently are being added. Therefore, we believe that it is important to be vigilant and adaptable since proposing an outdated methodology may pose risks to the financial stability. Improved methodologies will most likely be devised and it is important for banks to stay updated and not only comply with FI's proposed methodologies currently in force.

Regarding the Granularity Adjustment methodology, one might ask if the gamma distribution on the systematic risk factor X is a suitable distribution to assume. The conducted comparison is performed with this assumption, since it is incorporated in FI's proposal. The gamma distribution indeed implies a larger and wider tail than the normal distribution, which means that it becomes more of a "safe bet". However, there exists other distributions that implies even larger and wider tails, that would lead to even higher capital requirements. Perhaps, such a distribution is even more appropriate to use? This is a suggestion for further research, which is built on in the following paragraph.

8.1 Suggestions for Further Research

An interesting topic for additional research is that someone with more time and resources can perform a similar comparative study, yet more comprehensive. Such a study could consist of all possible combinations of portfolios and the resulting capital requirements for each portfolio combination, i.e. combinations of different HI , PD and AHI , APD . Furthermore such a study could instead present the expected outcome of the methodologies' resulting capital requirements, when applying them on a sufficient number of portfolios with a certain combination of measurements. The uncertainty in our portfolio generation to some extent effects the resulting capital requirements, but for the proposed study the uncertainty would drastically reduce. Furthermore, when performing such a more comprehensive study, a suggestion is to add an additional set of axes, where the measurement APD/PD -ratio is on one axis. This would probably allow for additional interesting result. For those who want to replicate or further develop our comparison, the implemented Matlab code can be found in Appendix D.

Another interesting topic for further research is the assumptions of the parameters γ and δ . An examination of their relevance to the conclusions of the comparison of the two methodologies is very interesting.

Furthermore, the appropriateness of the gamma-distribution on the single systematic risk factor X could also be studied and evaluated, since it is an assumption that significantly influences the Granularity Adjustment methodology.

Finally, it would be interesting to conduct the comparison for additional methodologies than the two selected. Examples of such methodologies are Monte Carlo simulations and other variations of the Granularity Adjustment. The article *Measuring Concentra-*

tion Risk in Bank Credit Portfolios Using Granularity Adjustment: Practical Aspects, however, states that tests show that a large number of Monte Carlo simulations needs to be performed in order to even come close to the precision that the proposed Granularity Adjustment methodology results in (Beivydas et al, 2009, p. 57). Therefore a variation of the Granularity Adjustment would be more interesting to include in future comparisons. Such a variation could be to change the assumption regarding Value at Risk, VaR, in the methodology and instead use Expected Shortfall, ES.

A Appendix

A.1 Derivation of the Granularity Adjustment Formula

This derivation of the Granularity Adjustment is strongly influenced by the one performed by Gordy and Lütkebohmert in their article *Granularity Adjustment for Regulatory Capital Assessment*, see (Gordy & Lütkebohmert, 2013), complemented with additional clarifications.

To provide a good understanding of how the additional capital requirement for concentration risk is calculated, an explanation and derivation regarding the construction of general GA is presented.

Let X assign the systematic risk factor. X has a certain distribution, most often assumed to be normally distributed. X is unidimensional and for each given value in the distribution X is assigned a value.

Let L_n denote the share of loss for a portfolio, also called portfolio loss rate, as follows:

$$L_n = \sum_{i=1}^n s_i U_i \quad (10)$$

where s_i represents every exposures share of the total exposures, that is:

$$s_i = \frac{A_i}{\sum_{j=1}^n A_j} \quad (11)$$

and U_i denotes share of loss for the exposure. This share increases when the systematic risk factor X increases.

Define the conditional expected loss $\mu(x)$ by strictly increasing in x .

$$\mu(x) = E[L_n | X = x]. \quad (12)$$

Observe that the notation $\mu(x)$ not corresponds to $E[X]$. $\mu(x)$ is assumed to be strictly increasing when x is increasing. Let $\alpha_q(Y)$ correspond to the q^{th} percentile of the random variable Y , so that the Value at Risk (VaR) at the q^{th} percentile can be written as $\alpha_q(L_n)$. For details regarding VaR see Appendix B.12. As n grows large it can be seen that:

$$|\alpha_q(L_n) - E[L_n | X = x]| \rightarrow 0 \quad (13)$$

which with the insertion of x can be written as:

$$|\alpha_q(L_n) - E[L_n | X = \alpha_q(X)]| \rightarrow 0. \quad (14)$$

Equation 14 shows that $\alpha_q(L_n)$ converges to the conditional expected value of L_n when the number of credits grows. This is because, all else being equal, s_i decreases for any

given exposure when several exposures are added. When each exposure contributes less to L_n , the L_n -distribution's right tail decreases. The gap between $\alpha_q(L_n)$ and its asymptotic lower limit $\mu(\alpha_q(X))$, according to Equation 14, is attributable to non diversified idiosyncratic risk in the portfolio. This idiosyncratic risk cannot be obtained in exact analytical form, but approximated via Taylor-series expansion.

$E[L_n|X = \alpha_q(X)]$ is the expected percentage loss for the portfolio given a certain systematic risk factor; X , when adopting q-percentile. $\alpha_q(L_n)$ is the percentile of the random distribution (includes non diversified unsystematic risk) and when n increases, $\alpha_q(L_n)$ decreases and converges to $E[L_n|X = \alpha_q(X)]$ (can also be intuitively explained as the unsystematic risk being diversified when n increases).

The Granularity Adjustment methodology identifies systematic (undiversifiable) risk and unsystematic (idiosyncratic, diversifiable) risk. The terms defined are:

W = total risk,
 Y = systematic risk ,
 Z = unsystematic risk.

This implies that the total risk can be written as $W = Y + Z$ It is the unsystematic risk Z which is out of interest, which arises when the portfolio's exposures are no longer assumed to be homogeneously distributed or portfolio invariant, since it is this risk that forms one of the basis for the additional capital requirement under Pillar 2. The difficulty of directly identifying the unsystematic risk forces a computational detour, where the distribution of total risk (W) is calculated as a density function. The total risk (W) can be subtracted with the more easily calculated systematic risk (Y) in order to finally result in an approximation of the unsystematic risk (Z).

To make the previous calculations understandable the terms denotes:

L_n = total risk, W
 $\mu(x)$ = systematic risk, Y
 $L_n - \mu(x)$ = unsystematic risk, Z .

When adding two variables, each with a density function, it requires their respective density function to be convolved to result in the dependent variable density function. If they are dependent on each other it is done in accordance with Appendix B.2. The joint probability density function $f_W(w)$ is formed as follows:

$$f_W(w) = \int_{-\infty}^{\infty} f_Y(w - z)f_Z(z|w - z)dz. \quad (15)$$

Applying a Taylor-series expansion, as explained in Appendix B.11, of $f(w - z)$ around w gives

$$f_Y(w - z)f_Z(z|w - z) = \sum_{i=0}^{\infty} \frac{1}{i!} \left[\frac{d^i}{dw^i} f_Y(w)f_Z(z|w) \right] ((w - z) - w)^i, \quad (16)$$

which with the first term of the sum explicitly written can be expressed as

$$= f_Y(w)f_Z(z|w) + \sum_{i=1}^{\infty} \frac{(-1)^i}{i!} \left[\frac{d^i}{dw^i} f_Y(w)f_Z(z|w) \right] z^i. \quad (17)$$

Inserting Equation 17 in Equation 15 and applying Fubini's theorem, see Appendix B.4, gives

$$f_W(w) = \int_{-\infty}^{\infty} f_Y(w)f_Z(z|w)dz + \sum_{i=1}^{\infty} \frac{(-1)^i}{i!} \frac{d^i}{dw^i} \left[\int_{-\infty}^{\infty} f_Y(w)f_Z(z|w)z^i dz \right]. \quad (18)$$

Let $m_i(w)$ denote the i^{th} moment of Z conditional on $Y = w$, i.e.,

$$m_i(w) = E[Z^i|Y = w] = \int_{-\infty}^{\infty} z^i f_Z(z|w)dz. \quad (19)$$

Substitute

$$\int_{-\infty}^{\infty} f_Y(w)f_Z(z|w)z^i dz = f_Y(w) \int_{-\infty}^{\infty} f_Z(z|w)z^i dz = f_Y(w)m_i(w) \quad (20)$$

and

$$\int_{-\infty}^{\infty} f_Y(w)f_Z(z|w)dz = f_Y(w) \quad (21)$$

into Equation 18, along with the definition of $m_i(w)$ result in the following:

$$f_W(w) = f_Y(w) + \sum_{i=1}^{\infty} \frac{(-1)^i}{i!} \frac{d^i}{dw^i} [f_Y(w)m_i(w)], \quad (22)$$

which can be written according to:

$$f_Y(w) = f_W(w) - \sum_{i=1}^{\infty} \frac{(-1)^i}{i!} \frac{d^i}{dw^i} [f_Y(w)m_i(w)]. \quad (23)$$

Equation 21 can be expressed that way since integrating over a probability density function results in 1 and $f(w)$ does not depend on the integrating factor z . Definition of the quantiles yields the following:

$$\int_{-\infty}^{\alpha_q(Y)} f_Y(w)dw = \int_{-\infty}^{\alpha_q(Y+Z)} f_W(w)dw \quad (24)$$

and

$$\int_{\alpha_q(Y)}^{\alpha_q(Y+Z)} f_Y(w)dw = \int_{-\infty}^{\alpha_q(Y+Z)} f_Y(w)dw - \int_{-\infty}^{\alpha_q(Y)} f_Y(w)dw. \quad (25)$$

Inserting Equation 23 in the second term in the LHS in Equation 25 gives:

$$\int_{\alpha_q(Y)}^{\alpha_q(Y+Z)} f_Y(w)dw = \int_{-\infty}^{\alpha_q(Y+Z)} \left(f_W(w) + \sum_{i=1}^{\infty} \frac{(-1)^i}{i!} \frac{d^i}{dw^i} [f_Y(w)m_i(w)] \right) dw - \int_{-\infty}^{\alpha_q(Y)} f_Y(w)dw. \quad (26)$$

First and third term in the RHS cancel each other out according to Equation 24, which means that

$$\begin{aligned} \int_{\alpha_q(Y)}^{\alpha_q(Y+Z)} f_Y(w)dw &= \int_{-\infty}^{\alpha_q(Y+Z)} \sum_{i=1}^{\infty} \frac{(-1)^i}{i!} \frac{d^i}{dw^i} [f_Y(w)m_i(w)] dw \\ &= \sum_{i=1}^{\infty} \frac{(-1)^i}{i!} \frac{d^{i-1}}{dw^{i-1}} [f_Y(w)m_i(w)] dw \Big|_{w=\alpha_q(Y+Z)} \end{aligned} \quad (27)$$

An integral approximation and assumption that only the second order approximation of the Taylor expansion is needed⁷ gives:

$$f_Y(\alpha_q(Y)) \cdot (\alpha_q(Y+Z) - \alpha_q(Y)) \approx f_Y(w)m_1(w) - \frac{1}{2} \frac{d}{dw} [f_Y(w)m_2(w)] \Big|_{w=\alpha_q(Y)}. \quad (28)$$

Dividing the term on the left hand side gives

$$(\alpha_q(Y+Z) - \alpha_q(Y)) \approx \frac{f_Y(w)m_1(w)}{f_Y(\alpha_q(Y))} - \frac{1}{2f_Y(\alpha_q(Y))} \frac{d}{dw} [f_Y(w)m_2(w)] \Big|_{w=\alpha_q(Y)}. \quad (29)$$

Replace Y with the asymptotic loss percentage of the portfolio $\mu(X)$ and Z with $L_n - \mu(X)$. For all $w = \mu(x)$ it is known that

$$m_1(w) = E[Z^1|Y = w] = E[Z|X = x] = E[L_n|X = x] - E[E[L_n|X = x]|X = x] = 0 \quad (30)$$

$$\begin{aligned} m_2(w) &= E[Z^2|Y = w] = E[Z^2|X = x] = [\text{see Appendix B.9, Equation 66}] \\ &= V[L_n|X = x] + E[Z|X = x]^2 = V[L_n|X = x] = \sigma^2(x) \end{aligned} \quad (31)$$

⁷The assumption that only the second order approximation is needed is due to that the first derivative in the Taylor expansion vanishes, since the idiosyncratic component conditional on the systematic component $E[L|X]$ vanishes. The second derivative in Taylor expansion is the Granularity Adjustment, because it represents the additional fraction to the VaR due to the undiversified idiosyncratic component. (Beivydass et al, 2009, p. 47)

The first term in Equation 29 then has the value 0 and the Equation can be written as

$$\alpha_q(Y + Z) - \alpha_q(Y) \approx -\frac{1}{2f_Y(\alpha_q(Y))} \frac{d}{dw} [f_Y(w)m_2(w)] \quad (32)$$

insertion of $Y = \mu(x)$ and $Z = L_n - \mu(x)$ gives:

$$\alpha_q(L_n) - \mu(\alpha_q(X)) \approx -\frac{1}{2f_Y(\mu(\alpha_q(X)))} \frac{d}{d\mu(x)} [f_Y(\mu(x))m_2(\mu(x))] \Big|_{\mu(x)=\alpha_q(\mu(X))} \quad (33)$$

Using the relationship $f_Y(w)dw = \mu'(x)h(x)dx$ which corresponds to $f_Y(\mu(x)) = h(x)$, then Equation 33 can then be written as

$$\alpha_q(L_n) - \mu(\alpha_q(X)) \approx -\frac{1}{2h(\alpha_q(X))} \frac{d}{dx} \left[\frac{h(x)\sigma^2(x)}{\mu'(x)} \right] \Big|_{x=\alpha_q(X)} \equiv GA. \quad (34)$$

Equation 34 then express the capital requirement for name concentration risk, as a share of the total portfolio EAD .

A.2 Granularity Adjustment Assigned for Basel

$\mu(x)$, $\sigma^2(x)$ och $h(x)$ are model dependent parameters. To be consistent with models that form the basis for credit capital requirement under Pillar 1, the share of loss for the exposure is defined as $U_i = LGD_i \cdot D_i$. Where D_i is an default event indicator which takes the values 1 or 0 with respect to whether the exposure defaults or not. The systematic risk factor X generates correlation between borrowers defaults, since an increase in X causes a shift in the default probabilities for all borrowers. This is due to the assumption that $\mu(x)$ is strictly increasing when x is increasing. Given the systematic risk factor, events of default are independent and occurs with probability

$$\pi_i(x) = PD_i \cdot (1 + w_i(x - 1)) \quad (35)$$

where PD_i is the unconditional probability that borrowers i defaults. To control the sensitivity of borrower i to the systematic risk factor a w_i is defined. Assume that the systematic risk factor X is gamma distributed with $E[X] = 1$ and $V[X] = \frac{1}{\epsilon}$ where $\epsilon > 0$ is a precision parameter. This leads to that all D_i are conditionally independent Bernoulli random variables with the conditional probability of defaulting $Pr(D_i = 1|X = x) = \pi_i(x)$. If the D_i on the other hand are unconditionally they are dependent Bernoulli random variables. The probability of default for unconditionally Bernoulli variables consists solely of PD_i , i.e. $Pr(D_i = 1) = PD_i$. To achieve an analytical solution of the model, Credit Risk ⁺, which is used in the formula for credit risk, it is assumed that the distribution of D_i is Poisson distributed. Assuming that a Bernoulli default event is Poisson distributed is critical to achieve analytical tractability. Approximation error that occurs is proportional to PD^2 which means that it is small when most borrowers

have low PD . To fit the model assumptions under Pillar 1 this extended Credit Risk⁺ method allows LGD_i to be a random loss given default with expected value $E[LGD_i]$ and variance $V[LGD_i]$ in comparison with Credit Risk⁺ (not extended model) which assumes that LGD_i is known. The uncertainty of LGD_i is assumed to be idiosyncratic and thus independent of the risk factor X . According to scholars this assumption may be somewhat limiting but are retained to be consistent with the model assumptions for the formula for credit risk under Pillar 1 and for ease of handling. Starts to develop $\mu(x)$ and $\sigma^2(x)$ for the model. Define functions $\mu_i(x) = E[U_i|X = x]$ and $\sigma_i^2(x) = V[U_i|X = x]$. By the assumption of conditional independence it is given:

$$\mu(x) = E[L_n|X = x] = \sum_{i=1}^n s_i \mu_i(x) \sigma^2(x) = V[L_n|X = x] = \sum_{i=1}^n s_i^2 \sigma_i^2(x) \quad (36)$$

Lenders conditional expected loss function is

$$\mu_i(x) = E[LGD_i] \cdot \pi_i(x),$$

and the conditional variance of loss is

$$\sigma_i^2 = E[LGD_i^2 \cdot D_i^2|X = x] - E[LGD_i]^2 \cdot \pi_i(x)^2 = E[LGD_i^2] \cdot E[D_i^2|X = x] - \mu_i(x)^2 \quad (37)$$

As D_i given X in Credit Risk⁺ model is assumed to be Poisson distributed is $E[D_i^2|X = x] = V[D_i|X = x] + \pi_i(x)^2$, see Appendix B.10, which means

$$E[D_i^2|X = x] = \pi_i(x) + \pi_i(x)^2 \quad (38)$$

The term $E[LGD_i^2]$ can be expressed as

$$E[LGD_i^2] = V[LGD_i] + E[LGD_i]^2 \quad (39)$$

and be replaced in Equation 37 leading to

$$\begin{aligned} \sigma_i^2(x) &= (V[LGD_i] + E[LGD_i]^2) \cdot (\pi_i(x) + \pi_i(x)^2) - \mu_i(x)^2 \\ &= \frac{V[LGD_i] + E[LGD_i]^2}{E[LGD_i]} \mu_i(x) + \mu_i(x)^2 \cdot \frac{V[LGD_i]}{E[LGD_i]^2} \end{aligned} \quad (40)$$

where

$$C_i = \frac{V[LGD_i] + E[LGD_i]^2}{E[LGD_i]} \quad (41)$$

assigned for simplification of the expression, leading to

$$\sigma_i^2(x) = (V[LGD_i] + E[LGD_i]^2) \cdot (\pi_i(x) + \pi_i(x)^2) - \mu_i(x)^2 = C_i \mu_i(x) + \mu_i(x)^2 \cdot \frac{V[LGD_i]}{E[LGD_i]^2} \quad (42)$$

Insertion of the expressions for $\mu(x)$ and $\sigma^2(x)$ in Equation 34 and evaluating the derivative at $x = \alpha_q(X)$ results in

$$\begin{aligned} GA &= -\frac{1}{2 \sum_{i=1}^n s_i \mu_i'(\alpha_q(X))} \frac{h'(\alpha_q(X))}{h(\alpha_q(X))} \cdot \sum_{i=1}^n s_i^2 \times \left(C_i \mu_i(\alpha_q(X)) + \mu_i^2(\alpha_q(X)) \frac{V[LGD_i]}{E[LGD_i]^2} \right) \\ &\quad - \frac{1}{2 \sum_{i=1}^n s_i \mu_i'(\alpha_q(X))} \cdot \sum_{i=1}^n s_i^2 \mu_i'(\alpha_q(X)) \times \left(C_i + 2\mu_i(\alpha_q(X)) \frac{V[LGD_i]}{E[LGD_i]^2} \right) \end{aligned} \quad (43)$$

Reparameterisation of the input data by allowing R_i be the capital requirements for credit losses as a percentage of EAD for borrowers i . Within the model, Credit Risk⁺, this means

$$R_i = E[U_i] = E[LG D_i] \cdot PD_i \quad (44)$$

Let K_i be asymptotically capital requirement for unexpected loss, UL , as a percentage of EAD .

$$K_i = E[U_i|X = \alpha_q(X)] - E[U_i] = E[LG D_i] \cdot PD_i \cdot w_i \cdot (\alpha_q(X) - 1) \quad (45)$$

At portfolio level, weighted average R and weighted average K is defined analogously to capital requirements for credit losses and capital requirements for each unit of exposure as a percentage of EAD for the portfolio as a whole, namely:

$$R = \sum_{i=1}^n s_i R_i \quad \text{och} \quad K = \sum_{i=1}^n s_i K_i \quad (46)$$

After inserting R and K in the formula for GA at Credit Risk⁺ model it can be seen that PD_i and w_i can be eliminated, which means the following formula

$$GA = \frac{1}{2K} \sum_{i=1}^n s_i^2 \left[\left(\delta C_i (K_i + R_i) + \delta (K_i + R_i)^2 \cdot \frac{V[LG D_i]}{E[LG D_i]^2} \right) - K_i \left(C_i + 2(K_i + R_i) \cdot \frac{V[LG D_i]}{E[LG D_i]^2} \right) \right] \quad (47)$$

where

$$\delta = -\frac{h'(x)}{h(x)} (\alpha_q(X) - 1) = (\alpha_q(X) - 1) \cdot \left(\epsilon + \frac{1 - \epsilon}{\alpha_q(X)} \right) \quad (48)$$

The formula for GA can be simplified when R_i and K_i are small and the products of these quantities can be expected to contribute very little to the GA . If these second-order terms are dropped the simplified expression is achieved:

$$\widetilde{GA} = \frac{1}{2K} \sum_{i=1}^n s_i^2 C_i (\delta (K_i + R_i) - K_i) \quad (49)$$

B Appendix

This chapter explains mathematical conditions such as distributions and convolution. These terms and explanations are placed in alphabetical order.

B.1 Capital Adequacy Requirement and CAR

Capital adequacy requirements implies a certain level of equity in relation to risk-weighted assets. This level is defined by a ratio, which is called Capital Adequacy Ratio (CAR). The Capital Adequacy Ratio is defined as regulatory capital as a percentage of a bank's risky assets (BCBS, 2006, p. 12). The ratio is expressed as

$$\text{CAR} = \frac{(\text{Tier1} + \text{Tier2})}{\text{RWA}}. \quad (50)$$

Note that parts of a firms equity can be divided into Tier1 and Tier2 capital according to its liquidity. Tier1 capital is regarded as the most liquid, i.e. easily converted into cash. (Hull, 2012, p. 289-290)

B.2 Convolution

A mathematical operation on two functions f and g , producing a third function that is typically viewed as a modified version of one of the original functions, giving the area overlap between the two functions as a function of the amount that one of the original functions is translated. Let $f(t)$ and $g(t)$ be functions defined on \mathbb{R} . The convolution $f * g$ of f and g is defined as the integral of the product of the two functions after one is reversed and shifted. As such, it is a particular type of integral transform:

$$(fg)(t) = \int_{-\infty}^{\infty} f(\tau)g(t - \tau)d\tau \quad (51)$$

(Spanne & Sparr, 1996, p. 69)

B.3 Factorial

In mathematics, the factorial of a non-negative integer k , denoted by $k!$, is the product of all positive integers less than or equal to k . For example, $4! = 4 \times 3 \times 2 \times 1 = 24$. (Persson & Böiers, 2009, p. 59)

B.4 Fubini's Theorem

If the function $f(x, y)$ is XY integrable, meaning that it is measurable and

$$\int_{X \times Y} |f(x, y)| d(x, y) < \infty, \quad (52)$$

then

$$\int_X \left(\int_Y f(x, y) dy \right) dx = \int_Y \left(\int_X f(x, y) dx \right) dy \quad (53)$$

(Shiryaev, 1989, p. 198) Note that a summation is a special case of integrating and therefore Fubini's theorem is used in the derivation of Granularity adjustment according to:

$$\int_X \left(\sum_Y f(x, y) dy \right) dx = \sum_Y \left(\int_X f(x, y) dx \right) dy. \quad (54)$$

B.5 Gamma Distribution

The probability density function of a random variable X that is Gamma-distributed can be written as

$$f_X(x) = \begin{cases} \frac{\lambda^n}{\Gamma(n)} \cdot x^{n-1} e^{-\lambda x} & \text{if } x > 0 \\ 0 & \text{if } x \leq 0 \end{cases} \quad (55)$$

where $\Gamma(n)$ is the gamma-function evaluated at n , with $n > 0$ and $\lambda > 0$. (Blom, 2005, p. 64)

B.6 Gamma-function

The Gamma function is defined as

$$\Gamma(n) = \int_0^{\infty} x^{n-1} e^{-x} dx \quad \text{where } n > 0. \quad (56)$$

If n is a positive integer, then the function is an extension of the factorial function. That is,

$$\Gamma(n) = (n - 1)! \quad (57)$$

(Blom, 2005, p. 64).

B.7 Herfindahl Index or HI

(Also know as Herfindahl–Hirschman Index, or HHI.)

$$HI = \sum_{i=1}^n \sigma_i^2 \quad (58)$$

where

$$\sigma_i = \frac{EAD_i}{\sum_{i=1}^n EAD_i}. \quad (59)$$

(U.S. Department of Justice, 2014)

B.8 Normal Distribution

A random variable X that is normally distributed is denoted by

$$X \sim N(\mu, \sigma^2) \quad (60)$$

and have the probability density function

$$f(x, \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \quad (61)$$

where the parameter μ is the mean or expectation of the distribution. The parameter σ is its standard deviation; its variance is therefore σ^2 . If $\mu = 0$ and $\sigma = 1$, the distribution is called the Standard Normal Distribution or the Unit Normal Distribution. (Blom, 2005, p. 62)

B.9 Moment

If f is a probability density function, then the value of $E[(X - a)^n]$ is called the n :th moment around the value a of the probability distribution. (Blom, 1984, p. 129)

B.10 Poisson Distribution

A discrete probability distribution that expresses the probability of a given number of events occurring in a fixed interval of time and/or space. These events occur with a known average intensity and independently of the time since the last event. Let $N(t)$ be the number of events taking place in the time interval $[0; t]$. If $N(t)$ is a Poisson process with constant intensity λ , then $N(t) \in Po(\lambda t)$.

Time lags between consecutive events are independent and exponentially distributed with expectation $1/\lambda$.

The number of events occurring in a time interval I_1 and the number of events occurring in another time interval I_2 are independent if I_1 and I_2 are disjoint. A Poisson process $Po(\lambda)$ has the probability mass function

$$p_X(k) = \frac{\lambda^k}{k!} \cdot e^{-\lambda}, \quad k = 0, 1, 2, \dots \quad \text{and } \lambda > 0. \quad (62)$$

The positive real number λ is equal to the expected value of X and also to its variance $\lambda = E[X] = V[X]$. (Blom, 2005, p. 180-182)

B.11 Taylor Expansion

Taylor expansion is a method to approximate a function $f(x)$ with an interval covering a fixed point a . The approximation of the function is a polynomial of the argument for the function, which in this case corresponds to x . Assume that the function f and its derivatives to the order $n + 1$ are continuous in a neighborhood of a . Then, for all x in this environment can a Taylor expansion of order n be written as

$$f(x) \approx f(a) + \frac{f'(a)}{1!}(x - a) + \frac{f''(a)}{2!}(x - a)^2 + \dots + \frac{f^{(n)}(a)}{n!}(x - a)^n \quad (63)$$

where n is a positive integer. (Persson & Böiers, 2009, p. 411)

B.12 Value at Risk (VaR)

Value at Risk is a risk measure that states where the loss probability density function with a certain probability and given time period exceeds the value VaR. Mathematically, if L is the loss of a portfolio, then $VaR_\alpha(L)$ is the level α -quantile, i.e.

$$P(L > VaR_\alpha) = 1 - \alpha \quad (64)$$

$$VaR_\alpha(L) = \inf\{l \in \mathbb{R} : P(L > l) \leq 1 - \alpha\} = \inf\{l \in \mathbb{R} : F_L(l) \geq \alpha\}. \quad (65)$$

(Hull, 2012, p. 183-185)

B.13 Variance

One definition of variance used in derivation of Granularity adjustment:

$$V(x) = E[(X - E(X))^2] = E(x^2) - [E(x)]^2 \quad (66)$$

(Blom, 2005, p. 117)

C Appendix

The focus in this Appendix will be placed on presenting the altering implications of Basel III that have an indirect affect on credit concentration risk.

C.1 Altering Implications of Basel III

Purely computationally, there is only one minor alteration to the risk-weight formulas under Pillar 1, where exposures to large financial institutions are assumed to have a higher correlation with the portfolio (BCBS, 2011, p. 39 §102). This will affect the capital adequacy requirement under Pillar 1, which indirectly will affect the capital adequacy requirement under Pillar 2 including credit concentration risk.

Furthermore, Basel III implies an increased quantity of the regulatory capital, as a consequence of three new additional capital buffers during periods outside of stress (BCBS, 2011, p. 6). They are implemented so that breaches of minimum capital requirements shall be avoided (BCBS, 2011, p. 54), and they will be phased in until 2019 (KPMG, 2013, p. 3). The result will be that in 2019, the buffers of totally 5% are added to the minimum total capital requirement for risk during periods outside of stress. Thus, banks will then need a capital ratio of at least 13% under Pillar 1. Note that when entering a tougher period, the buffers will be decreased or completely removed, i.e. the minimum total capital requirement will then remain at 8%. (KPMG, 2013, p. 3) The Pillar 2 add-on for credit concentration risk still needs to be considered, i.e. it remain as a separate requirement over and above the new capital buffers (KPMG, 2013, p. 3). The increase of the capital adequacy requirement under Pillar 1 will indirectly affect the capital adequacy requirement under Pillar 2, including credit concentration risk (BCBS, 2011, p. 69).

An additional alteration is that Basel III implies an increased quality of the regulatory capital, increasing the proportion of Tier 1 capital out of the regulatory capital (KPMG, 2013, p. 3). The same ratio will apply for the capital requirement resulting from the Pillar 2 add-ons, including the add-on for credit concentration risk. To conclude, banks consequently have been forced to redesign parts of their ICAAP and this redesign will continue during the upcoming years in order to account for the new levels of regulatory requirements. (KPMG, 2013, p. 3)

D Appendix Matlab Code

```
1 %Illustrating example portfolios
2 %R = [N HI AHI Sch GA PDwa ADP]
3 format long
4 N = 10000;
5 a = 0.001;
6 EAD = zeros(N,1);
7 PD = zeros(N,1);
8 LGD = 0.45*ones(N,1);
9 M = 2.5*ones(N,1);
10 R = ones(5,7);
11
12 %P1 Reference Portfolio
13 EAD(:,1) = 1/N;
14 PD(:,1) = a;
15 portfolio = [EAD PD LGD M];
16 R(1,:) = GAall(portfolio);
17 % P2
18 EAD = zeros(N,1);
19 EAD(1) = 0.10;
20 EAD(2) = 0.09;
21 EAD(3) = 0.08;
22 EAD(4:end) = (1 - EAD(1)-EAD(2)-EAD(3))/(N-3);
23 PD(:,1) = a;
24 portfolio = [EAD PD LGD M];
25 R(2,:) = GAall(portfolio);
26 % P3
27 EAD = zeros(N,1);
28 EAD(1) = 0.05;
29 EAD(2) = 0.04;
30 EAD(3) = 0.03;
31 EAD(4:end) = (1 - EAD(1)-EAD(2)-EAD(3))/(N-3);
32 PD(:,1) = a;
33 portfolio = [EAD PD LGD M];
34 R(3,:) = GAall(portfolio);
35 % P4
36 EAD = zeros(N,1);
37 for i =1:30
38     EAD(i) = 0.03 - 0.001*(i-1);
39 end
40 b = sum(EAD(1:30));
41 EAD(31:end) = (1 - b)/(N-30);
```

```

42 PD(:,1) = a;
43 portfolio = [EAD PD LGD M];
44 R(4,:) = GAall(portfolio);
45
46 % P5
47 EAD = zeros(N,1);
48 for i =1:30
49     EAD(i) = 0.015 - 0.0005*(i-1);
50 end
51 b = sum(EAD(1:30));
52 EAD(31:end) = (1- b)/(N-30);
53 PD(:,1) = a;
54 portfolio = [EAD PD LGD M];
55 R(5,:) = GAall(portfolio);
56
57 %Plot , axes (HI,PD*,CapitalReq)
58 figure
59 HI = R(:,2);
60 Sch = R(:,4);
61 GA = R(:,5);
62 PDwa = R(:,6);
63 plot3(HI,PDwa,Sch, 'bo', 'MarkerSize',6, 'LineWidth',2)
64 hold on
65 plot3(HI,PDwa,GA, 'rx', 'MarkerSize',6, 'LineWidth',2)
66 hold on
67 xlabel('HI')
68 ylabel('PD')
69 zlabel('Capital requirement')
70
71 %Plot , axes (AHI,APD*,CapitalReq)
72 figure
73 AHI = R(:,3);
74 Sch = R(:,4);
75 GA = R(:,5);
76 APD = R(:,7);
77 plot3(AHI,APD,Sch, 'bo', 'MarkerSize',6, 'LineWidth',2)
78 hold on
79 plot3(AHI,APD,GA, 'rx', 'MarkerSize',6, 'LineWidth',2)
80 hold on
81 xlabel('AHI')
82 ylabel('APD')
83 zlabel('Capital Requirement')

```

```

1 % Main
2 N = 1000;
3 a = 1;
4 P = zeros(N*0.2*N*a,4);
5 R = zeros(N*0.2*a,8);
6
7 for n =1:a
8 [EADvariations,PDvariations] = varyEADandPD(N);
9 nbrOfPortfoliosEAD = size(EADvariations,2);
10 LGD = 0.45*ones(N,1);
11 M = 2.5*ones(N,1);
12 for i = 1:nbrOfPortfoliosEAD
13     EAD = EADvariations(:,i);
14     PD = PDvariations(:,i);
15     portfolio = [EAD PD LGD M];
16     P(N*(i-1)+1+N*nbrOfPortfoliosEAD*(n-1):N*(i-1)+N*N*
17         nbrOfPortfoliosEAD*(n-1),:) = portfolio;
18     values = GAall(portfolio);
19     portfolionbr = i+(n-1)*i;
20     R(i + nbrOfPortfoliosEAD*(n-1) ,:) = [portfolionbr
21         values];
22
23 %% Comparison , axes (HI,PD,CapitalReq)
24 %close all
25 figure
26 HI = R(:,3);
27 Sch = R(:,5);
28 GA = R(:,6);
29 PDwa = R(:,7);
30
31 plot3(HI,PDwa,Sch,'b. ')
32 hold on
33 plot3(HI,PDwa,GA,'rx')
34 hold on
35
36 xlabel('HI')
37 ylabel('PD')
38 zlabel('Capital Requirement')
39
40 %% Comparison , axes (AHI,APD,CapitalReq)
41 %close all

```

```

42 figure
43 AHI = R(:,4);
44 Sch = R(:,5);
45 GA = R(:,6);
46 APD = R(:,8);
47
48 plot3(AHI,APD,Sch,'b.')
49 hold on
50 plot3(AHI,APD,GA,'rx')
51 hold on
52
53 xlabel('AHI')
54 ylabel('APD')
55 zlabel('Capital Requirement')
56
57 %% Difference , axes (HI,PD,diffSchGA)
58 figure
59 HI = R(:,3);
60 Sch = R(:,5);
61 GA = R(:,6);
62 Diff = GA-Sch;
63 PDwa = R(:,7);
64
65 plot3(HI,PDwa,Diff,'b.')
66
67 xlabel('HI')
68 ylabel('PD')
69 zlabel('Difference')
70
71 %% Difference , axes (AHI,APD,diffSchGA)
72 figure
73 AHI = R(:,4);
74 Sch = R(:,5);
75 GA = R(:,6);
76 Diff = GA-Sch;
77 APD = R(:,8);
78
79 plot3(AHI,APD,Diff,'b.')
80
81 xlabel('AHI')
82 ylabel('APD')
83 zlabel('Difference')
84

```

```

85
86 %% Including Ikanos portfolio
87 HI=0.00258747707;
88 PDwa=0.00376658546;
89 AHI=0.01313221251;
90 APD=0.00194561928;
91 Sch=0.000688737724;
92 GA=0.002265134719;
93 Diff = GA-Sch;
94
95 %%
96 plot3(HI,PDwa,Sch,'go','MarkerSize',6,'LineWidth',2)
97 hold on
98 plot3(HI,PDwa,GA,'g+','MarkerSize',6,'LineWidth',2)
99 hold on
100 %%
101 plot3(AHI,APD,Sch,'go','MarkerSize',6,'LineWidth',2)
102 hold on
103 plot3(AHI,APD,GA,'g+','MarkerSize',6,'LineWidth',2)
104 hold on
105
106 %%
107 plot3(HI,PDwa,Diff,'go','MarkerSize',6,'LineWidth',2)
108
109 %%
110 plot3(AHI,APD,Diff,'go','MarkerSize',6,'LineWidth',2)

```

```

1 function [EADvariations, PDvariations] = varyEADandPD(N)
2 EAD = zeros(N,1);
3 PD = zeros(N,1);
4 nbrOfBigExposures = 0.20*N;
5 EADvariations = zeros(N,nbrOfBigExposures);
6 PDvariations = zeros(N,nbrOfBigExposures);
7
8 for i = 1:nbrOfBigExposures
9     if i<6
10         EAD(1:i) = 0.01 + 0.06*rand(i,1); %assignes values
11             in the interval [0.01 - 0.07]
12         PD(1:i) = 0 + 0.0001*rand(i,1); %assignes values in
13             the interval [0 - 0.0001]
14     elseif 5<i && i<0.2*N
15         a = 0.3/i;
16         avvikelse = a/2;
17         EAD(1:i) = a-avvikelse + 2*avvikelse*rand(i,1);
18         PD(1:i) = 0 + 0.001*rand(i,1); %assignes values in
19             the interval [0 - 0.001]
20     end
21     b = 1-sum(EAD(1:i)); % remaining share the other
22         exposures will share
23     b = b/(N-i); % approximately how much each remaining
24         exposure should be assigned
25     l = 1/(N*10); %how much the remaining exposures can
26         deviate from the estimated value the should be
27         assigned
28     k = 0.1*N; %how many exposures that corrects in the end
29     EAD(i+1:end-k) = (b-1)+l*2*rand(N-i-k,1);
30     EAD(end-(k-1):end) = (1-sum(EAD(1:end-k)))/k;
31     EADvariations(:,i) = EAD;
32
33     PD(i+1:0.5*N) = 0 + 0.002*rand(0.5*N-i,1);
34     PD(0.5*N+1:0.85*N) = 0.002 + 0.018.*rand(0.35*N,1);
35     PD(0.85*N+1:0.9*N) = 0.035 + 0.01.*rand(0.05*N,1);
36     PD(0.9*N+1:end) = 0 + 0.001.*rand(0.10*N,1);
37     PDvariations(:,i) = PD;
38 end
39 end

```

```

1 function [values] = GAall(portfolio)
2 %portfolio in the form [EAD PD LGD M]
3 EAD = portfolio(:,1);
4 PD = portfolio(:,2);
5 LGD = portfolio(:,3);
6 M = portfolio(:,4);
7
8 N = length(PD);
9 s = zeros(N,1);
10 VLGD = zeros(N,1);
11 C = zeros(N,1);
12 Corr = zeros(N,1);
13 b = zeros(N,1);
14 R = zeros(N,1);
15 K = zeros(N,1);
16 delta = 4.83;
17 gamma = 0.25;
18
19 for i=1:N
20 s(i) = EAD(i) ./ sum(EAD);
21 VLGD(i) = gamma*LGD(i)*(1-LGD(i));
22 C(i) = (VLGD(i)+LGD(i)^2)/LGD(i);
23 Corr(i) = 0.12*(1-exp(-50*PD(i)))/(1-exp(-50))+0.24*(1-(1-exp
    (-50*PD(i)))/(1-exp(-50)));
24 b(i) = (0.11852-0.05478*log(PD(i)))^2;
25 R(i) = LGD(i)*PD(i);
26 K(i) = (LGD(i)*normcdf(1/sqrt(1-Corr(i))*norminv(PD(i)))+(Corr(i)
    /(1-Corr(i))^0.5*norminv(0.999))-PD(i)*LGD(i))*(1+(M(i)
    -2.5)*b(i))/(1-1.5*b(i));
27 if K(i)<0
28     K(i) = 0;
29 end
30 if isnan(K(i)) == 1
31     K(i) = 0;
32 end
33 end
34
35 Kstar=sum(s.*K);
36 GAall=1/(2*(Kstar))*sum(s.^2.*C.*(delta*(K+R)-K));
37
38 % Standardised Approach
39 % Sort out the 30 biggest exposures
40 k = 30;

```



```

41 c = [EAD PD];
42 temp = sortrows(c,1);
43 temp = flipdim(temp,1);
44 EADbiggest = temp(1:k,1);
45 PDbiggest = temp(1:k,2);
46
47 % Calculate AHI for the portfolio
48 sigma30 = EADbiggest./sum(EADbiggest);
49 HI30 = sum(sigma30.^2);
50 AHI = HI30*(sum(EADbiggest))/(sum(EAD));
51
52 % Calculate APD for the portfolio
53 APD = sum(sigma30.*PDbiggest);
54
55 % Assigning corresponding share based on the value of AHI
56 if AHI <0.01
57     Schablon = 0;
58 end
59 if AHI >=0.01 && AHI<0.02
60     Schablon = 0.02;
61 end
62 if AHI >=0.02 && AHI<0.04
63     Schablon = 0.04;
64 end
65 if AHI >=0.04 && AHI<0.08
66     Schablon = 0.06;
67 end
68 if AHI >=0.08
69     Schablon = 0.08;
70 end
71 sigma = EAD./sum(EAD);
72 HI = sum(sigma.^2);
73 Schablon = Schablon*Kstar;
74 PDwa = sum(s.*PD);
75 values = [N, HI, AHI, Schablon, GAall, PDwa, APD];
76 end

```

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⁸This document is a compilation of the June 2004 Basel II Framework, the elements of the 1988 Accord that were not revised during the Basel II process, the 1996 Amendment to the Capital Accord to Incorporate Market Risks, and the November 2005 paper on Basel II: International Convergence of Capital Measurement and Capital Standards: A Revised Framework. No new elements have been introduced in this compilation.

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