"An exploration of the use in practice of credit risk models"

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Abstract

Credit risk is treated as a major risk in banks and has become more important with the 2008 financial crisis and the subsequent regulatory controls, mainly in the form of new changes in Basel II and the proposed Basel III requirements. The use of credit risk models grew in the 2000s due to both the use of internal models in Basel II as well as bank use for economic capital calculations. These models have a large and growing influence on how credit risks are managed, yet there is a gap in the current literature on how these models are used in practice. This research explores their use in banks to help provide academic and management insight into the actual use of credit risk models.

An interpretative approach using qualitative case study was undertaken in three banks using face-to-face interviews with the key credit risk managers that worked in the methodology, decision making, monitoring, control and reporting areas. While interviews were the main source of data for the research, it was supported by observation and a review of documentation that related to the use of credit risk models in the bank. The research findings show the merits in examining the social, organisational and cultural constructions as well as the role of individuals in this process. This evidences the usefulness of interpretive research, which thrives on diversity of meanings as opposed to comparing just the technical aspects of the models as found in more traditional studies.

This research provides a contribution to the academic understanding of the use of credit risk models not found in any of the studies to date. This includes new insights into the use of qualitative information, the use of expert judgement (including an element of gut feel), how model complexity can detract from model use and the importance of aligning models to the risk appetite of the bank. These findings are significant both from an academic and practitioner aspect as they open up commonly-hidden processes on how these models are used in practice.

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1 Introduction

The purpose of this research is to add to academic and management knowledge and understanding of the use of credit risk models in practice. By analysing how and why these models are used, this thesis provides an understanding of the management use of these models not found in quantitative studies to date. This is important as credit risk model development has historically been based purely on theoretical, mathematical and economic frameworks, which do not necessarily take into account the actual use of these models in real business environments. Research into decision-making processes in credit risk management enhances our understanding of the use of credit risk models within banking and provides substantial insight to developers working on the design of models, to less advanced banks that are looking to implement these models and to market participants in looking at improving ways of using the output of the models in decision-making. It also assists regulators to better understand the practical use of these models and help better monitor use of credit risk models in banks.

Section 1.1 of this chapter, provides background to the research by setting the scene to show how the author's interest in this area developed and discusses the gaps in the current literature. Section 1.2 presents the research problem and the research questions. Section 1.3 introduces the methodology utilised in the research and the approach taken. Section 1.4 provides the justification and the contribution of this research. Section 1.5 concludes this chapter with a description of the structure and organisation of the rest of the thesis.

1.1 Background to Research

According to research by Kaminsky and Reinhart (1999) and Kuritzkes, Schuermann and Weiner (2003) credit risk is one of the oldest and one of the largest elements of risk in the books of banks. They suggest that failures in the management of credit risks have weakened individual banks and, in some cases, the banking system as a whole. The regulators find that effective management of credit risk is a critical component to risk management and essential to the long-term success of any banking organisation (Basel Committee on Banking Supervision, 1999). The goal of credit risk management is to identify and control credit risk inherent in individual bank transactions as well as at the portfolio level in order to achieve the maximum risk adjusted rate of return on capital. Credit risk models are quantitative models that are meant to quantify the likelihood and impact of credit losses.

Credit risk modelling is a fertile field for financial researchers (the leading website for credit risk is www.defaultrisk.com and as at 31st December 2010 listed 1,665 academic references and papers on credit risk management and modelling related research). Currently, there are many theoretical models to choose from and the list keeps growing. However, as shown in chapter 2, most of the work is focused on developing and debating the mathematical models, with very little research into how these models are used in practise.

Based on discussions with heads of the credit departments in banks and the author's experience of twenty years in banking, there does not seem to be industry wide agreement on following any particular model type (either Structural or Reduced Form). Another issue that has been debated in the industry is if some of the demands of regulators for certain levels of accuracy can ever be achieved. For example Rebonato (2007) takes as an example how a 99.9% confidence, as defined by regulators in a statistical model for credit risk, can never be attained accurately. A 99.9% confidence level means an accuracy of just one credit loss event in a thousand. Assuming a yearly credit loss distribution (this is the most common view in banks), Rebonato argues we would need accurate data from 1,000 years to be able to measure the risks accurately. Credit events do not happen with regular frequency and therefore there is not a sufficient amount of data available for those levels of accuracy. With the lack of sufficient or accurate data, the prediction of credit events can be made with imperfect data with potentially large variances depending on the parameters. These parameters and the variances are important but often ignored in the search for a headline figure.

Rebonato (2007), a modeller himself and Head of Market Risk at the Royal Bank of Scotland, argues that managing risk is about decision-making under uncertainty. He mentions two dangerous beliefs held by modellers. First, that risk metrics can be estimated to a precise value. Rebonato argues that this level of precision does not exist.

> *"This is not because we must "try harder" – say, collect more data or use cleverer statistical techniques. It is because given the problem at hand, this degree of precision is intrinsically unobtainable"* (Rebonato 2007, preface p. ix)

Second, that the modellers also assume that the results from the output of the models will self-evidently guide risk management choices. This means that the design of models assume certain precise management actions. Rebonato argues that in reality how management uses the output of these models is not known (Rebonato, 2007).

The researcher's interests about credit risk developed in the 1990's over the same time period that credit models gained prominence. These models have held a promise of better credit risk management and the researcher has an interest in how these credit risk models have improved risk management in banks but also questions if they have potentially contributed to additional systemic risks in the market. The researcher has worked in several banks including Barings Bank where failure in the bank due to the lack of operational controls caused credit issues in the market until rescued by ING, in Bankgesellschaft Berlin where the bank almost collapsed due to credit losses, and more recently in the Irish National Asset Management Agency (NAMA) where the Irish government rescued five banks and building societies from credit losses to the tune of €72 billion.

Failures in credit risk management that have contributed to several episodes of financial instability include Bank Hersatt (1984), Bank Rafidian (1990), BCCI (1991), Metalgesellschaft (1994), and Long Term Capital Management (2000). The recent 2008 financial crisis has added to research interest in this area as a number of banks failed due to credit risks, notably Lehman Brothers and Washington Mutual in the US, Fortis bank in Belgium, Saschen Landersbank in Germany and Northern Rock in the UK. A very large number of banks have reported losses and a number of financial intuitions have been bailed out by their government (notably RBS and Lloyds in the UK, Bear Sterns and Warchovia in the US (both were encouraged to merge with other banks), IKB and ING Bank in the Netherlands and Anglo Irish and Allied Irish bank in Ireland). These high-profile banks all apparently had more sophisticated market and credit risk systems than at any point of their past and yet, in spite of this, suffered large losses that compromised their independent financial viability.

The FSA report on investigations into the Royal Bank of Scotland's (RBS) failure in 2008, find that the RBS failure has imposed large costs on UK citizens (FSA, 2011). To prevent the collapse of RBS, the UK government injected £45.5bn of equity capital. The report stresses that this loss is only a small part of the cost resulting from the financial crisis. The larger costs arise from the recession which resulted from that crisis, within which RBS's failure played a significant role. The report holds that that recession has caused unemployment for many, losses of income and wealth for many more.

The failure of RBS can be explained by a combination of key factors including poor management choices, significant weaknesses in RBS's capital position as a result of management decisions and the inadequate regulatory capital framework at the time. The report also points to deficiencies in the market risk and credit risk capital regime, including its over-reliance on value-at-risk (VaR) models and credit risk models which were based on the reliance of forward-looking risk that was mainly drawn from the observation of past patterns of price movement. There is some evidence from the report that RBS's models were towards the weaker end of its peers and there were also weaknesses in model validation processes (FSA 2011)

1.1.1 Gap in knowledge in the use of credit risk models

Chapter 2 of this thesis analyses the literature around credit risk modelling and identifies a gap in knowledge where there is very little evidence on the use of the credit risk models in banks. As shown in Chapter 2 there are many theoretical mathematical models to choose from and the list keeps growing.

Miller and Page (2007 p. 140) point out:

> *"Often, tools get mistaken for theories with unfortunate consequences; elaborate computer programs...or mathematical derivations are originally assumed to make a real scientific statement, regardless of their scientific underpinnings. Indeed, entire literatures have undergone successive refinements and degradations, during each generation of which the original theoretical notions...are crowded out by increasing focus on tool adeptness. This often results in science that is "smart but not wise"".*

Although the statements by Miller and Page (2007) were made in a different context, they apply to credit risk models where there is a reliance on the complex model in banks and where extensions are made based on mathematical arguments without necessarily understanding how and why these models are used.

While there have been papers that have discussed and compared at a high level the models within banks, notably Jackson and Perraudin (1999); Lopez and Saidenberg (2000) and Crouhy, Galai and Mark (2000), these papers themselves did not specifically look at the use of credit risk models in practice. Importantly, there is no research on management attitude, understanding or reliance in the use of these models. It could be that instead of relying on the

models, management relies on experience, intuition or guesswork to make risk decisions. Without knowledge of how these models are used in practice, deciding on the appropriate model and deciding on appropriate actions based on model output remains a difficult task for academics, credit risk managers and regulators.

1.2 Research Problem

The overall goal of this research is to help provide academic and management insight into the use of credit risk models. The research objective is: "**To better understand the use of credit risk models in banks**". This has been phrased as the research problem: "**To understand in practice the overall framework for the use of credit risk models in banks, to study the preferences of banks, if any, to particular credit risk model approaches (Structural versus Reduced From), how and why the models are used and how outputs of these models are used in management decisions**"

The research findings presented here are based on the gaps discovered in the literature and, in order to answer the primary question, there are a series of secondary questions which can be broken down into three general areas:

RI-1 - What is the organisational structure and overall governance in the bank that manages and governs the use of credit risk models? How does this relate to the strategy of the bank and how are board decisions implemented (in relation to credit risk models)?

RI-2 - In relation to the types of credit risk models that are being used in the bank, does the bank have a particular preference on type of model used (Structural versus Reduced Form) and if so, why? How and why are these models used within the organisation?

RI-3 - How are the outputs of these models used as part of decision making?

RI-3.1 -Is non-model information used to guide decision-making around models? If so, why?

RI-3.2 -Do regulatory pressures influence the management decision-making process around the use of the models?

RI-3.3 –What are the management views on improvements needed on the models and why are these improvements deemed necessary?

1.3 Methodology and approach taken in the research

There are several ways of framing an academic study on the use of credit models in banks. Chapter 3 of this thesis describes the philosophical stance of the researcher where the researcher's view is that the use of these models must be set within the wider context of the social construct within banks. As a result credit model use would be governed by human behaviour, culture, capability and competence, organisational factors and strategy within a bank (i.e. the status of social reality within a bank), as well as the theoretical mathematical and economic framework from which the model itself was derived, therefore, the researcher's philosophical stance is based on the understanding and interpretation of model use through the human, sociological and organizational context within banks (Schwandt, 1994; Gephart, 2004).

Also decisions made on the basis of these models are dependent on managerial, strategic and organisational factors. This supports the researcher's view that, in reality, management's use of models is based on a social construct (Berger and Luckmann, 1966). This means an interpretive approach, describing distinct patterns of behavior through a series of case studies, was considered the most appropriate methodology with which to research this area. Specifically it fits into the philosophical stance of the research, as well as helping to answer the questions of "*why?*" and "*how?*" the observed behaviour arose.

The research design followed Stake (1995), and Yin's (2003) recommendations where a case study protocol was created to guide the research. This helps the focus and clarity of the data collection process. The case study protocol served as the overarching reference point and framework for the data collection process of this research. Three banks were selected for this research and chapter 3 covers how these candidate banks were selected, the pilot that was done and the makeup of the research participants within each of the banks. The tools used in the case study research followed Stake (1995), and Yin's (2003) sources of evidence and included documents, interviews, archival records and direct observation.

Inductive reasoning was applied as established and accepted theories were not available (Remenyi, 2000). Comparative analysis was employed as the standard analytic method, being commonly used in case study research, as well as fitting the epistemology of the researcher. The main tool used was thematic analysis, where significant themes were drawn from the case studies. The frame of reference for the themes was in observations of the data, the research

questions and the literature. The process involved reviewing the available literature, the research questions and answers, analysing and annotating the data extensively with a view to identifying particular objects of interests and patterns. The themes which emerged helped develop the descriptive information from the transcripts into a structure that could be analysed and interpreted.

While some may argue that case studies provide only individual views of the world, Yin, in particular, refutes that criticism by presenting a well-constructed explanation of the difference between analytic generalisation and statistical generalisation: "*In statistical generalization, an inference is made about a population on the basis of empirical data collected about a sample. In analytic generalisation, previously developed theory is used as a template against which to compare the empirical results of the case study*" (Yin, 1989 p. 38). The criticism of generalising based on case studies assumes that some sample of cases has been drawn from a larger universe of cases. In fact case studies are rigorous examinations that focus on the "how" and "why" questions of the research enterprise (Yin, 2003; 1989), which is appropriate in the context of this research to describe the context within which credit risk models are used.

Throughout the analytic process, the researcher has tried to ensure the principles that were stated in the case study protocol based on Yin (2003) were adhered to by:

- ensuring that the analysis relied on all the relevant evidence (via the coding, and the comparative analysis methodology)
- including, where relevant, any major rival interpretations in the analysis (the literature provided the basis for this)
- addressing the most significant aspect of the case study (this was done by using the case study protocol and in having an interview guide for the semi-structured interviews)
- using the researcher's prior, expert knowledge to further the analysis

1.4 Justification of the research and the contribution

This research can be justified because it addresses an existing gap in the literature, along with providing beneficial practitioner insight into use of the credit risk models.

First, no previous research has been done to investigate how and why risk models are used in banks. As shown by the literature review in chapter 2, almost all research has been has been

about the theoretical development and analysis of credit risk models. There have been a small number of studies (Jackson and Perraudin (1999); Lopez and Saidenberg (2000) and Crouhy, Galai and Mark (2000) on types of models that were being employed in the market, these papers themselves did not specifically look at the use of credit risk models in practice. There have also been high level surveys undertaken by the regulators, such as the paper from the Basel Committee on Banking Supervision (2000) which was part of the research done in preparation for Basel II. The survey included sections that asked banks about their use of credit risk models. However the questions were at a fairly high level and the paper did not seek to explain how and why these models were used.

Second, an important element of the doctorate of business administration is contribution to practitioner use. Research into decision-making processes in credit risk management will help provide new insight into the use of formal models which will benefit (a) developers working on the design of models, (b) risk managers in banks that are looking to implement these models or who are reviewing their decision-making processes based around model output, and (c) regulators who need to monitor the use of credit risk models in banks.

Third, this research is believed to be the first study of risk models that has used qualitative techniques which allows a detailed investigation of the use models in their natural setting. The research findings show the merits of examining the social, organisational and cultural constructions as well as the role of individuals in this process. This evidences the usefulness of interpretive research, which thrives on diversity of meanings as opposed the traditional viewpoint of researching the models via comparing the technical aspects of the models found in the credit risk modelling literature (much without observations and empirical evidence to support them). This research provides a contribution to the academic understanding of the use of credit risk models not found in any of the studies to date. This approach to the research about credit risk models will also make a useful contribution to the extent that it opens up commonly-hidden processes governing the practical use of these models and provides some explanation about why such processes are used in practice.

Finally, a key finding of this research was that the participants saw a need to align credit risk models to the risk strategy of the bank. In the research, the risk strategy was in most cases expressed via the definition of the risk appetite for the bank. Section 7.4 incorporates the findings of this research into the Institute of Risk Management risk appetite implementation

framework (Institute of Risk Management, 2011). This adds to the body of knowledge on risk appetite as well as provides practical examples on how the banks aligned their risk processes around risk models to the risk appetite

1.5 Structure of the thesis

The rest of the organisation of this thesis is as follows: Chapter 2 provides a literature review how changes in banking and regulations affected credit risk management within banks and how this led to growth in the use of the credit risk models. The 2008 financial crisis has had significant impact on banks and included in the literature review are regulatory and UK government sponsored papers that have emerged as part of investigations into the financial crisis. The chapter then lists the current empirical evidence available on the models and identifies a gap in the literature in the use of the models.

Chapter 3 of this thesis explores the methods suitable for researching the gap in the current understanding of the practical use of the models. It explains the philosophical and methodological approach taken in this research and argues that through the use of qualitative research methods, one will be able to develop answers to the research questions. It also covers the data collection method, the proposed measurement, data analysis as well as addressing research quality issues and ethical considerations.

Chapters 4, 5 and 6 provide the findings from each of three case studies and looks at the data in order to identify trends and differences of views between all the responses within the case study. By highlighting similarities and differences from what was said or how the participants said it, an understanding can be built on the use of credit risk models within each of the banks.

Chapter 7 concludes the thesis with first part presenting the cross-case comparison to identify key common factors and differences across the three cases. This is followed by the significant findings of the research, contribution of the research, limitations of the research and recommendations for future research.

2 Literature Review

2.1 Introduction

This chapter covers a review of literature relevant for this research. To research the use of credit risk models, one needs to understand some of the background on how they developed. The literature review covers a brief history of banking, how it evolved as a whole and how changes in banking lead to growth in the use of credit risk models.

After this introduction, section 2.2 provides a definition of credit risk. Section 2.3 covers a brief history of credit risk in banking and how it developed. It then looks at the regulatory environment and credit risk management to the end of the 1960s. Section 2.4 looks at banking changes in the 1970s, the regulatory changes and changes in credit risk management including the emergence of credit risk models. There were large changes to banking in the 1980s due to deregulation and Section 2.5 looks at these changes, related credit risk model changes in the period and the emergence of the Basel related regulations. Section 2.6 looks at the expansion of financial products within banking during the 1990s, changes to regulation and growth of model use. Section 2.7 looks at banking in the 2000s, the financial crisis, the regulatory response, how these in turn affected risk exposures, the risk culture and the risk philosophy. This had also an impact on management board structures, board decision-making processes, risk appetite, risk organisational structures and risk reporting in banks. This chapter ends with the gaps in the available literature and the goals of this research.

2.2 Definition of Credit Risk

Risks in banks can be broadly broken down to financial and operational risks. Financial risk is the possibilities of certain events adversely affecting a firm's financial performance, whether by reducing its profitability, cash flows or net asset value. The most common forms of financial risk managed in banks are market, liquidity and credit risks. The Bank for International Settlements (BIS) which serves as the global forum for policy analysis among central banks defines operational risk as *"the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events"* (The Bank for International Settlements, 2006 p. 144). This includes IT systems risk, human resources risk, operational controls risk, business disruption risk, compliance and business practise risk, project risks, security risks and legal risk, (The Bank for International Settlements, 2009a)

The BIS defines credit risk as *"the risk that a borrower will not be able to repay his loan when due"* (Basel Committee on Banking Supervision, 1987 p.9). There is no other formal definition to be found in the BIS's published papers with a number of other BIS papers referencing the 1987 paper[1]. A problem with the BIS definition is that this classical definition only mentions loans and ignores the more modern or less direct forms of credit risk such as derivatives, letters of credit, underwriting risks and commitments. For bonds and securitised assets, it also does not take into account the risk to the underlying issuer. It also doesn't consider the impact any credit enhancement of these instruments which can include collateral, guarantees or credit derivatives which may transform the risk and transfer the risk to another party. Greenbaum and Thakor define credit risk as *"the risk that the party to whom you contract fails to fully discharge the terms of the contract. For a bank this is the risk the borrower fails to make the contractual payment on a timely basis"* Greenbaum and Thakor (2007, p129). This definition is an improvement on the BIS definition as it covers all parties that an entity may contract with, including derivatives counterparties, but it still does not include issuer risk nor indirect forms of risks for example in the case of guarantees or underwriting.

As part of Basel II (Basel II is explained further in section 2.6.1), the components for the calculation of the credit loss are defined as the probability of default (likelihood of default), multiplied by the expected exposure at default (the exposure of the bank at the time of default) multiplied by the expected loss given default (this is the inverse of the recovery rate). There are academic papers (e.g. Brown 2004) which focus on the credit loss aspects of credit risk and use the Basel II formula as their definition of credit risk. The theme of credit risk being part of credit loss can be found in DefaultRisk (2001), the largest website for credit risk papers which defines credit risk as *"The risk of loss from not receiving one's reward for being on the right side of a bet about a market move, due to the losing counterparty's failure to meet his obligations"*[2]. The weakness of the DefaultRisk definition is that it mainly focuses only on the trading aspects and focuses on direct counterparties rather than indirect credit risk to issuers or guarantors. Malz (2011, p.192) defines credit risk as *"the risk of economic loss from default or changes in rating or other credit event"*. While this extends the definition in

[1] An exception to this is the BIS Risk Management Guidelines for derivatives (1994) which does attempt to qualify the credit risk specifically to derivatives. In the main though the BIS does put the onus on the banks to provide sufficient qualitative description about credit risk to enable the users of financial statements to understand how the bank itself defines credit risk. See the BIS Best Practices for Credit Risk Disclosure (2005)

[2] This definition can be found in http://www.defaultrisk.com/glossary_c.htm

that it also considers losses from credit rating changes or credit events, it doesn't cover the scenario where there isn't a credit rating available or where ratings are not regularly updated, nor defines what "other credit events" are.

A more complete definition of credit risk can be found in the European Central Bank that defines credit risk as *"the risk that a counterparty will not settle the full value of an obligation – neither when it becomes due, nor at any time thereafter. Credit risk includes replacement cost risk and principal risk. It also includes the risk of the settlement failing"* [3]. For the purposes of this thesis, this is the definition that will be used with two changes. The first is that the word counterparty is replaced with *"obligor"* where the obligor can mean *"the borrower, counterparty, an issuer or a guarantor"*. Second that the risk covered can also include promised payments such as interest or fees. While the impact of credit risk typically happens when an obligation becomes due, this definition allows for credit risk before any default happens (e.g. caters for changes in credit ratings of the obligor).

2.3 A brief history of credit risk to the end of the 1960s

The earliest reference to credit is found in Hammurabi's Code, which codified legal thinking from around 1750BC, where it describes the principles of the legal process pertaining to debt and that the failure to repay a debt was a crime. The Old Testament of the Bible refers to the punishment of being sold into slavery for failing to repay a debt (2 Kings 4:1-7).

Over the centuries, the growth of lending has led to growth in the management of credit risk with credit decisions made using local knowledge. An example would be a wholesale supplier of goods who would make credit decisions based on reputation and direct observation of local retailers. There would no sharp distinction between credit judgments and general business judgments; and there is no demand for credit ratings, because the credit suppliers know more about their customers than outside agencies.

Banks were chartered in the late eighteenth and early nineteenth centuries mainly to act on behalf of governments or to achieve objectives of the government. The scarcity of such charters meant there was a monopoly for the activities of these banks.

[3] This definition can be found in http://www.ecb.int/home/glossary/html/glossc.en.htm

Greenbaum and Thakor (2007) describe traditional bank lending as financial intermediation of capital between providers and users which as part of the process, produces credit information to control a borrower's credit risk. Traditional credit risk management, mainly in the form of providing and managing credit limits, has grown with the growth of bank lending as banks in their classic form took deposits and made loans and profit from the spread between the higher lending interest rates and the lower deposit rates (Malz, 2011 p.2).

Rebenato and Malz both refer light-heartedly that in the 'good old days' the only piece of quantitative information a bank manager needed to know was the 3-6-3 rule, which was, raise money at 3%, lend it at 6% and be on the golf course by 3pm (Rebonato 2007, p.118 and Malz, 2011 p.3). While this light-hearted reference might oversimplify things, it still helps to explain the relatively straightforward nature of the banking industry in the past, where there were a limited number of products and where prevailing regulations made it difficult for new entrants to provide lending services, and that prevented competition to the range of services that were provided by the banks (Strahan, 2003 p. 115).

There have been exceptions to the straightforward nature of lending. Railroads in the United States in the mid 19th century required huge capital investments thousands of miles distant from providers of capital. The corporate makeup of the railroad companies meant creditors had to depend on the assets and earnings of the business, rather than a government or bank guarantee. Railroad creditworthiness could not be determined by local observation, but required knowledge of overall transportation infrastructure and the economics of all goods that were shipped by rail. Generic information about freight tonnage, rates and costs is more important than specific knowledge of things like track quality or personal honesty of managers. Potential creditors could not get this information from companies directly, because consistent and reliable financial statements were a century in the future. This led to the original rise of the rating agencies, Standard and Poor's and Moody's (Brown, 2004).

In the main, the management of credit risks has been closely associated with the direct lending of money and where there were investments made, for example in the railroad companies or government bonds, these were decisions made with the goal of holding them to maturity.

2.3.1 Banking regulations to the end of the 1960s

In the 1930s, 1940s, 1950s and 1960s, banking was a heavily regulated industry that was focused on lending to retail customers and nonfinancial corporations (the money markets were not well developed and there was little interbank lending). Interest rates and foreign exchange rates were controlled by the regulators (based on government decisions). Banking was regulated on a national basis with no agreed global standard by the regulators. Legislation provided barriers to competition in deposit taking and in lending (an example is the Banking Act of 1933 in the United States).

2.3.2 Credit risk measurement to the end of the 1960s

The main approach used in the measurement of credit risk was mainly qualitative and based around heuristics of good lending practices. An example of this is the "5 Cs of Credit" which are "Character", a measure of the reputation of the firm including the desire to pay back; "Capital", the equity in the company and the ratio–to-debt (leverage); "Capacity", the ability to repay; "Collateral", the value of any pledges and "Cycle or Conditions" which looked at the firm's vulnerability over the business cycle (Greenbaum and Thakor, 2007 p. 185).

Credit risk control and measurement was via the settling of qualitatively set limits per counterparty or group of counterparties and were measured against the total amount borrowed by the counterparty (also called nominal amount or notional amount). Often the limits would be set in the general ledger system of the bank and would be measured when the general ledger was updated with the exposure (in most cases overnight or even over a longer period of time if the exposures had to be keyed in from different systems). There was no real concept of a real-time pre-deal check. Measurement of portfolio risk or country risk would at best be rudimentary against a limit set for the portfolio or country. Settlement risk would not be commonly measured and there was no requirement for the calculation of regulatory capital based on credit risks.

The first major attempt at risk quantification not linked to straight loans was Hickman's three-volume study of US corporate bonds, published between 1953 and 1960 (as found in Brown, 2004). Hickman tabulated default rates and investor returns from bonds of different credit ratings and other characteristics. Hickman had extensive data, although Brown (2004) finds Hickman's economics training led him to the wrong conclusions and planted seeds that

contributed to the junk bond bubble, the S&L and pension fund crises and the growth of the ratings agencies.

2.4 Banking in the 1970s: Moving away from intermediation to fees

In the 1970s banks increasingly diversified their business from the classic deposit taking and lending function and engaged in other functions where they could earn fees in addition to earning net interest (Malz, 2011 p.3). As well as traditional banking books that were held to repayment or maturity, banks also began to operate trading books of securities and loans held for potential sale. The 1970s is recognised as the time when new types of financial instruments were started to be introduced although the wave of innovation was at a relatively slow pace when compared to the 1980s. The three main innovative instruments were the introduction of Money Market negotiable certificates of deposit (CDs) which the depositor could sell early (unlike time deposits that had to be closed at penalty rates when a depositor wanted their money early), the Foreign Exchange currency swap that was introduced in the mid 1970s (Malz, 2011 p.7) and there was also the creation of the junk bond (or high-yield) market. Banks would earn fees for providing these services to customers and investors although the junk bond market opened up a new channel for borrowing directly from investors.

The 1970s also saw the beginnings of deregulation in the United States and other countries. Until the 1970s US banking was governed primarily by state laws, and banks could do business only in their home states. In what is called the "Marquette Decision," the US Supreme Court in 1978 ruled that banks could export interest rates into other states. This prompted banks to establish headquarters in states that would allow them to charge the highest interest rates, and subsequently tax income for those states grew substantially. To stay competitive, other states raised caps on the interest rates that banks could charge.

Another change that helped to accelerate innovation was globalisation. Many banks opened branches in foreign countries and were able to offer investment banking and asset management products that were previously off-limits to those tightly regulated countries. In addition, lower capital standards in some regulatory jurisdictions enabled banks to undercut their foreign competitors (Guill, 1999).

Finally another ingredient that forced banks to change was macroeconomic trends in the 1970s of rising inflation, oil price shocks, slowing economic growth, and periods of volatile interest rates. Rising interest rates undermined bank deposits as individuals transferred their savings out of bank accounts and into higher-paying money-market mutual funds and to other securities that provided a better return.

2.4.1 Regulators and regulation changes in the 1970s

The most influential body in banking regulation is the Basel Committee on Banking Supervision. It was formed at the end of 1974 in response to a problematic liquidation of a Cologne-based bank called Herstatt Bank. The background was that on 26 June 1974, a number of banks had released deutschmarks to the Bank Herstatt in exchange for dollar payments deliverable in New York. Due to differences in the time zones, there was a lag in dollar payment to these banks. Before the dollar payments could be effected in New York, the Bank Herstatt was liquidated by German regulators which meant the counterparties based in other countries suffered large losses. This incident prompted the G-10 nations to form the Basel Committee on Banking Supervision, under the auspices of the Bank of International Settlements (BIS) located in Basel, Switzerland. The mission of the BIS is to serve as a forum that allows for decision making across all central banks in their pursuit of monetary and financial stability, to foster international cooperation in these areas and to act as a bank for central banks.

The purpose of banking regulation according to Greenbaum and Thakor is to foster competition, to protect institutional safety and soundness, to protect consumers, to allocate credit, and to effect monetary control. This is with the overall goal of safeguarding moral hazard by regulating banking behaviour. The objectives for the regulators (and the BIS) are to regulate:

- Market Structure and competition (entry restrictions, restricting mergers and bank holding companies, separation between banking and commerce)
- Oversee safety and Soundness (deposit insurance, capital requirements, market value accounting and limits to lending to an individual borrower)
- Consumer protection (ceilings in consumer loan interest rates, consumer protection regulation and disclosures)
- Credit Allocation (deposit interest rate ceilings),
- Monetary control (reserve requirement and the discount rate)

(Source: Greenbaum and Thakor, 2007 p. 442)

While there was no agreed global regulatory standard produced in the 1970s, the Basel committee went on in the 1980s, 1990s and 2000s to produce the Basel accords which were globally adopted regulation standards that specified minimum capital, control and regulatory reporting requirements. These regulations allowed the use of internal credit risk models in the calculation of capital requirements for the bank. The Basel regulations and growth of the models are described in more detail in the sections 2.5.1, 2.6.1 and 2.7.1.

2.4.2 Credit risk models in the 1970s

While there was no real change in practical credit risk measurement in banks in the 1970s when compared to the 1960s, the decade did see the birth of credit risk models. There were two groups that are attributed with having developed methodologies for credit risk models in the 1970s (as described in Altman and Saunders, 1998). The first model group developed models called Credit Scoring models which are based on determining points for pre-identified factors, which are then combined to predict the loss probability and the recovery rate. Accounting data is used as data to populate the factors. The second was based on a Structural Approach framework developed by Merton (1974)[4].

The Basel Committee on Banking Supervision (1999) describes credit risk models as models that attempt to aid banks in quantifying, aggregating and managing credit risk across geographical and product lines, and the outputs can be very important to banks' risk management as well as economic capital assignment. Those models, despite the possible differences in assumptions, share the common purpose to forecast the probability distribution function of losses that may arise from a bank's credit portfolio (Lopez and Saidenberg 1999).

Credit risk models are defined in this research as mathematical models that try to calculate the default probabilities and loss given default in order to quantify the credit risks within a group of trades. The grouping of trades is more commonly known in banking as a portfolio. The exact makeup of a portfolio is specific to a bank. Typically banks would have separate portfolios of loans, off-balance sheet items, debt instruments, equities and commodities but

[4] Note: While there was academic debate on credit scoring models and structural models, there were no commercially available versions of credit scoring nor structural model models available in the market in the 1970s. The main credit risk measurement and control found in the banks in the 1970s was similar to the 1960s

banks can also have larger combined portfolios or smaller more defined portfolios (e.g. a credit derivatives portfolio or a portfolio made up of emerging market equities). The growth of securitisation activities by banks, wherein portfolios of related assets can be re-packaged as new marketable securities has allowed banks to separate original individual lending decisions into a portfolio of credit risks where typically these risks are measured by credit models on a portfolio basis. The reason why research into these models is important is that they have changed the way lending decisions are made within banks (Rebonato, 2007 pp. 244-245). Regarding the potential benefits from the application of credit risk models in banking sectors, the Basel Committee on Banking Supervision (1999 p.1) concluded that they are responsive and informative tools offering banks "*a framework for examining credit risk in a timely manner, centralizing data on global exposures and analyzing marginal and absolute contributions to risk*".

Within Credit Scoring, there were two varieties of models, univariate and multivariate (Altman and Saunders, 1998). Univariate were accounting-based credit-scoring systems, where the bank compared various key accounting ratios of potential borrowers with industry or group norms. Multivariate Credit Scoring were where the key accounting variables were combined and weighted to produce either a credit risk score or a probability of default measure. There were many flavours of univariate and multivariate credit scoring systems developed. The most common model used was one developed by Altman, Haldeman and Narayanan (1977) called the referenced ZETA discriminant model (more commonly known as a Z-Score model). Section 2.6.2 of this thesis shows why after the late 1990s credit scoring went into decline. The main two criticisms of credit scoring models were that first, as their predominant explanatory variables were based on accounting data, these models could fail to pick up fast-moving changes in borrower conditions and second, that they were not suitable for analysis of financial intuitions where there were large off-balance sheet exposures (Hao and Zhang, 2009).

Structural Approach models begin with an economic argument about why a firm defaults. In this framework, the default process of a company is driven by the value of a company's assets relative to the value of the firm's debt. Structural Approach models are based on the work of Merton (1974) using the Black & Scholes option pricing model. Default happens when a firm's liabilities are greater than its assets. The risk of a firm's default is therefore explicitly

linked to the variability in the firm's value. Default occurs after ample early warning in the Structural Approach model[5].

The first credit risk models were proposed in the 1970s and were based on the original framework developed by Merton (1974) using the principles of option pricing (Black and Scholes, 1973). The basic intuition behind the Merton model is relatively simple: default occurs when the value of a firm's assets (the market value of the firm) is lower than that of its liabilities. Altman *et al*, (2002) uses the example that if one assumes that the company's debt can be entirely represented by a zero-coupon bond, at maturity of the bond if the value of the firm is greater than the face value of the bond, then the bondholder gets back the full face value of the bond. However if, at maturity, the value of the firm is less than the face value of the bond, the firm is in default as equity-holders get nothing and the bond-holder gets back the market value of the firm. Merton (1974) describes the bondholder payoff at maturity as equivalent to the face value of the bond minus a put option on the value of the firm, with a strike price equal to the face value of the bond and a maturity equal to the maturity of the bond. Hence the value of the contingent claim is derived using option pricing theory.

A full mathematical example of the Merton model can be found in a paper by Giesecke (2003) called "Credit risk Modelling and Valuation: An Introduction".

2.4.3 First-generation Structural models (1970s).

The line of research that followed the Merton approach has proven useful in addressing qualitatively important aspects of pricing credit risks and addressing the issues of automation, consistency and subjectivity found in the traditional credit measurement methods. However, empirical research has shown that implementation of the original Merton model has produced discouraging results (notably research by Jones, Mason, and Rosenfeld, 1984, and Ogden 1987), and researchers more recently (for example work by Jarrow, van Deventer and Wang, 2003, and work by Mishra, Kulkarni and Thakker, 2008) continue to reproduce negative results. These negative results are not always of the same magnitude. There are several ways of testing the results of the Merton model. Other than looking at the results of the model with actual bankruptcy/default numbers, which can be very complicated to calculate, a common method of partially checking the accuracy of the models is by using bond spreads.

[5] An exception to this can be found in Zhou (2001) who incorporates jumps (surprises) into the Merton model.

Theoretically, the difference between a risky bond yield and a risk-free bond yield is called the bond spread and should be due to credit risk. Therefore it is possible to compare what the model predicts should be the spread against the actual bond spread found in the market. The Merton model performs badly in this area, severely understating credit risk (Eom, Helwege and Huang, 2002).

Advocates of the Structural Approach method believe the problem lies in the unrealistic assumptions used in the Merton model and in particular that:

a) bondholders receive the entire value of the firm in distress
b) interest rates are constant
c) payment is based on seniority of debt
d) debt consists only of zero coupon bonds
e) default only happens at maturity of the zero coupon bond

In response to such difficulties, extensions to the model were developed, commonly called first-generation Structural models, which still adopt the original framework developed by Merton on the default process but at the same time try to remove some of the unrealistic assumptions of the Merton model.

These first-generation Structural models include Black and Cox (1976) and Geske (1977) (Vasicek, 1984, is also categorized as a first generation structural model and is therefore included in this section of the literature review). Each of these models try to refine the original Merton framework. Black and Cox (1976) focuses on the debt side introducing the possibility of more complex capital structures using subordinated debt rather than just zero coupon bonds. Geske (1977) introduces interest-paying debt, where the equity holders at each coupon date decide whether to service the coupon or not. If they pay the coupon the firm stays alive. The default boundary for all the first-generation models is endogenous. Endogeneity is where default is driven by factors only within the firm. In the Geske model it is endogenous because it occurs when the equity holders cannot service the debt by issuing new equity and thus the firm defaults. The distinction between endogenous and exogenous is an important one. In the Reduced Form School, the modelling of risk is as an exogenous

process, external to the firm[6]. Some second-generation Structural Approach models described below in section 2.6.2.1 introduce exogenous factors to the original Merton (1974) model.

2.5 Banking in the 1980s

In the 1980s several countries restructured and deregulated their financial services industry and this introduced competition to activities that previously only banks could undertake. This meant that non-banks could offer lending, fixed income, foreign exchange and fees-based banking services. Greater competition diminished the cost advantage banks had in acquiring funds and undercut their position in loan markets. As a result, traditional banking became less profitable, and banks began to diversify into new activities to bring a higher return Examples of deregulation include:

- the Depository Institutions Deregulation And Monetary Control Act of 1980 in the US which allowed credit unions and savings and loans to offer banking services including cheque accounts
- Garn–St. Germain Depository Institutions Act of 1982 in the US which deregulated savings and loan associations allowing them to enhance their earnings by expanding their powers. The act also allowed banks to provide adjustable-rate mortgage loans
- Building Societies Act 1986 in the UK which lifted restrictions on the range of services Building Societies could offer, so that they could compete with banks on a level basis
- Banking Act 1984 in France which opened up competition to banks in France
- Foreign Exchange and Trade Control Act (1980) and enforcement of the New Banking Act (1982) in Japan deregulated the foreign exchange and lending markets in Japan

The 1980s also saw further growth of new innovative products in the derivatives markets with the introduction of swaps and the expansion of futures and options trading facilitated by the Black Scholes option pricing model. The first interest rate swap was concluded in 1981 between IBM and the World Bank. Subsequently, the interest rate derivatives market expanded enormously and in 2010 the International Derivatives and Swaps Association (ISDA) calculated that the total combined notional amount outstanding of interest rate, credit, and equity derivatives at June 30, 2010 was $466.8 trillion[7]

[6] Reduce Form models developed in the 1990s are seen to be the competing type of models to the Structured Approach models. Section 2.6.3 of this thesis covers Reduced Form models in detail.
[7] As found on the ISDA website http://www.isda.org/statistics/recent.html#2010mid.

While mortgage-backed loans were in existence before the 1970s, these were mainly collateralised loans. An innovation which started in the 1970s and developed in 1980s was securitisation of mortgage loans. Called mortgage-backed securities (MBS), these were firstly issued in the form of "pass-through" certificates (where the interest was passed through from the mortgagor to the bondholders, less fees and costs). The next step in the evolution of securitisation was the issuance of the first collateralised mortgage obligation (CMO). This differed from the MBS in that collateral was placed in trust and cash flow was distributed in tranches based on different bond classes. A sequential pay structure was used after coupon payments where all further prepayments would go to the first tranche until it was fully redeemed and then the second and so forth.

Another product that was created in the 1980s was asset backed securities (ABS). These were similar to CMOs except the collateral was non-mortgage loans and could even be made up of a blend of very different types of collateral and generate cash flow assets. Like CMOs, bonds are issued that distribute cash flows and credit risk is segmented via creation of bond seniority classes.

Other changes involved the market changes that provided new routes to the markets rather than new products. An example of this is lending via the repurchase agreement which was originally limited to the government bond markets, then expanded to corporate bonds in the 1980s and from the 1990s was used to finance mortgage bond positions. Another example is that via the growth of capital markets, more firms found they could raise money more cheaply by selling bonds directly, or raising money in the money markets, instead of borrowing. This process of moving away from direct lending by banks is termed disintermediation. Via this disintermediation mechanism a firm could by-pass the banks and borrow directly from investors.

Banks adapted to the changing environment by specialising in new areas by advising corporate clients on their capital raising as well as trading in securities, equities and foreign exchange. They also created derivatives of these new products with a large number being off balance sheet to reduce the level of capital required by the banks to trade these new products. The banks held on to some of the risk but also embarked on selling these products onward to investors, asset management firms and hedge funds either directly (e.g. firms could hold options on fixed forward interest rates or fixed foreign exchange rates) or indirectly by

offering investment products that were securitised with embedded derivatives that modified the risk profile of the securitisation to provide levels of different return linked to differing risk levels. This activity was initiated by the investment banks but was also prevalent in the 1990s and 2000s among the retail and commercial banks which provided similar securitised products.

Beyond the growth in disintermediation and new product innovation banks sought higher returns through the credit intermediation process, which also become decentralised in the 1980s (Malz, 2011, p. 2). This provided intermediation between savers and borrowers through mechanisms largely outside the classic banking system. This is commonly known as "the shadow banking system" (Malz 2011, p.8). Exposure to the shadow banks through decentralised intermediation processes may be harder to identify and measure.

There is some evidence from the US that during the 1980s, performance ratios of banks of all sizes weakened and exhibited increased risk. Profitability declined and became more volatile, while loan charge-offs rose dramatically.[8] Large banks assumed greater risk in order to boost profits, as is indicated by the sharp rise in the ratio of loans and leases to total assets for these banks. In contrast, equity ratios increased over the period, particularly for large banks, in line with increased regulatory capital requirements (see next section 2.5.1) and perhaps also in response to market concerns at the time about distress in the banking system.

2.5.1 Regulation changes in the 1980s

In 1988, the Basel Committee published a set of minimum capital requirements for banks. This standard known as the Basel Accord was adopted in most countries in the early 1990s. The Basel Accord, more commonly known as Basel I, stipulated a new set of regulatory capital guidelines which were primarily focused on credit risk. Regulatory capital refers to the amount of capital a financial institution must hold because of regulatory requirements. One of the functions of capital is as a buffer against losses and this was the main driver for the regulators under the Basel I accord.

[8] The question of whether banking in the 1980s was a declining industry and the related question of overcapacity in banking are explored in Federal Reserve Bank of Chicago, *The (Declining?) Role of Banking, Proceedings of the 30th Annual Conference on Bank Structure and Competition* (May 1994)

Under Basel I assets of banks were classified and grouped in five categories according to credit risk, carrying risk weights of zero (for example home country sovereign debt), ten, twenty, fifty, and up to one hundred percent (this category has, as an example, most corporate debt). Banks with international presence are required to hold capital equal to 8 % of their risk-weighted assets.

Basel I, while recognised for setting a global standard for regulatory capital, had a number of shortcomings, the largest being that the capital calculations did not take into account the credit quality of the borrower or the type of lending. Another weakness was that banks could undertake regulatory capital arbitrage to lower the regulatory capital that they needed. They did this because if banks held less capital, they could utilise the money that would have been set aside for capital purposes to actively generate higher profits. An example of a mechanism used for regulatory capital arbitrage was the use of securitisation, where assets were securitised and moved to an offshore special purpose vehicle (SPV). By using derivatives, the bank would still benefit from the cash flows of the original assets except the exposure appeared as off-balance sheet items.

2.5.2 Credit risk models in the 1980s

Partially as a reaction to the market changes and partially to greater interest in this field, academics and practitioners started to research and develop more sophisticated credit-scoring systems and Structural Approach models. Attention moved from just analysing risks to individual loans towards analysing portfolio risk and also trying to better measure the credit risk of off-balance sheet instruments (Altman and Saunders, 1998).

Extensions to the first generation Structural Approach include work by Vasicek (1984) which focused on the debt side by introducing a distinction between short and long-term liabilities, not found in Merton (1974). Commercial versions of the Structural Approach model were still not available until the 1990s.

The use of credit scoring expanded in the 1980s and Z-scores gained wide acceptance by auditors, management accountants, courts, and database systems used for loan evaluation (Eidleman, 1995). However Eidleman also found that Z-scores were not appropriate for analysis and measurement of financial institutions because of the opacity of financial companies' balance sheets, and their frequent use of off-balance sheet items. Due to this

weakness, in the 1990s and 2000s the Structural and Reduced form models grew in prominence while use of credit scoring declined.

The other change to credit risk measurement in the 1980s was that advances in technology allowed banks to receive more timely data, to better consolidate information and improve on internal risk reporting.

2.6 Banking in the 1990s

The 1990s showed a significant change in the performance of the banking industry and demonstrated a number of distinct trends. The first was the accelerated move towards globalisation, initiated in the previous decade. The 1990s saw middle-size banks absorbed by nationwide or large global banks. In the US, the number of separate banks decreased considerably in the wake of mergers and consolidation in the U.S. banking sector. According to the Federal Deposit Insurance Corporation, which monitors all federally insured banks in the US, the number of insured commercial banks declined by almost 35 percent in the late 1980's and 1990's (Jones and Critchfield, 2004).

Second, the 1990s was characterised by a number of high-profile failures affecting medium-sized institutions (e.g. BCCI, Barings and LTCM). These banks did not have the capital to withstand downturns and the capital squeeze in the middle-tier banks contributed to the decline in the number of banking institutions. The 1990s were also characterised by full-blown national and regional crises. Examples include the European Exchange Rate Mechanism crisis of 1992–1993 when the UK was forced to withdraw from the mechanism and France was forced to devalue, the Asian currency crisis of 1997–1998 that had a severe impact on the South East Asian countries and the 1998 Russian financial crisis resulted in a devaluation of the rouble and default on Russian government bonds.

Third, the impetus for deregulation of the 1980s continued with the global take up of the initiatives that started in US, Europe and Japan. Examples range from Argentina that underwent heavy deregulation during the Menem administration in the 1990s, Mexico that implemented their Credit Institution Act in 1990, and Russia which went through wide-ranging deregulation in the late 1990s under Boris Yeltsin. The setting and monitoring of

regulatory capital was the main form of regulatory control in the 1990s. Deregulation and change continued in the leading economies with the following key acts passed in the US:

- 1991 FDCIA Act which further liberalised banking and was aimed at promoting the global competitiveness of American banking intuitions. It also reduced the taxpayer's exposure via deposit insurance and included accounting reform to allow reporting of off balance sheet items on the financial statements
- 1999 Gramm-Leach-Bliley Act (also called the financial services modernizing act) which repealed the Glass-Steagall Act and allowed banks, securities firms and insurance companies to affiliate with each other and enter each other's markets

Fourth was that the growth of product innovation in the banking sector continued apace with several new traded products that had not previously existed. The risk profiles on these products were very different from straightforward loans and bonds. One such product was credit derivatives. The most widely used example of this product was the credit default swap (CDS). The seller or issuer of a CDS agrees to pay the buyer a predetermined amount should a named credit event or credit default occur. In return the buyer of the CDS makes a series of payments (called "fee" or "spread") to the seller. Thus assuming the seller honours the agreement, the CDS allow the potential removal of credit risks from the buyer.

The early 1990s importantly saw the introduction of the Commercial Mortgage Backed Securities (CMBS). This was a new source of funding for the commercial real estate area and was a securitised credit product that allowed loans for the purchase and development of commercial properties such as offices, apartments, shopping malls, hotels and cinemas to be pooled and then sold to investors. These were very like CMO's created in the 1980's except the pool was made of commercial property loans which were much larger then residential loans and therefore there would be fewer loans in the pool supporting the bonds.

The CMO concept was further extended to a product called a Collateralised Debt Obligation (CDO). CDOs contain any assets that provide cashflows that are not real estate asset based. CDOs could even contain pools of other CDOs as well as synthetic assets that were based on indexes (the first being one called Broad Index Secured Trust Offering or BISTRO that was created by JP Morgan in 1997)

There was also innovation in the form of combinations of several existing products to create new derivatives. For example, swaptions are combinations of swaps and options, samurai bonds which are combinations of bonds and foreign exchange, and barrier options are combinations of call options and put options. The combinations of complex instruments made these instruments hard to price and to calculate the actual credit risks.

Fifth, in the 1990's continued improvements in communications and technology helped open new channels for execution of traditional deals and electronic trading became the dominant form of trading.

Finally, the shadow banking system allowed some large non financial corporations such as General Electric and General Motors to offer financial services. Because these companies were large, they could borrow at relatively low interest rates in the capital markets or sell their paper through securitisations. They created subsidiaries (GE created GE Capital and General Motors created GMAC) which offered securitisation services to the market. In the shadow banking system there was also very large growth of lightly regulated hedge funds and structured investment vehicles (SIVs) which offered a very broad range of investment and trading activities.

2.6.1 Regulation changes in the 1990s

The early 1990's saw the implementation of the Basel 1 regulatory requirements. Basel I was seen as a major improvement over what preceded it (Greenbaum and Thakor 2007, p 511). It was also an important milestone in harmonising regulation across banks in differing countries. However the larger and more sophisticated banks felt that they should not have to put aside the same amount of capital as smaller or less sophisticated banks, arguing that they had better management structures, better processes and more complex monitoring systems (Danielsson, 2003). They lobbied the central banks to bring in more granular calculations of risk and the use of internal risk models (for credit and market risk) as they believed these models provided a better ability to manage risk, and they believed their sophistication provided a competitive advantage.

The BIS started discussion of Basel II in 1996 with the formal launch of the committees to introduce the second of the Basel Accords in 1998. In June 2004 the official Basel II

requirements were published where the capital calculations were changed to be more appropriate to the risk the bank exposes itself to, and it introduced the ability for banks to use internal credit and market risk models. Basel II has been subsequently refined with new improvements requiring greater complexity which has, in turn, fuelled growth in the use of credit risk models as well as the intricacies of these models.

The concern by the regulators that gave rise to the creation of Basel II was that in this new world, there were new systemic risks where the higher potential of losses could lead to the failure of banks, which in turn could spread through the economy. An example of systemic risk is the 1930s when banking failures had severe repercussions for the global economy. An important driver for Basel II was to reduce systemic risk by ensuring that banks were adequately capitalised (there is some debate on whether Basel II really reduces systemic risks or in fact increases systemic risk. This is covered in section 2.7.2).

Basel II covers credit, market and operational risk (although under a separate section called Pillar 2, it allows the banks to report other types of risk such as concentration or liquidity risks and to set capital against these). For credit risks, Basel II permits banks to use internal models rather than the fixed weight standard approach. The broad conceptual framework of the internal model approach for credit risk is similar to that of a single factor model found in the structural approach. Four key parameters are used to calculate the risk weighted assets (RWA) under Basel II. The four parameters are:

a) Probability of default (PD)
b) Exposure at time of default (EOD)
c) Loss given default (LGD)
d) The maturity of the exposure

(Source: Basel Committee on Banking Supervision, 2006)

The internal models also contain guidelines to take portfolio effects (i.e. default correlations) into account by relating them to the probability of default.

Basel II recognised credit derivatives, collateral and guarantees as tools that reduce credit risks and banks are able to reduce exposures/reduce loss given default by these instruments (however Basel also recognised that these could not fully mitigate the risks due to the

possibility of "double default" where the counterparty and the source of the risk mitigant defaulted).

Basel II covered some of the criticisms of Basel I that are covered under section 2.5.1 where there is recognition in the calculations to take into account the credit quality of the borrower (via potential of default calculations) and the type of lending (via calculations of the size of the exposure at time of default). Finally Basel II contained detailed provisions for securitisations and handling the mechanisms used for removing assets from bank balance sheets while retaining economic interest in the performance of the assets (this removed some of the loopholes that allowed regulatory capital arbitrage).

2.6.2 Credit risk models in the 1990s

Within this environment of increasingly sophisticated banking products and regulatory pressures, Structural Approach models and Reduced Form models (described below) were seen to be important in quantification, and thus control, of risks (see Altman and Saunders, 1997; International Swaps and Derivatives Association, 1998; Jackson, Nickell, and Perraudin, 1999; Basel Committee on Banking Supervision, 1999; Gordy, 2000). Interest in credit risk models was further stimulated by the suggestions that these models be accepted as a basis for banks' calculations of regulatory capital by authors such as Crouhy *et al* (2001 pp 62) and Kealhofer (1998), as well as by the International Swaps and Derivatives Association, (1998).

Earlier work in the application of credit risk modelling in banks was characterised by a dominant focus on credit scoring and static assessment of default probabilities (Altman and Saunders, 1997). However, use of credit scoring declined in the late 1990's. One of the main criticisms about credit scoring models was that, because their predominant explanatory variables are based on accounting data, these models may fail to pick up fast-moving changes in borrower conditions. Hao and Zhang (2009) find of recent finished articles since 1999, only two salient studies are found on credit scoring as opposed to the thousands on the Structural and Reduced Form approaches, and they conclude that the focus of the studies on credit risk modelling has moved from away from credit scoring.

2.6.2.1 Second-generation Structural models (1990s and after)

Extensions to the Merton approach proposed within first-generation models did not result in successful practical implementations (Black and Cox, 1976; Ho and Singer, 1982, and Mella-Barral and Perraudin, 1997). Similar to the findings of Jones, Mason, and Rosenfeld (1984) on the original Merton model, more recent empirical studies by Eom, Helwege and Huang (2002) find that all first-generation models are often unable to price investment-grade corporate bonds better than an unsophisticated model that assumes no risk of default.

This has led to further extensions and alternatives, which are still based on Merton (1974) model foundations. These models are defined by Altman *et al* (2002) as second-generation models and include the work of Kim, Ramaswamy and Sundaresan (1993), Nielsen, Saa-Requejo and Santa-Clara (1993), Hull and White (1995), Longstaff and Schwartz (1995), Leland and Toft (1996) and Collin-Dufresne and Goldstein (2001).

The original Merton model proposed that default only happens at maturity of the debt when the firm's assets are no longer sufficient to cover debt obligations. Kim, Ramaswamy and Sundaresan (1993) proposed extensions that allow for the fact that default can occur at any time between the issuance and maturity of the debt. Also, Kim, Ramaswamy and Sundaresan (1993) allowed for a default that can be triggered when the value of the firm's assets reaches a lower threshold than proposed by Merton.

In the original Merton (1974) model, interest rates are assumed to be constant. Nielsen, Saa-Requejo and Santa-Clara (1993) relax that restriction and build extensions to the Merton model that make use of default-free stochastic interest rates. From an economic perspective, it appears natural that high interest rates are correlated with harsh business conditions and thereby increased default risk. This introduces exogenous factors to the Structural Approach School. Previous to this, the Structural Approach dealt with default as internal to the company and did not consider external factors. The Reduced Form approach, on the other hand, considers default as totally external to the firm (which is normally referred to as exogenous).

Hull and White (1995) expand the Merton model by building extensions on the debt recovery by the creditors and calculate the proportion of the non-defaulted value that is repaid in the event of a default (the recovery rate). Both the probability of default and the size of the

proportional recovery are seen as random. They also try to improve the data by showing how data on bonds issued by the counterparty can be used to provide information for the model parameters. More recently Hull, Nelken and White (2004) developed an implementation of the Merton model where parameters are estimated from the implied volatilities of "options" on the company's equity and argue that these produce better results. (As inputs, the Merton model requires the current value of the company's assets, the volatility of the company's assets, the outstanding debt, and the debt maturity. The most popular way of implementing Merton's model estimates the current value of the company's assets and the volatility of the assets from the market value of the company's equity and the equity's instantaneous volatility following the approach suggested by Jones, Mason and Rosenfeld, 1984. It is suggested by Hull, Nelken and White, 2004, that this produces inaccurate results).

Leland and Toft (1996), rather than concentrating on Merton (1974), extend the ideas of Geske (1977). The firm in the Leland and Toft model continuously issues a constant stream of debt with a fixed maturity that pays continuous coupons. Coupons can be paid from the firm's net payout (this relaxes one of the restrictions in Geske, 1977). Like Geske (1977), if the payout is not enough to cover a coupon, the equity holders, as the decision-makers of the Geske model, can decide to issue new equity to service the debt. In the Leland and Toft model the default boundary is endogenous.

The Longstaff-Schwartz model (1995) considers the valuation of a coupon bond when interest rates are stochastic. The Longstaff-Schwartz model depends on the interest rate dynamics as calculated by the Vasicek (1977) interest rate model. In their model, default occurs when the asset value of the firm declines to a pre-specified boundary (they use the par value of the bond in their implementation). As a result the default boundary is defined as exogenous (external to the firm). In the event of a default, the bondholders recover a constant fraction of either the coupon or the par value of the bond.

One of the main changes of second-generation models is the development that the recovery rate in the event of default is exogenous and independent of the firm's asset value. It is generally defined as a fixed ratio of the outstanding debt value and is therefore independent of the potential of default (in first-generation models, the recovery is either zero or linked to the potential of default). Longstaff and Schwartz (1995) argue that, by researching comparable firms and looking at the history of defaults and recovery ratios, one can form a reliable

estimate of the recovery rate which can be used to extend the Merton model. The Longstaff and Schwartz (1995) model also allows for the correlation between defaults and interest rates (the original Merton model assumes constant interest rates). The Longstaff and Schwartz (1995) approach differs from the first-generation models by simplifying the bankruptcy process and exogenously specifying the cash flows to risky debt in the event of bankruptcy.

The Collin-Dufresne and Goldstein model (2001) is similar to the Longstaff-Schwartz model (1995), and is exogenous. The difference is that the Collin-Dufresne and Goldstein (2001) model is much more complex as it introduces leverage ratios (gearing) and looks at the leverage ratio as following a mean-reverting process. When the speed of the mean reversion is set to zero, the recovery is the same as the Longstaff and Schwartz (1995) model.

Despite these improvements with respect to the original Merton framework, second-generation Structural Approach models still deliver poor empirical results (Eom, Helwege and Huang, 2002). Adherents of the Reduced Form School have been particularly scathing of the Structural models (Jarrow and Turnbull, 1995; Jarrow and van Deventer, 1999). Even within the Structural School, Hull, Nelken and White (2004) write: *"A number of authors such as Black and Cox (1976), Geske (1977), Longstaff and Schwartz (1995), Leland and Toft (1996), and Collin-Dufresne and Goldstein (2001) have developed interesting extensions of Merton's model, but none has emerged as clearly superior".*

Altman, Brady, Resti & Sironi (2002) list three main drawbacks which are seen to be behind the relatively poor empirical performance of Structural models. First, they still require estimates for the parameters of the firm's asset value, which are non-observable. The current market value of most firms is not readily observable (unless it is a firm quoted in a stock market and the stock is liquid).

Second, Structural models cannot incorporate credit-rating changes that occur quite frequently for default-risky corporate debts. Altman *et al* (2002) points out that most corporate bonds undergo credit downgrades before they actually default. As a consequence, they believe that any credit-risk model should take into account the uncertainty associated with credit rating changes as well as the uncertainty concerning default.

Finally, most Structural models assume that the value of the firm is continuous in time and default is predictable and not a surprise. This however contradicts with observations in real life that defaults can exist as surprises (Duffie and Lando, 2001).

2.6.2.2 Origins of the Reduced Form models

The Reduced Form models are viewed as competing with Structural Approach models (Altman *et al*, 2002; Giesecke, 2003; Eom, Helwege and Huang, 2002), and there is currently a heated debate in the credit risk profession as to which of these two model types are appropriate for default prediction and in the hedging of credit risks (Bohn, 2000)

Reduced Form models have their roots in mortality models within the insurance industry and are based on statistics and stochastic processes where hazard rates or default intensities are calculated. Reduced Form models fundamentally differ from standard Structural Approach models with respect to the degree of predictability of the default. A typical Reduced Form model assumes that the probability of default over any time interval is non-zero. Default occurs when the random variable undergoes a discrete shift in its level. These models treat defaults as unpredictable Poisson events (the Poisson distribution can be derived as a limiting case of the binomial distribution and can be applied to systems with a large number of possible events, each of which is rare. An example commonly used is the nuclear decay of atoms.). The time at which the discrete shift will occur cannot be foretold on the basis of information available today.

Because Structural Approach models look at the assets of the firm, the default process is an endogenous one while in the Reduced Form models, the default process is an exogenous one which is external to the firm[9].

2.6.2.3 Development of Reduced Form models

The first published Reduced Form model within credit risk appears to be Jarrow and Turnbull (1995, hereafter referred to as JT). They developed their Reduced Form model to look at

[9] there are exceptions to this with the Longstaff and Schwartz (1995) model, the Colin-Dufresne and Goldstein (2001) model and the Nielsen, Saa-Requejo and Santa-Clara (1993) building extensions to the Merton model that make use of exogenous factors, while Duffie & Lando (2001) and Cetin *et al* (2004) have been able to obtain Reduced Form models in which the intensity of default is not given exogenously, but determined endogenously.

risky bonds[10] modelled as foreign currency bonds denominated in "promised" dollars (this is based on their work in Jarrow and Turnbull, 1992). The exchange rate equals 1 if default has not occurred and equals the recovery rate if it has. This framework allows for a variety of specifications for the default risk-free rate process, making the model quite flexible along this dimension.

JT assume that the Loss Given Default (LGD) is constant (Loss Given Default or LGD is the measurement of loss at the point of default) and that the default (stopping) time is exponentially distributed. The default time distribution in the JT model is parameterised by what they term a hazard rate (default intensity). They further assume that in the default-free rate process, the hazard rate process and the LGD function are mutually independent. While their ideas were well received (Bohn, 2000), the assumptions of a constant default intensity or that the hazard rate process and the LGD function are mutually independent have proven to be unrealistic (Cetin, Jarrow, Protter and Yıldırım, 2004). While the JT specification implies that default is a Poisson arrival making the model easier to estimate, in reality firms normally have different default intensities depending on the time horizon being considered (e.g., even a AAA counterparty, which has low default intensities today, could have higher default intensities in the distant future as there is potential for future problems).

Jarrow, Lando, and Turnbull (1997, hereafter referred to as JLT) overcame the weakness in JT by presenting a more sophisticated Reduced Form model by assuming the default time follows a continuous-time Markov chain. This Markov chain is specified with K states (where states 1 to K-1 could be associated with credit ratings, 1 being AAA and the K^{th} state being D, which is the Standard & Poor's default rating). Default happens the first time that the chain hits the absorbing state K (default state). They suggest the use of historical transition probability matrices available from companies like Standard and Poor's (this data would be an expanded version of Table A found in section 2.6.2.2 of this thesis, where additionally there would be probability numbers for credit migrations to different credit ratings). In this case, the default process is modelled as a finite-state Markov process in the firm's credit ratings. While these historical matrices are easily obtained, the empirical validity of this approach has yet to be proven. Mathematical tractability, not economics, drives the choice of how to specify a Reduced Form model.

[10] Risky bonds are defined as bonds that carry credit risk (normal bonds) as opposed to risk free bonds where there is no risk of default. The risk free bond rate is useful as a benchmark that is used to calculate the credit spread on a Risky bond.

JLT also combine this Markov chain specification with LGD, characterised as a fraction of an otherwise similar default-risk-free claim. This specification nests (loops around) the simpler JT model (i.e. default follows a constant hazard rate or Poisson arrival process) and provides the opportunity to specify a more realistic evolution of default intensity. The increased flexibility comes at a cost of estimation difficulty. The Markov chain greatly increases the number of parameters to be estimated, as the model requires specification of an entire generator matrix to arrive at transition probabilities for each possible change in state.

Duffie and Singleton (1999, hereafter referred to a DS) introduce a slightly different type of Reduced Form model, where the default process is modelled as a stochastic hazard rate process where the hazard rate indicates the conditional rate of the arrival of default. Nothing is assumed about the factors generating this hazard rate. DS use their model to value risky debt as if it were default-risk free by replacing the usual short term default-risk-free rate with the default-adjusted, short-rate process. Their model is distinguished by the parameterisation of LGD in terms of the fractional reduction of the market value of the debt that occurs upon default. They then present examples of how to specify a Reduced Form model in the context of popular default-risk-free term structure models (e.g., Heath, Jarrow, and Morton, 1992). The advantage of this specification is that currently-available term structure models for default-risk-free debt can be applied to this problem with little adjustment. Using available credit-spread data, an implied risk-neutral mean loss rate can be estimated. DS also introduce liquidity effects or a liquidity premium within their model. There are also alternative specifications possible of the DS model focusing on different assumptions regarding the processes governing the following:

- Default process embodied in the hazard rate
- Default-risk-free process embodied in the short rate
- LGD process embodied in the fractional reduction (of the debt's market value rather than the face value).
- A fractional carrying-cost process

These estimates can then be used to price other debt and credit derivatives. A particularly thorny problem in this framework involves disentangling the hazard rate and the LGD. Without a wide range of debt securities deriving value from the same issuer (e.g., liquidly traded bond or credit derivatives), the components of the mean loss rate cannot be estimated

separately. Given the scarcity of data in this field, efficient estimation of each individual parameter in this modelling framework can be a daunting task.

Cathcart and El-Jahel (1998, hereafter referred to as CEJ) present an example of a Reduced Form model that uses some of the Structural Approach concepts. In their model, default occurs when a signalling process hits some constant barrier (similar to the concept in the Structural Approach that the firm's asset value is a trigger). The CEJ model assumes a signalling process for each firm that determines the occurrence of default rather than the value of the assets of the firm. When the signalling variable drops below the default barrier, bondholders receive an exogenously specified number of risk-free bonds. The underlying interest rate is assumed to follow a mean-reverting square root process that is uncorrelated with the signalling process. An analytical defaultable bond price solution is derived from the model. They argue anecdotally that their model produces credit spread term structures more consistent with observed credit spreads than other formulations. However, these claims are yet to be tested rigorously.

A paper by Lo and Hui (2003) looked at extending the CEJ model for defaultable bond valuation. Their extension incorporates a default barrier with dynamics depending on the volatility and the drift of the signalling variable (it can be likened to a moveable bankruptcy barrier). The level of the barrier is adjusted by a free parameter. The numerical results calculated from the solution show that the risk adjustable default barrier has a material impact on the term structures of credit spreads and provides potential new insight for future research on defaultable bonds analysis and credit risk modelling.

2.7 Banking in the 2000s

The trend in banking consolidation continues to increase in the 2000s as do transactional volumes. Choi, (2002), finds that at the end of 2000 there were record levels of financial services transactions, with a market to the value of $10.5 trillion, the top ten banks estimated to have commanded a market share of more than 80%, and the top five banks 55%. Valdez and Molyneux (2001, p. 266) find that part of the volume increase was because "*a whole range of financial market participants were incentivised to take more risk to obtain greater return*". There were several triggers for the consolidations, including: competitors interested in adding market share, the spread of upscale retail banking as a dominant service-delivery

method and a quest for global reach. There were many examples of bank acquisition and merger during this period including:

- RBS acquired NatWest in the UK (completed in 2000)
- US-based Chase Manhattan acquired Robert Fleming Holdings in the UK, and also soon after merged with J.P. Morgan & Co. Inc (2000)
- Japan-based Sanwa, Tokai, and Asahi banks merged into Sanwa Bank (2000)
- BNP merged with Paribas in France to form BNP Paribas and then purchased BancWest of Hawaii (2001)
- Switzerland-based UBS AG purchased Paine Webber in the US (2001)
- Japan-based Bank of Tokyo Mitsubishi, Mitsubishi Trust, Nippon Trust, and Tokyo Trust banks merged to form the Mitsubishi Tokyo Financial Group (2001) in Japan
- US-based Citigroup Inc merged with Golden State Bancorp (2002),
- US-based Bank of America Corp. merged with FleetBoston Financial Corp. (2004)
- US-based J.P. Morgan Chase & Co. merged with Bank One (2004)
- US-based Bank of America merged with MBNA Corporation (2005)
- Italian UniCredit and Capitalia banks merged and became the second largest bank in Europe after HSBC (2007)
- ABN Amro N.V in the Netherlands was acquired, in what was at that time the biggest bank takeover in history, by a consortium made up of the Royal Bank of Scotland Group in the UK, Fortis bank in Belgium and Banco Santander in Spain (2007)

There were also a number of mergers due to the financial crisis. Some banks' failure or near-failure combined with government influence and healthier banks taking the opportunity to purchase assets cheaply resulted in the following mergers:

- JPMorgan Chase and Bear Stearns (2008)
- JPMorgan Chase and Washington Mutual (2008)
- Bank of America and Merrill Lynch (2008)
- Wells Fargo and Wachovia (2008)
- Lloyds TSB and HBOS in the UK (2008)
- Nomura purchased Lehman Brothers' assets in Asia and Europe (2008)
- Barclays Bank purchased Lehman Brothers' assets in the US (2008)
- Commerzbank and Dresdner Bank in Germany (2008)

The 2000s also sees continued growth in the shadow banking system. While there are no officially-published global statistics on the shadow banking system, Maltz provides some evidence that in 2007 in the US, the innovative sectors of the financial system including the shadow banking system accounted for nearly 40% of total intermediation, with traditional banking shrinking to just over 60% (Maltz 2011 p 18). Also, data sourced from Wikipedia[11] shows that by the end of 2001 the market capitalisation of the world's 15 largest financial services providers included four non-banks.

The 2000s sees the continued rise in banking regulations. Section 2.7.2 covers specific credit risk related regulation but is it important from a banking context to draw attention to the growth of thousands of pages of regulations that the banks had to comply with including the Markets in Financial Instruments Directive (MiFID), the Payment Services Directive (PSD), The Dodd–Frank Wall Street Reform and Consumer Protection Act, the Foreign Account Tax Compliance Act (FATCA) and the Volcker Rule. The new regulations meant increasing levels of effort and costs were spent on meeting these new requirements. This section of the thesis does not attempt to explain these regulations except to make the reader aware of the increase of regulation at this period of time.

The main area that dominated banking in the 2000s was the financial crisis that started in 2007. The financial crisis is also commonly referred to as the "subprime crisis". This is because the crisis started from the subprime residential mortgage sector in the United States but spread to the entire world causing a significant number of failures in financial institutions. This forced governments to bail out a large number of banks as well as influence healthier banks to rescue those that were in trouble. The FSA report on investigations into one of these banks that were bailed out, the Royal Bank of Scotland's (RBS) in the UK, find that the RBS failure had imposed large costs on UK citizens (FSA, 2011). To prevent the collapse of RBS, the UK government injected £45.5bn of equity capital. The report stresses that this loss is only a small part of the cost resulting from the financial crisis. The larger costs arose from the recession which resulted from that crisis, within which RBS's failure played a significant role. The report holds that that recession caused unemployment for many and losses of income and wealth. The following section, 2.7.1 covers the financial crisis in detail.

[11] As found in http://en.wikipedia.org/wiki/History_of_banking

2.7.1 Late 2000s financial crisis

The late 2000s financial crisis caused significant stress on banks around the world. Several causes for the financial crisis have been suggested. The European Commission in their report of the crisis find that the relatively benign period of low interest rates and high liquidity in the late 1990s and early 2000s allowed too-rapid credit expansion and this was one of the large causes of the crisis (European Commission, 2009). Strong macro-economic growth over this period with low inflation meant that many governments did little to curb the credit expansion. However this excess liquidity showed up in rapidly rising asset prices. This was particularly seen in the US where very low US interest rates helped create a widespread housing bubble. This was fuelled by insufficiently regulated, complex securitisation financing techniques.

Strong political pressure on US-government-sponsored entities like Fannie Mae and Freddie Mac to promote home ownership for low income households aggravated the situation. While personal savings in the US dropped from 7% of disposable income in 1990 to below zero in 2005, consumer credit and mortgages expanded rapidly. In particular, subprime mortgage lending in the US rose significantly from $180 billion in 2001 to $625 billion in 2005 (European Commission, 2009).

The US Financial Crisis Inquiry Commission report published in January 2011 (also known as the Angelides Commission) found that recognition of calculated profits which the accounting rules allowed led both to a view that risks were falling and to increases in financial results. This was allowed to happen in part because there was no restriction on leverage, but instead limits on the ratio of capital to 'risk-weighted' assets. But the supposed risk weights turned out to be unreliable measures of risk in that they were going down when risk was in fact going up (Vickers, 2011). This combination, when accompanied by constant capital ratios, resulted in a fast expansion of balance sheets and made institutions vulnerable to changes in valuation as economic circumstances deteriorated (Financial Crisis Inquiry Commission Report, January 2011). Added to this, the extreme complexity of structured financial products, sometimes involving several layers of CDOs, made proper risk assessment challenging for even the most sophisticated financial companies in the market.

The financial crisis when it occurred developed very quickly and dramatically '*...when the housing market went south, the models on which CDOs were based proved tragically wrong. The mortgage-backed securities turned out to be highly correlated — meaning they performed*

similarly. Across the country, in regions where sub-prime and Alt-A mortgages were heavily concentrated, borrowers would default in large numbers. This was not how it was supposed to work. Losses in one region were supposed to be offset by successful loans in another region. In the end, CDOs turned out to be some of the most ill-fated assets in the financial crisis. These players had believed their own models and retained exposure to what were understood to be the least risky tranches of the CDOs: those rated triple-A or even 'super-senior,' which were assumed to be safer than triple-A-rated tranches.' Financial Crisis Inquiry Commission (2011, p. 71)

Another issue that aggravated the financial crisis was the lack of transparency and the build up of the shadow banking system. There was little knowledge of either the size or location of credit risks. While securitised instruments were meant to spread risks more evenly across the financial system, the nature of the system made it impossible to verify whether risk had actually been spread or simply re-concentrated in less visible parts of the system. This contributed to uncertainty on the credit quality of counterparties, a breakdown in confidence and, in turn, the spreading of tensions to other parts of the financial sector.

Other than innovation on the securitisation having a large part to play in the cause of the crisis, financial innovation in the 1990s and 2000s especially in the derivatives markets was also seen as a cause of the financial crisis, as it amplified the excessive liquidity. The explosive growth of the over-the-counter credit derivatives markets, which were supposed to mitigate risk, in fact added to it (European Commission 2009).

The Walker Report (2009) and the Financial Crisis Inquiry Commission (2011) showed that many of the checks and balances of corporate governance also failed. Many boards and senior management of banks (and shadow banks) neither understood the characteristics of the new, highly complex financial products they were dealing with, nor were they aware of the aggregate exposure of their companies, thus seriously underestimating the risks they were running. As such many board members did not provide the necessary oversight or control of management. Subsequently the shareholders were unaware of some of the credit risks faced by these organisations.

Remuneration and incentive schemes within banks contributed to excessive risk-taking as they were based on rewarding short-term expansion of the volume of more risky trades rather than

investments based on long-term profitability (Walker Report, 2009). This finding is shared in the Financial Crisis Inquiry Commission (2011) who found that the bonus compensation systems in banks were designed in an environment of cheap money, intense competition, and light regulation and often rewarded the short-term gain without proper consideration of long-term consequences. Shareholders' pressure on management to deliver higher share prices and dividends for investors also meant that exceeding expected quarterly earnings became a key performance measurement for a company.

The Financial Crisis Inquiry Commission (2011) finds that there were also failures in financial regulation and supervision. Deregulation and faith of the regulators in banks being self-regulating and a belief in the correcting nature of the markets meant that key regulatory safeguards were not available. *"The sentries were not at their posts"* (Financial Crisis Inquiry Commission, 2011 p. 20). The regulators were not fully to blame as *"various legal structures that the banks had created off balance sheet in order to engage in the securitization business shielded much of this activity from the regulators"* (Valdez and Molyneux (2010 pp 267).

The financial crisis was compounded by financial institutions and supervisors substantially underestimating liquidity risk. What looked like an attractive business model in the context of liquid money markets and positively-sloped yield curves (borrowing short and lending long) turned out to be a dangerous trap once liquidity in credit markets dried up and the yield curve flattened.

Another area that has been identified as an area that contributed to the crisis was an over-reliance on value-at-risk (VaR) models and credit risk models which were based on the reliance of forward-looking risk that was mainly drawn from the observation of past patterns of price movement (FSA 2011). The FSA report that examined the RBS failure found evidence that there were also weaknesses in model validation processes (FSA 2011). Other model issues include model-based risk assessments underestimated the potential default risk at the time of the financial crisis as many relied on incorrect credit ratings. They underestimated exposures to common shocks and tail risks and they overestimated the recovery rates on collateral. This meant there was significantly understatement of the overall risk exposure. Stress-testing was often based on mild or even wrong assumptions as many banks were using historic data based on benign economic conditions. The Financial Crisis Inquiry Commission (2011) found that *"Financial institutions and credit rating agencies embraced mathematical*

models as reliable predictors of risks, replacing judgment in too many instances. Too often, risk management became risk justification".

In September 2008, the crisis reached a major milestone with the failure of Lehman Brothers and the collapse of the insurance giant American International Group (AIG). Panic spread due to the lack of transparency of the balance sheets of the banks and financial institutions and the market being aware of the tangle of interconnections among financial institutions, causing the credit markets to seize up (Financial Crisis Inquiry Commission, 2011). The financial system was on the point of seizing up. There was very little liquidity in the market, trading ground to a halt and the global stock market plunged. Realising that the world's economy was plummeting into a deep recession, the main world's governments via the G20 took coordinated actions which included the lowering of interest rates to stimulate the markets and via unprecedented fiscal injection (estimated to total US$5 trillion at the end of 2010),. The main central banks of the world also took coordinated actions to help increase liquidity to banks. Governments prevented banks from failing because the alternative of allowing them to go bankrupt was regarded as intolerable. Vital banking services, the continuous provision of which is imperative, would have been disrupted at potentially enormous economic and social cost (Vickers, 2011). There were a number of government bailouts in banks in 2008 (for example Northern Rock, Bradford and Bingley, Lloyds TSB and RBS in the UK, Anglo Irish bank and Allied Irish banks in Ireland, Fannie Mae, Freddie Mac, Bank of America, JP Morgan, Goldman Sachs and Morgan Stanley in the US, and WestLB, HSH Nordbank and Commerzbank in German) as well as government pressure on healthier banks to merge with banks in trouble (as shown in section 2.7).

As a result of the financial crisis, a number of recommendations have been provided by the commissions that were set up to investigate it. A common theme has been in strengthening corporate governance. The Walker Report (2009 p.1) states that "*given that the overriding strategic objective of a Bank or Financial Institution is the successful management of financial risk, board-level engagement in risk oversight should be materially increased, with particular attention to the monitoring of risk and discussion leading to decisions on the entity's risk appetite and tolerance*". The Walker report also recommended there should be an independent board risk committee and that in preparing advice to the board on its overall risk appetite, tolerance and strategy, the board risk committee should ensure that account has been taken of the current and prospective macroeconomic and financial environment. As part of

the Walker Report's support of board-level risk governance, it states that a bank board should be served by a CRO who should participate in the risk management and oversight process at the highest level on an enterprise-wide basis and have a status of total independence from individual business units. Within the context of stress testing, the board risk committee and board should understand the circumstances under which the entity would fail and be satisfied with the level of risk mitigation that is built in and the actions that would be taken in such circumstances (Walker Report, 2009).

2.7.1.1 Risk appetite

The FSA (2006) report and the Walker Report (2009) raised the fact that the process around decisions on the entity's risk appetite was an important area to improve in a bank. A finding from this research in section 7.2.1.2 was that the participants saw a need to align their risk models to the strategy of the bank as expressed via the risk appetite in the bank. This section of the literature review looks at risk appetite in more detail.

The International Standards Organisation (ISO) in their ISO 31000 guide-73, defines risk appetite as the "*amount and type of risk that an organisation is willing to pursue or retain*" (ISO, 2009). The British Standards Institute (BSI) in their BS31100 guide defines risk appetite as the "*amount and type of risk that an organisation is prepared to seek, accept or tolerate*" (BSI, 2008). While both definitions explain that risk appetite is an expression of the amount and types of risk that an organisation is willing to accept, it does not have a lot of detail and it does not link the risk appetite to the strategic objectives of the firm, which may have a large influence on the appetite of the firm in avoiding risk or taking risk. A recent paper by the Institute of Risk Management covers the link between risk appetite and the strategy and objectives of the bank and defines risk appetite as "*the amount of risk that an organisation is willing to seek or accept in the pursuit of its long term objectives*" (Institute of Risk Management, 2011).

The most appropriate definition found in this research is provided by the Senior Supervisors Group (SSG) which is a group made up of the regulators in ten of the world's largest economies (with the exception of China) who provide the following definition "*Risk appetite is the level and type of risk a firm is able and willing to assume in its exposures and business activities, given its business objectives and obligations to stakeholders. Risk appetite is generally expressed through both quantitative and qualitative means and should consider*

extreme conditions, events, and outcomes. In addition, risk appetite should reflect potential impact on earnings, capital, and funding/liquidity" (Senior Supervisors Group, 2010). Other than covering the areas mentioned in the ISO, BSI and Institute of Risk Management definitions, the SSG definition is useful as it brings in stakeholders, qualitative and quantitative measures as well as covering the need to handle extreme events that have a large impact on the bank as well and providing some guidance on areas of potential impact.

Risk appetite is interlinked with the strategy of a bank and is the part of the strategy that defines the types and maximum quantity of risk that the bank is willing to pursue in achieving its strategic goals, and it communicates this to the stakeholders (staff, shareholders, bondholders, customers and regulators). It acts as a monitoring as well as a control mechanism. If the risk appetite threshold has been breached, there should be risk management actions and business controls to bring the exposure level back within the accepted range. The risk appetite therefore influences behaviour and is an important consideration for this research.

Regulators like the U.K's Financial Services Authority have commented on the importance of the risk appetite: "*Risk appetite defines the level and nature of risks to which the board considers it is acceptable to expose the firm. It therefore defines the boundaries of activity that the board intends for the firm. It is an essential component of risk frameworks.*" (FSA 2006, p4). The Financial Services Authority also comments that the concept of risk appetite "*is not well understood*" in the financial sectors (FSA, 2006, p5). This is also supported in research into risk appetite by Ashby and Diacon (2009) who find that the principal challenges in the creation of a risk appetite statement are in achieving management understanding of the concept of risk appetite and the difficulty in incorporating risk exposure numbers into ill-defined risk appetite statements. The Association of Insurance and Risk Managers in Industry and Commerce finds that while risk appetite is now common in corporate reporting, with many organisations broadcasting their appetite for risk in public statements and annual reports, a general understanding of the conceptual meaning and more importantly practical implementation of risk appetite remains elusive (AIRMIC, 2009).

There are many frameworks for the implementation of risk appetite found in practice. Many of these are provided by consultancy groups. To illustrate an example of a framework

common in practice is figure 2.3 which shows the Ernst and Young (2010) framework (note similar frameworks exist in PWC, Oliver Wyman and KPMG)

Figure 2.3 Risk appetite framework from Ernst & Young

The risk appetite framework from Ernst and Young shows how the capital and the strategic goals of the company link into a risk appetite level across four main risk categories which are strategic, compliance, operations and financial (this is similar to a COSO, 2004 framework where the four objectives categories are strategic, operations, reporting, and compliance) . This is then translated into risk targets which are used to determine risk limits. The framework provides a cohesive approach where capital usage and strategic objectives are translated to risk limits that can be monitored. Where the framework could be improved is in the level of detail on the quantitative and qualitative monitoring and controls as well and as how model-derived information or stress testing fits into the framework. Finally, while capital (shareholder value) is shown as a driver, it is not clear in the framework how other stakeholders influence the framework.

Other than the frameworks promoted by the consultancy firms, another framework that can be utilised is one provided by the Institute of Risk Management (2011) which analyses the BSI

(2008) BS31100 guidelines. Using BS3110 paragraph numbers as a guide, the following can help establish the risk appetite policy and framework in an organisation.

Paragraph 3.1 The risk management framework should have "defined parameters around the level of risk that is acceptable to the organisation, and thresholds which trigger escalation, review and approval by an authorised person/body."

Paragraph 3.3.2 Content of the risk management policy has explicit reference to risk appetite saying that this should be included in the policy and should outline "the organisation's risk appetite, thresholds and escalation procedures".

Paragraph 3.8 on risk appetite and risk profile provides comprehensive commentary on risk appetite and these are:

- "Considering and setting a risk appetite enables an organisation to increase its rewards by optimizing risk taking and accepting calculated risks within an appropriate level of authority"
- "The organisation's risk appetite should be established and/or approved by the board (or equivalent) and effectively communicated throughout the organisation"
- "The organisation should prepare a risk appetite statement, which may:
  - "provide direction and boundaries on the risk that can be accepted at various levels of the organisation, how the risk and any associated reward is to be balanced, and the likely response"
  - "consider the context of the organisation's understanding of value, cost-effectiveness of management, rigour of controls and assurance process"
- "Define the control, permissions and sanctions environment, including the delegation of authority in relation to approving the organisation's risk acceptance, highlighting of escalation points, and identifying the escalation process for risk outside the acceptance criteria, capability or capacity";
- "Be reflected in the organisation's risk management policy and reported upon as part of the organisation's internal risk reporting system;
- "Include quantitative statements, described as limits, thresholds or key risk indicators, which set out how certain risks and their rewards are to be judged and/or how the aggregate consequences of risks are to be assessed and monitored.
- "The risk appetite should be monitored by the Board (or equivalent) and formally reviewed as part of the organisation's strategy and planning process. This should consider whether the organisation's risk appetite remains appropriate to deliver the organisation's objectives in light of internal and external drivers and constraints."

While the BS31100 standards are a loose framework and may not have the explicit linkages between strategic goals of the company to risk targets, it does provide an over-arching framework that includes a lot of detail on best practice and guidance on the implementation of a risk appetite framework. Where the framework could be improved is that it mainly covers quantitative monitoring and controls rather than looking also at qualitative monitoring and controls. Like the Ernst and Young framework, it also could be enhanced by including more detail on the use of models and of stress testing.

One issue that has sparked quite a lot of comment in the literature is whether an organisation should set its appetite for risk using a top-down or bottom-up approach. A top-down approach is where risk appetite is determined by the board and cascaded down the organisation. A bottom-up approach is where expressions of risk appetite at ground level are aggregated to develop an overall appetite for risk. Most of the recent literature including the BSI (2008), Institute of Risk Management, (2011) and Ashby and Diacon (2009) appear to take the view that a top-down approach is best. This is on the grounds that the top-down approach helps to reinforce the governance and risk culture of an organisation by setting an appropriate 'tone from the top'.

2.7.2 Regulation changes in the 2000s (in relation to credit risks)

As mentioned in section 2.6.1, the Basel II regulations were first discussed in 1996; the directive was published in 2004 and implemented in banks in 2006. Bank regulation does not adapt continuously to achieve the most efficient outcome; it reacts to extreme circumstances. Like Basel I before it, a number of changes have been made to Basel II since publishing the regulations. Much of this came about as an outcome of the findings on the financial crisis, but there were also the normal fine-tuning of the rules.

Most observers believe that Basel II came too late and banks were already too highly-leveraged (see section 2.7.1 on the financial crisis). Some feel that Basel II rules amplified the financial crisis. Greenbaum and Thakor (2007) state a concern that capital requirements under Basel II are possibly to be procyclical. The reason is that the accord seeks to link capital requirements closely to risks and as risks increase, the capital requirements will increase. However actual risks are not observable and are estimated via the use of models. Models tend to provide higher estimates of risks in a downturn and lower estimates in an

upturn. However it is not obvious that risks increase in downturns or decrease in an upturn. In fact risks may well be increasing in an upturn when imbalances that generate the next recession are building up (Greenbaum and Thakor 2007 p 511). This is supported by Ayuso, Pérez and Saurina (2004) who find that it is at least arguable as to whether credit risks really worsen in the course of an economic downturn. Taking changes in credit risk as a change in the probability density function associated with future credit earnings, it is not clear why risk changes, and if it changes whether it actually does so in that predicted direction. It is also conceivable, instead, that banks simply assume high risks in a boom which then materialise in the following downturn.

A criticism of Basel II is that it has its roots in the general problem of risk measurement models. Within the traditional risk modelling methods, forecasting requires historic data which may not be fully comparable with current conditions and what will happen in the future. Further, when estimating risk, there is always the problem when using methods based on mean and standard deviation, it does not focus on the tails of the distribution where credit default occurs. Valdez and Molyneux (2001, p. 471) find "*There are obvious major weakness in risk measurements that rely too slavishly on risk distributions. It has seemed that risk managers too readily ignore the extremes of distributions*".

Work started on Basel III at the end of 2007. The Vickers Report (2011) which looked at the financial crisis, supported the changes to be made in Basel III and believes it will strengthen the regulation, supervision and risk management. It specifically mentions that the main improvement will be by improving the banking sector's ability to absorb shocks arising from financial and economic stress and also strengthens the transparency and governance in banks and disclosure standards of banks. The complete regulation is expected out in January 2013. For credit risk, most of the changes are already known for Basel III as these have been discussed extensively since 2008. Some of the changes for Basel III have been already been phased into the implementation of Basel II as part of Capital Requirements directive in Europe (called CRD II and CRD III). The Basel III changes include the introduction of a capital charge for mark to market fluctuations in counterparty valuation adjustment (CVA) and with incentives to reduce counterparty risk via the use of CDSs. Basel III encourages the use of centralised clearing by penalising capital required for OTC derivatives including CDSs. Another change is that under Basel II there wasn't much clarity on how to handle "wrong way risk", where there is a high correlation between credit losses on a structured product and seller

offering the protection. Under Basel III, the treatment is more prescriptive with the capital charge increased for the position. Finally Basel II contained details of reducing capital arbitrage via the use of securitisations. As explained in 2.6.1, the financial crisis highlighted some issues with ratings and some highly-rated securitisations had favourable treatments when in fact they should have never have been rated as highly. Basel III has increased the capital requirements for these securities.

2.7.3 Review of the empirical results on models

As this research looks at risk models, this section examines the empirical evidence available on the Structural Approach and the Reduced Form Approach.

2.7.3.1 Empirical evidence from Structural Approach

While there have been a lot of papers generated by the Structural Approach school and stimulated by the original Merton (1974) paper, the empirical testing of these models is quite limited (see Eom, Helwege and Huang, 2002). Indeed, only a few papers actually implement a structural model to evaluate its ability to predict prices or spreads (part of the reason may be that reliable bond pricing data has only recently become available to academics).

In cases where empirical studies exist, they do not always find support for the models and several conclude that the models severely under-predict spreads. The work from Eom, *et al* (2002) finds that contrary to the previous empirical literature, the difficulties are not limited to the under-prediction of spreads. Eom *et al* find that the Merton (1974) and Geske (1977) models generate spreads that are too narrow on average, as previous studies have indicated, but the Longstaff-Schwartz (1995), Leland and Toft (1996), Collin-Dufresne and Goldstein (2001) models generate spreads that are too high on average. Moreover, Eom, *et al* find most of these models suffer from the problem that predicted spreads are often either too narrow or too large, while the average spread prediction error is not particularly informative.

Other empirical research that has produced discouraging results are work by Jarrow, van Deventer and Wang (2003) and by Mishra, Kulkarni and Thakker (2008) which looked at evidence based on research of Indian data.

Discussion and research has also been stimulated on whether the Merton model, with all the refinements by first and second-generation models, explains sufficiently the default probabilities. Two papers that dispute this are Falkenstein and Boral (2001) and Frey, McNeil and Nyfeler (2001). To quote Falkenstein and Boral (2001, p. 5) *"It is purely an empirical issue as to whether the Merton model, with all the refinements to interest rates, liability structure, default points, and other inside-the-box adjustments, says everything there is to say about default probabilities. Our data suggest it doesn't."*

2.7.3.2 Empirical evidence from Reduced Form models

Similar to the circumstances found with Structural models, few empirical studies have been undertaken on Reduced Form models. These models require that credit spread data accurately reflect market expectations about risk, recovery, and liquidity. Credit spread data can be noisy and there can be difficulty in finding credit spreads for certain regions, instruments and maturities. Questions also remain on whether the more complicated Reduced Form models are designed to fit noise better or uncover systematic relationships. Research has been done by Duffee (1996) based on a JLT model where he finds strong evidence of misspecification, with the model having particular difficulty in handling investment-grade bonds with different credit risk profiles. Including non-investment grade bonds magnifies the issue due to the humped and downward-sloping term structures that are commonly observed (see Sarig and Warga, 1989). While on average the model appears to fit investment-grade, corporate bond prices "reasonably" well, there are issues with non-investment grades as well as instruments other than corporate bonds. Duffee did provide some empirical evidence of the models partially working but concludes that *"This paper reports discouraging news. Single-factor models of instantaneous default probabilities such as the square root model examined, face a substantial challenge in matching the dynamic behaviour of corporate bond term structures.... Additional discouraging news is that models of instantaneous default risk have a very limited ability to price instruments that have payouts that depend on multiple firms" (Duffee, 1996, p. 26).*

A working version of a Reduced Form model is provided by Duffie and Singleton (1997) who use defaultable swap yields based on Telerate data (which represent average bid and ask rates quoted by large dealers) from January 4, 1988 through October 28, 1994). They expressed the default-adjusted discount rate as the sum of two independent square-root diffusions, of which one part drives credit risk and the other, liquidity risk. They use this to calculate implied risky

zero-coupon bond yields. By subtracting the corresponding U.S. treasury zero-coupon yields (i.e. credit-risk-free yields), they are able to arrive at implied, defaultable swap spreads. They study these spreads in the context of a multivariate vector auto-regression with proxy variables for credit risk (using spread between Baa and AAA-rated commercial paper) and liquidity (using spread between the generic three-month repo rate for the ten-year treasury note and the repo rate of the current on-the-run treasury note). One of their findings is that liquidity shocks are short-lived, while credit shocks have little short-term impact followed by significant long-term impact. Bohn (2000) supports the Duffie and Singleton (1997) work and feels the DS model does a reasonable job of fitting the swaps yields, with the exception of the short-end of the term structure. However further research by Duffee (1999), using the DS model, finds that these models have difficulty in explaining the observed term structure of credit spreads across firms of different qualities. The reason may be from incorrect statistical specifications of default probabilities and interest rates or may be due to more fundamental issues in the model's inability to incorporate some of the features of default. Duffee also finds that the DS model has difficulty matching all the important features of actual corporate bond yield spreads, especially for both relatively flat yield spreads and steeper yield spreads.

Diaz-Ledezma and Gemmill (2003) provide some empirical support to the CEJ model described in section 2.6.2.2 by testing using sovereign Brady bond data. They find the CEJ model performs better than a simple Structural Merton model, implying better results from Reduced Form models. However their study is somewhat limited by their choice of Structural model and does not prove conclusively that Reduced Form models are better than Structural models.

Although there is a plethora of papers on risk models and on Structural and Reduced Form models, there is a lack of empirical work checking the validity of Reduced Form models and of Structural models.

2.8 Gap in the literature and research goal

While there have been papers that have discussed and compared at a high level the models within banks, notably Jackson and Perraudin (1999); Lopez and Saidenberg (2000) and Crouhy, Galai and Mark (2000), these papers themselves did not specifically look at the use of credit risk models in practice. There have also been high level surveys undertaken by the

regulators, such as the paper from the Basel Committee on Banking Supervision (2000) which was part of the research done in preparation for Basel II. The survey included sections that asked banks about their use of credit risk models. However the questions were at a fairly high level and the paper did not seek to explain how and why these models were used.

As shown in the review of the empirical evidence in Section 2.7.3, there is very limited validation of the models, and it is difficult if not impossible to show how these models are used in banks and demonstrate conclusively if one model is more or less superior to another. Most of the papers written in this area are theoretical, and while they are well argued, they are not based on observations or empirical evidence (see Falkenstein and Boral, 2001; Frey, McNeil and Nyfeler, 2001; and Rebonato, 2007). Many of the papers written are based on sophisticated mathematics to argue specific extensions to models, assuming that the results from the output of the models will self-evidently guide risk management choices. Rebonato argues that in reality how management uses the output of these models has not been fully researched and is not known (Rebonato, 2007 p 27, p67).

Importantly, there is no research available on management attitude, understanding or reliance in the use of these models. It could be that instead of relying on the models, management relies on experience, intuition or guesswork to make risk decisions. Without knowledge of how these models are used in practice, deciding on the appropriate model and deciding on appropriate actions based on model output remains a difficult task for academics, credit risk managers and regulators. As a result of the financial crisis, a number of commissions were set up to investigate it and they have raised questions on some of the governance in the banks, the processes around risk appetite, regulatory management in banks, model issues and use of models.

This research looked at the gaps identified in the literature review with a goal of "better understanding the use of credit risk models in banks". As shown in the introduction section (1.2), this has been phrased as the research problem: "To understand in practice the overall framework for the use of credit risk models in banks, to study the preferences of banks, if any, to particular credit risk model approaches (Structural versus Reduced Form), how and why the models are used and how outputs of these models are used in management decisions".

The next chapter of the thesis, chapter 3, covers why it is appropriate to use qualitative research to research this gap, details the research design, gives information on the background to the research participants, the tools used to gather the data, the analysis methods utilised and the method for presenting findings.

3 Research methodology

3.1 Introduction

As shown in the literature review in Chapter 2, there is a gap in our knowledge about the actual use of models in banks. Most of the academic research into credit risk models is quantitative and starts from a basis that one school of modelling is superior and more precise than the other (see Nickell, Perraudin and Varotto, 1998; Jarrow. and Turnbull, 2000; Rebonato, 2007). Without knowledge of how and why these models are used in practice, deciding on an appropriate model and deciding on appropriate inferences and actions based on a model's output can be a difficult task for academics, credit risk managers and regulators.

In order to research the existing gap in the literature and answer the research questions (found in section 1.2), this chapter explains why a qualitative research using case study methodology is an appropriate method for researching the use of these models. After this introduction, sections 3.2 and 3.3 cover respectively the ontological basis and epistemology of the research. Section 3.4 discusses the methodology to be adopted in the research. Section 3.5 covers the different qualitative research methods that were considered for this research. Sections 3.6 and 3.7 cover the research design, background to the research participants and the tools used to gather the data. Section 3.8 covers data analysis methods utilised and the method for presenting findings. Section 3.9 covers ethical considerations and the chapter ends with a summary in section 3.10.

3.2 Ontological basis of the research

From the analysis of the available literature in chapter 2, there is no empirical research into how these models are used by risk managers for decision-making. The use of these models is governed by human behavior, culture, capability and competence, organisational factors and strategy within a bank (i.e. the status of social reality within a bank) and therefore the researcher's ontology is based on understanding and interpreting the use of models which is concerned with understanding human meanings and the definition of respective contexts of the use of the models in banks (Schwandt, 1994 p 18; Gephart, 2004).

Decisions made on the basis of these models are dependent on management, strategic and organisational decisions. This reinforces the researcher's view that, in reality, management use of models is based on a social construct (Berger and Luckmann, 1966) and that it is a

dialectical process where subjective realities emerge and are shared among the participants. The researcher believes it is particularly appropriate to adopt an interpretative approach in the research in order to analyse and understand the viewpoints of the participants. Rather than use the traditional viewpoint of researching the models via comparing the technical aspects of the models, this research holds that there should be a greater sense of reflexivity in credit risk modelling research, and that there should also be analysis of the actual use of the models.

3.3 Epistemology

The researcher reasons that to answer the how and why questions in section 1.2 and the interpretive ontology stance in section 3.2, the use of credit risk models in practise is best researched via qualitative methods rather than via quantitative methods. Qualitative research methods fit into the research goals and will help to understand the participants and the social, organisational and cultural contexts within which they work (Orlikowski and Baroudi,1991). The reason for using qualitative research, as opposed to quantitative research, comes from the observation that to get the information on banks' use of models we need to discuss and talk to the people that use models within the banks. Qualitative research would allow the description of the use of the models in detail and in the original language of the research subjects. Other than observation and description, the research will also need to analyse and interpret the findings. Qualitative research fits into the research ontology as it can be based on an underlying research epistemology that is interpretive (Myers and Newman, 2007)

Use of qualitative research in credit risk models is supported by Riccardo Rebonato, one of the quantitative experts in credit risk modelling who speaks about alternative ways of researching credit risk *"risk management thinking seems to be anchored to a singularly unproductive view of probability"* (Rebonato, 2007 p.255). He further states *"...articles about how human beings react to risk have been written in their thousands. What is missing, again, is a constructive overlap with the theory and practise of risk management"* (Rebonato, 2007 p 226). This research aims to illuminate the practice of risk management in banks with regard to credit risk model use.

3.4 Methodology

Within the foregoing ontological and epistemological discussion, the researcher believes that the qualitative approach is the right one to gain insights into the use of credit risk models in

banks. Qualitative research can be broadly defined as *"any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification"* (Strauss & Corbin, 1990 p.17). Qualitative research using an interpretative approach will allow the researcher to answer the research questions and will help explore the richness, depth, and complexity of model use in banks.

Just as there are various philosophical perspectives which can inform qualitative research, so there are various qualitative research methods. There is no necessary overarching research framework in qualitative research. Myers (2009) describes four common qualitative methods which are action research, case study research, ethnography and grounded theory (for more detail see Myers, 2009). All four methods were looked at and the case study method was selected as the most appropriate methodology for this research. The next section covers the different methods considered.

3.5 Qualitative research methods considered

This section briefly describes the alternative research methods looked at and why they were not considered appropriate for this research. This followed by a section that discusses the nature of the case study and why case study methodology was appropriate for this research.

3.5.1 Action Research

Kurt Lewin is credited with creating the term "action research" and it appeared in his 1946 paper "Action Research and Minority Problems". In that paper, he described action research as *"a comparative research on the conditions and effects of various forms of social action and research leading to social action"* that uses *"a spiral of steps, each of which is composed of a circle of planning, action, and fact-finding about the result of the action"* (Lewin, 1946, reproduced in Lewin, 1948: p. 202-3). More commonly cited is Rapoport's definition of action research as *"Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework"* (Rapoport, 1970, p. 499) which draws attention to the collaborative aspect of action research and to possible ethical dilemmas that can arise from its use. It also makes clear, as Clark (1972) emphasises, that action research is concerned with adding to the body of knowledge within the social science community.

Action Research has not been applied to previous studies of credit risk models although it has been applied to fields such as organization development and education (see the collection of articles by Kemmis and McTaggart, 1988). While it may be considered a valid research method, there would be major ethical risks in allowing a researcher to participate and to influence credit decisions which affect the profit and loss of the bank. There would also be regulatory constraints on the use of action research in banks as it could change established credit risk processes and introduce operational risks. Therefore, while there is some merit in the use of action research in adding to the body of knowledge, the collaborative aspect of action research and ethical dilemmas do not make this a practical option.

3.5.2 Grounded Theory

Grounded theory is a research method that seeks to develop a theory that is based upon (or grounded in) data that has been systematically gathered and analysed. According to Martin and Turner (1986), grounded theory is an inductive discovery methodology that allows the researcher to develop a theoretical account of the general features of a topic while simultaneously grounding the account in empirical observations or data. The major difference between grounded theory and other methods is its specific approach to theory development - grounded theory suggests that there should be a continuous interplay between data collection, analysis and the resulting theoretical framework.

When the principles of grounded theory are followed, a researcher using this approach will formulate a theory, either substantive (setting specific) or formal, about the phenomena they are studying that can be evaluated. This contradicts the traditional model of research where the researcher chooses a theoretical framework and only then applies the model to the studied phenomenon. Glaser and Strauss (1967, p. 114) describe grounded theory as "*the generation of theories of process, sequence, and change pertaining to organizations, positions, and social interaction*". Urquhart (2001) emphasised two key beliefs of grounded theory: (a) the researcher has to set aside theoretical ideas; and, (b) the concepts are developed through constant comparison. The subsequent data analysis, through the constant comparison of incidents, will then falsify, confirm, or extend the applicability of the theory to the substantive area under study. As the credit risk department in a bank is an important part of day to day risk management function in the bank, it would be difficult to get enough time and attention from the members of the credit risk department to be involved in a study that required

constant comparisons of test incidents required by grounded theory. There are no existing theories on management use of credit risk models to compare against and importantly, the researcher is not attempting to formulate a theory about the phenomena being studied.

3.5.3 Ethnographical research

Ethnographic research comes from the discipline of social and cultural anthropology where an ethnographer is required to spend a significant amount of time in the field. Ethnographers immerse themselves in the lives of the people they study (Lewis, 1985, p. 380) and seek to place the phenomena studied in their social and cultural context. The distinguishing feature of ethnography, however, is that the researcher spends a significant amount of time in the field. The fieldwork notes and the experience of living there become an important addition to any other data gathering techniques that may be used. Ethnographic research is one of the most in-depth research methods possible. Because the researcher is at a research site for a long time and sees what people are doing as well as what they say they are doing, an ethnographer obtains a deep understanding of the people, the organization, and the broader context within which they work.

While there is no recorded use of ethnographical methods in credit risk modeling research, it does fit into the ontology and epistemology of the researcher and would be a valid research method. The main disadvantage of applying ethnographic methods to the research is that it presents some difficulties in finding appropriate sponsoring banks that will provide the necessary environment, and allow the researcher to spend substantial amounts of time onsite to undertake the ethnographic work on site. The researcher has approached seven banks where he was previously employed and none were interested in supporting this research approach. Ethnographical research, while valid, is not feasible due to the difficulty in finding any appropriate sponsors.

3.5.4 Case Study

Yin (2003) is widely cited in case study research and defines case studies as "A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin 2003, p.13). The use of credit risk models within banking does not fall within a well-defined context and, using case study techniques would provide an understanding on how the

bank uses these models in decision-making. Case study use of the participant's language could also help in the understanding of the use of models and Stake (1995) argues that the data generated by case studies would often resonate experientially with a broad cross-section of readers, thereby facilitating a greater understanding of the phenomenon.

Schramm and Roberts (1971 cited in Yin, 1989:22–23) notes that *"the essence of a case study, i.e. the central tendency among all types of case studies, is that it tries to illuminate a decision, or a set of decisions: why they were taken, how they were implemented, and with what result"*. This fits into the ontology and epistemology for this research, since the object of study is to look at the banks' use of risk models in decision-making. This is also supported by Benbasat, Goldstein and Mead (1987) who believe that case study methodology is appropriate where interest has shifted to organisational rather than technical issues.

Benbasat *et al* (1987) summarises the key characteristics of case studies where:

- the phenomenon is examined in a natural setting
- data is collected by multiple means
- one or few entities are examined
- the complexity of the unit can be studied intensively
- there is need for the exploration, classification or hypothesis development
- no experimental controls or manipulation are involved
- the investigator may not specify the set of independent and dependent variables in advance
- the results derived depend heavily on the integrative powers of the investigator
- changes in site selection and data collection methods could take place as the investigator develops new hypotheses
- the study looks at 'why' and 'how' questions because these deal with operational links to be traced over time rather than with frequency or incidence.
- the focus is on contemporary events

(Benbasat, Goldstein and Mead, 1987, p3)

This research has a majority of the key case study research characteristics identified by Benbasat *et al* (1987) as this research is to be conducted in banks in their natural setting with no experimental controls, there are various sources of data via interviews, documentation,

archival records and direct observation (as shown in section 3.6), there are few entities studied (three), the results need to be interpreted, the research focus on the how and why questions (as shown in section 1.2) and researcher has no control over the contemporary set of events in the banks studied. The use of case study in this research is further supported by Bonoma (1985) and Yin (2003), who hold that case study is best suited for research when the researcher is interested in understanding dynamic contemporary events in an environment over which the researcher has no control.

While case study methodology has not been used specifically in credit risk modelling research, it is a common tool in banks and has been used academically to research relationships and lending within banking. Examples are, Holland (1997) where he used case study in 15 banks to research into banking and bank lending in order to place the credit relationship within the broader context of a financial service supply relationship, Berry, Faulkner, Hughes and Jarvis (1993) where they looked at the importance of accounting information in bank lending decisions relating to small businesses, Berry, Crum and Waring (1993) that looked at the actual processes used by banks in evaluating corporate loan applications, Berry and Waring (1995) where they produced case study evidence showing that little attention was given by the banks to data other than that shown in the profit and loss account and the balance sheet and Mazahrih (2011) where he used case study to examine commercial banks' practice pertaining to the integration of external environmental issues into their lending activities.

While some may argue that case studies provide one view of the world, Yin in particular refutes that criticism by presenting a well-constructed explanation of the difference between analytic generalisation and statistical generalisation: "*In statistical generalization, an inference is made about a population on the basis of empirical data collected about a sample. In analytic generalisation, previously developed theory is used as a template against which to compare the empirical results of the case study*" (Yin, 1989 p. 38). The criticism of generalising based on case studies assumes that some sample of cases has been drawn from a larger universe of cases. In fact case studies are rigorous examinations that focus on the "how" and "why" questions of the research enterprise (Yin, 2003; 1989) which is appropriate in this research to understand how credit risk models are used.

From discussions with banks (see section 3.7 on research participants) there is support for using case study methodology by the banks approached, and as such case study is a feasible method for this research. Case study as a research tool fits into the research objectives, would be a valid method for answering the research questions and would be a practical way of researching this area.

3.6 Research Design

Having established case study as the best tool for this research, a case study protocol was completed prior to data collection in 2008. Yin (2003) suggests designing a case study protocol before embarking on the case study fieldwork as this helps the focus and clarity of the data collection process. The case study protocol served as the overarching reference point and framework for the data collection process for this research. The tools used in the case study research followed Stake (1995), and Yin's (2003) six sources of evidence and included:

3.6.1 Documents

The researcher had access to documentation relating to the model development process, to the process for validating the models, to minutes of credit committees that related to decisions on model use over a twelve month period and access to credit committee documentation on credit policy with regard to credit models. A twelve month period was chosen to cover any processes that are followed on a monthly, quarterly or yearly basis. This is to allow an in-depth look at the operating procedures for these models to allow insight to management use of these models in decision-making.

3.6.2 Interviews

Interviews were conducted to cover five areas:

- Head of Risk / Chief Risk Officer (This is the person that heads up the risk department in the bank. In the study this was a board member or someone who reported directly to a board member)
- Credit risk measurement and methodology (this is the area that defines the risk models)
- Credit risk verification (this is the area that implements the models and verifies the output of models on a regular basis)
- Credit risk monitoring (this is the area which uses the output of the models to monitor risk)

- Credit risk regulatory reporting (this is the area that looks after reporting to the relevant central bank or regulatory body e.g. FSA in the UK)

The interviews were semi-structured, where there was a script with a list of questions prepared but the research participants were allowed to decide how they wanted the interview to be conducted and were allowed to speak freely on their views on the use of risk models. Two-thirds of the participants preferred to go through the list of questions and answer them in order, with a third preferring a totally free format where they would speak on topics in no particular order. For those done in a free format style, the researcher had to ensure that all the questions were answered and that the interview flowed naturally. The participants were promised that their personal details would be kept confidential to allow them to speak openly.

Most interviews lasted just over an hour, with the shortest at fifty five minutes and the longest at two hours. With the participants' permission, all interviews were taped and then transcribed. The participants were sent a copy of the analysis of their interview to ensure the researcher captured their views correctly. Section 3.8 covers how the data was coded and analysed.

3.6.3 Archival records

This covered organizational structure and publically available documents such as annual reports, press releases and website details. Also researched were relevant exposure measurement minutes relating to credit modeling covering the previous 12 months. A twelve month period was chosen to cover any processes that are followed on a monthly, quarterly or yearly basis. These minutes were confidential documents that would not normally be shared with externals.

3.6.4 Direct observation

The researcher was allowed to observe and spend time with the different areas within risk management department of the bank. This included the ability to examine the existing processes and procedures which were related to credit risk models. This allowed the researcher to observe if any of these conflicted with the documentation provided or were different to what had been stated in the interviews. Provision was made in the research to record surprising or conflicting evidence via a site observation form which was created as part

of the case study protocol. There was no surprising or conflicting evidence observed in the three case studies presented.

3.6.5 Participant observation and physical artifacts

Participant observation is one of Yin's (2003) six sources of evidence and is a qualitative method with roots in traditional ethnographic research, where the researcher is an active participant in the research. As the researcher is not an active participant in the events being studied, this did not provide a source of evidence.

Physical artifacts are another of the six sources of evidence in the Yin (2003) and relate to technological devices, tools or instruments, works of art or some other physical evidence. The only source of evidence that may be relevant to this research would potentially be access to the IT systems in the bank. However as researcher did not have access to the banks' IT systems during the research period, physical artifacts was not a source of evidence for this research.

This section is included only to demonstrate that all of the sources for evidence suggested in the Yin (2003) framework were considered in the research.

3.7 Research participants

The researcher approached seven internationally recognised banks where he had worked in the past as well as others where he knew members of the senior credit risk management. The banks were open in the initial discussions and indicated their general willingness to share information pertaining to credit risks, as credit information is commonly shared between banks in order to reduce credit risks in the market, which in turn reduces the risks that banks have to carry (for example information on bad debtors is regularly shared). While banks are competitive, having their counterparts fail increases a bank's own losses. The views from the banks were that any efforts in the reduction of credit risks within the market would benefit all banks and therefore would be welcomed by them. There were certain areas of confidentiality which were highlighted as important at the start. These were:

- any information specific to particular counterparties
- any comments specific to any particular transaction or deal unless it pertained to generic and historic information that was available on the public domain

- items covered during interviews that were specifically flagged as confidential
- comments that were requested to be made non-attributable to an individual could be used if it is was not highlighted that that particular individual or bank made that that comment (there were none highlighted in the interviews)
- in the handling of ethical issues. For example discovery during the research of a member of staff not complying with stated credit policy of the bank or who was in breach of internal controls

As these areas were covered in existing confidentiality agreements between the researcher and the banks approached, the banks did not feel that there should be barriers to the research as long as the researcher complied with the existing confidentiality agreements. None of the areas mentioned above were material to the main research focus and have not impacted the overall research outcome.

Of the seven banks originally approached, when formally asked, four indicated interest in participating in the research and in receiving the findings of the research. The other three of the seven were not able to commit to the level of sponsorship and time required for the research. The four banks were a Dutch bank, a Swiss bank, a Russian bank and a South African bank. As part of the research proposal, it was agreed with the supervisors and advised by external examiners during the research proposal stage that three cases was probably the upper limit of what could be achieved in the DBA timeframes. The number of respondents in the sample and range of banks chosen should allow generalisation of the findings. Hamel, Dufour, and Fortin (1993) and Yin (1989, 1993, 2003) forcefully argued that the relative size of the sample whether 2, 10, or 100 cases are used does not transform a multiple case study into a macroscopic study. The goal of the study should establish the parameters, and then should be applied to all research. In this way, even a single case could be considered acceptable, provided it met the established objective of understanding the use of the risk models. However for this research, a single case is felt too small a research piece and three cases was felt to be the right number to fit into the DBA research timeframes and to allow adequate cross-case analysis. Based on size, reputation, sophistication and global coverage, the Dutch, Swiss and South African banks were selected as the research study sites.

A small pilot of two initial interviews in the Dutch and Swiss banks were undertaken to test the questions and interview process. The pilot highlighted issues on conducting interviews

and taking notes at the same time. For the formal interviews, it was decided recordings would help alleviate this issue and that full exact transcripts of the interviews be produced. To cater for any objections to recording the interviews, the respondents were given the option not to have a recording done or to pause the recording at any sensitive points. Neither of these options was exercised by any of the respondents when the formal interviews were conducted.

A letter from the research supervisor was sent to the potential study sites. Using the letter and the case study protocol as the basis for agreement, formal discussions then occurred with senior credit risk managers in these banks on the feasibility of undertaking the research. Unfortunately due to workload in the bank and internal changes in the bank from job cuts it was not possible to secure the Swiss bank as a research study site. After discussions with the research supervisors, it was agreed that the Russian bank that had originally indicated support for the research would replace the Swiss bank as the third research study site.

From this point onwards, the candidates are called Bank A, Bank B and Bank C. The research was completed in each bank before moving on to the next. The interviews were conducted first followed by the exercise of going through the documentation from credit committee decisions and filling in the site observation template. The interviews were scheduled based on the candidate's schedule although where possible the sequence that the researcher tried to follow in each of the bank's was chief risk officer (global head risk management or equivalent), followed by head of credit risk management, head of modeling/risk measurement, head of the credit risk monitoring area and the head of the credit risk regulatory reporting area. The reason for this running order was to ensure a top down approach where there would be a broad coverage at the high level before meeting the risk managers looking after the detail. Where required, the researcher followed-up with individuals to clarify points of detail they made in the interviews.

3.8 Data analysis methods and presentation of findings

As discussed in section 3.30 the underlying research epistemology is interpretive where knowledge is gained, or at least filtered, through social constructions such as language, consciousness, and shared meanings (Klein & Myers, 1999). Most qualitative researchers attempt to avoid prior commitment to theoretical constructs before gathering any data (Yin, 2003). This approach is generally known as induction. Inductive reasoning is applicable to

business and management studies where established and accepted theories are unlikely to be available (Remenyi, 2000), as is the case in this study.

The analytic method employed was comparative analysis, which is one of the standard methods of analysis found in case study research and fitted the research epistemology. The main tool used was thematic analysis where themes were drawn from the case studies. The frame of reference for the themes was in observations of the data, the research questions and the literature. This involved a process of reviewing the literature, the research questions, reading and looking at the data extensively annotating it and identifying particular objects of interests and patterns. The themes which emerged helped develop the descriptive information from the transcripts into a structure that could be analysed and interpreted.

A coding system was used that allowed a clear link from the themes back to the original transcripts. This followed Charmaz (1995, p.37) *"The first major analytic phase of the research consists of coding the data. In short, coding is the process of defining what the data are all about. Unlike quantitative coding, which means applying preconceived codes (all planned before the researcher even collects data) to the data, qualitative coding means creating the codes as you study your data."*.

Original text was grouped to relevant themes and a code was used to uniquely identify each theme with a link from the theme to the page and line number in the candidate's transcript. Appendix A shows the level of detail in the coding and the data captured. Microsoft Excel was the tool used to capture the data and link the themes back to the original text. The original transcripts were also coded and annotated to show the passages used and the themes.

By ensuring that all data in the analysis could be reconciled back to the original transcript, there was a clear level of transparency in the data found in the theme (i.e. that a reader could see very clearly how the interpretations of the data related back to the data).

Each respondent was provided with a copy of themes relevant to their interview, pointing out specific transcriptions that were used. The participants are asked to check the themes and relevant transcripts of their interview and that the account faithfully represents their interview and their views. Elliott (1991) refers to this as validating by appealing to the participants. This was done and only minor changes were necessary.

Wherever appropriate in this thesis, excerpts of raw data are included. In order not to change any of the meaning provided by the research participants, the researcher did not edit any of the respondent quotes and applied a strict rule of not changing any of the original text. This allows the participants to have a voice in the research and provides a validity check between the data and the analysis.

Throughout the analytic process, the researcher has tried to ensure the principles that were stated in the case study protocol based on Yin (2003) were adhered to by:

- ensuring that the analysis relied on all the relevant evidence (via the coding, and the comparative analysis methodology)
- including, where relevant, any major rival interpretations in the analysis (the literature provided the basis for this)
- addressing the most significant aspect of the case study (this was done by using the case study protocol and in having an interview guide for the semi-structured interviews)
- using the researcher's prior, expert knowledge to further the analysis

3.8.1 Cross-case analysis

Pattern matching is the mode of analysis used in cross-case analysis. The research followed analytical techniques of pattern matching from Yin (2003) and Miles & Huberman (1994). This type of logic compares an empirical pattern found across the cases with patterns found within the individual cases. The objective of cross-case analysis is to extend the sense-making into different contexts to transcend the particularities of a single case. Internal validity is enhanced when the patterns coincide. The use of multiple cases potentially strengthens the results by replicating the pattern matching, thus increasing confidence in the robustness of the findings.

3.8.2 Triangulation

Triangulation arises from the ethical need to confirm the validity of the processes. Snow and Anderson (1991) asserted that triangulation can occur with data, investigators, theories, and even methodologies. Stake (1995) stated that the protocols that are used to ensure accuracy and alternative explanations are called triangulation. Triangulation of data within this research follows the recommendations of Yin (2003) where section 3.6.1 of this document covers how the documentation, archival records and direct observations are used to support

the findings of the interviews. These are captured via the use of the site observation template and the use of publically available documentation.

3.8.3 Research quality issues

While there may be questions around the generalisation of the findings from qualitative research, Yin (2003) asserts that general applicability of the findings will result from the set of methodological qualities of the study, and the rigor with which the study is constructed. This research is based on a clear methodological approach and rigor is applied via the creation and adherence to the case study protocol, by the use of the themes and coding structure to link back to the original transcripts, by checking back with the original candidates the findings of the analysis and by the use of pattern matching and triangulation.

The tactics used in this case study to ensure reliability and validity can be summarised as follows:

Criteria	Tactics Employed
Study reliability	Use of the case study protocol based on Yin (2003) Creation of case study database Script for interviews ensuring consistency in the approach and questions
Construct validity	Triangulation using multiple sources of evidence following Stake (1995), and Yin's (2003) recommendations of sources of evidence There was a chain of evidence established via the case study database so that the route of data could be tracked to its sources
Internal validity	Use of pattern matching as the analytic strategy for analysis (Yin 2003, pp.106-110 Attention given to reflexivity (to avoid receiving answers that the researcher wants to hear) and memory recall biases
External validity	Multiple (three) case studies

Table 1-1 Case study tactics used in this research

3.9 Ethical considerations

This research follows the guidelines on Kingston University's code of good research[12] and the Economic and Social Research Council's (ESRC) framework for research ethics (FRE) and it adheres to the six key principles laid out in the ESRC (2010) framework:

[12] A copy can be found on the Kingston University website http://www.kingston.ac.uk/aboutkingstonuniversity/howtheuniversityworks/policiesandregulations/documents/research_good_practice.pdf

- The research was designed, reviewed and undertaken with the aim of ensuring integrity, quality and transparency. Ethical considerations were looked at from the start of the research, there was discussion with the research supervisors and the ESRC framework was applied in designing the case study protocol.
- The participants were informed about the purpose, methods and intended possible uses of the research and what their participation in the research entailed. Consent was also requested at the start of each interview.
- The research participants took part voluntarily and no pressure was applied to any of the candidates to take part in the research.
- By not disclosing the names of the banks or candidates, the anonymity of candidates was respected. The researcher's supervisors had full access to the research information to verify that the information used in this research was accurate but no confidential data was provided to any other parties.
- There was no harm intended to any of the research participants. Rowling (1994) recommends the return of interview transcripts to participants for confirmation as one technique which is aimed at protecting their interests. In this research, while individual transcripts were not returned, the themes from the within-case comparative analysis showing the participant's original quotes were returned to the individuals for comment. No issues were raised on the approach and, other than minor changes, there were no significant amendments to the data and findings.
- The independence of research was clear and as the researcher was familiar with banking confidentiality arrangements, all conflicts of interest were avoided.

Most of the ethical issues from this qualitative research are around confidentiality. Within banking, confidentiality is considered very important. Section 3.7 covered the points raised at the start of the research by the participants of this research on confidentiality and there are two levels of confidentiality considered important as part of this research, organisational confidentiality and individual confidentiality.

On organisational confidentiality, while all three candidate banks had agreed that the research could name their organisation, on analysing the data it was found that by naming the organisation, it was possible for the reader to potentially attribute a comment or view to a particular individual in a particular bank. This meant that if the banks were named, the

promise to individuals not to reveal their comments could be compromised. As such, in this thesis no banks are named.

On individual confidentially, other than not naming the participants, all participants were asked if the interview could be recorded and all participants were given the option to pause or switch off the recording at any point during the interview. All the participants agreed to the recordings and none of the participants availed of the option to pause or switch off the recording during the interviews.

3.10 Summary

There are several ways of framing an academic study about the use of credit models in banks. This chapter has described the philosophical stance of the researcher and shows why an interpretive approach adopting a case study methodology has been considered the most appropriate method to answer the why, how and what questions that are being researched. This is followed by a description of the research design that follows Stake (1995), and Yin's (2003) recommendations, the data collection method and the analysis methods that was followed in this research.

Chapters four, five and six will present the three intra-case analysis for each of the candidate banks. The final chapter, chapter seven, presents the cross-case analysis which draws on the commonalities and differences found in the within case analysis, the findings of this research and the conclusions.

4 Case Study Bank A

4.1 Introduction

This chapter provides a study of Bank A where it analyses the responses to the interview questions in order to identify trends and differences of views between all the responses. By highlighting the similarities and differences in what was said by the different participants, or how they said it, an understanding can be built on the use of credit risk models. The aim is to provide a holistic and in-depth description of management's use of credit risk models. The data and explanations are then used as the foundation for the cross-case analysis in chapter 7.

The data collection and data analysis have been previously discussed at length in the methodology section in chapter 3 of this thesis. Where necessary, interview quotations have been used to demonstrate the analytical interpretations and have been provided in the form of exhibits at appropriate junctures.

The next section (4.2) provides background with an overview of the bank, its governance structure and its general market strategy in order to provide the reader an organisational context to the case study responses. Section 4.3 analyses the risk management framework covering risk appetite, management team and organisational structure. Section 4.4 describes the participants who were guaranteed confidentiality; therefore, their roles are described and alphanumeric codes assigned. These codes are used to identify specific quotes included in the main body of this chapter. Sections 4.5 through to 4.9 investigate and discuss the main themes that emerged in order to understand their use of the models. Section 4.10 covers the secondary themes found and section 4.11 focuses on the participants' views of possible improvements or changes to the models. The last section, 4.12, summarises and characterises the approach of Bank A towards credit risk models.

4.2 Background of Bank A

4.2.1 History and coverage

This section provides background of the bank and its organisational structure in relation to credit risk.

Bank A is an international bank offering a range of services including transactional banking, saving, borrowing, lending, investment, insurance, risk management, wealth management and advisory services. There are three divisions in the bank, Retail and Business Banking, Investment Banking and Wealth Management. It has a presence in the Americas, Europe, Middle East, Africa, Asia and Australasia. The bank has built a deep understanding of the market dynamics especially in countries with rapidly developing economies.

The banking group's total assets were USD$180 billion on the 31st December 2009. Revenue growth had been steady, and doubled between 2004 and 2009. They employ more than 50,000 people worldwide. The bank's market capitalisation on the 31st December 2009 was USD$22 billion. Bank A was rated A3 by Moody's and BBB by Fitch.

The table below shows some key financial data for the banking group:

Key financial data (converted to USD billions and rounded)	2010	2009
Total Assets	167	162
Headline Earnings	1.4	1.5
Net fee and commission income	2.3	2.3
Net interest income	3.6	3.9
Trading Revenue	1.1	1.3
Net interest margin	3%	3.2%
Return on equity	12.5%	13.6%
Cost to income ratio	61.7%	52.3%
Capital Adequacy %	15.3%	15.1%

Tier I capital adequacy ratio %	12.4%	11.8%

Table 4.1 Bank A general financial data (converted to USD)

The table below shows the services and products for the banking group:

Services	**Products**
Advisory services	Corporate finance advisory, Research, Exchange control advisory
Financing	Term lending, Structured debt finance, Asset finance, Syndicated lending / distribution, Debt capital markets, Securitisation, Equity capital markets, Acquisition finance, Project finance, Structured trade & commodity finance
Global Markets	Foreign exchange, Money market, Interest rates, Credit trading, Equity derivatives, Commodities, Exchange traded notes
Retail Banking	Deposit, Current accounts, Overdrafts, Currency services, Loans, Mortgages
Transactional services	Cash management, International trade services, Custodial & securities services, Online banking
Property Group	Real estate investments, Property finance, Integrated residential developments

Table 4.2 Products and services provided by Bank A

4.2.2 Organisation and strategy

The bank has a significant retail operation within a small number of countries in the EMEA region. Corporate and Investment Banking is more broadly spread, geographically, with the bank holding a significant franchise in the emerging markets sector. This gives it a useful presence in the so-called BRIC territories (Brazil, Russia, India and China), augmented by a strategic shareholding of a major Chinese bank.

Whereas Bank A was not directly impacted by the worst aspects of the sub-prime crisis, it has suffered in common with other global financial institutions from the relatively subdued levels of corporate and investment banking activity throughout 2010, as well as the higher impairment rates and depressed lending volumes. These have caused Bank A to focus on controlling costs and streamlining operations, in the short-to-medium term. Bank A's strategy

for its Investment Banking business is to focus on origination of business, making less use of its own balance sheet and de-risked its balance sheet over time.

One of the stated objectives of Bank A is maintenance of a target credit rating as defined by their board. They do not reveal the exact target rating but the fact that it is a stated and published objective reveals the importance of credit risk to their business.

From information in Bank A's 2010 website and 2009 year-end accounts, the bank's stated strategy is:

- To build a leading emerging-markets financial services organisation
- To offer strong domestic universal banking services in chosen (geographic) markets
- To act as a connector between emerging markets by exploiting its recognised sector expertise

4.3 Risk management framework in Bank A

4.3.1 Governance structure

In line with legislation in America (after the Enron crisis) and Europe, overall responsibility for risk management rests ultimately with the Board of directors. Day-to-day responsibility is delegated to the executive committee of the bank and its sub-committees, which review, among other things, summaries of credit, market, liquidity, operational, country and regulatory risks.

The Board of Bank A also delegates certain key risk responsibilities related to risk control to the risk management committees and the audit committee. A diagrammatical Governance chart is as follows:

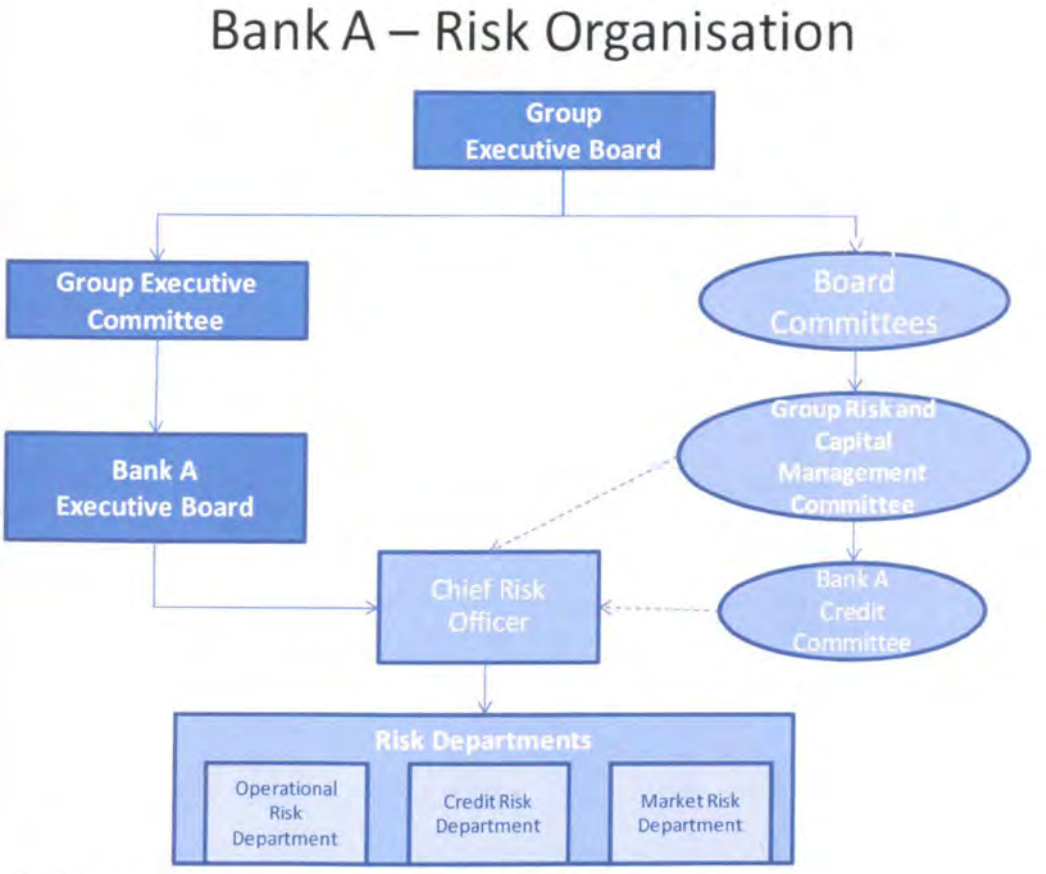


Figure 4.1 Risk management governance structure in Bank A

The bank's approach to risk management appears to be based on well established market standards for governance, and follows regulatory recommendations. Like all human processes it relies on both individual responsibility and collective oversight, but is supported by a good reporting structure and the ability to raise to senior management's attention to significant risk issues.

Key in the process are the business unit heads who are primarily responsible for managing risk within each of their businesses, ensuring that there are appropriate, adequately designed and effective risk management frameworks, in compliance with group risk governance standards.

To ensure there is independence and appropriate segregation of responsibilities between business and risk management, credit risk officers that are based with business units report operationally to their respective business unit heads, and functionally to either the group Chief

Risk Officer or the group Chief Credit Risk Officer. Compliance with risk standards is controlled through annual self-assessments by the business units and by the risk department, supported by internal auditors.

The 2008 economic downturn has had a negative effect on levels of interest payments by clients and hence an impact on the capital allocation on the retail and business banking loan books. Further, the level of impairments and non-performing loans means that Bank A has to make allowances for losses on these loans, which in turn impacts its profit and loss position. From the interviews and research of Bank A's internal risk documentation, Bank A's main response to this has been to focus on identifying potential issues at an early stage, to work with the borrowers to restructure loans (to allow the borrowers more time to repay or fixing repayment schedules that match the borrowers' cash flow better) and to ensure that the bank has first call on any assets or collateral that the borrowers may have. This provides the bank with an advantage over its competitors that are not as quick as Bank A in identifying or proactively managing distressed borrowers.

Bank A is also responding to potentially lower profits by trying to lower its cost base through reorganisation of its back office operations around lower cost centres. From analysis of the published accounts, the corporate and investment bank's operations are likely to move to its Group HQ (which is based in a lower cost centre). However, this trend may well expose challenges for the bank's day-to-day decision-making processes.

4.3.2 Risk appetite

Section 2.7.1.1 of the literature review covered importance of a bank's risk appetite. Bank A's risk appetite is governed by four goals

- Maintenance of a target credit rating for the bank, defined by the board
- Acceptance of a certain level of earnings volatility
- Maintenance of a level of capital adequacy as measured by Bank A's regulatory calculations
- Maintenance of a level of capital adequacy as measured by the ratio of available financial resources to economic capital consumption

From the annual accounts, the group's risk appetite statements are defined by five broad metrics:

- headline earnings (set at the board level);
- liquidity (set by risk and capital management committees);
- regulatory capital (set by risk and capital management committees);
- economic capital (set by risk and capital management committees); and
- target debt rating (set at the board level)

These metrics are converted into tolerance levels defined by the relevant committees. Limits are then set by these committees and monitored internally in the bank through an analysis of the risks that impact on them.

4.4 Credit risk management in Bank A

Credit risk is Bank A's most significant risk as measured by absolute value as well as by amount of capital consumed. In 2009 the credit risk portion of total Economic Capital for Bank A was 71% (76% in 2008). Credit risk was actively managed throughout 2009 and credit risk targets were set to reduce the credit exposures as well as reduce the average maturity across the portfolios. However this was partially offset by a smaller increase in capital arising from downgrades of counterparties' credit ratings.

Bank A's credit risk arises predominantly from lending and related banking product activities, including underwriting, as well as trading securities and derivatives products and securities borrowing and lending. In lending transactions, credit risk arises through non-performance of customers, or market counterparties for facilities granted. These facilities are typically loans and advances, including the advancement of securities and contracts to support customer obligations such as letters of credit and guarantees. In trading activities, credit losses arise due to non-performance by counterparties for payments linked to trading-related financial obligations.

The regional Heads of Credit report functionally to the Chief Credit Officer. The group's Chief Credit Officer has functional responsibility for credit risk across the organisation and in turn reports to the Chief Risk Officer.

4.5 Reporting lines in respect to credit risk modelling in Bank A

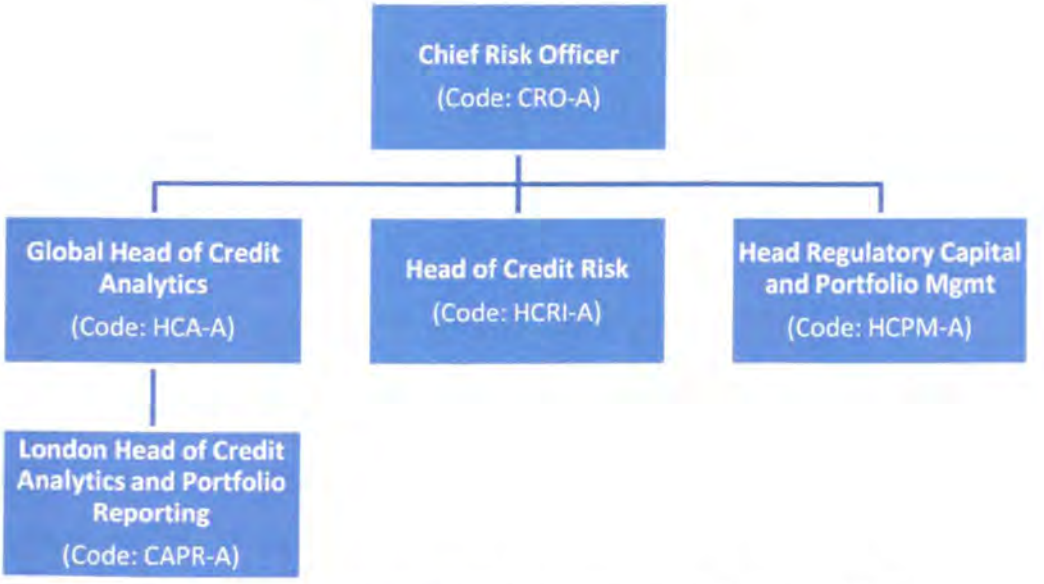


Figure 4.2 Credit risk organisation chart in Bank A in relation to credit risk modelling

4.5.1 Role of the participants

The risk organisation chart in relation to credit risk modelling is shown in Figure 4.2. The Chief Risk Officer (CRO) was the main sponsor for the research in Bank A. The five participants listed in the organisational chart were elected by the CRO to take part in the research and represent the heads of each of the areas involved with credit risk models. The fact that the CRO elected the participants for the research is not believed to impact the research as the same departments would have been targeted as part of this research and the same participants approached. The CRO's support meant that the participants had an additional motivation to contribute to the research. Senior support also ensured that internal documentation relating to models was made available to the researcher. All the participants were helpful and made time in their busy schedules to ensure enough time was allocated to the case study interviews, and to answer follow-up questions. The following is a description of their roles (note: the descriptions are in their own words but also cross-checked against the organisational charts in the bank).

The Chief Risk Officer (hereafter referred to as CRO-A)

CRO describes his role as being functionally responsible for all the risk types across the bank, both financial risk (market risk, credit risk and liquidity risk) and non-financial risk

(reputational risk, legal risks, operational risks, security risks, business disruption risks and fraud). CRO-A is a member of the Group Executive Committee as well as the Group Risk and Capital Management Committee. Ultimately CRO-A is responsible for ensuring that the board's risk decisions are implemented, and for providing risk information reporting both internally in Bank A and externally to shareholders and regulators. He has organisational responsibility for the people and the operational framework that the bank uses to discharge its responsibilities.

Head of Regulatory Capital and Portfolio Management (HCPM-A)

HCPM-A is responsible for both regulatory and economic capital and for the risk management within these areas. This covers regulatory models and economic capital modelling. HCPM-A is responsible for the management of the credit portfolios that have the biggest capital utilisation. HCPM-A sits on the executive board of the bank.

Head of Credit Risk (HCRI-A)

HCRI-A described his role as that of Head of Credit Risk and Chief Credit Officer with functional responsibility for credit risk across the bank, reporting to the CRO. He is in charge of the departments that look after the end-to-end credit process comprising research and analysis, credit making decisions, oversight of and checking the execution of the transactions and the monitoring of the transactions during the life of the exposure.

Global Head of Credit Analytics (HCA-A)

HCA-A described his role as being in charge of the Credit Analytics team. The Credit Analytics team builds the models used in the bank. This involves design, testing and deployment of the models and includes maintenance and support of the models. HCA-A manages a team of about 55 people, and reports to the CRO.

Head of Credit Analytics and Portfolio Management (hereafter referred to as CAPR-A)

CAPR-A is the Head of Credit Analytics and Portfolio Reporting for the Corporate and Investment Bank in London. He is responsible for policy, methodology, model development (reporting into HCA-A), implementation and, in practice, is responsible for the systems within which these models are implemented. While CAPR-A has a global remit, his main role is a UK-centric one. CAPR-A reports to HCA-A, and was nominated by CRO-A to be part of this

research due to his understanding of the model usage in the bank as well as his technical knowledge in systems implementation of these models.

4.6 View of the participants to credit models

This section follows the structure of the interview protocol used during the interviews with representatives of the risk governance and management organisation of Bank A. As described in section 3.6.2 the interviews were semi-structured, in that there was a script with a list of questions prepared but the research participants were allowed to decide how they wanted the interview to be structured, and were allowed to speak freely on their views of the use of risk models. As described in Chapter 3 on methodology, as there are no established theories of management use of credit models, this section uses the responses to draw a number of conclusions around use of credit risk models and highlight areas of potential improvement in practice and execution.

4.6.1 Credit model use

This part of the case study looks at what credit risk models are in use in Bank A, how and where are they used and why Bank A uses a particular type of model rather than alternatives.

4.6.1.1 Type and preference of model

For Bank A, the participants initially commented that a lot of their credit risk models were structural models. This was because they had purchased a package called KMV as the main basis for their economic capital modelling, and it uses an underlying structural approach. However, while KMV solution had been implemented, by questioning further, it became clear that the solution was not implemented in all areas and it was actually only one of the tools they used. Bank A uses other approaches which are a mixture of the theoretical schools including reduced form and incomplete information models. The use of KMV was also being reviewed internally by senior management as they feel that there may be better solution using a combination of different tools including solutions based on expert judgement. It would be accurate to summarise that Bank A does not actually follow an overall model preference. Instead they look at the use of models on a case-by-case basis depending on the specific business requirements for the business area, and would use what they feel are appropriate tools which may follow different philosophies as shown by the following quote:

> "We are at the moment - in terms of our model development philosophy if you like, we are at a second- or third-generation position in relation to some of the models - models based on, for example, Merton but we're now questioning whether we should be using different flavours for a particular type of model. So we have a mixed bag. We've got extensive Monte Carlo simulation models where we have the data that supports it and then we've got 100% expert-driven models. It actually depends on where that particular model is in its evolution, in its life cycle, and it depends on how much data we have for it and it also depends on its priority in terms of its size, for example asset classes in our portfolio" (Code HCA-A1)

and from the Chief Risk Officer:

> "From my perspective we don't have a specific choice. We have quite smart models, quite a few models that are expert judgement models" (Code CRO-A1)

We may infer from this that Bank A's approach to credit risk management is not anchored by any view that certain types of model suit their business requirements any better than others. This inference is further supported by the views of the Head of Credit Analytics and Portfolio Reporting who mentions:

> "I think it's perfectly reasonable for you to have more than one type of model" (Code CAPR-A1).

The academic literature treats the different model philosophies as mutually exclusive and views them as competing theories (Altman *et al*, 2002; Giesecke, 2003; Eom, Helwege and Huang, 2002). This appears to be different to use of the models in Bank A, to the extent that the bank's approach to credit risk management is able to accommodate the competing academic views and interpretations.

In the use of the models, the bank appears to be relaxed on philosophy and instead focuses on particular models in terms of fit. The Chief Risk Officer and Global Head of Risk Analytics point out that the key factors for model development are the model fit, the model life cycle, how much data they have and business priority. The model has to meet the needs of the bank and has to be validated with data.

> "The point is that whatever type of model we use, it has to go through a process of initial validation and then independent validation thereafter to confirm that the model is fit for purpose (code CRO-A1)"

It is possible to conclude that the use of the structural KMV model within Bank A is just one facet within a multi-faceted approach to credit risk management. Indeed, the view of management is almost to encourage a diversity of models in order to better inform the decision-making process.

4.6.1.2 Where models fit in the organisation

This section describes how Bank A uses the models and is to help understand the background for the use of the models and, using the participants' voices, provide insight into how these models are applied in the bank.

From a credit modelling standpoint, two main drivers emerge in Bank A - first, a transaction view, where Bank A models an individual trade and calculates the marginal impact of that trade on their hard limits and exposures; second, they separately look at the impact at a portfolio level. As an extreme example, while intuitively a very large exposure to a single counterparty may not be desirable from a normal risk standpoint, assuming that the transaction is still acceptable and within the overall appetite for that counterparty, and if that large exposure was to an industry or sector within a country with high credit rating to which the bank does not have an exposure, it may help diversify risk in the overall portfolio and, in a way, be potentially desirable.

> "Okay, so the first thing is when you're looking at an individual transaction you've got to make sure whether or not that transaction is an appropriate fit to the balance sheet. So in that sense you need to understand the transaction on a stand-alone basis, how much capital it's going to consume, what the risk-return on capital is going to be and also whether or not you're pricing sufficiently for the expected loss and whether or not you've got sufficient capital asset to cover the unexpected losses." (Code CRO-A3).

The risk model can assist in estimating default probabilities and losses for the individual transaction but also importantly its potential impact on an existing portfolio. However it is also important to factor in that typically, transactions do not take place with everything else in the portfolio remaining static. The profile of a portfolio normally changes with time. These changes are normally gradual, although there may be shocks to the system and changes could also happen suddenly. As such, the impact of an individual transaction could vary from one

day to the next. The risk managers of Bank A are therefore additionally sensitive to overall trends and exposures at a portfolio level, which the models may not account for.

> "So we take into account any other business that's going on and obviously the capital that that uses as well. So we're looking at the relationship of the two. In addition then there's the economic capital model and the kind of portfolio view. So that's at a kind of transactional level, relationship level and then there's the portfolio view which is looking at what you've already got as opposed to what you're about to put on the books. Well, it could guide the decision-making made for future business if we find that we're over-weight in certain areas – and there have been areas where we've done that and the action has been taken (Code HCRI-A1)".

The management in Bank A appears to use the data provided by the models to actively manage their portfolio as well as capital structure. The views of the Head of Credit Risk is echoed by the Chief Risk Officer, who also provides some further insights on the impacts of big transactions to the portfolio and equally how smaller transactions can impact the portfolio on a cumulative basis if risk is not considered on a portfolio basis..

> "But what you're also interested in is the marginal impact of that transaction on the portfolio. So there's no fixed and hard rule, but what you need to understand is whether or not the individual transaction meets your underwriting criteria and then you need to understand the marginal impact of the very big transactions on the portfolio and also the cumulative impact of smaller transactions on the portfolio" (Code CRO-A3).

The overall risk strategy and risk appetite also influences the decision-making process around the models, and this allows the bank to proactively define, modify and implement its overall risk strategy, where in some cases it decide to take on more risk and in others it may decide to reduce risk. The importance of this is that the decision-making process is not solely based on the model outputs.

> "And one of the other things we look at in that committee is its impact on the portfolio..... the Portfolio Risk Management Committee steers the portfolio in the direction we want it to go and that might be putting on more risk in total, it might be having less risk in total, it might be having more or less in particular sectors or particular countries, but it's generally around managing concentrations and managing the overall direction and whether we want to take more or less risk." (Code HCPM-A5).

This section opened a number of interesting insights into the use of credit risk models by Bank A. First, that there was no rigid adherence to one and only one type of model for credit risk management. Second, whereas the models have definite application at the individual transaction level, Bank A's management needs to pay particular attention to the overall structure and balance of its credit portfolio. Third, the use of models must be set within a qualitative framework that takes other factors such as risk strategy, risk appetite, market trends and management experience as well as insight into account. The next section covers in detail how management experience and insight can significantly alter and influence the use of models.

4.6.2 Qualitative factors that influence how the models are used

This section expands on the concept of the qualitative framework mentioned in the previous section to provide an illumination of these qualitative factors. Of particular significance to Bank A is the importance of experience, the use of non-model data to support or argue against the output from the model and an unexpected finding of a "gut feel" element.

4.6.2.1 Experience and use of the models

An area commented on extensively by all the participants of the research in Bank A was that experience had a large part to play in the use of models. Anecdotes are given where the shortcomings of models are counterbalanced by other considerations in order to yield the final outcome that is acted on. For example:-

> "So back in December 2007, which was still right at the height of the bull market, something like 20% of our credit economic capital was taken up in Russia with Russian counterparties. The model was telling us that was fine. I mean Russia was investment grade. Oil was 75 to 80 dollars a barrel, kept going up and it had massive balance of payments [surplus]. It looked absolutely fine on paper. As a management team we felt "No, that doesn't look right. Given the concentration that we have in Russia, and particularly to the second and third tier banking sectors, it wouldn't take much for that part of the economy to destabilise and, if it did, we'd have a problem." So we took a decision then to actually manage down our Russian exposure and today Russia contributes just over 8.5% of our economic capital. That's one very good example of where we looked at what the model was telling us and chose to ignore it and do something different." (Code CRO-A6)

It could of course be argued that in this particular case these models themselves were not taking into account concentration risk of one country adequately. It could therefore be argued that rather than applaud the management decisions taken that cater for model shortcomings, instead functionality should have been built into the output from the models in the first place. However, this line of argument would only be valid if all scenarios are known beforehand and these scenarios could all be built into models beforehand. In reality, models have limitations and much of the successful use of models involves understanding not only a model's output but just as importantly the model's assumptions and limitations. This was articulated by the Head of Capital and Portfolio Management:

> "No, I think interpretation is very important. Well, I think it comes back to what we were talking about before – that you've got to understand there are limitations in the models. They are just models, at the end of the day, and they are one input and I suppose anyone with no experience could potentially take the output from a model, but then you're just, you know, programme trading essentially or whatever equivalent. So yeah, overlaying experience with that and knowing how to interpret and knowing what the drawbacks of the models are, is quite important". (Code HCPM-A14)

Another practical example of the use of interpretation was provided by the Chief Risk Officer where the models informed the management team of the likelihood of impacts to the portfolio but the management team via their experience decided on a different course of action.

> "We were being told by the models and to a certain extent by economists that there's a very high probability of a double-dip recession. We didn't believe that as a management team. We felt that yes, it was out there, but it wasn't something that was going to bite us round the ankles in the next 3 to 6 months, so we chose to ignore it and we stuck with the base case scenario and didn't take any management action at all with the portfolio." (Code CRO-A11)

The picture is emerging of a confident management team which, in certain circumstances, will ignore the advice of the models (and economists). The degree of consensus and the relative importance of individual views when there is no unanimity is an important factor in this respect. Also emerging is the importance of differences in individual experiences and the concept of collective knowledge within the organisation.

The concept of collective knowledge has been studied by economists Blinder and Morgan (2005) who have shown in several experiments that students who work together to solve a

problem obtain a better result than the average of the students who work alone. These experiments indicate that there may be benefits to be gained from group interaction, which can provide increased access to varied knowledge, challenge of accepted opinions and testing of alternative viewpoints. Blinder (2008 p3) finds *"...the group seems to foster some sort of collective wisdom that makes the whole greater than the sum of its parts."*.

Furthermore organisational psychologists Andersen, Baustad and Sørsveen, (1994) argue that there may be a relationship between intragroup communication and task solving. Some tasks within credit risk, such as researching credit histories or analysis of credit histories, are relatively simple so what they call "unilateral communication", where feedback is not important, is sufficient. For deliberative tasks there is more of a need for feedback and discussion. In credit decisions, "bilateral communication" is necessary, with a willingness to listen to the views of the others in the group. For more strategic decision-making, as in changing risk profiles in the credit portfolios or changes that significantly affect concentration risks, the level of communication has to be more complex, where it needs to include a level of curiosity about the other person's views, a level of challenge and the ability to broaden one's views or change one's mind as a result of discussion with others. This type of communication normally requires a high level of professional competence, debate, to be able to critically analyse the arguments, to have mutual sympathy, trust and a large degree of openness.

However, balancing the argument that the process around group decisions potentially provides better collective knowledge and better solutions than individual decisions, there is an argument that the collective process does not necessarily lead to a better decision. For example, when some of the group members share the same world view and thinking, they can become convinced that their common standpoint must be right. Janis (1972) calls this "groupthink" and groupthink can lead the group astray and isolate individuals with a different view. There is typically little dissent in discussions where participants think alike. The Janis (1972) research has shown that when people are in groups of like-minded persons, they are prone to taking more extreme positions than they would on their own.

Bank-A seems to strive to get the balance right in its credit and risk committees, where there are elements of listening, challenge, debate and respect for individual views to arrive at group decisions.

"Looking at somebody across the table and do you trust them or not, then clearly there's an element of gut feel there, but when it comes to actually managing a bank portfolio, when it comes to taking views around how that portfolio should develop in relation to the macro economic environment and everything else, from my perspective I think it's basically down to experience, but equally at the same time you've also got to recognise that each of us have got different experiences and the strength comes from being able to debate and discuss those experiences and get the benefit of that collective knowledge rather than obviously relying on one particular view." (Code CRO-A6)

There is also acknowledgement that, in any evaluation of model results, there is not only a question of "whether" the recommendations from the model output should be heeded, but also questions about "when" and "how".

" If I go back 12 to 18 months and I look again at what we were doing around the stress testing, the interesting thing there is that we did decide to take action on the portfolio, but we took it too late and given the amount of inertia that you see in a credit portfolio, it's very difficult to change the risk profile very quickly because in terms of your banking pipeline you have commitments in there that aren't drawn, for example, and so the overhang you have in terms of assets coming down the pipeline and hitting the balance sheet can be quite considerable. That's why it's important to be able to identify management action and the right management action at an early stage and then be comfortable with taking the appropriate action at a more granular level to act on the portfolio." (Code CRO-A16)

Here, another interesting facet is exposed – that of implementation. In a simple transactional decision, the risk manager can decide whether or not to proceed (binary) or, in the event of a positive outcome, can choose how much exposure he wishes to take on (direction and magnitude). Where a change of direction is advocated, the choices available to the managers will depend on timeframe as well as more complex structural qualities of the overall portfolio and may well take many months to execute. In these circumstances, timing and depth of response is essential.

"What is our experience of this and do we think that what the model is telling us is right? So in terms of calibration there was involvement there as well based on, you know, our own experience and track record if you like. It wasn't a time when you could actually reduce your exposure because the markets just weren't there, there was nobody to buy the risk from you. [And ours] is very much a create and distribute model, so we would have already distributed a lot of the risk, but we were obviously creating more. So we cut back over time on our exposure to financial institutions to a point where it's

no longer a concentration..... Do I believe that management experience has any part to play in the use of the output of the models, absolutely I think it's very important. – the actual credit process I don't think has changed dramatically. You've got more tools to help you with the decisions that you make. I do think where the difference has come is really at the portfolio level rather than at the individual decision-making level. Where active portfolio management becomes possible, management has to trust better tools or models for some of the decision-making at the portfolio level, but I do think you have the opportunity to see better now where your concentration risks are, what trends are happening in the market, what is happening to the shape of your portfolio and to be able to do something about it – and I think that's the change that's happened. I think it's probably ignorance that makes you resistant. (Code HCRI-A2, HCRI-A3, HCRI-A9, HCRI-A12, HCRI-A16, HCRI-A21)

From the participants' comments there were certainly elements within the bank that appeared to resist the use of output from models. There appeared to be a link to length of service in the bank, where the older bankers were thought to be more resistant to change or perhaps seen as healthy sceptics. It would be incorrect to assume that length of service means greater experience, in the context of this research, as while the parties are clearly experienced, they may not be as familiar with the details of the models and the model outputs.

There's still old-school within the bank that still won't use models at all. They still prefer to do traditional credit analysis on a transaction by transaction basis and they don't even think about portfolios and portfolio effects. You get the younger generation coming in who are very comfortable using statistical models. I think it's the role of senior management like myself, and like the Chief Executive and what have you, to make sure that we have the right balance between the use of models and the use of [our staff's] expert judgement, and the weighting for those will change depending on the circumstances. The more experienced bankers, the older bankers and what have you, are perhaps more reticent to move to a fully fledged model based approach than the new generation of bankers." (Code CRO-A11)

4.6.2.2 Non-model information to guide the decision

The previous section looked at Bank A's approach to using credit risk models in its decision-making processes. It was clear that the model results are supplemented and evaluated along with a number of other factors. It is also clear from the interview results that the weight given to these other factors will vary in accordance with the markets, geographies and individual borrowers being considered:-

"Our country risk team provide us with macro-economic, political, legal type inputs into the country in which we're doing business. We have research analysts that give us both substantive research on the sectors in which we're doing business as well as research on individual companies within sectors, and peer group analysis of the client's lending with, I guess, other similar companies in the sector. So there's both the quantitative and the qualitative. But equally when you're looking at, for example, the PD [potential of default] model, the PD model has both a quantitative and a qualitative input and if you're dealing in a G7 developed country that uses IFRS as its accounting principle and what have you, then probably 90% of the PD model input is a quantitative input. If you're going to Africa where they don't have standardised accounting principles and readily and transparently obtainable information, then 65% - 70% of your model input into your PD rating could be a qualitative judgement. It has to be qualitative as well, for other risk types." (Code CRO-A9).

This provides supporting evidence of qualitative judgement being used to analyse exposure as well as the management team taking into account the risk strategy and risk appetite in Bank A, where even with a lack of data for the models to operate or where the models produce results that would prevent a normal bank from taking the risks, Bank-A will still operate in these markets. The Chief Risk Officer also pointed out it was important to ensure adequate capital and that credit risk decisions based on model information had to consider impacts on non-financial risk (such as operational risks and reputational risks). Another factor that will influence decisions are regulators:

"So I think the regulator's got to look at essentially management's holistic view of all of the risks that may impact their financial and non-financial objectives. So it's not just around P&L; it's around how you position the firm and how you want to grow the firm and where you want to grow the firm, and understand the risk to that. And obviously in articulating a risk appetite for the bank, you've got to take into account both the financial risk side and the non-financial risk side and be able to demonstrate first of all you have sufficient capital to cover any down-side on the financial risk, but also that you understand how the non-financial risk may impact the viability of your franchise and your ability to meet your non-financial objectives and have the appropriate mitigants around that." (Code CRO-A12)

It is apparent that management's approach to risk management and decision-making is often driven by the perceived expectations of regulators (as well as its understanding of its wider corporate governance responsibilities mentioned in the previous paragraph). These considerations move the task of credit risk management, even at a portfolio level, to a wider

context. How do the credit risk management mechanisms in place support the optimal allocation of capital and how do they reconcile competitive tensions between demands for credit across disparate business units? The credit risk models that Bank A is utilising are unlikely to be able to give clear answers to these questions – even if the quantitative framework within which the models operate is extended to inform some kind of risk-adjusted capital allocation matrix.

> "....a market's background or business background...two views on the world and people often kind of try and debate which is the right one. I mean portfolio management called a credit treasury – a central portfolio management group that owns all the assets of the bank and therefore you often have a transfer pricing arrangement. I think they may have something similar in ING or whatever where you originate it and then you have a transfer price and off it goes into the central portfolio. And then the big question is, how do you calculate the transfer price? Well, there's two essential ways. You can do it market price or some sort of return on capital hurdle rate, and I would always argue that actually you need to look at both and that looking at one is frankly a bit... It only tells you half the story and one is completely inward looking and one is much more outward looking, and you really need both. So the first question is, you know, "Does this deal make enough to cover my cost of capital?", essentially, and if it doesn't then you shouldn't do it. Having decided that it does, then the secondary question is "Am I doing this at the best rate I can?" I wouldn't want to do it below market. So it's a two-stage process. So this kind of maps in a little bit to our 'through the cycle' and 'point in time' view of the world. 'Through the cycle' tends to be inward looking. They're long-term averages, they're based on much more historic internal data, whereas our 'point in time' comes from market data on a daily basis. So yeah. And in pricing terms I always look at the two views of the world, the return on capital and the market view of the world. And yeah, we try and check trends across market spread, across all sorts of things happening in the real world – defaults levels and so on.....We don't just look at models." (Code HCPM-A6)

It is worth noting, however, that the participants at Bank A varied in terms of their assessment of the relative weightings applied to model and non-model-based information when making credit risk management decisions. All acknowledged the need for, and importance of, non-model-based data but there seemed to be some lack of clarity as to whether the model was to be regarded as just one of several equally-weighted inputs to a decision-making process or whether the quantitative models were to be seen as the decision-guides, against which, in certain circumstances, exceptions would be permitted:-

What the model isn't telling you when you're looking at concentration risk is whether that's a good or a bad thing to have in terms of what's happening to that industry. There are things you look at from the industry perspective like "What is the rating trend and so on within the industry?". Obviously we use market research, but we also get ourselves in front of the clients and their competitors. (Code HCRI-A5)

".... non-model type information which goes to drive decisions, although I think we do have good discipline and try to stick to the models and always use the models as a guide." (Code HCA-A13)

4.6.2.3 Gut feel

An unexpected finding of the research was that all five participants, unprompted, used the words "gut feel" within the interviews. It was one of three themes that everyone in Bank A spoke about (the other two themes were experience and model improvements). The term 'gut feel' was not found in Bank A's operating model nor documented in the bank. The term was also not found in the credit risk literature (based on the literature referenced in this research and an automated search via www.defaultrisk.com). A search of the papers in the Bank of International Settlements (BIS) website (www.bis.org) revealed some reference to gut feel in relation to monetary policy but there were no references found within their credit risk section. The BIS, as described in the introduction part of this thesis, is the forum for central banks to agree global banking regulation and their website contains key papers relating to the implementation and use of credit models in banks.

A general search on Google to find a combination of 'gut feel' and 'credit risks' found no academic papers on the subject, though there were several vendors that were marketing their modelling software as superior to old style credit measures and gut feel. The reason that the vendors probably look down on gut feel is its likely association with emotion, and it can be viewed as instinctive feeling or intuition - which is perceived in the quantitative world to have little place in what they call "the science of credit risk". The lack of published work does not take anything away from the risk management team in Bank A who appear to believe that models alone do not provide the only guide to decision-making and there must be other elements in the decision-making process. This section of the research is to provide some understanding of "gut feel" from the participants' point of view and provides some analysis on why it may have featured so prominently in the interviews.

"However, that's no substitute for experience and quite often gut feel. So in coming to a decision, you know, you take into account many different inputs, of which the model input just happens to be one. Quite frankly, in the last 12 to 18 months we have on a number of occasions overridden the model and gone with essentially what was gut feel because we didn't really believe what the model was telling us." (Code CRO-A5)

While the participants linked gut feel to experience, it was different from experience as it is based on looking at something not encountered previously and is linked to intuition. The Head of Credit Risk in the course of the interview highlighted an example of this.

"In a previous job I was at a credit committee in a UK bank and there was a transaction and it got around to one of the senior credit guys and he said "I don't know what it is....I can't put my finger on it. You know, the numbers say this and the model says that, but my gut feeling is that we should not be doing this," and the Chairman ...said "I don't know what it is either, but I'm going with your guts and we're not going to do the deal." (Code HCRI-A27)

The participants were asked for their definition of gut feel. The Head of Credit Analytics and Portfolio Reporting defined it as an instinct based on internal back test (testing against what a person has seen in his or her past). Internal back-testing can often be formalised by creating real scenarios based on historically accurate data that replicate the outcome estimated by the internal back test or gut feel. However the scenarios cannot replicate everything as there is an element of judgement to know if something feels too large or small as explained by the head of credit analysis and portfolio reporting.

"These models, the first time they turn the handles, they can produce numbers that are out by a factor of 10. You know, they can be 10 times too small or 10 times too big, so at that point it's clear that something's wrong. Gut feeling or your instinct is based on your own internal back testing – sort of undocumented, no methodology, but it's effectively you've never seen that before and therefore you wouldn't expect to see it now." (Code CAPR-A2)

When asked for a definition the Head of Credit Risk, perhaps thinking of negative connotations of "gut feel" in reference to emotions, was reluctant to place too much weight on the term "gut feel" that he had mentioned previously (it was unsolicited), preferring instead to express it as "common sense".

"It's more about, I think, common sense – which implies a lot more logical thinking than gut feel – and that experience where there's a track record in your mind that says

"This is what works and this is what doesn't work," or "This is what has worked in the past and this hasn't," and applying that kind of informal database of knowledge to the decision that you're making." (Code HCRI-A11)

Another participant referred to conditions, anomalies or behaviours in the markets that arouse suspicions or set alarm bells ringing. In these circumstances, there may be an opportunity to take precautionary steps before major adverse market corrections.

"It comes with age and experience. The first crisis I saw was October '87 and then from there we've seen the oil crisis, the Russian meltdown, we've seen two Argentinean crises, we've seen the South East Asia crisis, we've seen a real estate crisis here and obviously the big financial crisis last year. If you think back, there are always early warning signs that something's probably telling – whether it be too much liquidity chasing yield, whether it be the formulation of, you know, trades which are hard to value or whatever it happens to be. There's always something that's bubbling under and unless you have lived through that in the past and also unless you have, you know, made mistakes and learned from those mistakes, it's very difficult to pick up. We're fortunate that we had in our management team here a number of individuals that have got the scars of living through those things, but also the interesting thing about this bank is that yes, it's relatively big in compliance, but not so big in compliance that you can't get your arms around it. So we have a very good understanding of what's in our portfolios and how that portfolio performs and what the portfolios are vulnerable to both on the banking book side and the trading book side. You know, we'd seen the before story, we'd got the T-shirt and we knew what to do and because the organisation is small enough and with a sufficiently flat structure, we could intervene pretty quickly and get things done. (Code CRO-A10)

Most participants agreed that there was a significant place for gut feel in the credit risk decision-making process. They seemed to be open to the idea that any input that could move the decision-making and evaluation process forward was welcome. This would always be applied alongside the other recognised data and would certainly not be discouraged.

"Well, our belief in Bank A is that if you only collect data after something has happened, there is very little you can do about it (the problem or issue)." (Code HCA-A12)

Gut feel use was not only restricted to members of the credit risk team and the Head of Analytics and Portfolio Reporting also mentioned he would seek external views and

gave the example of seeking traders' views (albeit the traders would not have the ability to countermand or veto results when the outputs did not suit them).

> "First of all I have a gut feeling and a good understanding of what I'd expect the numbers to be. We've also started spending more time doing back testing. While front office don't have a sort of right of veto or a sign-off, we certainly get their consensus view for what the output of the model should be" (Code CAPR-A1)

Due to the emerging markets Bank A operate in, one can expect the quality of current pricing and financial data as well as accumulation of historic data to be lower, when set against more developed economies and companies with longer financial records.

The inadequacy of model assumptions and the lack of model data is covered in the literature by Triana (2009) and Mandelbrot and Hudson (2008) where it shows some of the shortcomings of the model assumptions as well as the need for real world data and not just historical data (which in themselves can be hard to source for each different product type and country).

> "I mean the model is never perfect. There are always a number of peripheral factors that play into... that can justify an over-ride of a model output especially if you have limited data. The other aspect is that your business strategy itself... I mean <Bank A> is a good example of that. Our business strategy actually might not be supported by models' output directly. So, you know, our risk is very high and the outputs from the model are very severe, specifically for the counter-parties that we strategically are wanting to target." (Code HCA-A18)

Credit models typically need a lot of accurate data and the standard technique for compensating for lack of data in credit models, of interpolation or proxy measures, will weaken the significance of results, perhaps dramatically as the interpolations may not be accurate measures of the missing data and there is a dependence on a high degree of correlation for the proxies used (and the data on the correlation may not be available or accurate). With the potential data issues, the management team in Bank A have a lot experience in those markets and may have built a lot of expertise in what the researcher believes they described as gut feel. This thesis sees the comments from the risk management team at Bank A as an expression of the shortcomings of basing risk management purely on statistical models and acknowledging that other factors need to be taken into account alongside model results.

4.7 Keys to credit management decision-making and where models fit

The previous sections and analysis make it apparent that Bank A sees credit risk models as just one tool available to the risk management team in deciding its strategy and approach to credit risk management. The non-prescriptive approach adopted in Bank A leaves room for over-riding or ignoring model recommendations.

The credence afforded a model's prediction will depend on the specific market conditions as well as other more general factors applicable at the time. Particularly, any credit risk management decision needs to be made in full recognition of its impact on the credit portfolio as a whole. It is a characteristic of nearly all risk models that they feed off data points and that the more data that is provided, the more significant will be the results. However, correlations between data items can produce an effect similar to the law of diminishing returns. Some commentators (Schönbucher 2001) have sought to give more weight to prior and conditional probabilities in an effort to produce a more reasonable outcome (i.e. consistent with received wisdom). However, the derivation of such probabilities is often highly subjective, challenging the rationale for applying a mathematical model in the first place.

> "Credit limits are there to deal with the risk of default and even if that risk of default is small, it's real and I think you need to have that measured. I think that because the model only gives you 70% ... I mean yes, they are redefining how credit departments are organised and the tools, and give the credit decision makers and the analysts better tools to do their analysis.....The less liquid the instrument, I think the less relevant what the model and market is telling you, and you have to use your own understanding and your own fundamental research to make your decisions." (Code HCRI-A13)

This supports Rebonato (2007) who argues that trying to collect more and more data as the solution for statistical problems can overlook the fact that data has to be relevant and that the concept of relevance (our prior beliefs) goes beyond just collecting raw data.

4.7.1 Management setting of guidelines about the use of model output

Bank A moderates the use of credit risk models through the overall management of risk appetite, which is laid out as subject to five key high-level metrics (See section 4.3.2). The bank regards the trending and the risk component measures as described by the models as equally important in informing sensible credit risk management decisions.

> "That does actually map into our overall risk appetite statement to the bank so, you know, there is a sort of constraint on the internal number but it's actually the analysis and then the trend is the other big thing. So the way these things are moving and what is causing them to move are the things that we look at. But as an organisation with various committees, yeah, we believe very strongly in that. I mean particularly in emerging markets and some of the places where we do business, you know, knowing the client and having a good relationship with the client is essential in (1) making the right decisions and (2), you know, taking mitigating action when things start to go wrong." (Code HCPM-A4)

Bank A subjects its credit models to regular review in line with changing business needs (e.g. new lines that have additional credit demands) as well as the necessary re-calibration of models in the light of changing historic datasets.

> "So we need to recalibrate our PD models and we need to reassess our LGD models in the light of our experience in the last 12 to 18 months. We're always looking at how the business develops over time. So certain niche businesses today like carbon trading, for example, may become mainstream businesses in 2 to 3 years time. So we move away from a more generalist, expert-general model to a much more specific tailor-made, quantitative model for that particular business. So we're always looking to develop and evolve those models." (Code CRO-A15)

The recalibration may not only apply to the formal models; this research finds there is also recalibration or fine tuning based on the collective experience of the institution, the general market and a certain gut feel element.

> "Your rating model will tell you something about the organisation, but there's more to it than that. And also...ahem, I mean I think as a general rule credit is also about applying, you know, a hefty wad of common sense to your decision-making process. You know, the numbers say this and the model says that, but my gut feeling is that we should not be doing this" (Code HCRI-A8)

4.7.2 Ignoring model output?

As noted in previous parts of this section, the output from models can be treated with differing levels of credence and acted upon accordingly. It is unlikely that Bank A would ignore completely the output from a credit risk model without good reason. However, all participants acknowledged that the overall credit risk management framework allowed for the model to be over-ridden where it was felt other factors and the considered experience of the decision-makers needed to be given more weight. This is shown by the following quotes from the Head of Credit Analytics and the Head of Credit Risk.

> "Well, we never completely ignore it. We certainly have policies in place in terms of the ability of credit managers to over-ride a model output. There's a very strict policy with reference to people who are actually allowed to override model outputs and only within one or two notches. On their own they might not meet the lending criteria but because of government support, the system and the corporate support that they get in various ways and other mitigating factors." (Code HCA-A20)

> "I don't know that you can ignore it [model output]. I think you have to make a decision as to whether you agree with what the model's saying, but then you have to debate with yourself and with others perhaps what you think the right answer is – and this is the common sense I guess, where the common sense comes in. But you can't ignore it." (Code HCRI-A19)

4.7.3 Overriding the model

The previous section prompts the question; under what circumstance would one override the model? The interviews with Bank A risk managers provided a range of answers from that of overrides being permissible but always subject to recording and scrutiny...

> "So they do have that ability to change the number and use models as a guide, but generally it's quite hard and fast and we monitor how many over-rides we have." (Code HCA-A5)

... to the position where it was felt that direct end-users of the models could always over-ride but with reliance on managerial hierarchy to moderate the decision-making process ...

> "The users of the model should always be allowed to override it. You need to have certain levels of authority to make sure that the person who's doing the overriding is sufficiently knowledgeable and experienced and that there are no conflicts of interest" (Code CAPR-A9)

It would seem that there was no "across the board" guidance governing model over-rides and that management was able to use its discretion in arriving at a final decision.

4.7.4 Strategic view and model output within decision-making

Bank A's business strategy takes it towards a major role in offering universal banking services to customers in the emerging markets segment. The challenge for the risk management department within Bank A is that this sector exposes limitations in the quality and effectiveness of the most widely-used credit risk model techniques.

> "If you have some strategy to develop the rest of Africa, no risk model you can run with any of those calculations doesn't result in horrible numbers." (Code HCA-A17)

There is also the sense that the shortcomings of the models in certain markets or conditions may influence the types of deals done by banks, i.e. transactions which allow models to return seemingly sensible risk parameters will be favoured over those that do not. This could incorrectly implement board strategy and may explain why Bank A's management is willing to entertain alternative assessments in arriving at its credit risk management decisions.

> "If you don't have the top management backing for strategy to actually go into business where the risk is high with a difficulty to measure the true risk, you will have a herd mentality and actually just focus on deals or transactions or counter-parties that come off lightly in the models. So in our case, I mean I can definitely see the potential for that, and in some cases it plays out. ..." (Code HCA-A17)

Business strategy plays a key in Bank A's credit management process. Because the bank's strategy is to target emerging markets where models can lack data and accuracy, the risk department is structured accordingly and has management processes to manage this. Bank A believes that in the emerging markets, they are better suited than conventional banks that have no experience of emerging markets by being able to understand their customers better and understand the background behind the model.

> "So having senior management involvement in terms of understanding the people behind the model, understanding the process that we follow, understanding the data sets that we've used in terms of getting those models implemented, that makes a huge positive difference to us as well. So they provide strong support, given that they are

comfortable with the methodologies that we follow and the inputs that we've taken, that those numbers are as accurate a reflection of the true risk as possible."
(Code HCA-A15)

Therefore they look at model output against the backdrop of their collective experience and an awareness of the market indicators, to understand the risk better than any other bank operating in the same market that has a decision-making process that is solely or largely based on models. The risk managers in Bank A also believe that purely relying on models opens up the risk of herd mentality where all the banks in the market would react the same way.

"Yeah, I think that's true and also, you know, with the trading type models that you see, you see that actually, you know, the models are actually making the decisions. I mean one of the good things about certainly the advanced approach and using economic capital as your model – the advanced approach, you know, in Basel 2 – is that you are encouraged to build your own model and I think that means that you don't necessarily follow the herd. While you may calibrate your model to an extent on what other people have done or what the rating agencies have done, it's still going to be based on what your portfolio looks like or is likely to look like and so it doesn't have to be quite as dramatic as the kind of trading type models might be or their impact doesn't have to be. But there's certainly a risk that that happens, but if that also means that everybody realises that something's going wrong, you know, something might happen and something might be done about it. If only one person realises, then they save themselves, but everybody else gets hurt. So I think there are pluses and minuses. I suspect that it does encourage a bit of herd action." (Code HCRI-A17)

The Head of Regulatory Capital and Portfolio Management expanded on this point and pointed out the issues of blindly looking at the model numbers from just a 'point in time' perspective rather than longer-term trends. Bank A views risk both from a short-term perspective as well as looking at historic information over the full credit cycle.

"I mean 60% of the market, if you believe some of the surveys that have been done, use KMV. If you just use it in a very kind of robotic way, if you like, then in certain situations it'll tell everyone the same thing and then everyone will go off and react in the same way and so, yes, I'm sure it can lead to that [herd mentality]. It's one of the things we've debated a little bit and it's one of the reasons why we use both 'through the cycle' and 'point in time' calibrations of the model and bizarrely we think that 'point in time' – which intuitively most people think is more strongly procylical – we actually in the way we use it think it's the other way because what we do with it, ... because

ECAP is kind of calculated to a certain confidence interval, we move that confidence interval around in the 'point in time' world as market spreads move. And that's one of the arguments – that, you know, if you use that approach, then everyone's trying to reduce their risk at exactly the same point. They're all trying to sell risk into the market when no-one wants to buy and this is why you get these very extreme moves." (Code HCPM-A12)

Several other techniques additional to model use within Bank A, including the use of gross limits in credit derivatives and repurchase agreements (a form of bond lending) were mentioned in the interview by the Head of Credit Analytics and Portfolio Reporting. The alignment of the risk management credit modelling function to strategy is not specifically documented in the current literature. But it is clear from this evidence that the decision-making process around credit risk modelling and tools used within the risk area is centred around the business strategy of the bank.

4.8 Model improvements and issues

This section examines how the participants viewed the adequacy of the credit risk models and what improvements were felt necessary. As a norm, the models are subject to a process of re-calibration as time moves forward and more data is available.

4.8.1 Model improvements

The capability of the models is assessed regularly in respect to current and future business requirements. There is a more or less continual list of items such as new traded products, derivatives based on existing products, new traded currencies, fine tuning based on model output and better data sources to name a few, that get raised and need to be addressed. This is effectively "business as usual" for sophisticated risk model management.

"My own experience is that the more people use them, the more they understand what's coming out of them and the more they understand the impact of the various inputs into the model that that has. Models are also now, I think, more transparent than they used to be. The danger with transparency is that people might try to of course fiddle things [the implication here is too many cooks, all trying to change things], but then as long as you've got the controls around that, then it's not so bad. I mean it's a human thing – you know, people are inherently suspicious of new machinery, if you like, or a new technology until they get used to it and then they're fine with it, until they start realising where... And then they find out what's wrong with that and then it gets developed

further. So yeah, I think it takes time. We're continuing to build and improve our rating models." (Code HCRI-A25)

The Head of Credit Risk analytics above mentions a long list of improvements they would like to undertake given enough time and resources and this was supported by the Head of Risk Analytics and Portfolio Reporting in London:-

> "Constantly we have a long list of models and for each of them we have a plan in terms of how often we want to fundamentally review them and potentially re-write the model." (Code HCA-A23)

> "If I had unlimited resources I would say I would expect about half of them to be improved."(Code CAPR-A3)

It was not possible to get a measure of the urgency or length of time required for the improvements although it is possible to deduce that the models have not met all the needs of the Risk Department (they seemed happy with 50% of models if we assume 50% of models need to be improved according to the Head of Credit Analysis and Portfolio Reporting). There was a sense of moving towards having a full and stable set of models, rather than already being there. A number of participants also expressed the view that the models that needed improvements were ones that dealt with exotic, niche or new products.

> "So certain niche businesses today like carbon trading, for example, may become mainstream businesses in 2 to 3 years time. So we move away from a more generalist, expert-general model to a much more specific tailor-made, quantitative model for that particular business. So we're always looking to develop and evolve those models."(Code CRO-15)

4.8.2 Model issues

The participants identified a number of areas where there were "issues" with the models, although it was unclear whether or not these were felt to represent deep systemic issues with the model methodologies used. Many of the observations made by the participants could be accepted as consequences of the overall framework within which the models operated, given that they were subject to overall qualitative assessment.

"Quite frankly, in the last 12 to 18 months we have on a number of occasions overridden the model and gone with essentially what was gut feel because we didn't really believe what the model was telling us." (Code CRO-A4)

The sophistication of the models from a theoretical point of view, combined with the challenges of applying these to emerging market instruments in many cases where the data would not be readily available, means that there is a degree of realism on the risk of over-reliance on the model results.

"Whatever models you use, there is always model risk, particularly on things like CVAs (CVA is explained later on in this case study) and so on, you know, there's derivative risk and it is a really complicated area. There is all sorts of, you know, convexity risk in there, liquidity risk in there. Most of what we do is very illiquid and a lot of it is very structured and because it's structured it doesn't necessarily lend itself to be easily liquidated. So that's to the extent the models were deficient and so I suppose people over-rely on them and, you know, the banks that had... I mean for example, particularly in, I suppose, the asset-bound world and home equity world where a lot of triple AAA bonds became worthless, you know, that is beyond the tail of an event that most people ever look at and yet it happened in a very, very large part of, you know, the kind of asset world, across billions and billions of debt. So I think the models didn't do a very good job of predicting that, which I suppose if you want to drill down a little bit more, a lot of models rely on ratings and the ratings probably were flawed. So, it was probably more that input was flawed in many cases rather than just the model itself." (Code HCPM-A11)

There is acceptance that the model for credit risk particularly is only able to provide so much information as it is based upon historical data and relationships. Since credit can be regarded as a function of future expectations which may not have any causal relationship with past performance, it may not always accurately account for upcoming events. One of the mitigants of this is to have an early warning system by being close to the customer.

I guess there's a lag in what the model's going to tell you compared with being in front of people and finding out, so it is important that we get in front of the clients. The model tells you some of the information. Your rating model will tell you something about the organisation, but there's more to it than that. And also...ahem, I mean I think as a general rule credit is also about applying, you know, a hefty wad of common sense to your decision-making process. It wasn't a time when you could actually reduce your exposure because the markets just weren't there, there was nobody to buy the risk from you. [And ours] is very much a create and distribute model, so we would have already

distributed a lot of the risk, but we were obviously creating more. So we cut back over time on our exposure to financial institutions to a point where it's no longer a concentration. (Code HCRI-A7)

While a number of issues raised were related to data, the Head of Credit Analytics and Portfolio Reporting did point out that it was also important to apply the right model to the right circumstance. Making an assumption that a model is always fit for all purposes and works in all circumstances, without understanding the model's assumptions and any model shortcomings, can be dangerous. The Head of Credit Analytics and Portfolio Reporting provided an example of where he thought the models had failed.

"One where it's an operational error – effectively the wrong data has gone into the model. And then the other case is where the models are not applicable. That's just all finger in the air and the simpler LGD model is, in my view, the better and in fact probably the guys in the Basel 2 that came up with the foundation approach of 45% for unsecured subordinate or senior and all the work that we've done I haven't seen any evidence to say that that's not right. Maybe that number should be a bit higher, but who's to say.

Most people playing poker will play to more or less the same model and I would bet that you could have a computer that you could programme the model and give it a pretty good idea... I mean you could make it be an expert poker player, but you put it on a table of 10 human players and one computer, I can assure you that it'd be one of those humans that would win because they'd look in the whites of the eyes of the guy who was bluffing and they would know. So I think that these models, and there you've got something that's fairly tractable like poker that is something that's fairly tractable. Your model should be pretty good. But you look at our rating models – rating models are just full of holes. They're rubbish." (Code CAPR-A6)

The example is not the easiest to follow but the point made was the importance of understanding customer behaviour and the perceived shortcomings of Bank A's rating models in this respect.

4.8.3 Understanding model assumptions

Following up from a point made in the last section, while model assumptions are probably understood by the quantitative analysts, many of the users of the risk models would not understand the underlying theories and mathematics of the models. Understanding the

theories behind the models may not be important, but one area where more understanding is needed is in respect to some of the simplifying assumptions used to develop practical credit risk pricing models. Lacking this understanding, the interpretation of results can be flawed when some of the assumptions do not to hold for some specific part of the credit portfolio, or for individual transactions.

> "....quite often the scenario you're looking at clearly contradicts some of the assumptions you made from the model in the first place. We have a correlation between our transactions and our counterparties. Except for certain PFE models, our PFE models assume no correlation between the counter-party and the transaction. Model the real world, and in order to try and model the real world you have to make a lot of simplifying assumptions; and obviously those assumptions are at a portfolio level or on the whole they are acceptable, otherwise you wouldn't make them the model, and you wouldn't do it in the first place and the model would never get developed, would never get validated etc. but as soon as you get into an individual specific instance, that assumption can easily break down. So, relatively, they know, but then how it sort of goes into the capital calculation as a PD, no, I don't think they (the users) have a feel for that. (Code CAPR-A7)

4.9 Regulatory influences on models

It was noted in section 4.6.2.2 that a number of non-model-based factors were instrumental in arriving at credit risk management decisions. Some of these were attributable to the perceived expectations of the bank's regulators on its risk appetite and consequent lending and credit trading behaviour. It is clear from the management team that regulators had a key part to play in the bank's use and development of the models. This section of the case study analyses how the regulators influenced model development via regulation around the need for models in calculating regulatory capital. It further investigates the issues around regulatory models, likely future direction from the regulators and if there are advantages for banks to focus on their own models for capital management.

4.9.1 Regulatory drivers have been significant in model development

During the interviews, there was agreement by the participants in Bank A that regulators had significantly influenced model development in the general market, although there was also an expectation that certain large global banks had been motivated towards more sophisticated internal models in order to utilise capital more effectively and to be more competitive (i.e.

obtain more accurate pricing of credit). For Bank A, it was acknowledged that the primary motivator for the bank, at the point when this research is undertaken, was to meet the regulatory rules and the conservation of regulatory capital.

> "Let me answer it this way. I think for the very big and more sophisticated banks the primary driver for them was using internal models to get competitive advantage. Basel 2 came along and it just so happens that their internal model approach was super equivalent to Basel 2 and they ticked the box and moved on. I think for the less sophisticated banks who hadn't focused on internal models, the regulatory models in Basel 2 became a prerequisite in order to drive down their capital utilisation. Now that was the driver there, not getting competitive advantage in the way of price risk, but just to drive down capital consumption. I think going forward the jury's out. I think obviously there's a big issue around the perceived procyclity of the Basel 2 models and whether or not that contributed to the crisis." (Code CRO-A19)

The point made that regulatory models contributing to the financial crisis is an interesting one, as one of the goals of BASEL II was to help prevent financial crisis. The concept of models causing herd mentality was explored in the section of this thesis on the importance of strategy within the decision-making processes. The following two quotes reinforce the view that the regulation has the largest influence on model development in Bank A.

> "Well, the key use of those models is actually to generate the regulatory capital calculation." (Code HCA-A4)

> "I think it's probably true to say that this organisation only developed economic capital models because the regulations effectively forced it to." (Code HCPM-A20)

There was also recognition that regulatory scrutiny and intervention had further shaped the risk management departments and their procedures as a whole within banking, and that this influence went far beyond the development and deployment of models and associated systems.

> "Our key regulator was an early adopter of Basel 2. So certainly, if they hadn't done that, <Bank A> wouldn't have had my department now. That's pretty much for that. There's a few areas of discussion between the bank and the regulators but largely it's the FSA or other regulator, but certainly they also, as you know, are particularly influential in terms of "Are your models adequate? Do you have the proper

governance? Do the average parameters that come out make sense? Is it in line with the rest of the industry?" So we have many reviews that [are] driven by the regulators and we have annual reviews. At the moment they've commissioned auditors to come and do in-depth, quantitative audits of the models themselves and they also question many of the principles on which we build our models. For example, government support within our bank models, our calibration, rating etc... So there are a number of things, but yes, they're most certainly heavily involved in driving us to do it..... I don't think we would have the models if the regulator wasn't forcing us." (Code HCA-A25)

The next section of this chapter looks more into the details of the regulatory models as well as how Bank A uses models beyond regulatory requirements.

4.9.2 Regulatory capital versus Economic Capital

As mentioned in the previous section, the regulators have had a key part to play in Bank A's use of models. In the UK, they do this by several mechanisms including setting the rules around the calculation of the banks' regulatory capital, by audits of the banks' monitoring systems (including the use of models) and by assessments of the banks' qualitative controls via a process called the Internal Capital Adequacy Assessment Process, or ICAAP. Regulatory capital can be defined simply as "the minimum capital required by the regulator" (Elizalde and Repullo, 2006)

"If you're in a bank, what you're trying to do is maximise your economic profit and maximise your return. To do that you need to maximise your revenue and minimise the amount of capital you consume. I mean if you're a regulator what you want to do first and foremost is to make sure that the industry is insulated from shocks and therefore you require banks not just to carry sufficient capital to cover the risk on the books, but you want to make sure they've got capital plus buffers to cover any shocks. They're just forcing banks to hold higher and higher levels of pure capital." (Code CRO-A21)

Bank A, in its annual accounts defines economic capital as the amount of permanent capital that a transaction, business unit or risk type must hold to support the economic risk. For potential losses arising from risk types that are statistically quantifiable, economic capital reflects the worst case loss (commensurate with the group's targeted financial strength). Economic capital is meant to be the basis for measuring and reporting quantifiable economic risks faced by Bank A and is used for risk management, capital management, capital planning, capital allocation, evaluation of new business and performance measurement.

To help explain economic capital in simpler terms, a more generic definition of economic capital is "*the capital level that bank shareholders would choose in absence of capital regulation*" Elizalde and Repullo (2006 p2).

Bank A calculates economic capital in a similar way to regulatory capital as they multiply three elements to provide their risk-weighted assets and this defines the required capital threshold needed to cover expected losses. The three elements that are modelled are:

- the potential of default or likelihood a counterparty will default (commonly called PD)
- the loss given default, where they model likely recoveries once default happens, taking into account recovery rates, guarantees, collateral and credit derivatives (commonly called LGD)
- the expected exposure at default. Exposures change on a daily basis especially for volatile products such as foreign exchange, equities or interest rate derivatives. This element calculates the total exposure that is likely if there is a default was to happen on that day.

> ".. in terms of the PDs and the LGDs we have a roughly common approach between regulatory capital and economic capital. It's a very fine balance actually within the regulations because of the use test. I mean the regulations are almost contradictory in that, you know, Pillar One is very prescriptive and in Pillar Two it says we want you to do it your own way. At the same time it says you've got to use your IRB [internal ratings based approach that calculates the PD] input in the business otherwise you fail the use test. So it's kind of telling you to do contradictory things, so it's a bit of a fine balance. The way it worked up to now – the PDs and the LGDs have developed within <name removed, referred to CPRA>'s world, which is part of risk as opposed to capital management. Well, obviously we look at capital. I mean in the economic capital world we run capital to a 99.925 confidence interval, which other than for capital is not particularly interesting, in being roughly a 1 in 1400 year event, I guess. So we also do UL being a one standard deviation point. We define it. I don't think in the regulatory world they have a specific definition of UL which is not kind of common usage. The way we use UL is one standard deviation – so roughly a 1 in 7 year event – and EL. I suppose we use all three of those metrics in probably, I suppose, two different ways. (1) To drill down into the portfolio to see attribution of those to different parts right down to the deal and then re-aggregation up into a country view, a sector view and a regional view. So in and of itself the total economic capital and the total UL is not of great interest. That does actually map into our overall risk appetite statement to the bank so, you know, there is a sort of constraint on the internal number but it's actually the analysis and then the trend is the other big thing. So the way these things are moving

and what is causing them to move are the things that we look at. I mean what Pillar Two essentially says is... I mean Pillar Two doesn't tell you that you have to have an economic capital model. What Pillar Two tells you is that you have to calculate and hold capital against risks which are not properly taken account of under Pillar One. And one of the things that that doesn't take account of is concentration risk, and so that's largely the reason why we use an economic capital... Also sometimes the reg rules are just stupid. I suppose the main reason for having a whole different model is largely for correlation and the reason why we use different inputs sometimes is because some of the reg rules are arbitrary, and collateral would be one of those, and there are only certain things in the reg rules that qualify for collateral. So in the reg world it's binary – it either has a value or it doesn't. To me that's nonsense. If something has a value, then it has a value and we try and quantify that value in the economic world. And likewise where you have collateral, you cannot assign it any value if it has a material positive correlation. So again it's binary – it either is materially correlated in the regulator's view or it isn't – whereas in the real world life's a bit more complicated than that. So I suppose we just try and actually model the risk in a more accurate way. So that would summarise overall why we use the economic capital model rather than the regulatory. I think there's an argument why they should, but I don't think they will. They probably intended there to be a Basel 3 at some point. So many of these banks were ones that blew up. So I'd be very surprised if we ever went to a world where only internal models were used because if one potentially came up with a completely different one, it would be so hard to police or regulate it." (Code HCPM-A2, HCPM-A16)

Both economic capital and regulatory capital numbers are used in Bank A. Regulatory capital numbers are the ones that most of the focus is on due to capital constraints in the current market. However the management team felt that the economic capital models could be more accurate.

"We use both in our decision-making, mainly regulatory because that's the main constraint on our business is regulatory capital, not economic capital and so regulatory is the one that we have to pay more attention to, but if I really want to understand the risk, I think the economic capital model is more accurate because they are much closer to real risk." (Code HCRI-A23)

The twin requirements of both regulatory and economic capital reporting have meant that Bank A has had to spread a risk and regulatory budget over these two complementary but nevertheless separate sets of reporting requirements. Whereas it is acknowledged that a higher budget is allocated to meet greater reporting needs, there does not seem to be much confidence that economies of scale are being achieved in meeting both sets of requirements.

Nevertheless, there is recognition within Bank A that as a result of the more stringent capital adequacy reporting requirements, economic capital reporting models have been developed (and by implication improved the risk management performance of the business).

> "So you could argue that we've only spent half as much money on risk management as we would have done if we didn't have the regulatory model, if we didn't have the regulatory rules. If the budget was 100, we've had to spend half of it on regulatory compliance and half of it on risk management, but if we had to spend the whole 100 on risk management, we'd have a better risk management framework. Against that – the fact that it is a regulatory requirement means that the budget is 100 in the first place. If it wasn't a regulatory requirement, the budget might only have been 20, so we might only have spent 20 on risk management (Code CAPR-A19)

4.9.3 Regulatory calculation issues and future influences of regulators on model development

In section 4.9.2, economic capital was discussed and the section touched on a number of issues with regulatory capital. This section further explores issues in models used for regulatory capital and what Bank A feels about the influence of future regulatory changes.

It was noted by one of the participants in section 4.9.1 that probably only major global banking groups had the resources to seek and achieve genuine competitive advantage through their use of credit risk pricing models. The rest of the banking community appeared to apply these models for reasons of prudential management and regulatory reporting.

There is also the issue of procyclicity of model deployment, wherein the application of sophisticated (advanced) pricing models encourages high capital leverage, which can accentuate the effects of market swings, rather than dampen them. The participants at Bank A did acknowledge there was a distorting effect from the regulatory framework which was likely to continue for some time. They also acknowledged the difficulties of regulators in understanding the full effects of regulations as well as banks in providing clear information in the face of differencing regulations.

> "I think that ICAAP [Internal Capital Adequacy Assessment Process] has only been in for a couple of years now and the FSA's still learning, the industry's still learning and, you know, no sooner have you got the ICAAP, then now you've got the ILAP. Well it's no longer capital triggers; it's the ICG, Internal Capital Guidance, and it's very difficult

to get transparency around that and how it works. So I think we've a way to go yet." (Code CRO-A13)

There was no clear view in Bank A on the impact of future regulations. They were aware of the newer Basel II amendments coming as well as the future Basel III regulations for 2013 but need to fully assess the impact of the new regulations to comment. One of the participants in the study felt it was better economically for banks to rely on their own internal capital or economic model then to rely on BASEL II models that constrain growth.

> "We're using Moody's KMV Risk Frontier solution the single factor model and the BASEL II model. The difficulty in modelling them [Credit, Market and Operational Risks] individually and the correlation between the three parts. When you try and put them together in your capital calculation, you're not going to get the right answer. The more rules you have, the more opportunity for arbitrage you create and I think that any regulatory capital rules kind of cause banks to enter into and start businesses that are not economically sensible. So my view is it would be better if management had its own internal capital model that it was allowed to use to manage its business regardless of the regulator and then the bank would have no bias on its model; it would try and produce the best model it could." (Code CAPR-A15)

An interesting comment made by the Head of Regulatory Capital Reporting and Portfolio Management was that regulators have a good feel of what a bank's capital should be. The implications of this is that regulators themselves have a gut feel on what a bank's capital level should be regardless of what the model outputs are.

> "The regulators generally have pretty good feel for how much capital they think you should hold and that's the answer they're going to get to, almost regardless of what your models say. Flatten out the amount of capital that they want you to hold anyway. Yeah, so in effect making the capital less sensitive to market movements" (Code HCPM-A 13)

4.10 Smaller themes raised in the case study

In the course of the analysis, several other themes were discussed by some of the participants which did not feature highly with the other participants. While not viewed in this research as a key part of the decision-making process, some of these themes merit mention as they help explain further how these models are used. They also help show how Bank A views the

progression of models within the bank and the likely future direction of risk models in Bank A.

4.10.1 Validation process

The regulators require that a model validation process is put in place to avoid adverse financial impact caused by misspecification, misapplication or wrong implementation of new financial models, or changes to existing financial models. Banks also are keen to ensure that models are correctly tested and regularly checked, although the rigour and frequency may differ from bank to bank. The testing and checking is done by ensuring models are properly researched, independently tested and adequately documented as part of the validation process.

The main driver in Bank A was to ensure that the models were appropriate for their use, and this involved regular checks on the models' outputs. New models go through a number of review passes at varying levels within the overall governance and control structure. The following summarises the model validation process in Bank A, using the participants' words.

> "Obviously there's input from various users and practitioners in the creation of the models. Once the model is agreed upon and all the inputs are agreed upon, then there's a calibration process and then we have a model validation team that checks all of that and they have to sign off on it and so on." (Code HCRI-A22)

> "Our validation team sits in London. Once the business has signed off it is taken to the Model Development Committee and that's a very high level committee who also then have to give us approval for the model. Sorry, I forgot to talk about Audit. Audit are involved in the process before we take it through the various committees, but they don't do quantitative analysis of the model. They audit that we've followed the approach and the proper governance and the proper signoff along the way and they give that assurance. After we've had internal assurance at the designated committee of the board, then it goes regular access..." (Code HCA-A22)

Even with good model validation discipline in the bank, there were still shortcomings with ensuring the models were fully accurate and there was qualitative judgement used within the validation process.

> "You couldn't test your UL, for example, over a short number of years. So it's a bit of a difficult thing, but we do try and back test that. But I suppose it's just kind of monitoring trends and gut feel and things like... we do more rigorous kind of testing of collateral, you know, P&L, volatility and so on" (Code HCPM-A18)

4.10.2 Link between Front Office and Risk

Two strands of influence emerged from the interviews as regards how the credit risk management framework in Bank A was able to moderate trading behaviour. First, the bank's Front Office staff were included in the model design and development process, so it was able to influence how the risk measures worked. Second, the Risk Management Department applied a more conservative assessment of market behaviours in order to counteract perceived bias to recent history on the part of the front office. Given the now widely accepted sentiment that so-called "outlier events" had a propensity to occur more frequently than models predicted, this counterbalancing exercise sat comfortably with both risk management and regulatory considerations.

> "I'm sure every bank complains about the models making them uncompetitive in their pricing practices and so on. I think it has fundamentally changed the way in which they (the front office) think about the risk of the counterparties, and it makes them more about the risk of what they're doing prior to actually doing it. So we might actually change the way in which do our business itself. The business wanted a large input into the model development and we actually changed our methodology in terms of model development to actually include them in the workshop, and up-front the message is saying we involve the business at the start and it is part of the development cycle." (Code HCA-A24)

One of the common themes in the recent literature since the financial crisis of 2008 (and frequently discussed by the regulators) is the reward that investment banks offer in terms of bonuses. Traders and bankers are rewarded for taking on more risks. Even credit departments are frequently rewarded on the increase of growth and in the profitability of the bank rather than specific management or in the curtailing of risks.

> "For risk management you need to be careful about taking recent experience too much into consideration and I also think you need to be consistent. I think if you do allow that you end up no different to the front office, and you'll just make the same decisions as the front office will make. Because the front office are making risk-reward decisions themselves all the time. That's what they do. That's what they're in the business for. If you've got some 30 year-old banker, it's not in his memory at all and if you've got a model that's somehow forgotten or doesn't include that in the numbers and certainly your pricing models, if you look at how the banks – UBS and similar cases – how they lost all that money, it was because they forgot how you can lose money. So I think for risk management your models need to not forget that, but at the same time now within

this recession, you don't your models to be too negative either. So yeah, risk management has to have a longer view and a more consistent and a steadier view and focus." (Code CAPR-A17)

4.10.3 Stress Testing

Stress Testing is a term used by regulators for describing the various techniques within banks (quantitative and/or qualitative) to gauge their vulnerability to exceptional but plausible events. These events are not meant to simulate worse case or nightmare events but instead to check the model output under stressed conditions. The participants acknowledged the importance of stress-testing over recent years and saw a significant amount of future work required in both fully integrating the stress-testing process into the overall credit risk management framework as well as the heightened importance of stress-testing and stress scenarios in credit decision-making.

"In terms of stress testing models, we certainly are grappling I think at <Bank A named> with them a lot. There's still a lot more to get at it around in terms of stress testing model outputs and how we actually use those and I think it's got a lot to do with the probability that you'll find in a scenario [this relates to the stress test parameters and the likelihood an event will occur]." (Code HCA-A28)

"So if you take the wrong management action or you take it too early or too late, it could have disastrous effects on the portfolio. If I go back 12 to 18 months and I look again at what we were doing around the stress testing, the interesting thing there is that we did decide to take action on the portfolio, but we took it too late and given the amount of inertia that you see in a credit portfolio, it's very difficult to change the risk profile very quickly because in terms of your banking pipeline you have commitments in there that aren't drawn, for example, and so the overhang you have in terms of assets coming down the pipeline and hitting the balance sheet can be quite considerable. That's why it's important to be able to identify management action and the right management action at an early stage and then be comfortable with taking the appropriate action at a more granular level to act on the portfolio." (Code CRO-A7)

Other than stress testing, the head of credit Analytics in Bank A spoke about early warning systems....

"The other area that we speak a lot about is our early warning system or early warning signals and this something that we don't actually have our own consolidated solution in..." (Code HCA-A9)

4.10.4 Concentration Risks

The Head of Credit Analytics and the Head of Credit spoke about how models could help the bank in better analysing and understanding its concentration risks. Concentration risks are risks to a particular area that could affect you drastically if that area is impacted. Examples are country, currency, customer type, sector or industry. The view that models help concentration risks was supported by the views of the Head of Credit Risk who noted that with active portfolio management, where the management team could actively change the portfolio make up, it was possible to reduce concentration risks.

> Where active portfolio management becomes possible, management has to trust better tools or models for some of the decision-making at the portfolio level, but I do think you have the opportunity to see better now where your concentration risks are, what trends are happening in the market, what is happening to the shape of your portfolio and to be able to do something about it – and I think that's the change that's happened. (Code HCRI-A4)

4.10.5 Credit Valuation Adjustment (CVA)

One of the themes discussed during the interview was Credit Valuation Adjustment or commonly referred to as CVA. CVA as defined by *Pykhtin &* Zhu (2007) is the difference between the risk-free portfolio value and the true portfolio value that takes into account the possibility of counterparty's default. In other words, CVA can be seen as a model that attempts to put a market value to a counterparty's credit risk. Based on a literature review, Canabarro and Duffie (2003) is a common reference for background on the subject.

The relevance for this research is that at the time of conducting the research, CVA was being keenly debated in the market and adding further momentum was recent paper from the BIS on Basel III endorsing a CVA approach[13] (, as referenced in their paper. There are differing CVA approaches and the BIS Committee propose the use of a bond equivalent (with its notional value equal to the total exposure at default of a particular counterparty) as a proxy for counterparty risk.

The BIS CVA (also known in the BIS paper as credit charging) proposal has two parts. First, charge the front office for expected losses and for the capital cost of credit risk. Second, create a specialised Credit Portfolio Management (CPM) desk to manage the credit risk that

[13] As referenced in the Basel paper "Strengthening the resilience of the banking sector" (BIS, 2009)

arises for the lifetime of the trade. In short, the idea is to delegate more P&L responsibility to traders, but to centralise CVA management.

The stated motivation is twofold. First, the proposal attempts to address the shortcomings of traditional credit management methods which were very strongly highlighted, during the recent financial crisis, by CVA-induced volatility in banks' reported earnings. Secondly, alignment of trader incentives leads to use of a more accurate (and most likely, more conservative) economic capital calculation.

> "We call it [CVA] continuing credit product. Essentially you've got to understand what your potential risk exposure is on a particular transaction, on your portfolio or whatever. That's the starting point before you can even think about hedging all or part of the risk. So assuming you want to hedge 100% of your risk on a particular transaction and you do that on day one, now the simplest way would be buying CDS, but in emerging markets where a lot of the counterparties don't have CDS you're trying to identify instruments or positions which would replicate the performance of a CDS in the case of a default. So you're immediately carrying basis risk. The point is though, of course, that the performance of the Hedge is continuously changing and the risk profile of your counterparty or your portfolio is continuously changing, so that needs to be re-balanced continuously. Now when markets are stable and there's sufficient liquidity around, then that may be possible, but what we do know is that when markets become stressed and liquidity dries up, you may not be able to re-balance your Hedge or you may not be able to re-balance your Hedge at an economic price, therefore you're still going to have to have a view as to how much residual credit risk you need to run. And the other thing here of course is that all of this hedging presumes that the hedging models work, and what we should have learned from the CDO experience and what have you is that quite often in times of stress these models don't work. I guess an analogous situation would be, Jacob, if you had netting agreements and CSAs in place for, say, FX or interest rate swaps, then arguably if you've got zero threshold, you could have infinite amounts of grossed exposure because on a net basis it's flat. But only an idiot would do that because you're still running legal risks, still running operational risk. Similar thing around continuing credit pricing. You always need to have some sort of back stop." (Code CRO-A14)

4.11 Viewpoint on the future

One of the questions from the interview questionnaire was if you could position yourself five years into the future, what changes would you expect to see in the context of risk modelling.

The reason for the question was to look at Bank A's management viewpoint of the direction of risk models. Two main themes emerged...

4.11.1 Likely increase in sophistication of models?

Two differing views emerged on the same theme of model sophistication. On the one hand, the Head of Credit Analytics felt that models would get more sophisticated in the future, especially in emerging markets as quite basic models were upgraded to match the ones used in developed markets.

> "I think we will - in 5 years from now - still in places have quite basic models [but] get more and more sophisticated going forward. As we've had all the debates and negotiations, and people being more accepting of them, and it'll be slightly more automated at that stage and I think that will then drive the way in which we're going to develop models, and the sophistication of the models which we are able to build." (Code HCA-A27)

The view that sophistication would increase was supported by the Head of Regulatory Capital and Portfolio Management, who emphasised the likely extended use of stress testing to provide a more holistic view of risk (the holistic view is explained in the next section).

> "second-order connections or correlations you can only really do if you have a more holistic view of the world, and use of stress testing to try and find that is where we'll be heading in the next 5 years." (Code HCPM-A22)

The Head of Credit Risk felt there was a case of simplification of the way models were used specially in the overlap of market risk and credit risk, where rather the overcomplicated regulations should be simplified. The overlap of credit and market risks is covered in the next section (4.11.2) of this thesis.

> "I think in traditional lending you don't really need all these models - exposure modelling and the capital modelling. Over the next 5 years I think we need to simulate the defaults [credit risk] and the market price [market risk] in the same model with the same correlations. Ultimately I'd like to remove the distinction even more and, if you like, I'd like to have a loss model because in the end that's what we're trying to manage. We're trying to minimise the loss. But today we split it into the sort of three parts – PD, EAD and LGD, and I think that was probably a necessity, but I think it is a mistake." (Code HCRI-A20)

While the views of more complex models and less sophistication may appear contradictory, both views are probably valid as there will likely be more sophistication in emerging markets, as well as some shift to streamlining how exposures are calculated and to remove some of the duplication in some of the credit and market risk measures.

4.11.2 Likely holistic view of risk over credit risk and market risk?

As shown in section 2, credit risk can be defined as the risk that a loss will be incurred if a counterparty to a transaction does not fulfil its financial obligations in a timely manner. Market risk can be defined as the risk that the value of a portfolio, either an investment portfolio or a trading portfolio, will decrease due to the change in value of the market risk factors.

Traditionally, market risk and credit risk have been different departments within the bank, where they calculate risk differently. The standard market risk measure is via Value at Risk (VaR) calculations, and in credit risk via different calculations of expected and unexpected losses.

Where there is an overlap between credit and market risks is that both will calculate pricing of the transaction and both will model default (albeit differently). This is linked to a point made by the Head of Credit Risk in the previous section where he mentioned in section 4.11.1 that "we need to simulate the defaults and the market price in the same model with the same correlations" (Code HCRI-A20).

> "A blurring of the edges between credit and market risk, and I think with the advent of CVA contingent credit product, that blurring is just going to accelerate. We've already seen that in times of stress, market and credit risk converge anyway." (Code CRO-A23)

To add further complexity, both are affected by the liquidity of the instrument but liquidity risk is calculated and reported separately in both regulatory reporting and internal reporting. The Head of Regulatory Capital and Portfolio Management suggests that stress testing could look at all of these risks together, and the adoption of enhanced stress testing could be one of the future trends in the market.

> "Definitely a more holistic view. I think they'll need to align those a lot more and I think people need to align the way they look at capital and liquidity and not ignore them i.e. the link between them. All of those things [are] in stress testing. I think the other

change will be that stress testing will play a more and more important role because, as I said, the models clearly didn't identify what was going to happen and therefore I think, you know, everyone accepts that you need to do stress testing better, and it's therefore in a sense looking for correlations that are not necessarily obvious and you can only really do that.... I mean some things are obvious – you know, country concentrations, industry concentrations. In our world commodities is probably kind of the over-riding one because most of the countries where we do business dig stuff or pump stuff out of the ground." (Code HCPM-A21)

4.12 Summary of the approach of Bank A towards credit risk models

This chapter has shown that Bank A does not follow one particular model philosophy. Instead model use depends on where a particular model is in its evolution (if it is theoretical, newly produced or established) and in its life cycle within the bank (if it is in development, has been tested, in common use, a model that is mature in its use or if it is outdated). It also depends on how much data the model requires, on the model's fit to the product set and the results of validation that is performed on the model.

While models are an important part of the management decision-making process, it is clear that model output is not the main determinant in management decisions. In section 4.6.2 of this chapter, qualitative factors such as interpretation of the model results against the individual's experiences, the use of collective wisdom and the view of external environmental factors (market, political and legal) are also instrumental in arriving at management decision on credit risk. A quotation from the Chief Risk Officer summarises:

"The key point to make here is that the output from a model is only an input into a broader management decision. It's not the main driver in itself." (Code CRO-A2)

As part of its use of these models the risk management team were aware of its wider corporate governance responsibilities, as well as the importance of aligning the risk management processes with the strategy of the bank. The Head of Credit Analytics clarifies:

"Models will never remove the need for strong governance and credit management and credit involvement and business involvement as well." (Code HCA-A19)

An unexpected finding, not found in existing credit risk literature, is the informal manner that Bank A uses some of the qualitative factors such as experience, environmental information

(e.g. market information or political or legal information) and a 'gut feel' element alongside a model's output information to make risk decisions, occasionally overriding the model output.

Credit risk models typically require large amounts of good quality data. Due to the markets that Bank A operates in, availability of data as well as data quality impacts how Bank A is able to use these models. Many of the comments from the risk management team at Bank A are expressions of the shortcomings of basing risk management purely on statistical models, but these expressions are likely amplified due to the impact of data limitations on the models. This may also explain the reliance in Bank A on more qualitative measures such as experience and gut feel.

> But I think it also speaks for this bridge between the academic world and the real world. I mean when you really don't have the information and you are really your own source of information, that's kind of something that I think about" (Code HCA-A29)

Section 4.9 showed that the biggest single driver for Bank A's use of credit risk models has been regulatory pressures in the past and by the bank wishing to optimise its use of regulatory capital. One of the participants even went so far as to say that without the regulations, "*the bank would never have used risk models*" (Code HCPM-A20). While there is no doubt that regulations have been the most significant influence on the use of credit risk models, the bank does also recognise the usefulness of these models in day-to-day management of its credit risks, and have developed the models beyond their original regulatory needs. The Head of Credit Risk explained their approach:

> ".....so the regulators have certainly had a positive impact. So the regulator can get us so far, but I think as an institution and as an industry we can probably go further....." (Code HCRI-A26)

One of the areas touched on in this thesis is resistance to the use of the models' outputs and the potential link to experiences of older and younger members of staff. It is not an area that the research provides any conclusive evidence on, and probably merits further research.

The next chapter of the thesis presents the second of the three case studies.

5 Case Study Bank B

5.1 Introduction

This chapter provides a study of Bank B where it analyses the responses to the interview questions in order to identify trends and differences of views between all the responses. By highlighting the similarities and differences in what was said by the different participants, or how they said it, an understanding can be built on the use of credit risk models. The aim is to provide a holistic and in-depth description of management's use of credit risk models. The data and explanations are then used as the foundation for the cross-case analysis in chapter 7.

The data collection and data analysis have been previously discussed at length in the methodology section in chapter 3 of this thesis. Where necessary, interview quotations have been used to demonstrate the analytical interpretations and have been provided in the form of exhibits at appropriate junctures.

The next section (5.2) provides background with an overview of the bank, its governance structure and its general market strategy in order to provide the reader an organisational context to the case study responses. Section 5.3 analyses the risk management framework covering risk appetite, management team and organisational structure. Section 5.4 describes the participants who were guaranteed confidentiality; therefore, their roles are described and alphanumeric codes assigned. These codes are used to identify specific quotes included in the main body of this chapter. Sections 5.5 through to 5.94.9 investigate and discuss the main themes that emerged in order to understand their use of the models. Section 5.10 covers the secondary themes found and section 5.11 focuses on the participants' views of possible improvements or changes to the models. The last section, 5.12, summarises and characterises the approach of Bank B towards credit risk models.

5.2 Background of Bank B

5.2.1 History and coverage

This section provides background of the bank and its organisational structure in relation to credit risk.

Bank B is the Investment Banking subsidiary of financial group that describes itself as a dynamic and international financial organisation (from company website quote in 2010). It emerged in the early 1990s as the old economic machinery of the former Soviet Union was dismantled and private and commercial ownership of state-owned enterprises was permitted. The bank was set up with state support, in order to provide banking and transactional services to the emergent private corporate enterprises. The group comprises three main areas of banking activity, consisting of Retail, Corporate and Investment banking.

The group is active in the Commonwealth of Independent States (formed during the breakup of the Soviet Union and consists of the former Soviet republics), Western Europe, Asia and Africa. The group's majority shareholder is a national asset management agency that is controlled by the government, and it is therefore effectively state-owned. The group's subsidiaries operate under a single brand and are governed by a shared strategy and approach. The group has a strategic goal of increasing its Investment banking business which although is just under 10% of the size of the group, is highlighted by its prominence of having equal importance to the other parts of the group in its annual reports (the others being Retail banking and Corporate banking).

The banking group's total assets were USD$120 billion on the 31st December 2009. Revenue growth had varied a lot in recent years with profits in 2007 but losses in 2008 and 2009 and a return to profitability in 2010. They employ more than 40,000 people worldwide. The bank's market capitalisation on the 31st December 2009 was USD$36 billion. Bank B was rated Baa1 by Moody's and BBB by S&P and Fitch.

The table below shows some key financial data for the banking group:

Key financial data (USD billions rounded)	**2010**	**2009**
Total Assets	140	120
Headline Earnings	1.8	-2
Net fee and commission income	0.8	0.7
Net interest income	5.7	5
Income from financial instruments	0.50	-0.67

Net interest margin	5.1%	4.6%
Return on assets	1.5%	-1.6%
Return on equity	10.3%	-13.7%
Cost to income ratio	43%	45.7%
Capital Adequacy %	16.8%	20.9%
Tier 1 capital adequacy ratio %	12.4%	14.9%

Table 5.1 Bank B group general financial data (converted to USD)

The table below shows the services and products in the banking group:

Corporate banking	**Retail banking**	**Investment banking**
Provides services to large- and medium-sized companies, financial institutions, as well as government executive bodies and local authorities.	Focuses on working with individuals and small businesses.	The most dynamic area of activity of the banking group. This segment focuses on serving the investment needs of financial institutions, companies and individuals, as well as government bodies.
• Loans to large- and medium-sized businesses • Trade and export financing • Deposits and cash management services • Leasing, factoring	• Loans to individuals and small businesses • Deposits • Payments • Brokerage • Private banking	• Research • Global markets • Global banking • Investment management • Equities Products • Fixed Income products • Derivatives Products
64% of the total group's revenue in 2009	20% of the total group's revenue in 2009	11% of the total group's revenue in 2009

Table 5.2 Products and services provided by Bank B group

5.2.2 Organisation and strategy

Bank B has been affected by the liberalisation and evolution of financial services within the former Soviet Union and has been trying to develop new products and services that are common in more developed markets such as new mortgage products, foreign exchange services, sophisticated interest rate products, equity trading and commodity trading services. Current strategic goals for the group recognise the need to develop a more cohesive global

presence and to move from what was a holding company of several local businesses to a bank with a global strategy. This will require a stronger degree of coordination between the various businesses that make up the group as well as implementing a more stream-lined decision-making and execution process. In their 2009 year-end accounts they mention that they are implementing a common development strategy model across of all their entities with a single brand, centralized financial and risk management, coordinated budgeting and reporting systems, a focus on sharing best practices and applying the same standards across the group.

The group has recognised the need to establish a stronger governance framework, in keeping with the recognised best-practice for global financial services organisations. From their 2009 annual report this is a "work-in-progress" and they believe it will take a number of years to implement.

The website (2010) and annual reports (financial year end 2009) mention that a fundamental management mechanism used within the group is its corporate governance, i.e. implementation of the group's rights as a major shareholder through participating in the management bodies of its subsidiaries. An additional management mechanism is the functional coordination of the group's main business areas including support and control areas (e.g. risk management, planning, budgeting and management reporting, brand, internal control and audit).

The pulling-together of the various business strands that comprise the group requires more cohesion in their risk management activities across the group, as well as more effective deployment and management of capital, in order to become a credible global player in their chosen specialisations. These strategic objectives have clear implications for Bank B's organisation as well as its command and control mechanisms.

Bank B's group operates a two-tier board structure, as commonly found in continental European banks, consisting of a Supervisory Council and a Management (also called Executive) Board. The Supervisory Council is elected or ratified by the shareholders as part of the shareholder annual general meeting.

The Group Management Board is responsible for both the day-to-day management of the business and also the long-term strategy. The Supervisory Council is responsible for

monitoring and analysing management performance as well as advising the Management Board.

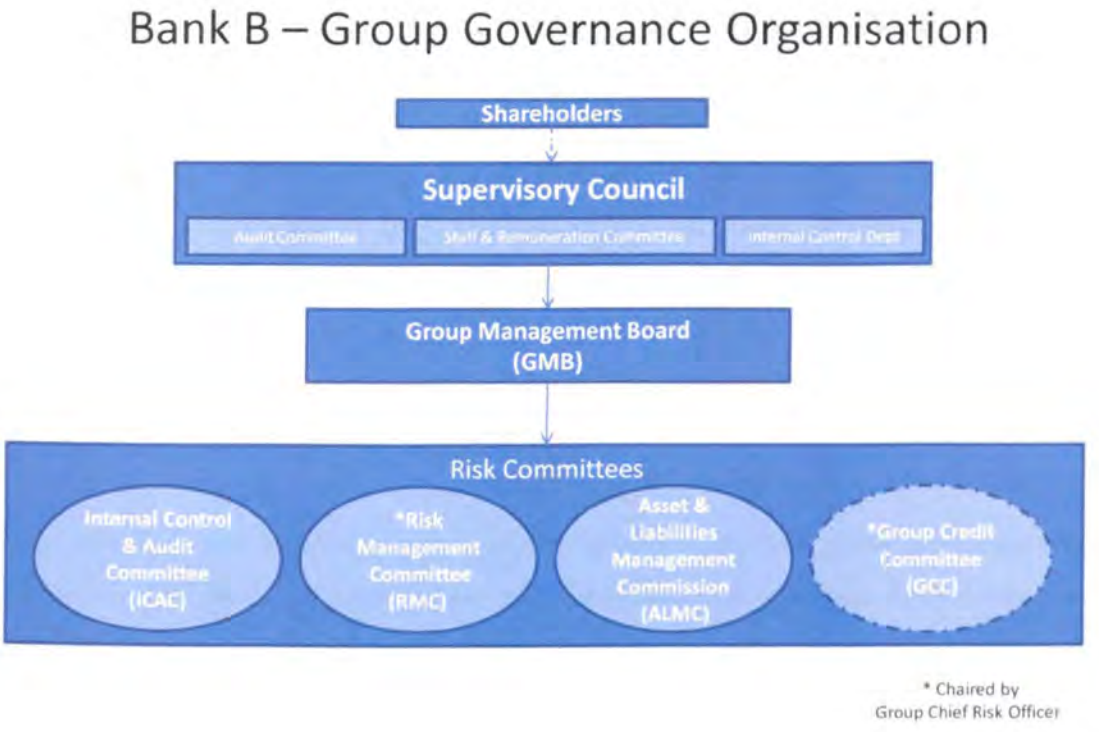


Figure 5.1 Management governance structure in Bank B's parent group

The main coordination and advisory body for the group companies is the Group Management Board (GMB). Among the Group Management Board members are the CEO and CRO of Bank B. This management committee makes all major decisions within the group, such as:

- approving business plans and development strategies for various business areas
- examining reports on the business performance of subsidiaries, as well as liquidity and risk parameters; overseeing the implementation of priority projects
- approving standards, approaches and principles of the group's operations prior to their approval by the relevant administrative authorities of the group's companies

Such additional management mechanisms are applied in order to achieve the greatest synergy within the group, to share best practices among the group's member companies and to limit the overall market risk and credit risk exposure to the group. Functional coordination also facilitates knowledge and experience exchange among the companies within the group, and

allows pooling of available resources to materialise certain projects. Fundamental coordination helps create common standards, principles and limits to be applied to certain business lines of the group activities. This is important in the control of credit risk within the group.

In order to provide a platform for an in-depth and expert analysis of group performance, the Group Management Board has set up what they term as "coordination commissions", which are effectively committees in the divisions, such as the Asset & Liabilities Management Commission (ALMC), the Risk Management Committee and the Internal Control and Audit Committee. Among their members are professionals from the group's member companies. The terms of reference of such Commissions include the identification of best practices and subsequent oversight of their implementation.

The group states that they have been persistently improving their group governance system through the application of what they believe is the best market practices. Over the recent past, the most significant events in streamlining the group's governance system have been as follows:

- formalising the group governance mechanisms in its by-laws
- developing and implementing standardized systems among the group's companies for business planning and reporting, common funding principles, single standards in lending and in relations with financial institutions
- streamlining the Group Management Board's procedures, including the mechanisms of its decision documenting and implementing and rotating its membership to reflect new companies in the group

Bank B group's stated strategy is to become a global universal bank with recognised expertise in the areas of emerging markets, servicing corporate clients from the CIS states. It has recognised that, in order to achieve this, organisational, governance and decision-making frameworks will need to be modified. To some extent, this will/may require devolution of authority into the functionally responsible areas, with support from improved systems and methodologies. Whereas this has widespread implications for all parts of the bank, the challenges for the risk management division are crucial for the longer-term success of the enterprise.

From observation of Bank B and its group's management structures, much of the senior level management structures have characteristics of a style of operating that is based on committees. This may be explained by the fact that it has emerged from the break-up of the former Soviet Union and from the influence of the majority shareholder (effectively the Russian state). In view of the centralised structure and political influences, there are likely to be many challenges that lie ahead of the group in its stated strategic objectives.

From this point on, this case study focuses on Bank B. The reason for focusing on this part of the group rather than on any other part is that a) risk management in Bank B is more sophisticated than in the rest of the group, b) the researcher had access to senior members of the risk management team based in London, and c) the Chief Risk Officer (CRO) in Bank B has been very supportive of the research and is the key sponsor of this research. The research does take some elements of the group into consideration as Bank B as there is a large cross over between Bank B and the other parts of the group. Bank B's CRO is also the group CRO and a member of the group board. He is therefore well placed to highlight any differences in the group on the use of credit risk models.

5.3 Risk management framework in Bank B

5.3.1 Risk governance structure

As mentioned in section 5.2.2, Bank B operates within a network of group companies whose businesses are coordinated under an overall governance structure via the Management Board in the group. Ultimately, responsibility for the management of risk within Bank B falls to this Group Management Board, although on a day-to-day basis operational responsibility rests with Bank B's board of directors. This day-to-day responsibility is further delegated to the board committees of the Bank and its sub-committees, which review, among other things, summaries of credit, market, liquidity, operational, country and regulatory risks. These reports are provided by the Risk Division which is run by the Chief Risk Officer. The board of Bank B also delegates certain key risk responsibilities related to risk control to the Risk Division under the Chief Risk Officer. A high-level risk governance chart is given below:-

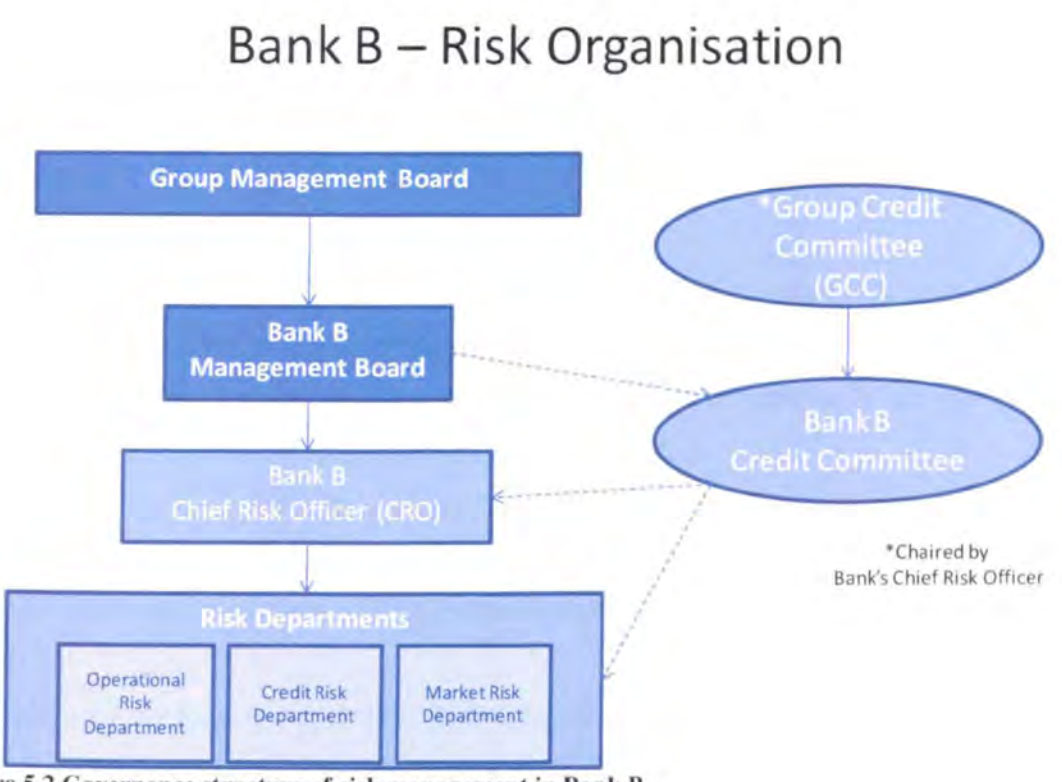


Figure 5.2 Governance structure of risk management in Bank B

The Risk Department is responsible for risk management for the Bank, including unification of credit-risk policies and procedures, risk management systems enhancement, allocation of economic capital within the bank, data reporting to Group and the development of the risk control system.

The Risk Department proposes risk limits on various banking operations, and provides reports to the Credit Committee and the Management Board. Credit risk limits are determined by the Credit Committee. Where the limit exceeds Credit Committee's approval authority, these then need to be approved by the Bank's Management Board. If the limits exceed the Bank Management Board's authority, these limits then need to be approved by the GCC.

The ALMC, the Credit Committee, the Risk Department and the bank's Treasury unit carry out risk management functions in respect of credit, market (rates, FX and instrument price) and liquidity risk.

Like many other banks, to ensure there is independence and appropriate segregation of responsibilities between business and risk management, credit risk officers assigned to the

business units report operationally to their respective business unit heads, and functionally to the Chief Risk Officer. Compliance with risk standards is controlled through self-assessments by the business units and the Risk Division, supported by Auditors.

5.3.2 Risk appetite

Section 2.7.1.1 of the literature review covered importance of a bank's risk appetite. Bank B states in its Basel II Pillar 3 disclosures for the year ended 31 December 2009 that the group's Board of Directors is responsible for setting the overall risk appetite of the group and for approving the overall risk management strategy employed.

Bank B does not disclose its actual risk appetite set by the board of directors in its annual accounts nor in any publicly-available documentation.

It does though mention that it entered 2009 with significant legacy lending exposures that fell outside its new (but not disclosed) strategy. Throughout 2009, the bank recognised impairments associated with that portfolio and raised its provisions accordingly. Since then, the risk reduction in the bank's lending portfolio remains a priority for Bank B until risk exposure is commensurate with the firm's targeted (but undisclosed) risk appetite.

5.4 Credit risk management in Bank B

From Bank B's 2009 annual accounts, credit risk has the highest weight among risks taken by the Bank in the course of its banking activities, and composed most of its Tier 1 and Tier two capital usage. Unlike Bank A and Bank C, it does not disclose the exact value or percentage of its credit risks. The bank's risk teams are focused on ensuring that credit risks are prioritised and that it adequately manages its risks to the Financial Institutions.

Credit risk management in the Bank is carried out using the following main procedures:

- putting in place limits to limit credit risk
- putting in place indicative limits for credit risk concentration and the share of unsecured loan portfolio
- creation of security for credit operations
- setting value conditions for operations with respect to payment for risks taken
- permanent monitoring of risks taken and preparation of management reports for the Credit Committee, the Bank's management and the individual units concerned
- evaluation of regulatory and economic capital necessary to cover the risks taken in respect of the Bank's operations and ensuring sufficient capital
- carrying out hedging operations
- compliance with regulations on operating procedures, and regular risk assessments by independent units

As mentioned, credit risk limits are determined by the bank's Credit Committee. If the approval amount exceeds the Credit Committee's authorised mandate, the limit must then be approved by the Bank's Management Board. The Credit Committee is chaired by the bank's Chief Risk Officer (CRO).

Along with its internal credit risk limits, the Bank observes the mandatory requirements established by its home regulator in terms of risk size by borrower, group of related borrowers and size of large loans.

5.5 Reporting lines in respect to credit risk modelling in Bank B

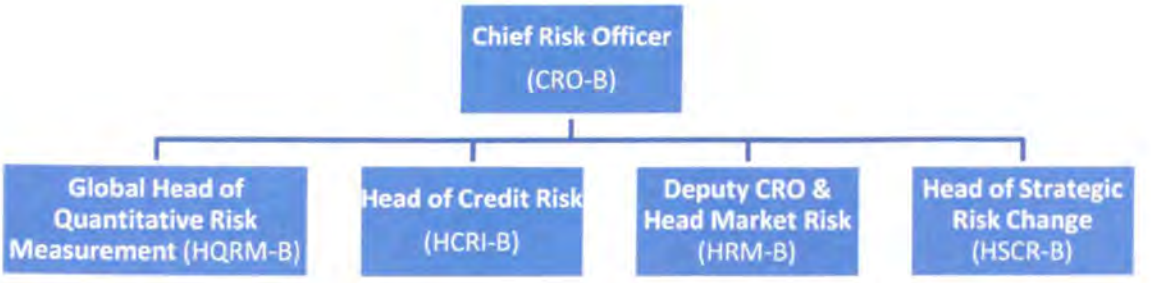


Figure 5.3 Credit risk organisation chart in Bank B in relation to credit risk modelling

5.5.1 Role of the participants

The risk organisation chart in relation to credit risk modelling is shown in Figure 5.3. The Chief Risk Officer (CRO) was the main sponsor for the project in Bank B. The five respondents listed in the organisational diagram were elected by the CRO to take part in the research and represent the heads of each of the areas involved with credit risk models. The fact that the CRO elected the respondents for the research is not believed to impact the research as the same departments would have been targeted as part of this research and the same respondents approached. The CRO's support meant that the respondents had an additional motivation to contribute to the research. Senior support also ensured that that internal documentation relating to models was made available to the researcher. All the respondents were helpful and made time in their busy schedules to ensure enough time was allocated to the case study interviews and to answer follow-up questions. The following is a description of their roles (note: the descriptions are in their own words but also cross checked against the organisational diagrams in the bank).

Chief Risk Officer (CRO-B)

CRO-B is the Chief Risk Officer for the Bank (and the Group). He has functional responsibility for managing market, credit risk and operational risk in Bank B. He has oversight of the liquidity risk. CRO-B chairs Bank B's Risk Committee and ensures that the board's decisions are implemented. He has day-to-day responsibility for managing all of the teams within the Risk Division in Bank B. CRO-B has worked 24 years in banking and risk. He has worked in a number of Tier 1 banks, as well as for the regulator in the UK (the FSA).

Global Head of Quantitative Risk Management (HQRM-B)

HQRM-B is the Global Head of the Quantitative Risk Management team. He has a PhD in physics and is a well-known speaker on modelling in risk conferences. His responsibilities in Bank B cover all model development teams across the bank's global business as well as maintenance and support for the models. He reports to the CRO.

Head of Credit Risk (HCRI-B)

HCRI-B is the Global Head of Credit Risk Management. She is the delegated credit authority holder within her department, so all credit decisions, whether limit setting, approval of new clients or approval of new transactions are directed through her. Credit authority that goes beyond HCRI-B's individual limit requires a second authority approval by the CRO. HCRI-B oversees the end-to-end credit process which includes research and counterparty analysis, credit decision-making and monitoring of the transactions through the life of the exposure.

Deputy Chief Risk Officer and Head of Market Risk (HMR-B)

HMR-B runs the Global Market Risk department and is deputy CRO in Bank B. HMR-B's main reason for inclusion into the research is that there is a close relationship between market risk and credit risk in the bank. HMR-B is familiar with credit risk models and was also previously head of counterparty risk in a Tier 1 Investment bank in London.

Global Head of Strategic Change for Risk (HSCR-B)

HSCR-B is Global Head of Strategic Change for Risk. She is responsible for implementing the programme of change affecting the risk management group globally. This includes credit risk models and the implementation of these risk models in the bank. This role necessarily performs management and oversight of implementations of risk systems, models, processes and procedures within Bank B.

5.6 View of the participants to credit models

Similar to Section 4.6 of Chapter 4, this section follows the structure of the interview protocol used during the interviews with representatives of the risk governance and management organisation of Bank B. As described in Chapter 3 on methodology, there are no established theories of management use of credit models, and this section uses the responses to draw a number of conclusions around the use of credit risk models and highlight areas of potential improvement in practice and execution. The interviews were semi-structured, in that there was a script with a list of questions prepared, but the research participants were allowed to decide how they wanted the interview to be structured, and were allowed to speak freely on their views of the use of risk models.

5.6.1 Credit model use

Compared with the other banks in this research, Bank B is in the initial phases of credit risk model implementation. The main reason is that the bank is a relative newcomer to the international investment and wholesale banking marketplace. In its past, due to it being ex-USSR and its profile being of local regional banks, it would not have been required to implement models by the local regulator. While the bank has not yet implemented complex models, it still merits research for several reasons. First, they would be starting from a clean sheet and would not be lumbered with legacy solutions. This means that they are not constrained by their existing solutions and they are looking at the models from a strategic viewpoint, allowing them to choose the model that they feel best fits into their business needs. Second, senior management in risk are all very experienced investment bankers that are known in the market and would have detailed knowledge of risk models. It would be a valuable source of information. Third, other than their views of models, they would also contribute to this research information related to implementation of these models, as this is one of the issues they are currently focused on. Finally, as there are clear plans in the bank to grow and to expand, there will be regulatory pressure (the FSA) on extending their risk capabilities and also the use of models within the bank. These factors would mean the bank could have a valid view of the models that may be different to the two other cases, and it would be useful to understand their views. Below a quote from the CRO of Bank B that explains their current use of models.

> "From the perspective of credit risk we have somewhat limited use of models. I would identify off the top of my head three places where we use modelling. The first one is for

credit grading. The way I would describe that model is it's a model that has been calibrated to try to take what is probably expert judgement and to factorise that and to put those factors into, as I said, quantitative and qualitative terms to rate them and, broadly speaking, as it was developed it was tested against the bank's expert judgement outcomes. So it's not a particularly complex model. I guess the validation of it was a regression based validation.

The other place that we most obviously use modelling - although, you know, I somewhat hesitate to call it that - is in the calculation of counterparty exposure. We've got a very simplistic approach at the moment which is consistent in the group and, in truth, it's probably all we could implement in Bank-B at the moment given, you know, the very simple credit system that we have, which is a transaction-based potential future exposure calculation. The models are based on transaction type and we certainly don't have full coverage at the moment, and then the calibration of those models is done separately for currencies or currency pairs as appropriate. We also have put in place to try to address the issue of loan equivalent, not really being something that can be described in PFE terms. There was an analysis done of the relationship between PFE and expected exposure across the commonly traded product types and we've come up with a very simplified conversion factor so that we can talk in terms of expected exposure and loan amount as being roughly equivalent concepts. What I would have to say though is that certainly at a [bank named] group level, that hasn't really been embedded into the thinking of the Group Credit Committee, to my understanding. And further, you know, the difficulty with generalised EE and PFE relationships is that it doesn't necessarily give you a clear framework within which to deal with wrong-way risk [this type of risk occurs when exposure to a counterparty is adversely correlated with the credit quality of that counterparty]. So wrong-way risk is something that we look at on a very judgmental basis and, you know, I guess if we believe there is strong evidence of wrong-way risk, we would actually use PFE as being the loan equivalent measure.

The third place I should say very quickly, in the context of our approach to capital adequacy – so specifically in our ICAAP process – what we also have looked at is the way in which we could address the question as to whether we have sufficient capital for the concentration risk in our portfolio. The concentration risk arises primarily because of the sheer small size of our portfolio and the fact that there can be within it a small number of significant assets. Because we're on a standardised approach so we don't actually have any, you know, fundamental credit modelling going on or portfolio modelling going on, within the ICAAP approach what we looked at was whether we could take the approaches to concentration risk that are outlined by Gordy and Lütkebohmert (2007), and adapt that for the fact that we're not using an IRB approach and for the fact that we are, you know, still a relatively simplistic shop. There is a short

paper which I wrote – so it's not a very good one! – where we use actually HHI and average portfolio PD to calibrate a concentration risk adjustment for capital planning purposes and that's also something we're proposing as part of our ICAAP as a Pillar 2 add-on for Pillar 1 insufficiency, but outside of that, you know, we really are not a credit modelling shop." (Code: CRO-B2)

On credit model use, the CRO did further explain that there were economic capital models used in the bank as well but because these were crude, he felt that they did not adequately measure economic capital and could be improved. This is covered in section 5.6.1.1 below.

5.6.1.1 Type and preference of model

In the interviews, the participants did not express a preference for one model type above another. The participants agreed that there was a clear need for different models to serve differing needs of credit risk management within Bank B.

Some saw that aligning the different models along the lines of economic capital, credit portfolio diversification and capital adequacy assessment was a practical approach to what they felt was a complex set of differing requirements and different viewpoints on risk. In fact with Bank B being aligned to very specific market segments, a generic modelling portfolio approach using the structural school was seen to have limitations and could actually be counterproductive.

"I mean I think that, for example, economic capital definitely has a role. I mean it should have a role in any organisation, providing it's calibrated correctly and, of course, every economic capital model really has to be able to deal adequately with credit risk. At the moment at a group level there is a very simple implementation of economic capital which is, broadly speaking, based around FIRB for credit risk, around VAR for market risk and, broadly speaking, a percentage of net income for operational risk. So it's a very sort of Basel 2 orientated economic capital calculation. We do those calculations for the group on a very approximate basis – I mean very, very approximate basis. Personally I'm not really very convinced, particularly given my comments about the role of concentration risk in this organisation, that that's a very adequate measure of economic capital, but what I guess I would stress is that I think economic capital is a tool that, you know, particularly in a business that is as specific and undiversified as ours, I think that any sort of portfolio modelling technique is going to hit limitations very early on. So, for example... And I excluded this when we talked about modelling

because this is blunt instrument, it's not modelling. For us, you know, one of the things that we're looking to embed is comprehensive stress testing. It's certainly something that we've done for the ICAAP and we're actually looking to take that framework and embed it as something that we do routinely probably on a quarterly basis for [Bank B]." (Code: CRO-B3)

5.6.1.2 Where models fit in the organisation

In Bank B's operational use, models are mainly used for calculating the potential of default. These were mainly in the form of rating models, extensively used in rating corporates for day-to-day lending decisions, and financial models, used in assessing financial health of counterparties.

> "Obviously the basic one is the rating, the scoring model, and we have scoring models for a variety of industries. The corporate rating model is the only one that has actually been validated and created externally by PWC. Everything else, every other model has been created internally by the analysts themselves and they're not backed up by large database data sources. Every corporate client, either a new one or one that we are re-rating, has to be run through that scoring model. We then save it and it has to be available to audit and to the external regulatory bodies if they wish to check, you know, the accuracy of our rating. And we also obviously maintain the logs that we record all the findings... you know, all the results of those scoring models and we look for the outliers and that. So once a year we do the validation of the model. Obviously everyone needs to understand the model and if something looks out of the ordinary or maybe doesn't quite sit right to the experience of the credit officer, they have the full right to go to the quants and ask them to re-check the results – which happens". (Code: HCRI-B1)

While at the time of the research, the bank was not a model-heavy organisation, they were in the process of implementing more comprehensive models to handle their credit risks. These were based on a vendor solution and were based on mainly counterparty risks. While the focus was on individual counterparties, the new solution being implemented would provide them the basis for also improving their portfolio models and economic capital models. Because the new system was not in place, Bank B was reliant on their older aging systems that had limited modelling capabilities and they had a heavy reliance on decision-making that was non-model-based. The other reason for the heavy reliance on decision-making that was non-model-based was that the all the members of the risk management team had joined the bank in

the last two years and the old management team had not been as active in implementing more modern risk measurement approaches. While the management team were pro-modelling and all felt that model information was valuable, the CRO also mentioned that he was sceptical on the benefits of economic capital portfolio models in view of the undiversified portfolio make-up in Bank B and its limited ability to hedge these risks.

> "I think particularly for our business. As I say, it's a very concentrated business, so the majority of our risk has a Russian nexus and it's a very small credit portfolio, and so you can probably convince me that, in the limitations we see, that if you have a geographically diversified portfolio that contains a very large number of, you know, individually insignificant loans, that in reality some form of portfolio modelling is a necessary tool. I would argue to you that for the size of the business that we have right now we could probably successfully argue that modelling is barely away from, for example, credit scoring because you have to have a consistent basis on which you can compare the strength of different credits. But I think, you know, as foolish as it would be to rely only on models, I also think it's foolish not to look at what models are telling you. You know, at the end of the day the issue's really just what do you place your reliance on and where do you place that reliance. But for us this is very much a prospect. As you know, we are in the process of acquiring a new credit system or credit framework and we are most definitely within that framework specifying two requirements to be able to implement two model approaches. One is, I suppose, what I would best call a credit VAR – so looking at unexpected loss in the credit space for the portfolio because, you know, as I said, I think we have to understand what that model approach tells us. And the other, very importantly for us, is to have a more comprehensively modelled approach to counterparty risk." (Code: CRO-B4)

5.6.2 Qualitative factors that influence how the models are used

Of the three banks researched, Bank B spoke the most about qualitative factors that influenced the use of models, especially on the importance experience plays in the use of outputs from the models. This was likely as a result of their considerable experience in other banks as well as the fact that Bank B is in the process of implementing the models and therefore they still require a large number of manual controls until these models are in place.

5.6.2.1 Experience and use of models

The area that Bank B spoke about most in the interviews where all five participants had strong views on was the importance of experience in conjunction with model use.

"A model helps you compare data in a standard kind of way, right. So you compare equity to equity, you know, capital to capital, debt to debt, but only experience can actually tell you where the model is slightly off track or where it's not picking up some interesting bits, you know. Experience should be a good thing. You know, it should be a good thing. I don't see why... providing you start with the model as just a starting point, as not the means to an end, it's just... it's not the final kind of solution for a credit rating or a credit exposure calculation. You know, there always has to be a balance to it – experience and model I think. " (Code: HCRI-B6)

The view was, though, that experience was not fully quantifiable which may explain why the current literature (as reviewed in section 2) avoids this subject.

Most of the participants pointed out that models should be used in conjunction with other means to arrive at a decision. There was a wide range of experiences from individuals regarding their views as to the relative weight and importance afforded credit risk models by practitioners.

"I think you have to have experience. Models will take you so far. Models are a guideline on how to do things and how to judge things, but you do need experience of the use of these models to be able to kind of get the best out of it. And the reason I say that is because it's knowing what goes into those models and what you should anticipate the output being. You have to have experience of knowing what it is because you can put something in erroneously and you'll get an output and if you just go with that, then effectively it's not going to really take you very far, or it's going to kind of get you in trouble – one or the other. But effectively you do need to understand. It still kind of goes back to the basic premise of you need to understand the tools with which you're working with." (Code: HSCR-B12)

They felt it is imperative that the inherent assumptions around models and the precise definition of the input and output parameters are understood, otherwise incorrect interpretations of model results will occur.

"I mean, experience is what makes us better at doing the things that we do, you would hope. And certainly, I think, to be able to make a considered judgement of the output of any sort of credit, you have to know what you're looking at and what you're looking for because it's often not just the information that's supplied to you and what that's made up of, but you also need to know what hasn't gone in there and what's missing and what you should also be considering outside of that." (Code: HSCR-B10)

The head of Credit Risk spoke about some of the characteristics of a good credit officer and the traits they should have and the backdrop they need to understand model output.

> "Models don't form that large a portion of a credit analyst's / credit officer's job. It's part of it, but I would say monitoring administration, writing, talking to the client, talking to the business is, you know, 90% of the job. Modelling is just a tool." (Code: HCRI-B8)

> "Obviously they need to have sound financial analysis skills. They also need to have a good understanding of the product the bank is active in. They need to understand what credit risks are associated with and embedded in each single product; and in some cases there are no credit risks, but risks are created through documentation, for example, unusual documentation, right? So they also need to understand the master legal agreements that are governing that exposure. They need to be very clear as to, you know, the legal jurisdictions in which they operate to understand what rules apply and what additional risks are there. So once they have all this universe of knowledge, they also have to be challenging the business. "Why are we doing this? Does it actually sit well with the strategy of the bank? Why is the client doing this?" Although sometimes we get a push-back from the business saying "But this is not a credit question," a good credit officer will adopt a sort of holistic approach, you know, and look after the risks in the bank and they often point out credit risks which have been missed out by other departments or, for example, when other departments were not engaged because nobody actually thought there could be a risk. So I sometimes call credit officers, you know, a Jack-of-all-trades." (Code: HSCR-B14)

While credit officers are good at challenging client information, the CRO raised the point of whether the credit officers (or others) are able to or equipped to properly challenge the outputs from the models. It was important that models provide accurate information and not to be parameterised too conservatively (or unrealistically). This would mean that faith in the models' outputs would be damaged and that the users of the output may not rely on the outputs.

> "It [experience] has an enormous amount to play in the output of models. I think the biggest mistake you can make is to set up models and then blindly follow them. You know, you always have to have a sense of context. You can build lots of conservatism into models and try to believe that they're somehow defining a boundary, but what will happen if you do that is that the confidence in those models will erode over time because they will just simply be seen as conservative and therefore unreliable. I mean as painful as it might be to implement, I think this is exactly why, for example, a clearer

regiment of stress and scenario testing is a very important component of risk governance and, you know, the reality is that that should be being used to challenge many of the perceptions that come out of your, if you like, BAU or local modelling. I'm not sure that's a feature of credit officers. I think it's a feature of humans that, you know, the longer we've done something, the more entrenched our views become. What I would hope is that part of that is, as we age as risk managers and as professionals of whatever sort, as we age we've seen more things and often we've seen similar things go wrong in different circumstances over time, and I certainly think that there has been... there had been a move to believe that markets were simply becoming more efficient and that things that had been seen historically that were related to inefficiencies or, you know, to put it more simply, liquidity in one form or another, you know, were becoming increasingly things of the past. And, you know, there that's probably where experience – as you nicely put it – has some value, but experience also tends to bring some sort of resistance to change, so a bit of a double-edged sword." (Code: CRO-B9)

The final point made on by the CRO on experience potentially also being a double-edged sword is an interesting point as it shows that experience may in some cases be negative as well as positive. The head of Quantitative Risk Management put a different light on it on this point in that he believed that it was not only the length of experience but the type of experience had a bearing.

"The traditional one is people who know how to look at the balance sheet of a company, look at the Accounting background and people with a CFA background – and I have CFA as well as a PhD.....I think those people make good credit analysts too. They may understand, even the good ones, may understand about the mechanics of doing a credit profile of a company, you know, using their CFA or whatever it is and using ratios, the balance sheet, cash flows and meeting with management, but when it comes to how that exposure impacts, how the exposure of derivative products impacts their company or can impact their company, particularly if it's linked to wrong-way risk [this type of risk occurs when exposure to a counterparty is adversely correlated with the credit quality of that counterparty], which is something we're very conscious of here because, you know, this big Russian equation... The Russians are holding assets, which are priced in American Dollars. I mean that's really what it's about. Vast majority of people in credit risk are not savvy enough to take that information in and use it properly. It's extremely tied to the relative risk aversion of the credit officer." (Code: HQRM-B7)

The head of Market Risk pointed out that they needed to understand the risk exposure and not rely only on historic information or a single measure (e.g. credit ratings). He also pointed out how credit risk was linked to liquidity risk. It is important to view credit risk in its entirety and not only on what the model tells you.

"Coherent, robust view on how your derivative counterparty exposures could change. Traditional credit risk modelling was somewhat similar to traditional value of risk in that it says "I want...", independent of whether you have ISDA in place and margins in place, "I want to know what my peak exposure to a 99% confidence over the life of the trade is," or "What's the 10 day 99 move?" Which is the same old thing and if you looked at the... So they were basically making the same bad assumption that market risk made, but extending it over a longer time horizon. The difference between the market risk trade and... and this is why credit risk, when the market got really bad, credit risk took over. So Merrill Lynch and Bank of America and Lehman Brothers all lost a lot of money on market risk. We lost it in 2007 as soon as the problem started. We lost far more on the credit risk side because of 2 things – the estimate of how.... "So what do we do?" We bought protection from a monoline insurer. The monoline insurer was rated Triple A. The protection was on something that was allegedly super-senior or Triple A etc. The market risk thing – at least you can do something about. If I get the trade wrong today and I lose $5m, I can at least try and liquidate myself in the market. From our perspective our Russian counterparties don't post. If we get the trade wrong, we're in the trade for 5 years. So using historical information to come up with a 99 percentile is bad when you're in a liquid or semi-liquid environment like market risk. When you're in an illiquid environment like credit risk – that's the key word, illiquid environment like credit risk – not recognising the fact that you could have an enormously fat tail [the credit loss distribution is not a normal distribution and the tails of the distribution can have a larger impact than the models were calculating] is probably the greatest sin from the traditional credit risk modelling. So it doesn't matter how safe you think this thing is, there has to be some absolute cap between your capital and your balance sheet size or certain parts of your balance sheet." (Code: HMR-B7)

The head of Quantitative Risk Management raised a number of points when speaking of experience, including institutional memory and the importance of rigour and transparency in helping build up institution memory. Institutional memory refers both to the collective experience and know-how of the members in the bank as well as data and documentation that helps to preserve the knowledge on situations that require experiences based in the past or in providing guidance on a situation not seen previously. It transcends the individual and preserves of working a group. The danger of institutional memory is that it may be ingrained to the point that it becomes hard to challenge if something is found to contradict that which was previously thought to have been correct.

"To me the strength of these approaches lies in the rigour that it incorporates into a corporate process. It's a great way to preserve institutional memory having a body of

knowledge that belongs to a risk management function; whether that's market or credit. I think that having historical data that everybody can see, having a benchmark and tested value of risk or PFE methodology that's completely transparent – and particularly for us... I mean this bank's a good example." (Code: HQRM-B13)

5.6.2.2 Non-model information to guide the decision

Specifically, participants felt that the rating models were frequently exposed to the likelihood of being over-ruled by an analyst's own assessment. Rating models may be felt to be entirely dependent on historic data, while the financial impact of specific items of news on a company's future earnings can be quantified and, if significant enough, can be seen to affect the rating.

"Well, let's put it this way. Let's take the QRM slightly out of this, but, for example, the scoring model used for ratings – if the model comes up with a Triple B rating but it doesn't sit right with the experienced analyst, they can look at the credit default swap rate and the asset swap margin. You know, have a look at what the market is actually telling them and if the market is actually indicating that this is a much lower rated counterparty, the credit analyst will override, right, and that's we maintain the logs." (Code: HCRI-B4)

In the minds of some risk practitioners in Bank B, the rating models do little more than provide quantitative support to an essentially judgemental assessment of the risk and quality of counterparties. Therefore the non-model-based contribution is crucial to the credit risk evaluation process. It enables the risk manager to stand back from the raw model outputs and to form a holistic view across the credit portfolio and bank's business areas.

Question "Would credit rely on other sources of information other than model data?

Answer: "Yeah, absolutely. I mean, you know, at the end of the day I guess we would still claim that we are using a predominantly expert judgement approach to grading. We do grade all of our internal counterparties. The model is an input into that. I mean at this point in time we have a relatively low number of over-writes to the model, but I couldn't tell you the precise number now. Part of the reason for redeveloping the model was because it was identified a couple of years ago – obviously before my time – that there was a very high percentage of over-writes. So, you know, as I said before you turned the machine on or maybe after, the idea of the credit scoring system is really to try to put a systematic framework around the expert judgement approach rather than to somehow be the expert itself." (Code: CRO-B6)

"What is the broad impact on the firm?" as opposed to "What is the model output?" (Code: HMR-B23)

Nonetheless, there is clearly uncertainty on the part of some risk managers as to how the model-based and non-model-based contributions can be effectively combined.

"Now maybe that's the way it's meant to be. I'm not sure, but I'm not sure how that can be formalised. I'm not sure. I mean from an institutional point of view I'm not sure how an institution actually sits down and says "Okay guys, you're our credit officers. This is our risk aversion." This is very hard to do. Risk aversion is typically measured by economists using utility. Utility is like one of these great French ideas. It works extremely well theoretically, but it's absolutely useless in practice. Nobody here is worried about it. We can't measure it." (Code: HQRM-B6)

5.6.2.3 Gut feel

Gut feel did not feature as much in the interviews in Bank B compared to the other two banks. Two of the five participants spoke about it and both agreed that there was a place for gut feel in the interpretation and acceptance of credit risk model results. However, there were concerns that certain members of the credit risk operations community might be limited regarding their ability to set "gut feel" assessments in a meaningful context. It suggested that these too needed to be evaluated carefully – not taken at face value.

"I would argue that statistically most credit officers don't know enough to have a gut feeling. I think in many cases it's arbitrary because it's easier to say you have a gut feeling and you don't actually have to justify it. Having said that, it is also a craft. It's much easier to trust people's gut feeling when it's gut feeling that is at variance with something really specific. It's easy to have gut feelings about vague concepts. We all do. I mean, you know, "I don't think North Korea should be doing what it's doing." You know, that's not that hard. It's easy to have gut feelings about simple things. It's much harder to have gut feelings when someone says "Okay, you know, this model that we've worked on for credit management of risky derivatives produces.... I mean we've worked on it for 10 years and it produces this set of numbers for this counterparty." "Well I, you know, disagree with that." But no, I think it's very important to have experience and I think it's very important... I think it's important that people have gut feelings, but I think they need to be considered. It's sometimes too easy, you know. So I think when people say they have a gut feeling I think you have to consider the source." (Code: HQRM-B26)

If the candidates spoke about gut feel, the researcher then asked what they defined it as. One of the two participants who spoke about it skirted around giving a definition of gut feel, although the other did offer some explanation as to what gut feel can do as a yard-stick for credit risk model results.

> "I think gut feel is the same thing to me as a judgement call and it's effectively an end user looking at the output from the model and actually questioning "Is that real? Is that right?" (Code: HSCR-B18)

5.7 Keys to credit management decision-making and where models fit

Interestingly, participants endorsed the view that models needed to be part of an overall decision-making framework and that the weight assigned to models should not be excessive. The head of the QRM (quants) mentions

> "I guess that brings me to the metrics. I'm completely neutral on this question of whether PFE [Potential Future Exposure] is better than, you know, loss given default (LGD) or whatever these other things are. You know, this is a measure of loss, given a loss happens which is less than certain and that probably makes more sense than the PE [Potential exposure] or PFE. But I suppose where I've found, in the last few years, a staggering lack of methodology is in the actual credit decision itself. Well, that's what I meant saying it's a craft. It's an art. It's not just the science" (Code: HQRM-B28)

The role of gut feel was suggested possibly as a way of combining quantitative and qualitative assessments into an overall outcome. Moreover, there was the suggestion that a degree of complacency with respect to model outputs and blind-spots was preventing the recognition of warning signs from other indicators.

> "What we discovered when we did our first stress test – because they'd never done it here – was that first of all when we moved the market, the exposure to the counterparty, you know, was orders of magnitude beyond what anyone anticipated because the potential market move that we said "Okay, this is a view of internal capital". This is what could happen to us and we need to have capital to cover this." So the first thing was that our potential moves were much larger than anything you would have got out of a traditional credit risk model by simply scanning yourself 99 or 95 percentile because we had very, very fat tails [the distribution was not a normal; distribution and the tails of

the distribution has a larger impact the models were calculating]. "By the way, the credit quality of our counterparties has gone down, so therefore our risky discounting on the derivative to calculate the counterparty valuation adjustment, that also exploded." If you put those two things together and your, in crude terms, your counterparty valuation adjustment moves by an order of magnitude. And that's a far more robust way of doing it. The challenge is that you can't do that on a daily basis or even a weekly basis, but what you can do is do it very, very well on a periodic basis and what that means you do is then inform how you recalibrate your day to day model. So you sort of end up with sort of feedback. "Okay, in this scenario what happens?" and then you can go back and recalibrate your model. But where potentially the mechanism failed in the last crisis is the fact that everybody accepted them and then, people became model dependent as opposed to maybe questioning the models." (Code: HMR-B11)

5.7.1 Management setting guidelines on use of model output

Bank B noted that their regular over-ruling of in-house rating assessments for certain core segments of its corporate client-base gave rise to a re-writing of the ratings model in order to provide a more accurate ratings framework.

Clearly, where credit risk rating models are being over-ridden in a significant percentage of instances, then either there is something wrong with the model or the controls in place do not represent the correct business strategy. The participants articulated the need for senior management to be able to review the assumptions on which credit risk models were built, to challenge them and, if necessary, to commission replacement of the models if they were proven to be inadequate.

"We have done an evaluation-based approach around looking at its applicability, and the logic behind this was that because we're quite a niche company, a standard rating model wouldn't necessarily reflect the... Most standard rating models are built in such a way to reflect diversity. Ours is a very concentrated risk portfolio and therefore what would typically happen when we're rating Russian counterparties is that we would override whatever rating system would be in place, which was leading to results that 2 out of every 3 items being rated by us were being overridden in the system, which led us to then kind of undertake a piece of work around "Well, if that's the case, why is that?" So we kind of engaged PWC to work with us in building a rating model that best reflected our niche capability and would kind of support the different inputs that would need to go into making a rating decision." (Code: HSCR-B1)

"The other category of users is, if you like, the risk takers, the front office, who clearly have to become users of these tools and actually in an ideal world have input into the design of these tools." (Code: CRO-B5)

"There is a relatively limited number of scenarios that truly threaten the viability of an organisation, whether it's a lending organisation or a derivative trading organisation or whatever it is, and therefore those things can be identified, but it's using those things to then recalibrate and say "Hang on! My tail is ten times fatter [the credit loss distribution is not a normal; distribution and the tails of the distribution can have a larger impact the models were calculating] than I thought it should be." (Code: HMR-B10)

5.7.2 Management queries

Bank B participants agreed that management did have the ability to question and review model assumptions and theory. The fact that the bank maintains a mixture of vendor-based (i.e. external) models and internally-developed models does not seem to affect management's approach to their use or scrutiny.

It is clear from some comments that Bank B's risk management department is keen to maintain focus on the essence of the financial and credit risk it is assuming, and to ensure that the models reflect this as accurately as possible.

"There's more of a change to put more confidence in the model, but at the same time I've kind of seen from a management perspective a healthy level of kind of sceptic views and continuous kind of review and assessment of the outputs of those models, because models in themselves are built by individuals or by humans and therefore are fundamentally flawed. So I would say from a management perspective there's the continuous, you know, questioning with regards to "Is the model giving the right thing?" (Code: HSCR-B17)

When external factors indicate the model outputs are not right, there can still be individual resistance to challenge the model itself. One reason for the reticence is that in doing so it may open the individual challenging the model output to explain where the model is wrong or provide the right answer. There is still a mechanism to challenge results, and the management team normally go back to QRM and ask for validation of a result rather than a direct challenge

"Commodity volatility is very high, right, so if the system's suddenly showing a low volatility product, they will probably query it from experience and will probably go to QRM and double-check what happened there. But I don't think we actually query the model itself. We just ask them to validate it themselves." (Code: HSCR-B17)

The Head of Market Risk explained the need to take a step back sometimes and to look at things holistically rather than be focused just on the model numbers. He gave the example of where there may be little perceived risk, but if the volumes are very large there could be a large impact to the bank if there was a credit event. Other than looking at just probability of risk happening or where there was a low risk exposure calculated, it was important to also look at areas where there could be large impacts to the bank.

"Because the thing that we were buying from them, the insurances we were buying from them were perceived to be of little risk, but the notional exposure was enormous. Start off by saying not what could happen to us coherently, but "What is our real notional exposure? What are we exposed to here?" and identify those big things and then say "Okay, now I'm just looking at one or two really significant drivers of risk in my organisation." (Code: HMR-B16)

5.7.3 Ignoring model output

Bank B's risk managers were aware of the fact that credit model development is often lagging behind the creation and trading of certain financial products themselves. This creates a dilemma. Should the credit risk models be allowed to run with simplified assumptions in order to capture new products on a notional basis, or should the bank's credit portfolio be assessed excluding the new products, and adjustments made at the aggregate level? In the event, the delay in properly validating models for new products may require the bank to enter into trades in new products but under special controls, pending full and complete approval.

"Possibly a good example for you would be if your model has got so many pre-defined parameters that you can put it in, but you have a variant that your model can't actually handle... And a good example here would be something [where we have done] – in a previous institution – and what we used to have was called overrides on the credit engine, and it was effectively that there is a lead time in some instances of changing the models or getting the model to reflect the product that you have, and you kind of often have in the industry where kind of the lead times is less patient with regards to actually start transacting these. So what you'll do is you'll put in a kind of tactical measure to kind of allow for the capture of those trades, but then you will actually override the

model output because you know there's an additional variant or parameter that you need to include or that the system or the model itself is not capable of incorporating. A good example is a lot of models don't actually deal very well with break clauses in terms of calculating output. So, for example, on a credit one you could have a 5 year deal, but you could have a break clause at 2 years which can then, you know, change the structure very significantly of what the pay-out might be on that particular product." (Code: HSCR-B13)

5.7.4 Overridding the model

Bank B's management was reluctant to acknowledge that credit risk models are completely over-ridden. However, there are circumstances where the models' output can be reviewed in conjunction with other factors and, if necessary, those factors afforded more weight.

Bank B's relatively narrow focus on Russian corporate customers makes the development of a specific credit rating model for this sector an important requirement.

"I don't think you can... Well, one of the skills which I didn't mention just now is a credit officer must know their client inside out and must understand the market the client is operating in and you can't automate that kind of knowledge. So yes, you can automate the spreading of financial statements by all means and you can automate the ratings, but you can't automate the override which is made because the credit officer has met the management and actually came out with a very, very negative experience or, you know, impression of the management. So that personal touch you can't. There are always exceptions to the rule. There will always be trades that the model cannot value precisely because it's an exotic trade, you know, will never be done again. You know, it's a one-off and we do our best to risk it. So therefore it can't be calibrated, it can't be, you know, validated because there just isn't enough data on this type of trade. In the rating world, for example, you know, there are no companies that are exactly alike. Each one of them has their own peculiarities and if one of them is so overwhelming that it warrants an override, then yes, we will ignore the model. For example, if you look at the Russian state-owned corporates, right, if you look at quite a few of them, in their own right you would never ever rate them even in the sub-investment grade because, you know, they're just weak financially, but given that they're state-owned and the state stands firmly behind them, a model is pretty much useless. You can ignore it and you have to make a judgement whether or not the state will be there for them to support them. So yes, there are some cases where you have to ignore the model. Well, what we've noticed in our validation process is that all the corporates within Russia, the overrides are minimum – about 10%, if that. But as I said, our business is skewed towards Russia. So save for creating a Russia specific corporate rating model, all those

clients will be overridden. So the bulk of my portfolio is in Russia, so...". (Code: HCRI-B13)

5.8 Model improvements and issues

This section examines how the participants viewed the adequacy of the credit risk models and what improvements were felt necessary.

The preoccupation of all participants within Bank B has been to set the application of credit risk models within the correct overall context. There is acknowledgement that the models have a role to play in contributing to setting and implementing a balanced policy and overall management framework. However, most academic literature concentrates on the theoretical framework surrounding a model, i.e. on whether its statistical output yields precise results. The parallel can be drawn in the application of techniques found in small laboratory to an industrial context. In a banking operational context, the availability of input data and the sensitivity of the model to data errors or gaps are very important, particularly for an institution such as Bank B, which specialises in certain emerging market sectors.

"At the same time you still get back to the point that the models that are built were built by humans and therefore have that possibility for error." (Code: HSCR-B19)

"So I don't think that models are going to go away and I honestly don't know how they could be improved yet. I'm working on it, but I don't know how they can be improved. You know, PFEs [Potential Future Exposures] sort of here to stay. You know, we think of it as a model, but really it's the right answer to the question, you know, "How much can this move in our favour, and we lose if a client defaults?" It's sort of trying to be a kind of Loan equivalent. It's not trying to estimate the PFE. CVA is different, but the PFEs are just trying to estimate "How much could we lose if the client defaults over the life of this period?" That's what it's asking and the answer is "Well, you know, if it's a hundred million dollar swap we could lose 5 million, we could lose 7 million. It depends on vols I put in" There's always going to be some uncertainty. If you do a simulation of the swap rate and you take volatility at 20%, well how do you know the volatility isn't 40%? How do you know it's not 60%? Well, it could be, you know. You don't believe me? Look at the Russian models recently. Russia is all over the place." (Code HQRM-B11)

5.8.1 Model improvements

Bank B's risk managers saw that the trend of continued improvement in model development would continue and that products would continue growing in complexity. They felt that increasing standardisation and more widely available credit data for the main markets would assist the quantitative evaluation of credit products and portfolios.

However, they did not believe the reliance on a multi-faceted approach to evaluation and management of credit risk would change in the near term.

> "So what we considered exotic years ago is now pretty vanilla but, that being said, it is I guess the continuous evolvement of these products and the move from what's exotic today will be considered vanilla in a few years. It's kind of showing an evolvement, shall we say, that we would anticipate to see because I guess with anything, whether it's banking or whether it's in any other industry, it's effectively a continuous search for improvement, evolvement and change and how do you do something better, how do you do something cheaper." (Code: HSCR-B11)

The Head of Credit Risk believed that the fundamentals of credit risk and models would not change in the near term. She felt that the largest changes would be in that models would get more precise. This view is supported by the literature review in section 2 where a lot of academic literature is based on developing more precise models.

> "There's clearly more automation of credit work. There's clearly a drive towards standardisation of credit work, but the fundamental approach to credit has not changed. You know, there's been a much wider acknowledgement of, you know, loss given default methodologies, probability of default, but all of these things have existed, you know, even 20 years ago when the credit departments were just being set up. In the investment banks in particular they were just... These are just formalised, more precise descriptions of what credit has always been concerned with. So I think credit will become more precise. You know, the approach will be standardised across the industry definitely, but the fundamental approach to credit won't change." (Code: HCRI-B10)

5.8.2 Model issues

Bank B's risk managers highlighted the challenges of deploying a truly multi-disciplinary approach to credit risk management. There seems to be conviction that the multi-faceted approach is correct but there are undoubted challenges in deriving consistent and accurate results within such a framework. Implicit is the understanding that models can be not just

wrong, but very wrong. Therefore all outputs need to be judged and articulated in an overall context.

In short, models are not infallible. They should form part of the foundations but Bank B felt it should not base all risk management decisions on the outputs alone. The head of Credit Risk explained this point but also highlighted that it is sometimes difficult to find the right skill-sets in the market. To find someone with the qualitative experience that a credit analyst needs as well as understanding what can be complex mathematics on the quantitative side of the models can be hard.

> "You know, we aim to implement best practices. It's difficult because also you have to bear in mind that credit departments traditionally are staffed with writing analysts, not mathematicians or quants, so they find it very, very challenging implementing that type of model in what traditionally is just a thinking environment, you know, and experience; sort of putting down on paper your thoughts, you know, rather than crunching numbers. I find that it's difficult sometimes to even find someone to manage a project like implementing a model because they just don't have that kind of experience." (Code: HCRI-B14)

The CRO also spoke about how models could get things wrong. He went on to explain that is was important to use it in tandem with other tools such as stress testing and scenario testing and how expert judgement was also a key part of decision-making.

> "I think you only have to look at the tranched credit derivatives market to see how true that is. I mean the entire market drove itself down a cul-de-sac and spent years looking at each other's offers to convince themselves that they knew where they should mark their books and, you know, the fallacy of that has been proved. So, you know, I don't see how anybody could deny that proposition right now. So from my perspective I think that stress and scenario testing is going to play an increasing role, but I don't really look at that as being modelling, its arithmetic rather than mathematics. Credit world mistakes can often not be corrected in any period and, you know, I think that demands that there is an approach that involves considerable expert judgement." (Code: CRO-B11)

The head of Market Risk, who is well-versed in quantitative mathematics, spoke about qualitative approaches in line with quantitative approaches. While quantitative measures are important (he says they can get it right 98% of the time), the impact of the failure of models is very large and qualitative approaches are important in ensuring that a more complete view is

taken. What is emerging from this section is Bank B's managers seeing that models have weaknesses and that qualitative measures are a key part of the decision-making process.

> "Theoretical modelling works 98% of the time and doesn't work on the 2% of the time that you really need it. So it always has to form your bed-rock because it covers you – whichever model you choose, by the way, it doesn't matter – it covers you most of the time. What's been missing has been a less quantitative approach and a more qualitative approach around, really, two aspects. First of all thinking broadly about what hurts you from a portfolio perspective. So what are your own risks internally that you're running and, secondly, a more robust way of quantifying what those risks could be in the more extreme circumstances when you actually are far more concerned. So those models started off with the assumption that the individual default frequency would broadly be something that they could derive from history and in terms of how those individual default frequencies aggregated together, some guess at best as to what the correlation could be and that's really where those models failed". (Code: HMR-B1)

The head of Market Risk went on further to explain why correlation assumptions are important, how we have lost something in qualitative judgement and how the models themselves may have created risk (operational risks as well as systemic risks). While the section below is rather long, it is enlightening to see how he links his points together and justifies his viewpoint on the importance of qualitative assessments in decision-making.

> "Look at the correlation assumption that broadly rating agencies made around how you could diversify away consumer risk, first of all they decided that individual categories of consumer risk had different ... were in themselves exhibited fairly low correlations and they also made the assumption that regions exhibited fairly low correlations. But this is based on limited historical evidence. The historical evidence had been taken from a benign period in history and, let's be honest, there was a guess on top. The correlations were all wrong. So the correlation assumption was hopelessly wrong. The default frequency was wrong as well, which is the economic down-turn because pricing would normally mean that any expected loss from your portfolio is absorbed by price.
>
> 30 years ago - to get your loan you would walk into the bank and you would sit down and a bank manager would interview you, and you'd tell him where you worked and he'd probably even know where you worked and he could actually form a view tailored to you as an individual. Pretty much we can get credit on-line by clicking some boxes now. So therefore by definition, in order to make the lending process more efficient, the lending process has become simplified to a model. Is that in itself a systemic risk? Yes, it is to some extent because we started off having, I guess, in the early 90s-ish some

reasonably robust models for prime consumer lending in this country – prime residential lending in this country. We started off with reasonable models and because people hadn't used them before, they were conservative in their approach. So when I wanted my mortgage I could get nearly 80%. As people became more comfortable with the models they relaxed those boundaries. Then they started to extend the models into "Well, if it works for this category of people, surely it'll work for this category of people?" If I look at some of the transactions that were done in 2006 / 2007 in the UK around consumer lending in particular, people were just going "Well, you know, we moved down the credit spectrum. We did that 6 months ago. It was okay. Nothing happened. We'll go down a bit further," and not only did they become model dependent; the model actually itself reinforced their opinion. "I had a model. It worked okay for 6 months. We can go to this category of people," and ultimately there were institutions... When I looked at some of the scorecards, particularly for what I call it secondary lending, remortgage purposes... So they've bought another house. They have a mortgage with a high street bank and there is some residual value in their house and they want to monetise that so they can buy a car or pay off their credit card or whatever it is. Some of the assumptions around affordability there were laughable! Sorry, the only thing that really got deducted was something along the lines of actual financial commitments – so if you owed - so, your loan repayments, child maintenance repayments, car hire repayments and you're going to leave them with this amount of money and the assumption was "Well, that amount of money will be okay," and they hadn't really taken into account all expenditure. So it just became a way of very quickly extending the extension of credit itself. "We've got a model. It works." You know, you can't extend credit very quickly by saying "I want to interview everybody," and that was the message really in the US – was the extension of "How do we extend credit quickly?" and therefore you start using the model and the model itself becomes a risk." (Code: HRM B2, HMR-B12)

The head of Quantitative Risk Management spoke about the importance of using your model output appropriately. There is no point basing your decisions on an inappropriate use of the model (which he illustrated with an example using baseball statistics).

"Baseball. I'm not a baseball person at all, but I know that one of the great things about baseball is it's one of the best ways for children to learn statistics because that's all they talk about. It's, you know, "Who hit the most? Who did this?" and all that sort of thing. Baseball has the statistic about the biggest hitters in the game – who hits the most home runs. Now of course the distribution is a distribution of an extreme value, so it's necessarily full of noise and it's very bad to base your conclusions about policy or bat type or ball type or ball composition on statistics of the guy who hits the most home runs because it's just too whacky, it's too out there, right, and that's sort of what we're

doing with VaR. That's why I'm convinced that it would take your breath" (Code:HQRM-B8)

The head of Quantitative Risk Management went on to say that while models may not get things right and that sometimes modellers take short cuts especially where the bank has a small exposure that is short dated, it was still important to understand the full risks. The discipline of ensuring that the bank was aware of shortcuts, assumptions and understanding the full risk on products was important.

"The discipline of having my team understand what short-cuts we'll take in the short-term for valuation purposes and how that affects margin and everything else, that is a fantastic discipline. And by the way, I think it's the only discipline that works. It keeps the institutional memory bank." (Code: HQRM-B14)

5.8.3 Lack of data

The participants in Bank B highlighted that the lack of valid data or distortions may impact models significantly and the paucity of quality data in Bank B's natural markets over the last 10 years affects the statistical significance of results. The lack of confidence in traditional theory, given such poor data, has forced practitioners and regulators to rely on more prescriptive means for controlling behaviour in these markets.

"Depends what you include! If you use two years, you're still including 2008. If you don't use two years, you're not including 2008. If you use six years, you're including 2008 and a whole bunch of other crap. So that averages it out, but what's the right answer? Honestly, I have no idea. This is where I think, for the regulators to be prescriptive and proscriptive, I'm not sure... I think it's good that they force people to think about it by making regulations. Maybe that's the answer. I think if they didn't have any regulations we wouldn't think about it at all." (Code: HQRM-B15)

5.8.4 Understanding model assumptions

The bank's risk managers were aware that there could be a sense of false security arising from the model outputs that could give rise to incorrect interpretation or presentation of results. There was a sense that the quantitative models applied to Bank B's core market (Russia) would not be reliable enough to assess the true risk and that the behaviour of markets in extreme conditions was not taken into account. Bank B's managers believe that the over-

reliance on model results and failure to understand fully the relevance of the inherent credit model assumptions precipitated the global financial crisis of 2008.

"They got it wrong because they wanted, in some ways, an intellectually pure model - intellectually sound model or the mathematically consistent model almost doesn't really help you in circumstances that you want, and everyone is now focused on stress testing. We're always wrong-way-round risk and the wrong-way-round risk element – and the reason I tell the story – is that's the ultimate example of the bad correlation. So yes, you know, if you looked at the Merrill Lynch or the Bank of America VAR number and compared it to the losses that occurred, it failed. But actually there was only two areas that failed. Credit – completely, and the reason credit fails is because credit is a well ordered market until it isn't. When it's not a well ordered market, the fact that you have very much an asymmetric pay-off, which is, I buy a bond, – in simple terms – I buy a bond and I receive a coupon and actually, you know, in the 2007 environment actually a relatively low coupon, that's my up-side. And my down-side is the equity market is far more well ordered. . There is liquidity there because at any point you are buying and selling... you know, you either have all the up-side or all the down-side, in very simple terms. So the regulatory response was actually focused, bizarrely, on things like exotic equity derivatives. How do you calculate correlations there? And I'm not saying that's a bad thing to do, but the amount of money that was lost in that area was very, very small compared to credit. The challenge with credit broadly is if you learn the lessons of history and say "This is how bad it can be," the potential ramifications for that if you're a regulator who's saying "I want to avoid systemic risk at all costs". The potential ramification of that is huge because you're not saying I want twice as much capital. In a sense you'll be saying I want 5 times / 10 times as much capital at the same time as politicians are saying "We want banks to lend more." That's actually how we got ourselves into this mess. It was lending. We developed some very fast ways of moving money and risk around the system – the credit derivative market for example – but at the end of the day the problem all came down to credit, asymmetric pay-off. When it goes wrong, there are only sellers and therefore your liquidity horizon is completely different and that is therefore obviously true for counterparty credit as well. You cannot assume there is liquidity there. The people at the top have become divorced. The people at the top are actually the people who are best placed to understand the business model. So one of the challenges has been to get a good understanding of what your business model is, all of the way up. People end up being silo-ed. Here's one group, here's another group, here's another group. You have to have an ability to look across silos and you have to understand what your business model is, and if your business model starts to change, that is your first warning sign. So two simple examples – as the price of liquidity and the price of credit fell, the response - in order to maintain revenue - was to lend more. No-one questioned it because people

ended up just focusing on the revenue line. "What is the revenue line?" The fact that the revenue was now being driven by a very different model was ignored. That was the fundamental warning signal. Right? If pricing has come down to the point where you can't maintain revenues at current levels and all you can do is lend more and lend riskier... It doesn't matter that it's much... Even if your perception is it's not much riskier, that's a significant change in your business model. If you looked at the CDOs, CDOs were supposed to be [forward] distribution. They were supposed to be a risk transfer mechanism. Merrills, Lehman and everybody else originated CDOs. We congratulated ourselves on making - let's call it - several hundred million dollars a year from originating CDOs. At some point we moved from that 'originate and distribute' model to a storage model. "Okay, what did we used to do and what are we now doing and what caused that?" We have the ability to have the model and see what the model tells us, but also to understand actually what most of our drivers of risk are. Your jump to default number was enormous on individual names, but the model told you were actually risk free." (Code: HMR-B5, HMR-B6, HMR-B13, HMR-B18, HMR-B19, HMR-B21)

The long quotation above captures in detail the experience of the head of Market Risk in his previous roles as head of Credit Risk and how there was too much faith put in models without understanding the assumptions of the models nor looking in detail at external factors in the market. This view is strongly reinforced by the head of Quantitative Risk Management when he says there are no good models or bad models. It is about knowing the strengths and weaknesses of the model that is being used. A key part of it is in understanding the assumptions made by the model.

"So the answer's yeah, I think it's important for people to have the right experience. I think that that's partly what happened with this CDO portfolio. The quants were too proud to admit they had no f***ing idea what was in the stuff, the credit risk managers had no clue because I mean there's no way a traditional credit risk person will understand this, and I think people had a general lack of numeracy which informs your decisions about "Well, let's see that CDO. Where are the correlations coming from?" "Oh, we'll just put in X." Well sorry, you know, that's not good enough like 50 billion dollars later. That's not good enough. So I think it's partly a cultural thing. You know, there are good models and bad models first of all, and models in themselves are not bad, but I think one has to question their assumptions. The assumptions in the CDO market were simply wrong by modellers, risk managers, everybody. Traders, sales guys, they were just wrong, so of course the model's not going to work in that case. And I think the answer is, you know, you need the internal discipline of having an approach to these derivatives. You know, even an interest rate swap you need relatively little capital to

put one on and they can move massively in your favour or against you." (Code: HQRM-B24)

5.9 Regulatory influences on models

This section of the case study analyses how the regulators influenced model development via regulation around the need for models in calculating regulatory capital. It further investigates the issues around regulatory models, likely future direction from the regulators and if there are advantages for banks to focus on their own models for capital management.

5.9.1 Regulatory drivers

Bank B participants felt there was a very large influence on their model development plans due to the need to meet regulatory requirements. They regarded this influence as positive on the whole but they did draw the distinction between jumping through regulatory hoops and the need for prudential management of economic capital. Too great a divergence of the factors (and the use of models in both) will increase costs unnecessarily and provoke regulatory arbitrage (a factor that is starting to have an effect in other banks considered in this work).

"[The] Regulator usually implements something after consulting the industry, and what is a positive element is that there are some things that you didn't think of but someone else in the industry did. You would not exchange those ideas face to face because it's sometimes a competitor or whatever. The regulator, by implementing those changes, by making those models mandatory, forces you to think about risk in a slightly different way. So that's certainly a positive thing. Gives me an opportunity to look at my own portfolio from a very different angle. So again it's a positive." (Code: HCRI-B15)

"A good example for you possibly right now would be the stress testing. Stress testing is a largely regulatory driven initiative, and we've seen a lot of papers kind of come out recently over I think it's CP 0824, and we're now kind of seeing all the kind of ones with regards to reverse stress testing and, you know, they're kind of identifying that there are certain models and tests that you should be running with regards to your portfolio, what you should be doing... There's kind of minimum criteria with regards to the kind of setting out there with regards to, you know, for example, "Have you got enough capital in order to continue?" and kind of like stressing it to defaults. You know, from that perspective there's a substantive amount of work that has to go in and I guess what you generally find is that the regulators come out with these consultative papers, they get the feedback in and then there's a long lead time with regards to before

kind of the industry gets back what their thinking is and, you know, considering... I guess the way I kind of always look at these is with a kind of level of cynicism I guess in that, you know, the people working in the FSA are not necessarily people that would be working in the industry on the basis of – and forgive me, it's very cynical – they're just not good enough. So therefore, you know, it isn't always the best people that are working in the regulatory space to police it. I guess it's kind of like the best kind of game keeper's always the poacher turned game keeper and that isn't always what you see from the regulator." (Code: HSCR-B20)

In the 1990s the larger Investment banks drove model development, as they believed it gave them competitive advantage and were lobbying the regulators to accept their sophisticated models. As an example the credit migration approach, as proposed by JP Morgan with their trademarked CreditMetrics methodology (Gupton, Finger and Bhatia,1997). As part of the Basel II consultative period, the investment banks also lobbied the central bankers to allow them to hold lower amounts of capital as they had more sophisticated measurements, systems and controls. However this approach may have back-fired on these banks, as in the current market there is a disincentive to move to more complex models, as the standard and less-advanced models calculate a lower amount of capital - as explained by the CRO in Bank B.

"I suppose what I would cynically say is that regulatory developments have provided a fairly significant incentive not to move forward from those standardised approaches at this point in time. I mean I think that what I would say as an observation is I'm very concerned about how medium-sized organisations – and I'd put ourselves in the bottom of that category right now – how medium-sized institutions who have made significant investments in model approaches are going to keep up with, you know, the rapidly increasing regulatory burden around, you know, improvements to modelling processes, changes in modelling processes, etc." (Code: CRO-B14)

The participants in Bank B felt that strong regulators were important. In the 1990, with deregulation of the market, many regulators applied a light-touch approach where it was left to banks to be self-regulating. This has changed in the financial crisis of 2008 and Bank B believed that the regulator should have strong powers and be independent (without government or political interference).

"We need strong regulators they're to do anything, must be telling us what our capital requirements are because, to me, that's ultimately how they control the businesses. To have a more robust capital calculation and ultimately that comes down to – in the case

of most of the big banks and including some of the failed ones – it comes down to the capital calculation for things that are off balance sheet. That's the key. If it's on the balance sheet it's relatively easy. But I think the answer is that from the regulatory perspective I think it's very important for the regulator to be able to control the amount of capital it's just absolutely critical. I think from that perspective I think maybe in a sense it doesn't matter which one they use. I think if you come to believe in its fool-proof-ness you're asking for trouble. I think that's the point. I think every bank, particularly in this derivative world, needs the discipline of a way of doing the calculations, but I think that if you believe in the failsafe-ness of those calculations you're just asking for trouble."Did you think that the scenario shocks that the FSA proposed were actually good enough, and did you have your own? Did you add anything that was missing? Did you include skew? Is the business controlled?" And that's much more important that they do that. You know, if they need to have some prescriptive way of calculating capital as a vehicle for that, more power to them. I'm a bit concerned about the future in terms of what's going to happen with the FSA [this comment was made at a point of time where the government in the UK were looking at disbanding the FSA with the Bank of England taking over regulatory supervision. The concern was likely on loss of personnel and knowledge as some people would leave as well as learning curve within the Bank of England]." (Code: HQRM-B16)

5.9.2 Regulation and improvements

Use of credit risk models and risk models in general should be judged by the benefits it yields to banks (in terms of lower loss experience, higher profitability of trading etc.). It is undesirable that regulators should force banks into using models purely as a regulatory constraint to the volume of business that they can undertake. The implication is that this will encourage regulatory arbitrage and, potentially, mean banks deploy models that are based on optimising regulatory capital savings rather than prudent risk management.

"[If] we can gain significant benefit from our own management of our risks from our own understanding of our portfolios by implementing a modelled framework, then we will look at doing that. If there is a regulatory benefit or capital benefit to be gained and it's aligned with that same process, well of course we'll try to get that benefit as well – driving the banks to this is probably not quite the right one." (Code: CRO-B16)

5.9.3 Regulatory Capital versus Economic Capital

In the research one of the interview questions was "are the bank's economic capital credit models the same as the ones used to report to the regulators of regulatory capital usage?". The reason for the question was to look at similarities and differences between regulatory capital

and internal economic capital. Ultimately both look at capital and it could be argued that there should be just one valid capital amount that a bank should hold. From the replies in Bank B, they see a correlation between economic capital and regulatory capital, but most thought they should be different. It was felt economic capital was needed to cover the bank's internal calculation of capital that they need to set aside for each business line and for decision-making, whereas regulatory capital was the capital that they need for the whole bank via calculations stipulated by their regulator.

> "I think there is correlation there, but I guess do you kind of see it? From regulatory requirements I guess this is what the regulators actually set down as what you need to kind of keep from a capital adequacy perspective, but economic capital is kind of looking at it from a different perspective in terms of how much value do you get back from doing a particular trade versus another particular trade. I don't think you can marry the two. I'm kind of struggling to see it because I guess the regulatory capital requirements are, to my mind, fundamentally different to the economic capital. From an economic capital then we're trying to say "Well, what is the better...? Where are we going to get the better return on a particular product – you know, if we lend to counterparty A or we do it to counterparty B?" So counterparty B is a kind of lesser quality, so we can charge a higher premium, shall we say, or rate on that, so effectively, you know, we still kind of maintain the regulatory capital by doing that. So it's not measuring the same thing." (Code: HSCR-B21)

> "Bear in mind we're a triple B-rated institution and that's important – the amount of economic capital I would need to hold [based on internal calculations] is less than the amount of regulatory capital that I actually need to hold. Economic capital for us is the efficient allocation of that capital to businesses internally. Any linear business that I have is probably going to be quite sensible in terms of its standardised rules and economic capital requirements – and I'm talking here, by the way, for market risk. Any non-linear business I have is going to have outrageous capital requirements. Standard rules capital requirement for my foreign exchange derivatives desk is just out of all proportion to the risk that they're running, You know, I think it's a good discipline to have a consistently calculated view of economic capital, but its practical application is very difficult for an institution like us. If you talk about the larger, more sophisticated banks where, for example, their target rating is significantly in excess of the supposedly implied regulatory rating – although one must assume that that implied regulatory rating is going up considerable – then I think it is actually quite a different conversation because one would hope that an internal economic capital model would be capable of picking up specific features of a business in a way that generalised regulatory models can't." (Code: CRO-B17, CRO-B18)

"I think they should be different. Economic capital is for the internal management use, you know, for setting up targets, you know, and for assessing the profitability of the business, the riskiness of the business and that kind of thing. Regulatory capital, you know... Each bank will have their own economic capital... well, perception of how the economic capital should be allocated, you know, to promote the business. Each bank has a different business model. The regulator doesn't have the luxury of looking at each individual business and saying "Mmm, you should have that much regulatory capital." So reg cap is strictly speaking as a standardised approach to risk in the banks." (Code: HCRI-B16)

The head of Market Risk felt there could be convergence as regulators were making the regulatory calculations more sophisticated and taking into account risks not previously in Basel II Pillar 1 calculation. Basel II has what is commonly referred to as three pillars. Pillar 1 calculations have always been very prescriptive. However Pillar 2 calculations or also called ICAAP in the UK, allows the bank to define its other related risks. Pillar 3 is the reporting of these risks. With Pillar 2 being expanded by the regulators, this meant that some of the risks captured under more sophisticated economic capital models were now also in the regulatory capital calculations.

"Well, I think as a starting point, the regulatory model is eventually going to move from one of... Regulatory capital was historically driven by, say, a CAD2 VAR model. Now, certainly in the UK under ICAAP [also known as Pillar 2 of Basel II], driven by "What is my Pillar 1 requirement plus all the risks that aren't in Pillar 1?" So that's bringing in stress testing. So I think at that point you're, I think, far closer aligning when you look at the totality of the capital you need for regulatory purposes with internal economic. So I think you will see a natural convergence there of some sort" (Code: HMR-B25)

5.10 Smaller themes raised in the case study

In the course of the analysis, several other themes were discussed by some of the participants which did not feature highly with the other participants. While not viewed in this research as a key part of the decision-making process, some of these themes merit mention as they help explain further how these models are used. They also help show how Bank B views the progression of models within the bank and the likely future direction of risk models in Bank B.

5.10.1 Link between Front Office and risk

The risk management team at Bank B saw the link between Front Office and Risk as an important bridge on a number of fronts. First, to ensure that models were correctly reflecting the risk characteristics of a trade.

> "There is an annual review that's being done with regards to its performance. It's a continuous review with regards to, you know, if things are being overridden, why are they being overridden." (Code: HSCR-B2)

Second, the Front Office has a role to play in imparting real market dynamics to the risk management team to enable better modelling of risk.

> "The other category of users is, if you like, the risk takers, the front office, who clearly have to become users of these tools and actually in an ideal world have input into the design of these tools. I mean in many senses, you know, these are the guys who are leading us into new forms of taking exposure and I think it's absolutely right that they should be part of the process of, if not defining, accepting the methodologies that we use for modelling. So if I take a parallel... When we implemented the market risk system, you know, the front office could not define the market risk system, but we've certainly made it a very key part of the process that they buy into what we're doing, even if they don't agree, and that they become knowledgeable users of the thing that is providing limits on their activities." (Code: CRO-B5)

Thirdly, the risk team can assist in the alignment of Front Office bonuses by independently valuing the risk and ensuring the correct pay-off profile of the books and trades they manage.

> "My old firm, Rabobank, a Triple A bank, had a huge capital markets group. I mean it's much bigger than ours. Huge! They probably now make a billion a year in the capital markets. They pay deferred bonuses. They pay money and they say, you know, X amount and half of that you get this year, a quarter next year, a quarter the year after, or something like that, and it keeps people thinking about the greater good in a way that shares don't." (Code: HQRM-B20)

5.10.2 Concentration risks

Bank B felt that concentration Risks were the largest part of the Credit Risk faced by the bank. This was because they were heavily exposed to certain sectors. One of the larger concentrations of risk for the bank was wrong-way risk. Wrong-way risk may arise in

transactions with a counterparty where an increase in the value to the bank of the underlying contract is likely to coincide with a weakening of the credit standing of the counterparty. As an example, the bank has significant exposure to Russian clients that buy US Dollars. If the US Dollar appreciates significantly against the Russian Rouble, the value of risk goes up as the Dollar appreciates but the credit rating of Russian firms goes down with the fall of the Rouble. Therefore as the exposure goes up, there is also a larger separate risk that the client could default. Another example is given by CRO-B was buying credit protection on the Russian Federation in unfunded form from a Russian Bank.

Although the bank does not have an explicit policy governing the acceptability (or otherwise) of wrong-way risk, it is a matter which is taken into consideration in the credit review of all proposed transactions with high-risk counterparties and, where appropriate, Bank B mitigated the risk through the use of structural features in such transactions.

> "As I say, it's a very concentrated business, so the majority of our risk has a Russian nexus and it's a very small credit portfolio and so you can probably convince me that in the limitations we see that if you have a geographically diversified portfolio that contains a very large number of, you know, individually insignificant loans, that in reality some form of portfolio modelling is a necessary tool. I would argue to you that for the size of the business that we have right now, we could probably successfully argue that modelling is barely away from, for example, credit scoring because you have to have a consistent basis on which you can compare the strength of different credits. But I think, you know, as foolish as it would be to rely only on models, I also think it's foolish not to look at what models are telling you. You know, at the end of the day the issue's really just what do you place your reliance on and where do you place that reliance." (Code: CRO-B4)

> "Concentration risk modelling that we've done was done in the context of the ICAAP process. So actually if it's accepted by our regulators, then actually it defines our capital requirements. Can't have a tractable, judgmental economic capital modelling system, so you're going to have to define the components of that system, one of which could well be C-VAR, another could be some sort of concentration over-write, almost create an internal market for it so that somebody's who's hedging somebody else's risk is appropriately incentivised." (Code: CRO-B8)

Bank B is also characterised by having a concentration of activities, customers and businesses in some particular niches. This certainly forces the risk managers to consider non-model-derived means for portfolio and trade assessment.

"So yes, it's definitely a step in the right direction, but people were still thinking about it. They were still thinking about it in the sort of 99 percentile world and therefore they were prepared to run much more risk. People maybe nowadays would think about it in terms of broader "What would happen to us? What is the scenario where we lose so much money that it really is serious?" and that's the message. The problem is the only way you ever do that coherently is to be at the very top... at the top of the firm to look across your entire organisation and say "Okay, what could happen to us that really would give us a major problem?" and you may find that that can be a credit risk counterparty problem, a lending problem or a market risk problem, but you have to look very broadly and say "Okay, what is the thing that intuitively if this happens to us and if all our models are wrong, what's the thing that really hurts us?" and that comes down to simple things, which is concentration.

So I'll give you a simple example. Exposure to monolines was astronomical. Why? Because the thing that we were buying from them, the insurances we were buying from them were perceived to be of little risk, but the notional exposure was enormous. So the notional exposure versus the perceived stress was to orders of magnitude. So people are sitting there looking at the stress numbers and going "Well, we could lose, I don't know, 30, 40, 50 million," but the reality was against that monoline you had 5 billion of exposure. Right? So you have to look for where the concentrations are and actually it's almost the most simple way of doing it, which is to start off by saying not what could happen to us coherently, but "What is our real notional exposure? What are we exposed to here?" and identify those big things and then say "Okay, now I'm just looking at one or two really significant drivers of risk in my organisation," and it will typically be credit risk of some sort – "Now I know what the one or two really big things are, now let me sit down and think about just those one or two things which means I don't need my model because my model is designed to take in thousands of inputs. Now I know what the really important things are, focus on them." (Code: HMR-B15)

5.10.3 Models and risk of herd mentality

There was consensus from the participations that poor application of credit risk models (and, presumably, other risk models) could encourage similar behaviours amongst market participants and therefore blind them to the impact of certain trades on their portfolios or on the dynamics of the markets as a whole. As such it was felt that models could cause systemic risk. Nevertheless, it was felt that models, if properly applied and properly understood, were not likely to accentuate this inherent feature of markets.

"Can [models] encourage herd mentality? Yeah, it's probably true. I think if you go with your judgement... and that's not to say... There is a lot of things that can, from a modelling perspective, really aid business. Let me just think about this one for a moment. Herd mentality is, I guess, if a model is in place it negates the need for people to actually know what went into the make-up of that model, and it's very easy then just to kind of use that model without actually questioning is that model giving you a realistic picture of what is the risk that you're looking at. So in terms of introducing systemic risk... I'm taking systemic risk there as being risk from the use of those systems.

Well, it kind of creates the capacity to do that. I wouldn't necessarily say it introduces any more systemic risk than what there is, but what it does facilitate is a larger taking in that risk as opposed to... I guess it encourages flow business as opposed to structured business, shall we say." (Code: HQRM-B10, HQRM-B17)

5.10.4 Stress testing boundries

Bank B felt stress testing was an important part of credit risk measurement to ensure that the results produced were robust and could handle credit events that impacted the portfolio. There was the question on where to draw the line, though, especially in relation to where to set the bounds for stress parameters. Setting them too conservatively impacted capital and trading activity. In Bank B it was a regular source of debate between Front Office and the Risk Management department.

"We redesigned some of our stress tests and we had traders telling us "Actually, that's impossible." We said "Okay, we agree it's less than likely, but actually don't tell me it's impossible because I can give you things that I thought were impossible, but I was wrong by an order of magnitude." So it's having that kind of constant appraisal. You need all those things to be efficient and be able to deal with large portfolios, but the most important thing is that sitting on top of each one of those models or across all of them, hopefully, is a human input. What changed management attitude was the combination of Basel 2, which brought in things like stress testing across the board, and the idea that things can go horribly wrong and senior management are accountable." (Code: HMR-B20)

5.10.5 Governance

Bank B spoke about the need to ensure that there is input into the systems from multiple areas to ensure all areas are covered and there is no skew due to influence from one area when

system is built (e.g. if IT drove it, or QRM drove it from a pure theoretically basis, or Change area drove it, or COO who wanted to just look at their key part).

The Bank B risk managers felt that ensuring adequate coverage of all relevant factors, from a model and framework perspective, was very important. Governance checks and balances had a part to play in this.

> "From a senior management perspective it's ensuring that the right key stakeholders are involved in that decision-making process, and in the vendor valuations of the system. As part of the requirements of the system, one of the components that we have actually looked at is the economic capital output that it would come under, to see what those systems are capable of providing. Decision-making process is made by a combination of the Head of Quantitative Risk, the Head of Credit Risk, Head of Change Risk, Chief Risk Officer and the Chief Information Officer, myself and technology." (Code: HSCR-B3)

5.10.6 Credit Valuation Adjustment (CVA)

CVA, as defined by Pykhtin & Zhu (2007), is the difference between the risk-free portfolio value and the true portfolio value that takes into account the possibility of a counterparty's default. In other words, CVA can be seen to be the market value of counterparty credit risk. Based on a literature review, Canabarro and Duffie (2003) is a common reference for background on the subject.

The reason why it is mentioned in this research is that over the period of the research, there was the BIS on Basel III endorsing the CVA approach as referenced in their paper "Strengthening the resilience of the banking sector" (Basel Committee on Banking Supervision 2009). The Basel Committee proposed the use of a bond equivalent (with its notional value equal to the total exposure at default of a particular counterparty) as a proxy for counterparty risk.

CVA is relevant as it changes the way credit risk is managed and it has to do with credit charging. First, the credit department would charge the Front Office for expected losses and for the capital cost of credit risk. This would imply that the Front office would price the risk of default into their pricing and thus hedge credit risk. Second, it proposes a specialised desk to manage the credit risk that arises for the lifetime of the trade (CPM desk). This desk would aggregate credit risks across the bank and hedge these credit risks. In short, the idea is to delegate more credit risk responsibilities to traders, but to centralise CVA management in Risk.

The stated motivation is twofold. First, to assign a value of credit to a trade and to actively manage the credit risks. Secondly, it is believed that the alignment of trader incentives leads to use of a more accurate economic capital calculation. The reason why CVA can be important is that it advocates more use of credit models and, importantly, using this to manage (and mitigate) credit risks rather than the use of traditional credit limits.

There was a lot of scepticism in Bank B on CVA as it appeared to them to be a nirvana.

> "I don't think it removes the requirement for credit limits. I think credit limits are there for... You know, I guess credit valuation adjustment itself, CVA, is effectively, as you say, it's a charging process, but it's not kind of looking at it from... I mean the way the

CVA is calculated, it looks at various different components, but again you've still got that's back to a model and back to a judgement. With any sort of credit limit, a credit limit is based on a credit officer's view and understanding of a counterparty and its possibility or probability to default. So I think if you lose that qualitative judgement with regards to how much are we comfortable lending to a particular counterparty and continuously assessing that ... If you just kind of go with a fixed point in time, you'll do a CVA, a chargeback, then effectively what you're doing is kind of saying that you're removing the need for continuous assessment of counterparties. I mean there is benefits to that, but again that's done at a point in time, whereas typically trade will actually be for a period of time and, you know, the credit quality of that counterparty could change over the period of the point from where it was transacted to when it matures." (Code: HSCR-B6)

"You charge CVA specifically to buy protection on the trade. There are no perfect hedges. There will always be a risk embedded there. I certainly believe in the first point that charging of CVA does encourage less risk taking, that's for sure, but will never be risk free and, you know, CVA cannot account for all the circumstances. You know, it's not.... You can probably hedge market risk, you know, but you can't hedge documentary risk. You know, that kind of thing, so...". (Code: HCRI-B9)

"A hell of a lot harder to mitigate credit risk in that way than people might have chosen to believe or assume or at least represent. From our perspective... I mean I think, you know, again if you look at our business model, it's a very concentrated business model and actually the vast majority of the credit risks that we're likely to take are not risks for which you could find a tradable off-set. So you would then be reduced to the notion of having some sort of generalised basis for hedging credit and... I mean I think you only have to look at some of the events that occurred, for example, around the Lehman default to understand that in fact that sort of approach to "credit hedging" can actually turn out to increase your credit risk and not reduce it. At the point those risks are being accepted for hedging, you will have lost a huge amount of information because your central hedging desk is simply going to see "I've got this exposure coming from there. I've got that exposure coming from here," and unless there is some, you know, huge visibility and great understanding of what the portfolio underlying that is and what the limitations of the models are, I really don't see how you can have total credit hedging." (Code: CRO-B10)

"CVA meant that the economic reality of that credit decision has to be reflected in the firm's accounting and therefore, theoretically, via credit derivatives or other things you can hedge your CVA. CVA by definition has to be calculated on all transactions you have with a counterparty and those transactions can be.... I mean this is a small firm, but if you're a Merrills it could be off your equity derivative desk, your credit derivative

desk, your interest rate swap desk and people were kind of struggling to say "Okay, so how do we allocate this risk and this cost? The cost itself is tough, but how do we allocate this risk out to desks?" and therefore – with one or two noted exceptions of which Goldman would be the best – if you looked at the Merrill model, some traders were put together whose job was to try and sort of hedge macro the CVA risk, but that was really only something that happened... not quite going into the crisis, but only very shortly before. Clearly managing your credit risk is a good thing. The down-side is you're still trying to manage credit risk. Estimate of what your exposure could be is probably too small. Won't be there. So the classic example was yes, leading up to Lehman we were all trying to get protection. Guess what? Who was going to sell you...? If somebody sells you protection, they're extending credit to Lehman's effectively. Gives you P&L volatility. P&L volatility only becomes extreme – in other words, really starts to hurt you as a firm – once the credit market has started to lose liquidity.(Code: HMR-B14)

Participants saw a need for the application of CVA adjustments alongside the exercising of credit limit frameworks. Whereas a CVA can be used to discount the future value of a receivable, a limit maintains a ceiling for exposure to a certain credit risk.

"Foremost benefit is the discipline of having institutional understanding of the products you're trading in, the risks that you're taking, the historical data that you're using to calculate your value at risk or your PFE, if that's what you're doing. I will say that I think... I got involved, for example, in some CVA calculations recently. I think that the CVA people are kidding themselves. Certainly in one of my previous firms it was an unmitigated disaster. We had a Head of Market Risk, who felt it was alright for us to short risk. One of the problems with the CVA desk is that you have two risks. You have risks that your counterparties have down-graded, but you also have a risk to yourself about your own grading and you have to hedge that as well because your pricing spreads, right? I've seen more cases where the banks – particularly through the on-set of the credit mess in 2008 – where banks tried to hedge their own exposure, so exposure to their own grading, by trading with similar bank gradings. So obviously if one of those banks was Lehman, you were screwed basically and I think the CVA folks... I think CVA is a moving target. I think it's extremely unscientific. I also am not convinced of the – what's the word? – the moral hazard of the credit default swap market... I think moral hazard's a word that's used a lot, but I just think its use is... In many of the cases that I see, it's just so clearly immoral or unethical. Was not the actual calculation, not the fact that there should or shouldn't be a CVA. What I was really speaking about there – I know it wasn't clear – is that I don't think the hedging of CVA works." (Code: HQRM-B9)

5.11 Viewpoint on the Future

5.11.1 Standardisation

Standardisation was a theme that all the participants in Bank B spoke about in different ways. While not an exciting revelation of the future, it is an important viewpoint. Bank B's participants see that the simplification of trading and settlement of credit will increase the accessibility of the market and reduce inherent systemic risk. Key to this was felt to be the migration away from bilateral trading to exchange-based trading, where effectively a recognised intermediary (exchange) takes on the credit and settlement risk.

> "I think, more than anything else is the success of the apparent regulatory drive to put more and more counterparty derivative trading on exchange, and to force more and more the use of standardised credit mitigation techniques. If you imagine a world in which all counterparty risk is on exchange, then actually the modelling in the banks migrates to the exchanges and so you would have a world in which modelling becomes much more uniform and much more centralised, (not necessarily much better), but there's a clear economic imperative for that modelling to be sufficiently conservative. Somebody was pointing out to me the other day that there is an irony in all of this in that those central counterparties at the end of the day are going to wind up being owned by the banks so, you know, if you get the modelling wrong, you still own the tails of risk." (Code: CRO-B20)

As pointed out by the CRO, it might not remove all the credit risk to the banks as it just transfers it from many smaller counterparties to a single very large one (which in turn may be owned by the banks themselves). The concept of the likelihood of exchange trading derivatives was shared by the head of market risk who also shared the view on exchanges reducing risks to many counterparties by concentrating the risks on derivatives in one place.

> "Derivatives effectively are over the counter transactions or bilateral. If they get done via an exchange, the risk becomes less systemic. In other words, if it's all concentrated in one place, there will be settlement there and we'll have one way of,... you have a safe marging in place – the same as a futures and options. The way the credit model changes most fundamentally is in that respect of having an exchange process rather than an over the counter bilateral process." (Code: HMR-B28)

The above quote assumes that credit risk disappears on exchange traded products. It is a common assumption as many banks do not assign credit risk to exchange traded products.

But, how true is that assumption especially in light of triple A sovereigns being downgraded in the financial crisis and institutions like Fannie Mae and Freddie Mac defaulting. If these can default, so can exchanges.

Two of the participants felt the wider use of a finite set of models (within a multi-faceted framework) should increase operational benefits and the standardisation of products would reduce complexity.

> "I'm hoping that in 5 years time we have a finite set of models. These may be provided by software vendors that develop their proprietary models and systems offering a multitude of solutions and a multitude of models, you know, to banks / to the financial community. Economic capital, capital at risk, you know. Very systematic and very similar manner." (Code: HCRI-B17)

> "I would think it'd be a case of what we're doing right now – products that we consider exotic will be vanilla. I would hope that, you know, we would be a lot more knowledgeable about those products and better ways to kind of see the down-side risk because I guess things like mono-lines and stuff like that, I guess with hindsight people would have modelled them differently. With hindsight a lot of things come into play. So I would say that, you know, we will probably see a lot of products that we're kind of considering now as potentially vanilla or kind of semi-exotic. We may have to revisit those because then some event will occur in the market and effectively we'll find that there's issues with that particular type of product, so we'll look at a different way of modelling them." (Code: HSCR-B23)

The comments do not cater for the fact though that there would be newer exotic or complex products. The general feeling was that the capital regulators required for exotic products would reduce these in the future. But this does not take into account the migration of hedge funds and asset managers' operations to locations that have less stringent regulations.

The Head of QRM also spoke about standardisation, and he believed the driver would be the reduction of bonuses. This he felt would drain the knowledge pool as he believed the high bonuses in banking had attracted the high achievers and the cream of the universities. Without that incentive these high achievers would move to other industries. This would reduce creativity and lead to standardisation.

"I think what's going to happen is that certainly in the UK and probably in the US – and the rest of the world will follow – first of all I think what's going to happen is that the bonus culture is going to get quashed. I think the result is that people are going to get paid a larger base. I think the creativity will go from the industry. I think we'll end up following very formulaic approaches to things like credit and market risk." (Code: HQRM-B29)

5.11.2 Sophistication of models

Bank B's participants were conservative in their assessment of the rate of progress in model development. They were clear that their bank had little to gain from over-reliance on certain types of model, whether it be structural, stochastic or otherwise and that the key criteria for a Tier 2 bank, such as Bank B, is the tolerance of the quantitative modelling process to imperfect data inputs.

"It will have to be around how you take human processes, the ones that I've described of 'Okay, I have a model, but then the model doesn't really work and I put this human process on top'. It will be taking some of that human process and systemising it in some shape or form. So that's why. Is it extreme value theory? I don't know. Possibly. And is it something like KMV on drugs? Possibly it's something like that. So I think people will attempt to build more and more robustness into their modelling. That's all that they can reasonably do and that's the way that the regulators are going to drive this thing forward anyway. We kind of intuitively know how to do some of this stuff and in some organisations it's small enough that you can really do it. In bigger organisations you need to think about how you change your systems to take account of some of these qualitative measures. Most indicators of risk are typically bad indicators. Anything that comes out of the marketplace is typically a bad indicator of risk. It's certainly not timely enough to work in credit risk model space." (Code: HMR-B26)

5.11.3 Blurring in the boundaries between credit risk and market risk

In the commonly-found structural and reduced form models, the estimations of credit risk are directly linked to market prices. Therefore an expression of credit risk can be regarded as a function of market risk. Bank B's risk managers appreciate the linkage and rely on a variety of broadly-based techniques to manage it.

"This marriage of derivatives, market risk and credit, you simply can't do without. I mean the answers we get are not perfect, but it's simply inconceivable that you would

take a reasonably sophisticated / reasonably simple derivative transaction like a swap and pretend to know what the potential exposure is given today's environment. You know, it depends on outcomes. Basically it's a new way of estimating the likelihood of those different outcomes, that's basically all the model's trying to do. They're better or worst placed to do it, but that's basically what the model's trying to do. There's no way you could make it up. Unless they came up with add-ons, you know, which they can always do." (Code: HQRM-B31)

5.11.4 Changes in Regulatory Capital

The CRO felt that there would be changes to regulatory capital that reflected some of the recent events from the Credit Crunch (between 2008 and the research in 2010). It was mainly the largest banks that had previously been keen for models to be adopted by the regulators. These banks had felt their modelling abilities provided them a competitive advantage as they would not need to hold as much capital as the smaller banks who did not have modelling capabilities, and who would need to invest large sums of money to be able to build the expertise. Now the view was that stress testing of judgemental models would likely gain prominence and the older modelling methods reduced from a regulatory capital point of view.

"I mean I said to you previously that I think that the banks have previously been dragging the regulators into a model space, but I think that we're actually now in an environment where potentially the regulators are going to drag the banks into some sort of model space; probably a less modelled space or certainly – to play back some of our words from earlier – a less precisely modelled space; I mean models that have, you know, much greater degrees of in-built conservatism. So my guess – and it really is a guess – is that, you know, we will be much more focused on the tails than we have been, you know, previously in modelling. Whether that ultimately will be through, you know, simple brute force methods like stresses and scenarios or whether it is going to be through more elegant approaches is kind of hard to say. I think it unlikely that you're going to see a regulatory step back from stress and scenario testing. I mean with the reverse stress testing requirements becoming real, you know, this is getting baked in increasingly different ways. So I mean I suppose that's my view of the world – is that models will still be there; they will probably have a weaker link to capital requirements than they have had in the past and that we will see, you know, an increasing requirement for severe judgement-based calculations to be applied. And I suppose I do see the potential that we are going to see modelling... you know, that type of stress modelling with a much greater degree of both internal and external feedback loops within in." (Code: CRO-B19)

5.12 Summary of the approach of Bank B towards credit risk models

Bank B is not advanced in their use of models as would also be the case with a number of small or medium sized banks in the market. The bank has though a clear perspective of models and their usefulness within the bank. They do not follow one particular model philosophy and instead believe in a combination of qualitative factors along with quantitative model output and have applied this philosophy in their implementation of the models.

> "I think that models should be looked at independent to the market, because at any point in time a model is just the sum of parts that you put into it. I don't think you can ever get away from the fact that you need a measure of quantitative and qualitative judgement in any decision-making process. Models are not perfect. They're an aid to making a decision." (Code: HSCR-B4)

The participants believed that models are guidelines that only get you so far and models were only one source of information. The other benefit of the models in Bank B was in that they enforce a level of rigour and discipline. The head of Quantitative Risk Management believed that this discipline helped to provide institutional memory that helped credit decisions.

> "The discipline of having a proper risk management framework is worth its weight in gold. I don't think there is any question. In terms of institutional memory, in terms of the discipline of forcing people to think about the consequences of products that they want to trade, that they'd like more... but the trader typically may not think that way because the traders really couldn't care less about VaR except that, you know, we need VaR and they have to help us get it set up. I mean why are we doing VaR? Do we think VaR is the right answer? No. We're doing it because the regulators wants it – apart from the discipline aspects, right". (Code: HQRM-B22)

The participants spoke most on the area of experience and how that was important in general credit risk management and the use of models. On models specifically, they highlighted the experience required to understand and use model output as well as individuals' experience as one of the non- model or qualitative factors within the credit making process. The participants did also point out that individuals' experience could be a potential positive and negative factor. It was positive in that it could help in using the model information correctly, as well as negative in that it could cause resistance to change, as the member of staff may be ingrained in the way that they used to do things and thereby openly or covertly ignoring part or all of the information from the model output. The participants spoke about the right type of experience being important.

On understanding the model outputs, Bank B spoke in detail on the need to understand the model's assumptions, and it was highlighted in several parts of the interviews by all but one of the participants. They felt it was important that the inherent assumptions around models and the parameters used were understood as there would be a high risk of incorrect interpretations of model results otherwise. By understanding the assumptions, senior management would be able to review the assumptions on which credit risk models were built, to challenge them and where necessary to commission replacement of the models if these assumptions resulted in incorrect interpretation of the results.

In Bank B, while models were seen as part of the management decision-making process, it was clear that models should not be the main determinant in management decisions without at least a detailed understanding of the model numbers and a large qualitative overlay. In section 5.6.2, qualitative factors such as interpretation of the model results against the individual's experiences, the use of collective wisdom and the view of external environmental factors (market, political and legal) were also instrumental in arriving at management decisions on credit risk. A quotation from the Chief Risk Officer summarises:

> Well, in terms of [Bank B named], I seriously hope the future credit department will be different from what we have today, but that's because as an organisation we have a fair amount of transformation to undertake. As I've said, I think modelling most definitely has a role in the credit process as it does in the market risk process and as it does even potentially in the operational risk process, but I think it absolutely has to be allied with what you might call more brute force techniques and traditional techniques (Code: CRO-B8).....I think models will remain. I think that, you know, perhaps hopefully with a little less slavishness around them, but it's, you know, inconceivable given the complexities of large credit portfolios that you can have a world in which there is no modelling. At the end of the day market risk, you know, when you get your trading book boundary right, is something where your mistakes can be corrected in the short-term. What should be clear to everybody is that in a credit world mistakes can often not be corrected in any period and, you know, I think that demands that there is an approach that involves considerable expert judgement (Code: CRO-B11.

The next chapter of the thesis presents the third of the three case studies.

6 Case Study Bank C

6.1 Introduction

This chapter provides a study of Bank C where it analyses the responses to the interview questions in order to identify trends and differences of views between all the responses. By highlighting the similarities and differences in what was said by the different participants, or how they said it, an understanding can be built on the use of credit risk models. The aim is to provide a holistic and in-depth description of management's use of credit risk models. The data and explanations are then used as the foundation for the cross-case analysis in chapter 7.

The data collection and data analysis have been previously discussed at length in the methodology section in chapter 3 of this thesis. Where necessary, interview quotations have been used to demonstrate the analytical interpretations and have been provided in the form of exhibits at appropriate junctures.

The next section (6.2) provides background with an overview of the bank, its governance structure and its general market strategy in order to provide the reader an organisational context to the case study responses. Section 6.3 analyses the risk management framework covering risk appetite, management team and organisational structure. Section 6.4 describes the participants who were guaranteed confidentiality; therefore, their roles are described and alphanumeric codes assigned. These codes are used to identify specific quotes included in the main body of this chapter. Sections 6.5 through to 6.9 investigate and discuss the main themes that emerged in order to understand their use of the models. Section 6.10 covers the secondary themes found and section 6.11 focuses on the participants' views of possible improvements or changes to the models. The last section, 6.12, summarises and characterises the approach of Bank C towards credit risk models.

6.2 Background of Bank C

6.2.1 History and coverage

This section provides background of the bank and its organisational structure in relation to credit risk.

Bank C is part of a diversified banking and insurance group domiciled in the European Union. It is the largest in terms of size of assets of the three banks covered in this research. The group has over 100,000 employees and operates in 48 countries around the world where it manages a total of 70 distinct businesses.

Bank C's parent group emanated from a merger of a national bank with a large insurance group in the 1990's. The resulting group has a structure typical of European BancAssurance models found in the European financial services marketplace of the 1980s and 1990s. Over the last 5 financial years, the banking side contributes approximately 50% of the combined profit before tax for the group.

Bank C sees itself as a global financial institution, offering a broad range of financial products to a multi-national customer-base (Bank C website 2010). Its stated mission is to focus on both banking and insurance sectors, while delivering products through a variety of channels to both retail and commercial clients. Recently, it has moved to establish greater separation between banking and insurance operations, citing both the need to increase focus as well as enhancement of shareholder value.

The banking group's total assets were USD$1,260 billion on the 31st December 2009. Revenue growth had varied a lot in recent years with heavy losses in 2008 and 2009 and a return to profitability in 2010. The bank's market capitalisation on the 31st December 2009 was USD$36 billion. Bank C was rated Aa3 by Moody's and A+ by S&P and Fitch.

The table below shows some key financial data for Bank C:

Key financial data (USD billions rounded)	**2010**	**2009**
Total Assets	1330	1260
Headline Earnings	4.3	-1
Net fee and commission income	3.8	3.8
Net interest income	19	18
Trading Revenue	1.7	1.2
Net interest margin	1.44%	1.34%

Return on assets	0.1%	0.1%
Return on equity	18%	-1%
Cost to income ratio	56%	68%
Capital Adequacy %	15%	13.5%
Tier I capital adequacy ratio %	12%	10%

Table 6.1 Bank C general financial data (converted to USD)

The table below shows the services and products in Bank C:

Retail banking	**Commercial banking**
Retail Banking provides retail and private banking services to individuals and small and medium-sized enterprises	Commercial Banking offers core banking services such as lending, payments and cash management in more than 40 countries
• Savings • Mortgages • payment accounts • Investment products • Consumer lending	• Corporate finance • Structured finance • Commercial finance • Equity markets, • Financial markets • Leasing

Table 6.2 Products and services provided by Bank C

6.2.2 Organisation and strategy

Bank C's parent group operates a two-tier board structure consisting of a Supervisory Board and an Executive Board.

The Group Executive Board is responsible for day-to-day management of the business and long-term strategy. The Supervisory Board is responsible for monitoring and analysing management performance as well as advising the Executive Board.

The Group Executive Board comprises its Chairman & Group CEO, the Group CRO and Group CFO. The Supervisory Board is made up exclusively of 10 external directors.

The group is prohibited by regulation in its country of domicile from operating banking and insurance businesses within one legal entity, resulting in a need for separate entities to manage the two businesses within the group. Day to day operations are therefore devolved to two separate management boards for the Banking and Insurance businesses respectively.

Figure 6.1 Bank C's Group Management Structure

6.2.3 Recent corporate strategy & direction

Bank C's parent group recently undertook a re-appraisal of its core activities in the context of the global financial crisis in 2008. In common with many major financial institutions in the Euro zone, this has resulted in a set of strategic initiatives which seek to align the businesses along more focussed and stable lines. For Bank C, this has resulted in a concentration of activities around less complex products and within territories or sectors where the bank has or is able to build a solid base.

These drivers are set within a global environment of greater regulatory and capital constraints so in addition the bank needs to increase its capital base and to simplify and make more transparent its operations and management reporting.

In order to progress towards these objectives the bank has adopted a series of initiatives in the areas of overall cost reduction, de-leveraging the balance sheet, risk reduction and capital exposure reduction. Once completed, it is expected that these initiatives will result in the disposal of between 10 to 15 businesses and the withdrawal from up to 10 of the current 48 countries, where Bank C is currently active. This is expected to free approximately 4 billion Euros in capital between 2013 and 2015.

6.2.4 Challenges in Bank C

The research within Bank C has taken place at a time when significant re-appraisal of group operations and structure was underway. Specifically, the case study responses need to be judged in the context of:-

- the challenge to separate banking and insurance activities in accordance with EU regulations
- the need to address the implications of the banking and insurance separation from a risk management perspective. There are clear organisational and risk governance issues here. For example, a lot of the risk governance machinery is developed to a group level but has its roots in the banking side of Bank C; it is not clear how or whether this will be recreated for the insurance arm, should full separation (disposal or formal independence) become necessary
- the group's pursuit of a strategy of rationalisation of its businesses with a view to focussing on core areas of expertise and geographic presence. The implications of this strategy on the application of risk management to day-to-day operations are as-yet unclear. However, in the case study analysis in later sections, it is possible to identify themes that will be important in this respect

6.3 Risk management framework in Bank C

6.3.1 Risk governance structure

Similar to the first two case studies in this research, the responsibility for the overall risk profile, risk return and capital in Bank C falls on the Group Executive Board. The group Chief Risk Officer (CRO), who is a member of the Group Executive Board, bears primary responsibility for Bank C's risk management.

The CRO is responsible for the management and control of risk on a consolidated level to ensure that Bank C's risk profile is consistent with its financial resources and the risk appetite defined by the Group Executive Board. The CRO is also responsible for establishing and maintaining a robust organisational basis for the management of risk throughout the group.

The CRO makes sure that the boards are well informed and understand Bank C's risk position at all times. Every quarter the CRO reports to the board committees on Bank C's risk appetite levels and on Bank C's risk profile. In addition the CRO briefs the board committees on developments in internal and external risk related issues and makes sure the board committees understand specific risk concepts.

The CRO is supported by separate departments for credit risk, market risk and operational risk. Unlike the first two case studies, due to the structure of the group there is additionally an insurance risk department that reports to the CRO. Also unlike the other two cases, the CRO has two separate staff departments, Risk Integration & Analytics (responsible for inter-risk aggregation processes and for providing groupwide aggregation) and Model Validation (carries out periodic model validations of all material risk models used) reporting directly to him. The probable reason that these two departments report directly to the CRO is the relatively high profile of modelling in the current market and to ensure independence from the business and the other risk departments. When discussed with staff in Bank C, another reason given by a couple of people was that these departments may have been ineffective in the past within the larger departments and it was decided to raise the profile of the departments by making them report to the CRO.

Unlike the other two case studies, the CRO does not take an active part of day to day Credit decisions nor is part of the Credit Committee structure. Instead this function is run by the General Manager of the Credit Risk Management department (CRM). The CRM General Manger is functionally responsible for the global network of credit risk staff, with the heads of the credit risk management functions for the business lines report directly to him.

The most notable change in terms of risk governance during 2009 was the creation of the Risk Committee. The Risk Committee is a sub-committee of the Supervisory Board, dedicated to risk governance, risk policies and risk appetite setting.

In addition to the Risk Committee, the Supervisory Board's Audit Committee also plays a role in the governance and management of risk within the group.

Broadly, these two committees set the risk strategy and operational framework for the group as follows:-

- Risk Committee addresses matters of risk governance, risk policies and the setting of the risk appetite for the bank;
- The Audit Committee assists the Supervisory Board in reviewing and assessing major risk exposures, the operation of internal risk management and control systems as well as policies and procedures associated with matters of compliance.

A diagrammatical governance chart is as follows:

Figure 6.2 Risk management governance structure of Bank C

The bank's approach to risk management appears to be based on well-established market standards for governance and follows regulatory recommendations. Although principally a

human process (involving qualitative assessment and review through organisational hierarchy and committee), it does rely heavily on quantitative input and evaluation of large amounts of data. Like all human processes it relies on both individual responsibility and collective oversight but is supported by an established reporting and escalation structure.

Key in the process are the business unit heads who are tasked with the primary responsibility for managing risk within each of their businesses, and are responsible for ensuring that there are appropriate, adequately designed and effective risk management frameworks, in compliance with group risk governance standards.

As in the first two case studies, to ensure there is independence and appropriate segregation of responsibilities between business and risk management, business unit Chief Risk Officers and Chief Credit Risk Officers report operationally to their respective business unit heads, and functionally to either the group Chief Risk Officer or the group Chief Credit Officer

Compliance with risk standards is controlled through annual self-assessments by the business units and group risk, supported by the group internal auditors.

6.3.2 Risk appetite

Section 2.7.1.1 of the literature review covered importance of a bank's risk appetite. Bank C's risk appetite is defined by the Group Executive Board as part of the strategic planning process. Boundaries are established with regard to acceptable risk types and levels. Bank C's governance framework helps ensure that risk is managed in line with the risk appetite as defined by the Executive Board of the Group, and then cascaded throughout the Bank via a "planning letter" which provides the organisation with the corporate strategic direction, and addresses key risk issues. The business lines have to maximise the value within these established risk boundaries. Each quarter, the Board monitors that the financial and non-financial risks are within the boundaries of the risk appetite as set in the previous strategic plan.

Bank C has integrated its risk management team into the annual strategic planning process and in helping define the bank's risk appetite for the coming year. The process includes a qualitative and quantitative assessment of the risks involved in the plans. It is part of the process to explicitly discuss strategic limits and risk appetite levels. At each level, strategies

and metrics are identified to measure success in achieving objectives and to assure adherence to the strategic plan. Based on the business unit and line of business plans, the Executive Board formulates Bank C's strategic plan which is submitted to the Supervisory Board for approval. Once approved, the emphasis is on managing business developments within the business lines by means of top-down concentration limits for countries, individual borrowers and borrower groups.

Bank C does not reveal its exact risk appetite in published financial statements. However in the 2009 accounts, it is mentioned that during mid 2009 the risk appetite framework for group was revised, and approved by the Executive Board of the group. This was due to the fact that the bank had large credit losses and government capital was used to help recapitalise the bank. One of the effects of the revision was to align more closely the risk appetite setting with the capital management targets for the capital ratios. The alignment of the risk appetite to capital management targets reflects the importance of capital post the credit crunch of 2008 and also reflects the regulatory pressures to ensure adequate capital in banks. When this research was conducted in 2010, capital was a scarce resource in the financial markets. Bank C seemed proactive in taking into account available capital as part of its risk appetite decision-making process and thus linking risk appetite to the determination of risk return on capital.

Another insight into Bank C's view of its risk appetite can be found in Bank C's credit policy in their financial accounts 2009, where they state their aim was to maintain an internationally diversified loan and bond portfolio, while avoiding large risk concentrations. This indicates a much more conservative approach in their risk appetite aims compared with the first two case studies.

6.4 Credit risk management in Bank C

Based on analysis of Bank C's 2009 financial accounts, credit risk at USD$14 billion is the largest financial risks Bank C is exposed to, followed by market risk at USD$11.7 billion and finally operational or business risk at USD$6.5 billion.

As mentioned in section 6.3.1, the management of credit risk in Bank C is the responsibility of the Credit Risk Management (CRM) department, reporting into the Chief Risk Officer. The CRM General Manager is functionally responsible for the global network of credit risk staff, while the heads of the credit risk management functions for the business lines report directly to him.

The credit risk management function in Bank C is supported by dedicated information systems which apply appropriate and approved methodologies for all categories of credit risk. The functions are aligned along the principal banking business lines of Commercial and Retail, as well as separate consideration being given to geographic and channel-based specialisations.

The CRM General Manager oversees a global network of credit risk staff distributed across all the territories where the bank is present. In addition, the credit risk heads of the main business lines (Corporate, Retail and direct channels) report directly to the CRM General Manager.

The CRM General Manager does not an active part in the credit risk modelling area. Instead he delegates authority to his deputy who is the Head of Credit Risk Management. The Head of Credit Risk Management is the official sponsor of this research in Bank C.

6.5 Reporting lines in respect to credit risk modelling in Bank C

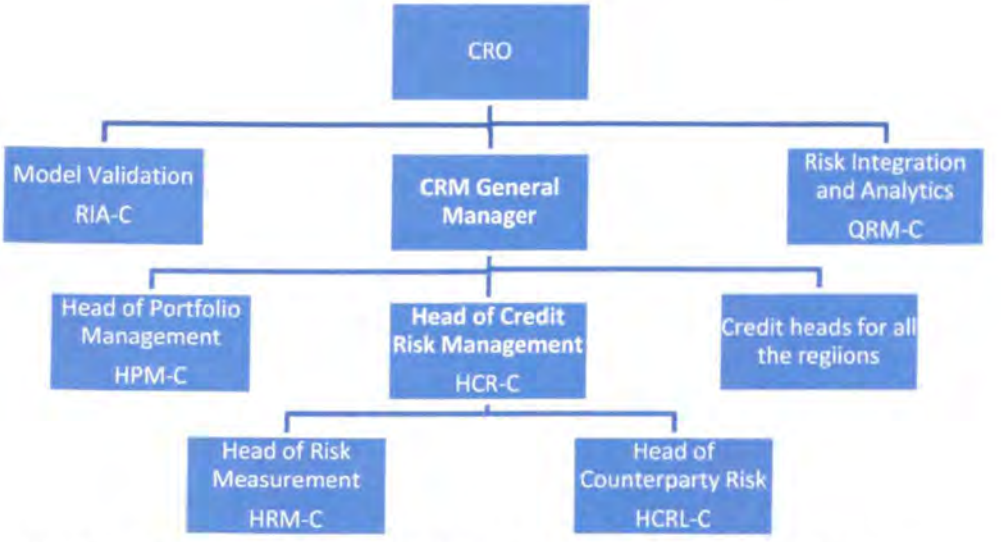


Figure 6.3 Credit risk organisation chart in Bank C in relation to credit risk modelling

6.5.1 Role of the participants

The official sponsor in Bank C is the head if the Credit Risk Management department for global investment banking (hereafter HCR-C). While this is a different level of sponsorship then the first two case studies, this reflected the way credit risk modelling outputs are managed and used in Bank C. There were two small departments that are part of the modelling area that does not report to HCR-C. These would have all been part of CRM in the past and as mentioned in section 6.3.1, the probable reasons for the different reporting lines are the relatively high profile of modelling issues in the market and Bank C wishing to ensure there is no interference from business or the other risk areas to the independent development and verification of these models.

Despite the differing reporting lines, all the areas listed in Figure 6.3 work closely together on a day-to-day basis with HCR-C being the most senior of the people involved with risk modelling in Bank C. Selection of the participants was based on discussions with HCR-C as well as the main credit risk department heads. The selection as based on their view that these were the key people in the departments impacted by credit risk models. The participants were individually approached and all six agreed to be part of this research.

Head of Credit Risk Management (HCR-C)

HCR-C is a managing director and the global head of Credit Risk Management for global investment banking. He is the main user of the output of the risk models and reviews the model results before acting on the information or presenting them to senior management. HCR-C has a wide remit in the bank and several departments reporting to him. The most relevant for this research are the counterparty risk and risk measurement departments. HCR-C is the sponsor in Bank C for this research.

Head of Portfolio Management (HPM-C)

HPM-C is head of the Portfolio Management department. This department manages the portfolio impacts and reduces the overall credit risk to the bank via hedging some of the risks. As such this area is a key input into the model development as well as acts, when needed, on the outputs of the models in relation to potential ways of reducing risks on a portfolio level. HPM-C has been an advocate for the use of portfolio modelling in the bank for a number of years and speaks on this subject to external conferences.

Model Validation (MV-C)

MV-C is the senior quantitative analyst within the Validation team. This is the team that independently checks and tests the models. This occurs initially when new models are built. It is subsequently done whenever they are amended or as part of an annual review. The models can also have an interim review if there are issues raised by the users or if management feel that outputs may be incorrect.

Head of Quantitative Risk Measurement (QRM-C)

QRM-C is head of the Quantitative Risk Measurement team. This is the team that designs the models, develops the models and tests them before they are validated by the validation team. They also maintain and support of the models.

Head of Counterparty Risk London (HCRL-C)

HCRL-C is a managing director and the head of Counterparty Risk in London. HCRL-C also is a member of the global credit risk committee where all large lending decisions are made. He is a delegated credit authority holder (authorised approver) within his department, for limits setting, approval of new clients, and approval of new transactions. Credit authority that goes beyond HCRL-C's individual limit goes to the regional credit committee or where the

credit decision is large (over €100million), the decision is made at the global credit risk committee level.

Head of Risk Measurement (HRM-C)

HRM-C is head of the Risk Measurement department. This is the team that defines the methodology and measurement of credit risk exposures. HRM-C has a limited remit in relation to the models but does provide some of the data needed by the models and has involvement when the model output has an exposure impact.

6.6 View of the participants to credit models

Similar to Chapters 4 and 5, this section follows the structure of the interview protocol used during the interviews with representatives of the risk governance and management organisation of Bank C. As described in Chapter 3 on methodology, there are no established theories of management use of credit models and this section uses the responses to draw a number of conclusions around the use of credit risk models and highlight areas of potential improvement in practice and execution. The interviews were semi-structured, in that there was a script with a list of questions prepared but the research participants were allowed to decide how they wanted the interview to be structured, and were allowed to speak freely on their views of the use of risk models.

6.6.1 Credit model use

This part of the case study looks at what credit risk models are in use in Bank C, how and where are they used and why Bank C uses a particular type of model rather than alternatives.

6.6.1.1 Type and Preference of Model

Compared with the other banks in this research, Bank C would be a relatively sophisticated user of credit risk models. For Economic Capital, Bank C previously employed structural models across all asset classes as the bank relied on the Moody's KMV model which is based on the Structural school.

> "Okay, if for Economic capital, then we're talking about structural models." (Code: QRM-C1)

However due to the fact that the KMV model was complex, the outputs found not to be accurate when compared against the market and that it was not easy to explain the outputs, the Bank had recently moved internally to simplify its model and use an in-house model also based on the structural school. There has been a large initiative within risk management in the bank to implement stress testing in conjunction with the models and to use stress testing as well in management decision-making and reporting.

Digging deeper in Bank C, other than structural models, they also employ expert judgement models and, in a number of key areas, hybrid models which are made up of a combination of the structural models and expert judgement models.

> "We use a combination of models, based on customer and portfolio" (Code: HRM-C1)

Bank C's definition of an expert judgement model is one based on the knowledge of experts from both Risk Management and Front Office staff and literature from rating agencies, regulators and academics. This kind of model is especially appropriate for those portfolios for which little internal (and external) data is available. These portfolios are also often referred to as "Low Default Portfolios". Depending on product and business line, the bank combines data from the models with the manager's or credit expert's views.

> "[I] believe several flavours are used, and [they are] mainly decided on a departmental-by departmental-basis." (Code: HCRL-C1)

Bank C internally considers its use of the structural model to be part of their statistical model set. Their definition of a statistical model is one where the required data set contains a large number of defaults or detailed loss components. There should be a sufficient number of data points to facilitate meaningful statistical estimation of the model parameters. The data set should contain data of sufficient quality, and the variables in the data set should be relevant for the estimation of the risk components (for example: variables on sales and income for PD models, and variables on value of the collateral for LGD models). The model parameters are estimated with statistical techniques and this method is usually based on either Bank C's internal data or externally sourced market data.

Bank C's definition of a hybrid model is one that contains characteristics of both expert and statistical models.

6.6.1.2 Where do models fit in the organisation

The credit risk models are created and maintained by a number of teams within Bank C. These have responsibility for the design and operation of the models. The primary users of the credit risk models are the Credit department as well as Front Office (trading) risk officers, the finance department and the regulatory and capital management departments.

> "Yes they are in common use within the bank in several departments. They are used by the analyst team and mainly in internal rating. They are used in regulatory reporting where [name of Bank C] uses the advanced internal ratings-based approach and in measurement/validation, where they are used to calculate economic capital." (Code: HCRL-C2)

To illustrate the use of different methodologies for the potential of default (PD) calculations, based on documentation provided by the participants, the methods used for each portfolio type are:-

Model type	Portfolio	Methodology
Expert	Commercial/Investment Banks	Expert Judgement
	Non-bank Financial Institutions	
	Project Finance	
	Real Estate Finance	
	Trade & Commodity Finance	
	Healthcare	
Hybrid	Large Corporates	Statistical regression with expert scorecards and expert judgment Modules
	Central Governments	
	Government Related Entities	
Statistical	Small and Medium-Sized Enterprises	1) Logistic Regression 2) Linear Regression 3) Decision Tree
	Residential Mortgages	
	Consumer Loans	

Table 6.3 Potential default model methodology used for each portfolio

For loss given default (LGD) and exposure at default (EAD) models they also use all three model methodologies, but these can be applied to different portfolios:-

Model type	Portfolio	Methodology
Expert	Commercial/Investment Banks	Expert parameter estimates based on external studies and sometimes supported by limited data sets
	Non-bank Financial Institutions	
	Project Finance	
	Real Estate Finance	
	Large Corporate	
	Central Governments	
	Government Related Entities	
Hybrid	Small and Medium sized	Statistical parameter estimates adjusted with expert opinion and conservatism added
	Enterprises	
Statistical	Residential Mortgages	Statistically estimated haircuts and scenario analysis, where conservatism added (as necessary)
	Consumer Loans	
	Leas	

Table 6.4 Loss given default and exposure at default model methodology used for each portfolio

Credit risk for regulatory purposes is calculated as 'potential of default' multiplied by 'loss given default' multiplied by 'exposure at default', and Tables 6.1 and 6.2 above are to show how, for the end-to-end calculation of credit risks for regulatory purposes, there are three methodologies used in Bank C. The literature review in chapter 2 shows that expert judgement models are not considered to be part of quantitative modelling, although parameters for the quantitative models based on expert judgement is part of the quantitative modelling literature (albeit these are not discussed in detail). In Bank C, one of the findings of the research is that they use a combination of quantitative and qualitative models to calculate and quantify their risk.

6.6.2 Other qualitative factors that influence how the models are used

Bank C illustrated significant variations of approach to their use of credit risk models within the organisation. This was seen to be a function of the confidence placed on model results by individuals, whose professional backgrounds and working experience would have influenced their views.

6.6.2.1 Experience and use of models

The area of experience was discussed at length by all the participants. This was especially so in credit decisions and loan/counterparty credit evaluation where these managers would be inclined to consider the model's output as just one factor in a multi-faceted process.

> "Yeah, my background and my experience is related to problem loan cases. So I have been able to pick that as my reference framework and put that next to what I see is happening now. So I think interpolating these things – yeah, gut feeling and experience is absolutely something which is a necessary added value to it. The other side is, I think, also very true. You cannot just do it on that experience or building it up on intuition." (Code: HCR-C1)

Other practitioners, whose working history was focussed more on the theoretical derivation of credit metrics, had more affinity to the models as a cornerstone of credit risk evaluation.

> "Management knowledge comes into play when the model needs to be calibrated. So probability of default, loss given defaults, those are always... Those PD and LGD models are always discussed with front office and the risk managers of the front office. So there you have expert opinion overlaying just, you know, historical data. You have some historical data with regression and then management has a look at it and all the experts...more experts rather than management have a look at the outcomes of the model and see whether they're in line with their experience or their gut feeling. So yes, in that sense, that is taken care of. When it comes to receipts, for example, and all of these things on portfolio level – no, there is not really. And it's also kind of difficult, isn't it, to establish a gut feeling on what should the true number be of the risks in the portfolio." (Code: QRM-C2)

In this context, the participant did not feel that model output would be wrong, rather that it might need re-calibration or fine tuned. One can interpret this as acknowledgement by the head of the Quantitative Risk Management team that while, at certain times, the detailed implementation of the model might require fine tuning, the underlying assumptions driving the model were in his view valid.

> "Let us make a split between various decision things. There are decisions when the model needs to re-calibrated or re-developed or improved, and there are of course decisions based on the outcome of the model. Now the first part we have governance around that. So it goes through, you know, where we have to write model validation, how to look at it, write a proposal to the credit committee; then it gets approved, then it

needs to be implemented. That holds for changes to the model when it comes down to up-dating some parameters or so. That's also done on, you know, a regular basis. A few of them it's just on-going and we just send them to the credit committee and then they get endorsed." (Code: QRM-C4)

6.6.2.2 Non-model information to guide the decision

The more senior and experienced credit risk managers of Bank C did acknowledge a significant need for non-model input in order to arrive at well-based decisions. Even the more quantitative managers or managers that designed the models felt non-model information played a significant part in the final decision.

"Well, of course partially it can be kept and the models are also partially based on non-quantitative information. So if I say the risk migration is purely financial information based, that's not completely true. However, things like whether senior management in a company is replaced, I haven't had that as an indicator in my models yet, but at this moment in time I think that's a crucial indicator. In a certain sector if one company really is in big trouble, I want to look at competitors or suppliers to it. That's not something I have in my models yet, but that's something I want to do and have feedback on. These kinds of non-financial and qualitative things. I think the last part is difficult to pick in a model. The first one – change of senior management or certainly inter-management coming in or whatever – well, that you could capture and say "Well, I use it in my model as an indicator," and maybe in doing a revalidation of your models, that could be something which you add and say "Well, in these times we think that's important." (Code: HCR-C3)

Given the recent history of extreme credit events and the atrophy of "normal" market mechanisms, some senior managers seem to have felt little option but to resort to non-model-based factors to inform their decision-making processes. This indicates that the managers believe the models operate less efficiently in periods of high volatility.

"There has been less belief in modelling on the current market. The market is operating outside expected norms." (Code: HCRL-C4)

Even those more inclined to require model output as the key determinant for a credit decision see that there may be extra-model considerations which have to take precedence.

"Now, you know, there can be two situations of course according to the model. There's a good risk return profile or it is below the hurdle, for example, but below the hurdle is

not necessarily a red traffic light for the whole deal. You know, there are also commercial reasons perhaps to continue with the deal. But since all transactions are going through a committee, the committee has a look at it and decides to over-rule, for example, the RAROC outcome and everybody... well, front office and the risk managers are aware of the flaws in the RAROC methodology." (Code: QRM-C5).

In the context of estimating potential future exposures, the head of the measurement function showed more inclination to involve non-model-based methods in arriving at exposure estimates.

"Our job requires some quantitative estimates for the counterparty and unlike models, we also use qualitative estimates because we know our counterparties." (Code: HRM-C2)

From the replies of all the participants, there seemed to be a significant amount of non-model information that is used in conjunction with model data to guide the final decision. This seemed to be especially so in times of uncertainty and high volatility.

"And those models are based on the past 5 to 7 years. But maybe this cycle is a bit different and is steeper, and certain sectors react to that differently and if I only would base myself on the model, I might miss." (Code: HCR-C10).

6.6.2.3 Gut feel

There appeared to be a difference amongst the managers of Bank C on the part gut feel played in decision-making. Those senior credit risk managers whose experience and career-path have taken them through non-model-based credit-decision methods seem to find themselves trying to reconcile model findings with what their experience in previous situations tells them. They sometimes rationalise this as a "gut-feel" about a particular situation.

"You have some historical data with regression and then management has a look at it and all the experts...more experts rather than management have a look at the outcomes of the model and see whether they're in line with their experience or their gut feeling." (Code: HCR-C2)

More quantitative managers (which tended to be less senior in the corporate ladder) felt that there was an inclination on the part of their more senior colleagues to dilute the results of credit risk model output with their own "gut feel".

> "The people who are working longer at the bank usually do not see that much in using a model. They prefer their own gut feeling. Like, you know, "We didn't use models in the past. Why should we use them now?" And they also usually don't have a very technical background. So there's a lack of understanding of the model and a lack of understanding of the model implies, of course, that you're not really willing to use it. I've had discussions with certain senior managers who've said "Yeah well, you know, I was around when the Russian crisis was there, and if I compare this is how much we lost in the Russian crisis and this comes out of the models, it can't be true, the models - either too low or too high." (Code: QRM-C9)

The quantitative managers did feel there was a requirement for management knowledge in parameterising and calibrating the models, but were sceptical on the arbitrary nature of gut feel. One of the quotes used in section 6.6.2.1 to explain how experience has a role is relevant here.

> "Management knowledge comes into play when the model needs to be calibrated. So probability of default, loss given defaults, those are always... Those PD and LGD models are always discussed with front office and the risk managers of the front office. So there you have expert opinion overlaying just, you know, historical data. You have some historical data with regression and then management has a look at it and all the experts...more experts rather than management have a look at the outcomes of the model and see whether they're in line with their experience or their gut feeling. So yes, in that sense, that is taken care of. When it comes to receipts, for example, and all of these things on portfolio level – no, there is not really. And it's also kind of difficult, isn't it, to establish a gut feeling on what should the true number be of the risks in the portfolio." (Code: QRM-C2)

6.6.2.4 Definition of "Gut Feel"

Clearly the commentary above begs the question, "What is Gut Feel?" When asked, the participants of Bank C did not offer any definition as to what precisely Gut Feel was but they mainly spoke about intuition and that it was linked to experience. They also acknowledged its importance in filtering the output from models and did provide some examples.

"So I have been able to pick that as my reference framework and put that next to what I see is happening now. So I think interpolating these things – yeah, gut feeling and experience is absolutely something which is a necessary added value to it. The other side is, I think, also very true. You cannot just do it on that experience or building it up on intuition. (Code HCR-C9)

6.7 Keys to credit management decision-making and where models fit

Two main views were expressed in determining the part that credit risk models played in arriving at effective credit decisions within Bank C. Firstly, that models always ran the risk of mis-representing particular transactions, either in terms of pay-off or the underlying risk profile. Whereas such errors could often be discounted at a portfolio level, it still begs the question that if such inaccuracies are recognised (and they cannot be overcome), why include such transactions into the model in the first place? The implication is that if these transactions or instruments are ignored then the model outputs for the remainder should continue to be trusted.

"The hurdles are set on a portfolio level, so on average the portfolio should be okay, but the models sometimes have flaws because certain transactions are not captured well, and it can be the revenue stream is not recognised correctly or other stuff and then you see, constantly, in the model that certain transactions are not meeting the hurdle – especially when margins are pretty thin – and then those are over-ruled." (Code: QRM-C6)

The second viewpoint is that the model sits within a wider context and that the models results for any transaction, for any product, should always be judged within the context of the assumptions that were made in deriving the output.

"We should rely on models in some extent but often find that it needs to be challenged. For example, in the market the Moody's Mortgage Backed Security (MBS) showed the models were not infallible and there is clear evidence of a cover-up by Moodys' management. A credible framework is better than nothing but it does not mean that it is always correct. For example Credit VAR only gives you an additional tool but not the answers. The user needs to have a feeling for how they evolved." (Code: HCRL-C5)

There was a view that for a period of time the models were not challenged mainly due to a lack of internal knowledge of these complex models, and the quantitative team in Bank C was

allowed to define much of the decision-making processes, but at the time of undertaking the research the viewpoint of the participants was that there was more challenge to the models and questioning of the model outputs in order to reach the final credit decisions.

> "In [Bank C], Economic Capital (ECAP) was flavour of the month up to 18 months ago. But now it is very much Regulatory Capital. ECAP [is] now out of favour because of the focus on regulatory capital and the need for capital. People [are] less afraid to challenge the figures from the economic capital models (previously the quants were in ascendency, and people that didn't follow the figures would have kept more silent).....People are now more suspicious of models. We also learnt that we need to be more alert of Market changes. The other area people need to be aware of is that even if a risk rating model is 99% accurate, the 1% may have a very significant impact." (Code: HCRL-C8)

6.7.1 Management setting guidelines on use of model output

Credit risk models are mainly used to help in decisions for new lending decisions. Currently, while reporting is run on existing portfolios and the decisions are used to guide management of the portfolios, it appears that within Bank C, these portfolios are not hedged or risks actively removed.

> Question from the researcher "What about existing business? Are there any decisions made based on the model valuation of the current portfolio" Answer: "No." (Code: QRM-C7)

Credit risk managers were confident that the role of models within the decision-making process was sufficiently well-positioned with adequate "expert" checks and balances and with enough scope for override if felt necessary.

> "These models are always used with managerial experience. Within <Bank C>, all rating models are expert models. Models will define a risk rating that will define a risk appetite. However this is capable of being overridden by Credit Committee. Also depends on the Analyst. We have a manual override. If we think we are underestimating the risk (e.g. too high a rating) we challenge and get it changed." (Code: HCRL-C6)

Management was aware of the persuasive influence of model-based statistical output, and was alert to the need to regard it as one "average" measure – not necessarily any more accurate than others but based on a logical, defensible and transparent set of inputs.

> "Very often, I believe, the results which are completely almost statistically-based are taken as granted as correct, which I believe it can be at a lot of times correct, but it shouldn't be accepted as a rule. It shouldn't be the rule. It should be actually the qualitative analysis should be made on top of these calculations which are historical data based, model based information."

> "I don't think that the statistics are completely and correctly reflect the actual credit risk of the counterparty. I don't believe that this is the case. First of all, even behind the statistics, as you know, there are assumptions which are made in the model and these assumptions are simplification assumptions." (Code: HRM-C4,HRM-C5)

6.7.2 Management queries

A number of the managers mentioned that the credit risk models were a useful tool but should not be the only source of data, nor should actions be taken solely on the output of the credit risk models.

> "We should rely on models in some extent but often find that it needs to be challenged. For example in the market the Moody's Mortgage Backed Security (MBS) showed the models were not infallible and there is clear evidence of a cover-up by Moodys management. A credible framework is better than nothing but it does not mean that it is always correct. For example Credit VAR only gives you an additional tool but not the answers. The user needs to have a feeling for how they evolved." (Code: HCRL-C5).

The head of Portfolio Management (HPM-C) mentioned that one of the big issues with models was that modellers were delivering headline single numbers and internally there were not enough challenges to this "one" number.

There can be different viewing points and time dimensions from the output of the models. The two differing viewing points mentioned by HPM-C were:

- "Price against the Market" where the model would value things on the current market values. This has an advantage of being a value that the traders could reconcile as it would be similar to their own valuations. The disadvantage is that in an illiquid market or a

volatile market the valuations could change dramatically and might not be accurate (i.e. the valuation done today may differ vastly from the one done tomorrow)

- "Through the Cycle" where the model would base the valuations over market data over a period of time and therefore remove short term fluctuations. The advantage of this is that it would be a more consistent view but the disadvantage is that it can be difficult to reconcile this value against a market value. The other difficulty with this view is the question on how long a cycle do you take. For example, with the financial crisis that started in 2008 and with today being 2011, if you took a three year view, this would have different results to a 7 year view. It is common in risk management to have debates on what is the appropriate length of time use for a credit cycle and what the data quality is like over that period of time.

The three time dimensions mentioned by HPM-C were:

- Spot time or the current view of time
- Shareholders view of time (normally a medium term view)
- Rating Agencies view of time (normally medium term to long term view)

If we draw this out into a table, it shows there could be six different results produced by the models depending on the dimensions and time slices used. HPM-C mentioned that when results were presented, it was commonly a single figure without explanation of what parameters were used nor on what the other values were.

	Price against Market	Through the Cycle
Spot/Current view	Result 1	Result 2
Medium term view	Result 3	Result 4
Long term view	Result 5	Result 6

Table 6.5 On how you could get should get six different results from your model depending on your dimensions and time slices

> "The biggest problem was with current use of models was they represented only one version of the truth, whereas there could be 2-3 versions of the truth. All depends on what you use the numbers for. Another way of looking at the time horizons are g Spot, Capital for medium term and Capital long term." (Code: HPM-C11).

> "You need to "challenge the scenario" and do some "what if" analysis on the numbers. These numbers needed to be stress tested as well." (Code:MV-C11).

6.7.3 Ignoring model output

Within Bank C, those risk managers most closely aligned to the model development and validation process felt that there would scarcely be a situation wherein the output from the model was completely ignored.

> ""I would doubt that because ... No, I don't think so. Why not? Because as I mentioned here, we have so much confidence now in the reliability of our Vortex information and the models we have in it that it is a very important indicator. The stability is there, so one cannot ignore what's there. However, it is an output and you have to then go to your conclusions and your decisions and you need to add to it - I think - non-financial information. So it's not... You would never question and say "Do you think you have situations where you only would rely?" (Code: HCR-C4).

However, there was a belief that senior risk managers would inevitably modify the output of credit risk models with their own interpretation based on earlier experience. Expanding on an earlier quote from the gut feel section 6.6.2.3 of this chapter.

> Question from the Researcher : "Do you believe there's a link between the experience of the credit risk manager and their view of the use of the models?"
>
> Answer: "I think so. I'm not necessarily... Yeah, the people who are working longer at the bank usually do not see that much in using a model. They prefer their own gut feeling. Like, you know, "We didn't use models in the past. Why should we use them now?" And they also usually don't have a very technical background. So there's a lack of understanding of the model and a lack of understanding of the model implies, of course, that you're not really willing to use it. I've had discussions with certain senior managers who've said "Yeah well, you know, I was around when the Russian crisis was there, and if I compare this is how much we lost in the Russian crisis and this comes out of the models, it can't be true, the models – either too low or too high." (Code: QRM-C9)

There was a feeling of cynicism from the quantitative team who felt the value of models was undervalued in the organisation.

> "Well, in transaction approval, obviously, and since the model outcomes are only used for reporting purposes and there are no real actions taken, I guess you can say they're always ignored." (Code: QRM-C10)

This view was not shared by the head of credit nor the credit team who were at lengths to explain that while they did use non-model information, the models were never ignored.

6.7.4 Overriding the model

Bank C participants intimated that the position of models within the credit risk management process was left very much to the individual practitioner – whether or not model output was ignored or even directly over-ridden. Managers felt that the part played by an individual's own experience, and his understanding of the factors involved in navigating through the credit risk landscape, were much more important and, as a result he was afforded a great deal of latitude in applying (or not) the model results.

> "The old-fashioned credit risk guys are not particularly into models. They have built their decision-making process and their information on, like I said, individual cases and "I've seen it before and that's why I think or I feel that we should go left or right." (Code: HCR-C5)

Nevertheless, risk managers did expect model results to be considered and to be taken into account in the risk management decision-making process.

> "However, I think even those die-hards have learned that the model part is absolutely a very important tool / indicator on what is happening with your existing portfolio." (Code: HCR-C5).

> "...And I think that is basically what these guys ignore because they react on what is moving, what you see, what you hear - and what you see and hear is only a small percentage of what your whole portfolio is. There is a substantial part which is in your books that is not very loud at that moment. So what your models show you there of that big majority is very important. I think it's very important. And in particular you need your models also for sensitivity analysis and for trends and strategic decision-making. So absolutely." (Code: HCR-C6)

However, there was a belief that senior risk managers would inevitably modify the output of credit risk models with their own interpretation based on earlier experience. In some cases, the role of models was deemed to be more evidential or documentary around the circumstances applicable when a particular credit risk decision was made. In that context it

was felt that the models themselves did not contribute to a decision but provided useful portfolio-level contextual information at the time of the decision.

> "Well, in transaction approval obviously, and since the model outcomes are only used for reporting purposes and there are no real actions taken, I guess you can say they're always ignored."
> (Code: QRM-C10)

Credit risk management did not believe that current models were capable of providing accurate estimates of expected losses, and would therefore need to be adjusted or over-ridden to reflect all available relevant information.

> "If credit risk should be the real estimation of the possibility of getting your money back, then any model should be able to strip noise, or market-driven or systemic-driven noise. I believe, the current models, they will not be able to do that. That is why the management experience, risk management experience and knowledge, even systemic factor plus specific factors has a role to play in defining the real credit risk." (Code: HRM-C7)

6.7.5 Strategic view and model output within decision-making

Model output and their use within the overall credit decision-making process was dealt in an open manner, given the responses from the Bank C risk managers interviewed. The term open manner means that the way model results are presented and the interpretation of those results (based on the participants own experience and pre-disposition towards models) seemed to be a crucial factor in deciding the weight given to model results and the decision outcome itself. There seemed to be the suggestion that more work needed to be done by Bank C in deciding whether or not to tighten the overall framework and how this might be achieved. One of the participants who made reference to the new risk appetite framework mentioned in section 6.3.2.

> "Okay. Yeah, you know, there are now some kind of rough limits based on economic capital which translate back to notional amounts and then, you know, front office has a sort of table and it says "Okay, if your rating is this, the maximum amount that you can do in a transaction is this," and then you can look at the Vortex – "Okay, how much do I already have on this? Okay, so this is the room we can have.....

.....What I also think, and which is perhaps more important than just how long have you been with the bank, is the understanding of the models. A lot of people in credit risk have a background just coming from either front office and have a commercial background or they have a transaction approval background, so they're not very much used to models and they think it's pretty complicated. Usually they don't have a mathematical background, so they prefer to stick with the easy stuff like PD x LGD x EAD for example – just expected loss. And regulatory capital, that's also kind of... No, they don't know what goes on in the risk weighted assets formula, but the outcomes somehow seem to be logical to them and that's what they prefer. They tend to prefer simple.... They have a preference for simple solutions and simple models. And it has to do with the sophistication of the manager and whether he or she will believe models or not ... or use them - perhaps would 'use' maybe be a better word than believe..."

"You know, this is my personal view on the models and so not necessarily [Bank C]'s view, but I guess I prefer a simple model – I don't prefer all bells and whistles around it – and use it consistently and then the model is fine because it can rank the risks of the transactions in your portfolio. It's not necessarily that the absolute level is correct, but it can make a great distinction in which transaction is more riskier, which business unit is more riskier than others. So it's good in ranking, but the absolute levels? I wouldn't believe that."

"So the use of models also to establish whether you have enough capital on the books is a tricky one, but for performance issues it's cool. It's like VAR also for market risk. I mean, you know, normal distributions and all of that – no, not true. So absolute levels don't hold, but it tells you something about the volatility, of the value of certain transactions and then you can link or, you know, rank them again and then it's okay, then it's cool. And what you need to do then is just stick with your model and don't change it all the time." (Code: QRM-C11, QRM-C12, QRM-C13)

There was a concern at times expressed that the role of models in the overall decision-making process was sometimes too big, giving rise to the concern that consideration of other factors was excluded.

"But in my opinion, the results of these models on their decision is very big. Sometimes I think that it shouldn't be so big. I believe that more qualitative estimates should be applied in order to adjust the results produced by models by both [QRM-C]'s group and our groups." (Code: HRM-C3)

There was also the sense that the data arising from the most recent market upheavals may provoke not only a re-calibration of models but also a re-evaluation of how model output should be calculated and interpreted.

> "...the crisis has provided - enriched - the data which can be used for quantitative models. This material can be used for a new generation [of] the quantitative models, which are not based on [the] assumptions of the previous model - of a smooth ... assumptions, but on things like jumps or surprises. I think the data allows the models to be better, I wouldn't like to use the word more precise, rather, I would rather use more 'realistic' or more 'conservative'." (Code: HRM-C8)

6.8 Model improvements and issues

This section looks at the steps that are being considered in order to improve the performance of models within the overall credit risk management framework.

6.8.1 Model improvements

Bank C's managers identified two main areas where they believed model improvements would be useful. The first was to make the appropriate changes to the model infrastructure such that the bank is better placed to manage its portfolio at times of greater risk appetite. The second is in the area of regulatory risk reporting and associated capital optimisation.

> "So you run a risk that you over-model yourself, almost, and there is a cost part in it, and whether or not we want that, but more importantly, do you have enough information to really do these models on your own information on what's coming out of your portfolio, or are we making it for such a small sub-portfolio that basically or statistically we cannot make these models really reliable?" (Code: HCR-C10)

> "Objective in the next year or two is to have the systems and people for the upturn. Prepare the defences. Memory is short, time when everyone will be more aggressive and risk averse. Next wave of investments (hopefully) will be built on more secure foundations." (Code HCRL-C10)

> "Refine models and learn from experience. Not a root and branch. There are also changes in regulatory environment. Government are not going to be held hostage to the Financial Institutions again. Banks will be forced to shrink. Capital will be punitive, restraints in the balance sheet for risk taking. Some of our models will have less value in the new environment." (Code: HCRL-C11)

"For the current market we need to also address questions like:
1) When do we take the current crisis into our calculations and models. Using data that is not relevant in this current market distorts the picture
2) We have today to take into the models the current crisis. Otherwise we understate in the market and cause future problems." (Code: HPM-C14)

In the eyes of some, the recent market upheaval has increased the emphasis on stress-testing of models at the expense of back-testing against historic data. The importance of models which demonstrate good performance under historic data sets is clearly less important as the major swings experienced recently have little or no precedence in the historical context.

"By the way, the recent events crushed all that back-testing based on older models. I would argue that none of the current models could predict the volatilities we observed in the last months, in the previous years."

"I believe that it should be the now considered more carefully how applicable are the risk-based models against other possible or types of risk estimation. I am talking here about stress testing, for example, where it is much, much more important than it was in the past. There was too much emphasis on simulation-based models previously ...even utilised e.g. Historic simulation. Even Monte Carlo has parameters that are backwardly looking. I believe now, stress testing, much more influence or a much bigger say on management decision." (Code: HRM-C10)

6.8.2 Model issues

Bank C's credit risk management felt that the correct balancing of a through-the-cycle vs. point-in-time view of credit risk was the most important factor affecting the overall reliability of and consistency of model output. Too much reliance on point-in-time-based predictions was likely to result in volatile and inconsistent output, whereas "through-the-cycle" views could prove costly in the short-term and remove the benefits of tactical (short-term) trading opportunities.

"So the balance between "through the cycle" and "point in time" is a very delicate balance in my opinion. I don't have the answer on it, but I think that's basically the Basel framework. How long is a cycle? Well, they started with 5 to 7 years, but there are certain sectors which by nature have a longer cycle or by coincidence have now a 10 year period instead of a normal 3 year period. So there is not a 'one size fits all' and what you have... Like the period now, now you could say we are in a very steep

downward side. "Okay, what does it mean? Do I have to build my models now on this year, 2009, and part of 2008 and maybe it goes half-way 2010?" Or should I say "Well no, that is only part of the cycle and what I see is only the downward side." Or should this be "Is this an extreme cycle which is once in like 50 years or is it a normal trend?" Nobody knows, of course, but that kind of debate is very fundamental in how you set your bottom parameter and how you interpret outcome. In particular, in capital requirements, I think that complicates stories which we will have in 1 or 2 years time. Interesting. I don't know. ....if you only have point in time, you have a serious risk of continuous over and under-stating. The risk of through the cycle is whether you really have through the cycle – because what is the cycle? But if you go only point in time, you continuously run behind yourself in being overly optimistic and being overly conservative. I think point in time is in that sense, for our type of industry, a relatively dangerous approach. I have a company which is facing troubles now as a result of markets. If I would go only point in time I would say "Stop. I need to help him and have confidence to get him through." It's a bit the same with the models. If I would only react on what happens in point in time, I would over-react by giving him no money now and giving a lot of money otherwise. He cannot survive. So I'm not convinced in that. I think we should be... you know, maybe have a longer cycle or have a stability block and do not move as quickly up and down." (Code: HCR-C11)

In addition, there was also the perception that there was a disconnect between senior management's understanding of what the credit risk models were saying and what in fact the models were reporting. This seems to have arisen from the fact that although Bank C has a history of development and adoption of structural credit risk models, these are sometimes difficult to reconcile to the credit exposure treatments inherent in Basel 2 and regulatory risk measures. It is perhaps no exaggeration that this distinction is being missed by senior management when considering the results of these two approaches.

"We used to have Moody's KMV plus some other stuff. We're now in a transition phase because we're going back to basics and we want to align our internal model a bit more with the Basel 2 model. So I'll talk about these two separately. First, what we used to have was very sophisticated with diversification in it – and I mean diversification in terms of sector and region. Because Basel 2, as you will know, it has diversification in terms of, you know, infinitely small portfolio stuff. So it has a diversified portfolio, but it doesn't recognise diversification in terms of region and sector and it doesn't measure Name concentration. In our internal model, as we used to have it, this was all taken care of. Basel 2 didn't have any value stuff, it's just book value. And the model that we used to have also incorporated economic value. The reason we have diversification here is because we were a global firm, so we wanted to

definitely have the sector and region diversification in; and we manage for value, so we also wanted to have the value part in. And there we touch upon the discussion that we had previously. It's a pretty sophisticated model, Moody's KMV, and it's not really linked to the concepts and the thinking of senior management because they are coming from transaction approval. So they look quite differently at the portfolio risks than Moody's KMV model. So there you have a disconnect between the concepts in the model and the perception of senior management, so they don't talk. That was one reason to switch to a more simple model and the other reason to switch to a more simple model is that the sophisticated Moody's KMV model ran into or gave counter-intuitive results like decreasing risks with increasing maturity and there are some risks where that's counter-intuitive; and they also depend a bit on the calibration and the settings of the model. Now those two reasons were the most important ingredients to switch to a more simple model; and the simple model says "Okay, we're going to use regulatory capital but without the caps and the floors for the PDs and the LGDs and no down-turn LGD because we feel that that's over conservative." So the new model has no value in it and it has no diversification in it any more. That's the down-side." (Code: QRM-C14)

In the context of determination of suitable (and prudent) stress-test scenarios, credit risk management believed that in future more consideration would have to be given to the extremities of scenarios, with qualitative input from an expert who was able to define holistic market conditions.

"What went wrong last time – learnt include rating agencies are not as reliable, stress testing is important, risk has concentration and contagion waves and finally, 99% confidence doesn't prepare you for the unexpected." (Code: HCRL-C12)

"Just that more stress-test scenarios should be applied and these should be via a qualitative expert. The biggest impact and the biggest affect should be the contribution by traders, economists, risk managers and regulators into the stress scenarios." (Code: HRM-C13)

6.8.3 Understanding model assumptions

Bank C's risk managers were aware that there was a large amount of variation in how comfortable they were with the underlying assumptions supporting models. It was one thing to understand the assumptions – and yet another to believe them to be credible in the existing market conditions.

"Although I'm Head of or I used to be Head of the modelling department and used to run Moody's KMV, I do not myself believe in Moody's KMV model. I think there are so many assumptions in the model and the model doesn't refer to really observable stuff in the market. That's the capital asset pricing model it depends on and it's got... The correlation it has, it's 120 factors which, you know, I think you're better having a model which refers to observable stuff in the market and that holds for spreads. When it comes down to correlations, 120 factors... I mean you're going to be modelling noise in the end. So I would say why don't you use a somewhat more simple one. One perhaps is not enough because diversification does exist and if diversification didn't exist, then [Bank C] wouldn't be around since we had so many losses in the Alt-A portfolio, but other parts of the portfolio still were okay. So diversification does exist and needs to be recognised, but why don't you do a so much more simple model like 5 factors instead of 120? It is more manageable and also you'll be running less counter-intuitive results. So I prefer a somewhat simple... Now there's beauty in simplicity sometimes. It's not necessarily that a sophisticated model is better, is more accurate or is more user-friendly. I mean user-friendly is very important for the managers, right? They don't want to see counter-intuitive results. They want to have an explanation that comes with the numbers which fits into their mind-set and the concepts that they're used to. So yes, I prefer a somewhat more simple model. I think Basel is a bit too over-simplified, but you don't need to change that much to come to a more realistic model." (Code: QRM-C18)

There was also a sense that assumptions would likely change as a result of recent market turmoil. The models themselves may have to give way to a new generation (once the hard job of establishing the revised theoretical framework had been done) and in the meantime model output would be regarded in a different light.

"A lot of researchers will incorporate this recent experience into the models. This will change assumptions and lead to doing some things differently. This might happen and might lead to new generations of models. I will welcome this way of improving model use and removing some of the assumptions rather than increasing the complexity of the mathematics." (Code: HRM-C19)

6.9 Regulatory influences on models

6.9.1 Regulatory drivers

Bank C's management was clear that regulation was a major factor in driving the development and deployment of credit risk models.

> Question from researcher: "Has the regulator influenced on new development of models and usage of models?"
>
> "Sure, undoubtedly the development of models. Yeah, absolutely. Absolutely, completely. Yeah, that's absolutely a very big driver." (Code: HCR-C6)
>
> "Yes, yes. Definitely." (Code: HCRL-C9).

The head of QRM area was also at pains to point out that while there was no doubt in his mind the regulators were responsible for model use in Bank C, the bank had since embraced models and expanded on the model use for their own internal purposes.

> "Well, at the beginning yeah, it was something that we needed to do by regulatory pressure and once you've got the models, you're going to be using them also for other purposes and then they start to... You know, first it's mandatory and then people are going to use them for their own purposes and other purposes as well, yeah. Yeah." (Code: QRM-C15)

The head of Credit Risk London felt it a positive influence by the regulators, as risk was sometimes under-resourced and competing for adequate budget. The regulations allowed growth of the risk influence and budget for modelling.

> "Regulation has helped ensure employing the best resource." (Code: HCRL-C16)

6.9.2 Regulation and improvements

Bank C's managers were in favour of keeping models relatively simple for use within the regulatory context. This has the benefit of engendering a wider understanding of the model's assumptions and outputs but meant that models needed to be supported with other decision-making factors.

> "Well, what we see – the model should still be relatively close to what management but also account managers on the floor are doing, that they still can understand what is

happening. If it moves too far away, if it gets too complicated, it's a bit the same like if we sell too complicated products and people don't understand exactly any more what they are selling, and if you cannot explain any more, then you run a real risk" (Code: HCR-C13)

"Yeah. Yeah, you should have your own internal models...Yeah, there are some certain aspects that you would like to see, I think. Like we are in the [Bank C's country of domicile in Europe named] and in the US, doing different cycle stuff, and you definitely want to see some results based on that, and different migration in the various regions and sectors you have. You know, banking goes very bad now but, you know, what goes very good now at the moment I don't know. But yeah, you do want to have some distinction within that. I wouldn't make it too granular, but a bit more granular than Basel 2 because that has no granularity at all." (Code: QRM-C16)

6.9.3 Regulatory Capital versus Economic Capital

Bank C employs separate mechanisms and systems for the calculation of economic and regulatory capital. Historically, the drivers for the evolution of these two separate approaches have been completely different – the former concentrating on internally-inspired motivations of profitability, market differentiation and competitive advantage, whereas the latter was essentially driven by the external demands from the regulators themselves. Curiously, this seems to have stimulated a contrary response within the organisation at large, whereby the understanding of the regulatory capital models is greater than that of the internally inspired economic capital models, whose design and structure seems to be much more opaque – even to managers within the risk management organisation.

"Well, the answer is no, that's not the case because the reg cap is a bit more simplified. What we have seen here is that the economic capital models have been a bit - almost too - complicated to really get it into the genes of the organisation. The vast majority of people could not understand or follow enough what the model was telling, and as a result saw it as a kind of black box and didn't work and act really with it because they said "Well, I don't know exactly what happens if I go left or what if I go right." Reg cap in that sense is easier and people see a direct result of how they influence and what they can do. So it is a more simplified version of the world, but it is closer to the people who do the ordinary, daily banking business and in that sense maybe then a bit better, although from a pure model perspective we miss certain elements which are definitely there and are important. But yeah, maybe it was our problem we were not able to get people close enough to the economic capital model." (Code: HCR-C12)

"Well, we have seen here clearly e-cap model was too far for the organisation. It didn't work. It never really landed in the organisation. I don't think that everybody was stupid, but it was a bridge too far apparently and the regulators hear the same story. If you only base your record, in my opinion, on what your reg cap model tells you, you also miss something and you should add something and sometimes it means adding capital or extracting capital" (Code: HCR-C14)

"So it is more simple to understand and also to explain to front office, to finance and all of that and we're also now pretty sure that if you have an incentive for regulatory capital, you will more or less get the same incentive for the internal capital stuff." (Code: QRM-C17)

"When we look at a proposal, we don't look at the impact on the Regulatory capital on the Investment Banking side. Previously capital wasn't an issue. Going forward Regulatory capital will be more important in decision-making. ECAP is a more refined calculation, but important is experience in executing transaction. Models have a use in ensuring capital efficiently, but still need to have validity. Generally, Regulatory Capital is a more blunt instrument." (Code: HCRL-C14)

HCRL-C sees regulatory capital as simplistic but feels this is where it has merit as it is easy to measure and compare against other banks. This allows it to be reasonable transparent and not overly complicated. Economic Capital can be subjective as it is to do with how the bank views risk and its internal measurement of risk.

"If too complicated, the risk is lose sight of what you need to do. ECAP is a form of efficient use of capital (looked from a shareholder's view, whereas Reg Cap looks from depositor's safety point-of-view). Role for both but different purposes" (Code: HCRL-C17)

Therefore management was clear in the need to maintain separation of regulatory and economic risk models – both in terms of the overall operational support and management structure as well as in defining the management agendas which each was designed to satisfy.

"They [regulatory models] should be different. Regulatory approach is the approach where underneath there is generalisation. Regulators have to measure different institutions using a similar method. Regulators have a different goal to Financial Institutions. Economic Capital should be more accurate maybe not more accurate, actually I should say more optimal. Optimal is a criteria that is linked to individual

banks and is linked to bank's allocation of resources. Regulatory weights are probably too rough for the tasks and therefore I think should be different." (Code: HRM-C15)

6.9.4 Regulatory calculation issues

Whereas there seems to be a view from the previous section that the internal structural credit risk models employed by Bank C were overly complex, there is still a belief amongst credit risk managers that the pure regulatory-oriented reporting is too simple. It would seem to make sense for the regulatory models to be derivable from exactly the same data that is used to produce the internal economic capital reporting data. There is still some way to go before this objective is achieved.

> "Now there's beauty in simplicity sometimes. It's not necessarily that a sophisticated model is better, is more accurate or is more user-friendly. I mean user-friendly is very important for the managers, right? They don't want to see counter-intuitive results. They want to have an explanation that comes with the numbers which fits into their mind-set and the concepts that they're used to. So yes, I prefer a somewhat more simple model. I think Basel is a bit too over-simplified, but you don't need to change that much to come to a more realistic model." (Code: QRM-C18)

In the case of regulatory capital calculations, Bank C's management saw little point in applying sophisticated mathematical models to produce the numbers. Simplicity and transparency were more beneficial.

> "For the moment, don't think would be expedient for either the bank or for the regulator to use higher maths for regulatory purposes." (Code: HRM-C16)

6.10 Smaller themes raised in the case study

In the course of the analysis, several other themes were discussed by some of the participants which did not feature highly with the other participants. While not viewed in this research as a key part of the decision-making process, some of these themes merit mention as they help explain further how these models are used. They also help show how Bank C views the progression of models within the bank and the likely future direction of risk models in Bank C.

6.10.1 Validation process

Bank C's management expressed satisfaction with the way the overall model validation process operated. Certain components of the credit risk modelling process were common to the Regulatory and Economic Capital management and reporting processes. These common components were subject to the most stringent validation. All model variation and validation exercises are put through a common review and approval process, subject to moderation by the credit risk Committee.

Maintenance of relevant reference data items (default rates, correlations, spreads etc.) is regarded as part of "Business as Usual" (BAU) and is handled separately. The participants also made reference to a unit dedicated to looking at Risk Integration across the major asset classes. This unit was charged with undertaking a number of "what-if" scenarios using the standard risk reporting tools in order to better understand the bank's reporting sensitivities to changes in market conditions, measurement horizons etc. Improvements to the model infrastructure can also be recommended by this unit.

> "Well, [QRM-C] can tell you much more on it, but we have a process here that there is approval via CRC, the Credit Risk Committee. That's where the models are brought to and there is independent valuation of models by the model validation team and they do that on a frequent basis, at least on a yearly basis, and these recommendations have to follow-up and they're looking to a lot of indicators. If it is a PD model, they'll look at appeal rates and they've got all kind of statistical analysis whether or not it still predicts right or wrong. So I think that is a framework which has developed itself very well over the past years basically as a direct consequence of what Basel has asked us to do, meaning that for 4 or 5 years now we have that process in place and up and running and that functions relatively well." (Code: HCR-C7)

> "I mean you've got the PD and LGD models and they're also input into the Basel II requirements. So there's a very firm governance around that model. Then you have the economic capital model, which is Pillar II basically where the governance is somewhat more loose, but nevertheless as soon as we change something in the model it needs approval from the committee. There's once a year a model validation check-up, I would say, based on model validation and sometimes also statistics looking at the audit, and we have to follow-up certain points within certain moments and, you know, change stuff, enhance, improve and then again we need to go through the credit committee. It's the same credit committee which also endorses the PD and LGD models.

Now, for example, there are regular up-dates on correlations, for example. There are regular up-dates on spreads and all of this stuff which is, you know, kind of ongoing. It's just regular times for those. Model validation you have. There's once a year a physical model validation which might lead to changes and there's also improvements put forward by the modelling team, and there always, you know, requests from the users and the business units, but it can also be capital management or risk integration analysts. Have you come across them, RIA? No. That's a department which combines market credit, operational, real estate, equity risk, interest rate risk into a risk dashboard – that's what they call it – and it's group-wide, so the bank and insurance and it covers all risk types. They also initiate improvements because they see certain... They want to have more accuracy in certain parts of the portfolio or they come across some counter-intuitive results which we need to dig in and then correct for. They also come up with ideas like now we have a horizon of one year, but what if we take a horizon of 3 years including management actions, for example? Now we have one year without management actions, but they also want to know "Okay, if we want to get back from a stress to a normal situation in 3 years time, what do we need to do that?" These types of things. So that initiates new model development and then the model gets enhanced to also provide that information." (Code: QRM-C19)

"Another one which we have, which is a good example, is of course the structured asset portfolio – so the CDOs, the RMBS and all of that. We have models in place to measure the risks. Now apparently what came out, of course, of the last year was that the risks were really grossly under-stated and, you know, since we saw the losses building up in the portfolio – "Okay, time to recalibrate that part of the model in that part of the portfolio and change it." But there it was our own initiative." (Code:QRM-C20)

"There is a model validation unit. If rate of appeal is > 10% means the model is not working. It is then redefined/redeveloped. The modelling area will interview users, sample of rating questions to users (e.g. is the model easy to operate?, why so many overrides? etc.). If there are a lot of "do not know's", the model is not working and is tweaked. If performance of model is bad, model is redeveloped" (Code HCRL-C15)

"Models should be validated quarterly (more frequently in new products)." (Code: HCRL-C18)

6.10.2 Link between Front Office and risk

Bank C's risk management practitioners recognised that the Front Office usually leads the way in terms of risk model innovation but that take-up downstream of Front Office will only increase if there is a regulatory reporting driver. This resonates with points made in the

previous section (6.9.3 Regulatory Capital versus Economic Capital), where it was acknowledged that widespread acceptance of certain Economic Capital requirement models was inhibited by a lack of understanding and lack of transparency in their application.

> "And the committee has members from risk and front office end and modellers of course." (Code: QRM-C21)

> "Well, in my experience... I've been working in different departments at <Bank C>. I've been working in the front office in the dealing room, which relies heavily on models. I've been working in market risk which relies heavily on models and I've been working in credit risk which relies heavily on models. In the dealing room when I was working there – like that's perhaps 9 or 10 years ago now – people didn't really... Senior management were kind of reluctant to really rely on models for new business development – like the CDS that were coming on at that time. I was working at that desk at that time and we had a hard time convincing senior management to expand our VaR limit and do more business. So they were kind of conservative in that sense. In market risk there was quite some sophistication, I would say, on VaR models and all of that and Monte.... No, I was not at Monte Carlo at that time, but variance and co-variance matrices we were using. Yeah, that was sophisticated and then I went to credit risk and in credit risk the models were not that advanced as in market risk and the management was not used to working with these models. So the management made a real transition in the last like 4 or 5 years because they were forced to use the models because, you know, Basel 2 came along and this whole RAROC concept was introduced." (Code: QRM-C22)

6.10.3 Models and risk of herd mentality

Bank C's participants did acknowledge that the blanket acceptance of credit risk model output was likely to be a thing of the past. Greater opportunity to scrutinise underlying assumptions and challenge the results was broadly welcomed.

> "There has been a perception shift in model use. The users are more suspicious. Management will still go on using the models. It is better than nothing. It is ingrained in the culture to use models now but there is more questioning of output though." (Code: HCRL-C19)

6.10.4 Stress testing

Bank C's credit risk management team saw stress testing as something that sat outside the normal credit risk reporting mechanism. The stress tests performed (both forward and

reverse) were acknowledged as necessary but the individual stress-test results needed careful interpretation. It was in this context that credit risk managers felt the contribution of experienced risk analysts was crucial.

> "Well, stress testing is something which is something I would almost say as an extra layer on it. If you go to the model itself, that is based.... We base ourselves on decisions on what we do in the portfolio – whether or not we want certain types of risks and how much capital we need to set aside and whether or not the risk reward is acceptable. So it's a combination of all these things. But yeah, sensitivity and stress testing is something which is – and definitely of course now in a crisis – something which is very important. I mean it's always there, but way more dominant now than it was and it is impossible if you don't have models. Absolutely, completely impossible. Because I can go to back to the old days and go to my experienced credit guy and say "What do you think will happen?" How experienced he may be, you will never come there. Now what we do is the other way round. Let's say we make a sensitivity, we make a stress test and then we go and talk to the experienced guy and say "How do you read it?" Of course you start with what you bring into your stress test, but then "Help me interpreting that in the outcome. Does it make sense? Is that what we can expect or have we somewhere a flaw in it? Are we over-stating or under-stating?" So you use these experienced guys now to interpret the outcome instead of just building yourself on those guys only." (Code: HCR-C8)

> "Yeah, exactly, and now the focus has also changed to stress testing. I mean stress testing is less sophisticated than this Economic Capital stuff because you don't have any correlations at all. You just say "Okay, these are defaulting and these are migrating," and "This happens in the US and this happens in the Netherlands," and "This happens to credit, structured credit assets and this happens to mortgages," for example. That's very concrete, right, because that's the world that they live in and not so much "Oh, through the cycle of correlations and asset returns and Merton models," etc. etc. and they like that.
>
> And, you know, they all say now "Okay, what is the current credit risk weighted assets of the portfolio and what is the current provisioning on the portfolio?" and if it's stress this and this, "Hmmmm." Yeah, then they understand.
>
> So that's good communication now. And then again coming back to what we discussed already earlier, the sophistication – you know, you don't have a tick because you can't correspond with them on this stuff and stress testing does and regulatory capital also." (Code: QRM-C23)

Bank C mentions that a number of upgrades to methodologies were achieved, and based on the experiences from the past two years more effort was put in stress testing. Besides the regularly-performed stress tests, stress testing was also used for planning purposes. Furthermore, the economic capital model for credit risk was being updated to bring it more in line with the regulatory capital framework, which excludes diversification benefits. The updated model would be implemented in 2010. The risk appetite framework was revised as well and better aligned with the capital management targets for the capital ratios.

6.10.5 Concentration risks

The importance of risk diversification was recognised by Bank C's management. This was felt not to be fully taken into account by the risk models currently deployed. (Potentially a function of poor or inadequate data).

> "What is also important to banks are concentration and correlation risks (which models sometimes don't take it all into account too well)" (Code: HCRL-C20)

6.11 Viewpoint on the Future

6.11.1 Sophistication of models

Bank C's management voiced the opinion that models may now need to become less rather than more sophisticated. This seems to be a reaction to the inability of existing models to predict large fluctuations in markets or to protect portfolios adequately from the effect of these extreme "outlier" events. More effort would need to be expended in ensuring the consistency of assumptions and stress scenarios as well as the correct interpretation of model results.

> "In our bank, in my department, the approach now to be more rudimentary. Rudimental means things are now more understandable. I believe estimations will be more common in the industry. I mention we currently risk weight approach, similar to regulator's risk weights populated separately outside the system. This is a more rudimentary application is applied through a cohesive netted exposure set. One of the biggest challenges will be for any bank and our bank in particular is improving system infrastructure for the quantification of risk. I don't believe the challenge will be to improve complexity of models but to improve the delivery of the model results to the users. Yes, it will be to improve of the application of the currently used models and delivery of the results to the users." (Code: HRM-C17)

6.11.2 Convergence of market and credit risk

The trend of increased convergence and consolidation of Market and credit risk measures was seen as likely to continue.

> "There is much more understanding and support for a centralised risk management quantification of risk. I believe there is backing for this." (Code: HRM-C18)

6.12 Summary of the approach of Bank C towards credit risk models

Bank C has a more complicated organisational structure in relation to model development and use when compared to the other two banks in this research. The main difference in organisational structure is in that it appears to be a less integrated structure with respect to modelling, although there is independence for the model development and validation teams, which reports directly to the Board via the CRO. This less integrated structure may be explained by the historic link to the insurance arm and its larger coverage of products and geographical locations. The independence of model development and validation teams is likely to have been a result of its experiences in the financial crisis.

Bank C does not follow one particular model philosophy but instead uses a combination of quantitative (structural models or derivatives of the structural model) and qualitative (expert judgement) models. Many of the participants made the point that recent history in the market and the bank showed that the quantitative models had failed. The main reason given was that the markets were operating outside expected norms and that since the models were based on historic data, they were not able to recognise the correct patterns in such periods of uncertainty. They have therefore worked to build solutions that they perceive are better at coping with uncertainties in the market. This is via the use of expert judgement models in combination with quantitative models, via implementation of more stress testing, via the ability to better challenge the output of the models and via the use of non-model derived information in decision-making.

In the Bank C's 2009 financial accounts and in their published credit policy, there is great emphasis on risk appetite (it is mentioned 27 times). However model use in respect to alignment to risk appetite was only mentioned by one of the participants. While there was a lot of documentary evidence on importance of risk appetite in Bank C, neither risk appetite nor strategy featured in the discussions on risk models when compared to the other banks

researched. Reasons for this may be that the models are already aligned to the risk appetite, or that it was not considered as important to Bank C. The likely explanation is with Bank C following a more conservative approach with respect to risk appetite, and with Bank C operating in established markets (where data for the models is less of an issue compared with the other banks in this research), there is less of a need to override the models and therefore the participants probably did not feel alignment of models with risk strategy was a particular issue for the bank.

There were differences in the people interviewed concerning the amount of non-model information that should be used alongside models although all agreed to some extent that this was necessary. While models are an important part of the management decision-making process, it is clear that model output is not always the main determinant in management decisions. The more quantitative people felt that while non-model information should be used with the model derived data, it was mainly as an influencer over parametric inputs and that the models should be the main component on decision-making while the credit managers felt that a lot of non-model information was not or could not be captured by the existing models (examples given were negative changes in senior management of companies, understanding of competitors and view of the suppliers)

Bank C seemed to have a balanced view on gut feel and experience where they acknowledged that while gut feel and experience could be important components when making decisions, it was not enough to just rely on intuition or experience. The head of QRM mentioned that while gut feel was an indication on whether a number was right or wrong, it by itself couldn't produce a quantitative true number for the risks in the portfolio.

Bank C felt it was important to understand not just the assumptions but also the context for the output of the models. Table 6.3 in section 6.7.2 of this thesis shows how there could be six different results produced by the model depending on the context that is used. A good explanation was provided by the head of Portfolio Management on the importance of assumptions and measures:

> "Assumptions and measures need to be clear. The truth comes with experience. The experience needs input from the Business Users not just the modeller's view which may not be grounded in experience." (Code: HPM-C13)

The biggest single driver for Bank C's use of credit risk models has been regulatory pressures. Bank C did develop Economic Capital models independently to the regulators, but the Economic Capital models failed to be used widely and stimulated quite a negative response within the organisation at large. The main failing was that the models were complex and the outputs were hard to reconcile back these numbers against other data that the managers and users had. In contrast, when the Regulatory Capital models were deployed, the understanding of these models was greater than that of the internally inspired Economic Capital models, whose design and structure seemed to be much more opaque, even to managers within the risk management organisation. Another reason that the regulatory models were easily accepted was that the bank had been under severe pressure on regulatory capital which meant that the front office, as well as risk managers, had to actively try and minimise capital use via the use of these models, whereas the economic capital controls were more difficult to enforce. The end result has been that the Regulatory Capital models have been driving model growth in Bank C. The bank recognised the need for Economic Capital, and all the participants clearly stated the need for Economic Capital models that would allow the bank to better optimise its capital in line with its strategy. But it was important to make the Economic Capital models easier to understand, with the ability for managers to relate to, understand and reconcile the results. As the head of Credit Risk mentions:

> "If a model is too complicated for them to really understand what happens, then there is a risk that people are going to just manipulate or ignore completely. So I would be a bit closer to the school and say don't make it too complicated. So that's in the simplified first and then at least the organisation understands it." (Code: HCR-C15)

This difference between the underlying motivations and approaches to Economic versus Regulatory models might be interpreted as a flaw in the present operation of Risk Management department. The more the motivations and objectives of the two sets of metrics diverge, the more likely they are to deliver conflicting or confusing messages.

The next chapter of the thesis presents the analysis across Bank A, B and C as well as presents the conclusions of this thesis

7 Cross-case analysis, the findings of this research and conclusion

7.1 Introduction

This concluding chapter presents the cross-case analysis, the substantive findings across the cases, the contribution of the research and implications for banks and regulators. First, Section 7.2 provides an analysis of all three case studies broken down into key areas of comparison as follows:

- Section 7.2.1 presents an analysis of the credit risk management strategies of the three banks
- Section 7.2.2 covers the credit model use in the banks
- Section 7.2.3 identifies the qualitative factors that are used alongside the quantitative model outputs in the decision making process
- Section 7.2.4 covers model issues that were raised
- Section 7.2.5 examines how the regulators influence model development
- Section 7.2.6 covers some of the smaller themes raised by the banks as well as views of future improvements to the models

Section 7.3 summarises the substantial findings of this research in light of the research questions. Section 7.4 extends the risk appetite framework in section 2.7.1.1 of the literature review with the findings in this research. Section 7.5 summarises the contribution that this research makes to our understanding of the use of credit risk models in practice. Section 7.6 discusses the limitations of this research and the opportunities for future research. Finally, Section 7.7 covers the practical implications of the research for the banking industry

7.2 Cross-case analysis

The purpose of the cross-case analysis is to identify key common factors in managements' use of credit risk models in the three banks presented. These common factors should aid analytical generalisation (Yin, 1989 p. 38) and allow the empirical evidence from these case studies to extend current understanding on use of quantitative credit risk models. As stated in the methodology section (chapter 3), the objective of this research is to help provide insight into the use of credit risk models and to study the actual use of the models operating in banks. In this section, a technique called triangulation of data is used for the analysis and follows the recommendations of Yin (2003).

In line with the case studies presented in previous chapters, key interview quotations have been used to demonstrate the analytical interpretations.

7.2.1 Credit risk management strategies followed by the banks in the case studies

This section covers the key strategies that affect credit risk management within the candidate banks, focusing on those areas that specifically involved the use of models.

This research supports findings by Kaminsky and Reinhart (1999) and Kuritzkes, Schuermann and Weiner (2003) in that credit risk is the largest type of risk faced by the banks (as shown in sections 4.4, 5.4 and 6.4). This shows the importance of credit risk management to banks (and by implication, the importance of the correct use of the credit risk models in the banks).

One finding common to all the three case studies is that design and use of the credit risk models is linked to corporate strategy and risk appetite. This is covered in the next sections, 7.2.1.1, 7.2.1.2 and 7.2.1.3.

7.2.1.1 Corporate strategy in relation to credit risk management

A finding across the three case studies is that risk modelling is linked to corporate strategy and risk appetite. All three banks had different corporate strategies, and while they also have similar governance structures for risk management, they use models differently. This is due mainly to the alignment of the models with the corporate strategy of the bank or parent company. Other factors would be corporate culture, size, product mix, geographical spread, local regulator influence (including pressures on increasing regulatory capital at the time of the research) and financial resources assigned to model development.

Across the three banks in this study, the main difference on their credit risk strategies, and hence model requirements, is that Bank A's risk approach is geared to the emerging markets, Bank B's approach is geared to CIS (predominantly corporate) clients, which, as discussed in Chapter 5, generates concentration and wrong-way risk, and Bank C's approach is geared to reducing the balance sheet and capital savings. The implications are that while in the main models would perform similar functions, they would need to be tailored for the different drivers, or if not tailored, the management team would then have to manually adjust for the drivers in their decision making process.

> "I mean the model is never perfect. There are always a number of peripheral factors that play into... that can justify an over-ride of a model output especially if you have limited data. The other aspect is that your business strategy itself... I mean <Bank A> is a good example of that. Our business strategy actually might not be supported by models' output directly. So, you know, our risk is very high and the outputs from the model are very severe, specifically for the counter-parties that we strategically are wanting to target." (Code HCA-A18)

There was indeed lots of evidence that such adjustments were applied; however, it was less obvious how (if at all) the individual institutions sought to benchmark these adjustments (and the resulting model's output) against a neutral strategic norm.

7.2.1.2 Importance of risk appetite

Risk appetite drives the risk methodology in a bank. It should be part of the corporate governance standards, and allows the bank to articulate internally to their staff the extent of the board's willingness to take risks in order to meet their strategic objectives. It allows the shareholders, bondholders and the depositors to be aware of the risks that the bank board is willing to take in achieving its strategic objectives. This research shows, from the case studies, the importance of risk appetite in defining the risk strategy as well as in model development.

All three banks mentions the importance of risk appetite in their annual reports, in internal documentation and external reporting to their regulators, but only Bank A publically revealed in detail the composition and profile of its risk appetite.

Bank C mentions the word "risk appetite" 27 times in its 2009 annual accounts, including the importance of aligning the bank's processes to its risk appetite. Yet, Bank C does not reveal what its risk appetite actually is. Potentially why Bank C (and Bank B), like many other banks, do not reveal their risk appetite may be due to the fact that they feel they could lose competitive advantage by disclosing this information (and by implication part of their strategy) to their competitors. But it could also be argued that the reason for opacity is that they don't want the general market to critique their risk appetite, especially if they have not fully defined their risk appetite or if it reveals potential inconsistencies with other aspects of their financial reporting. Another reason for the lack of transparency is that certain banks may

be undertaking risks that the board may not want the general market to know (for example it is likely that Lehman Brothers board did not want the market to know details on how heavily they were really involved in the sub-prime market). However it is the view of this thesis that there should be transparency in information relating to risk appetite as part of corporate governance and best practice. This would allow shareholders, bondholders and a bank's customers to be fully aware of the risks the bank is willing to take on in order to generate an appropriate return.

7.2.1.3 Governance and organisational structure

The three banks researched all had similar governance structures. The main reason for the similarities is due to consistent application of corporate standards as well as regulatory requirements that ensure industry best practice is applied. All three organisations had implemented segregation of the risk department reporting lines to the business reporting lines and reported to different board members. This was to ensure there was no undue influence on risk decisions and that there were also independent reporting lines for escalation of risk issues from the risk departments to board level. They also had similar committee structures, although they were called by slightly different names. For example, for risk policy, risk management and risk capital management, Bank A called its committee the Risk and Capital Management Committee (RCMC), Bank B called its committee the Risk Management Committee (RMC) and Bank C called its committee the Risk Committee (RC). All three committees undertook the same function in their respective banks.

While the governance structures were similar, there were differences in risk organisational structure and internal reporting. Bank A and Bank B were similar except for the fact that Bank A had a much larger modelling team. Bank C had a number of differences compared to the other two. The main ones were that risk and model policy was determined by a department that was shared with its insurance business (this was in the process of being separated), its model development and validation teams reported directly to the CRO, and they had many more levels of management as they were much larger than the other two banks. Also, the culture within the Bank C was more bureaucratic than Banks A and B. With the extra management levels there can be silos of knowledge, although the management in Bank C were aware of this factor and had experienced people managing the risk area to mitigate the risks.

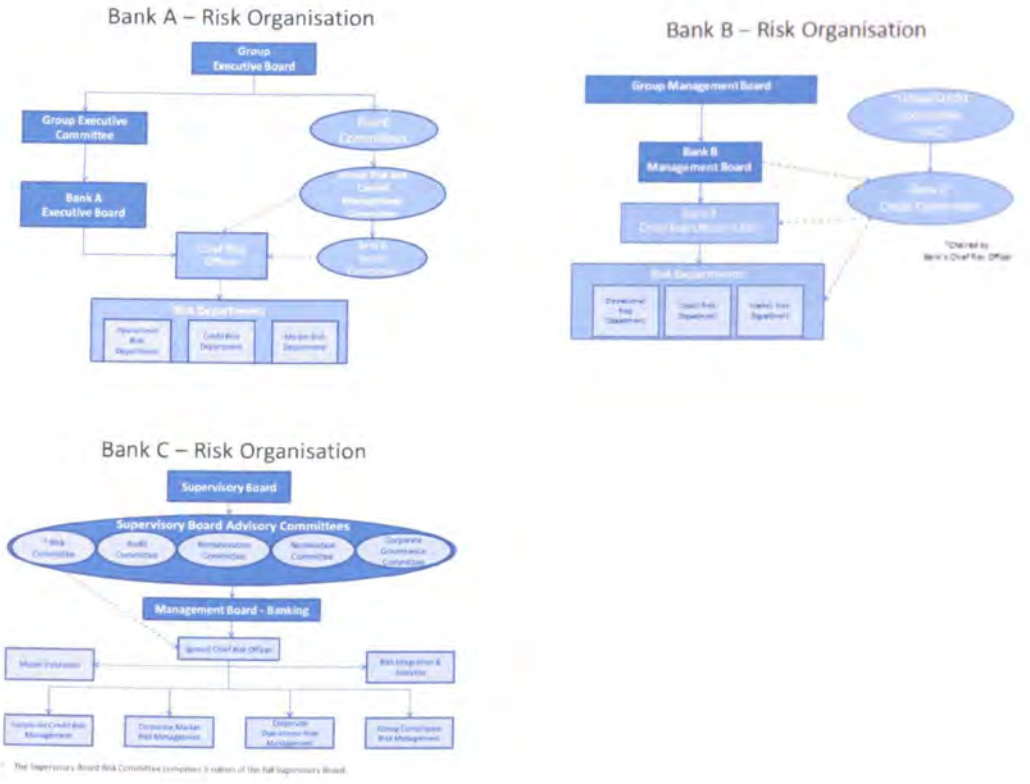


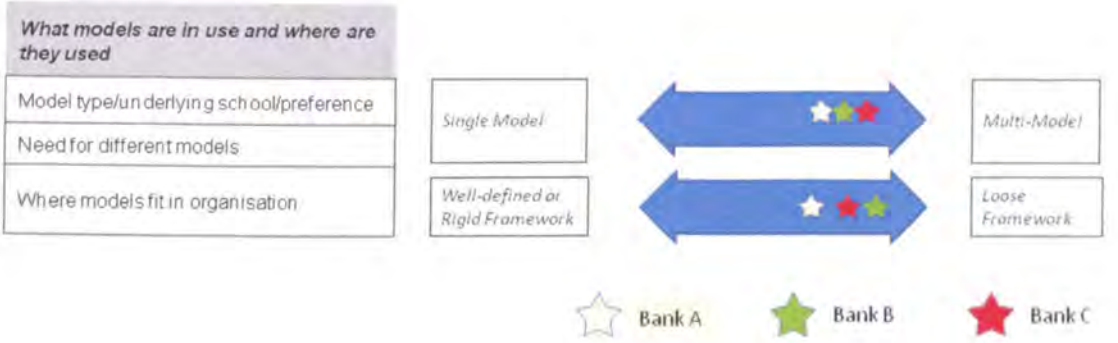
Figure 7.1 Risk management governance structures in the candidate banks

7.2.2 Credit Model Use

7.2.2.1 What models are in use

This part of the research looked into what models were used and where the models fitted into the organisations. The main finding from this section was that none of the three banks had a preference for a particular model type. Structural models were common in Bank A and Bank C, but these banks were also at pains to mention that they also used other model types. Bank C was moving away from their original Structural models for 'potential of default' calculations to more 'expert judgement' models for their banking, project finance, real estate finance, trade and commodity finance and healthcare counterparties. While some of the literature does see the models as competing (see Altman *et al*, 2002; Giesecke, 2003; Eom, Helwege and Huang, 2002), this finding actually shows that the banks actively use combinations depending on business area, data, competency, familiarity and individual preference.

Figure 7.2 What models are in use and where they are used in the candidate banks[14]



All three banks had similarities in having segregated areas for developing, testing and validating the models. There were differences in reporting lines in Bank C for the Risk Integration & Analytics department, and Model Validation directly to the CRO. As mentioned in section 6.3.1, the probable reason was due to the relatively high profile of modelling in the current market and to ensure independence from the business and the other risk departments. The banks felt the exact make-up of the model didn't matter, as their view was that the accuracy was not there yet today, however the ability to use the model in a consistent form as well as using the model output alongside other information was the key to good credit decisions. Expert judgement has a larger role to play than found in the literature. One possible explanation is that expert judgement models are not considered quantitative models and therefore have not been covered in the literature which, as chapter 2 has shown, has a quantitative bias. There is a well-documented precedent for such bias in academic scientific research, extending into mathematical physics. The conundrum goes something like this: when a simplifying assumption can be made to the description of a physical system which permits a neat (or analytical) mathematical solution to be derived, then for the sake of ease of application, that solution will often be adopted – and the simplifying assumption will be conveniently forgotten. The underlying assumption that a small variation to the mathematical description of the problem will result in a small variation (i.e. only of significance to a higher order of accuracy) to the result can be shown to be erroneous in many real and significant physical conditions. It is therefore arguable that mathematical models are often providing accurate solutions for problems that just do not exist in the "real world". Instead, they are being adopted as proxies for solutions to problems that do exist, sometimes without sufficient regard to the material differences between the statements of the real and

[14] Appendix B of this document describes the approach used to produce the graphic representations in Figure 7.2 through to Figure 7.6

theoretical problems. The purpose of any adjustment in such a case would be to take into account such differences.

The use of models was still being formulated in all three banks, and none of the three banks had an all-encompassing, rigid, fully-defined framework for model development nor had clear processes that prescribed a list of actions to be taken based on model output. Instead, most of the banks operated along much more flexible frameworks. Bank A had the most structured approach with Bank C having a fairly flexible framework, as they were still in the process of deciding and implementing their models.

7.2.3 Qualitative factors used alongside model outputs in the decision-making process

This section looks at how the models are used as part of the decision-making process. There was a lot of variation on how the models were used in the banks but what was common across the three banks was that the model information was not always the main determinant for decision-making, and that model output was never used in isolation in the decision-making process. All the participants across the three case studies spoke about qualitative factors that sit alongside the quantitative model output as part of decision-making.

> "I don't think you can ever get away from the fact that you need a measure of quantitative and qualitative judgement in any decision-making process. Models are not perfect. They're an aid to making a decision." (Code: HSCR-B4)

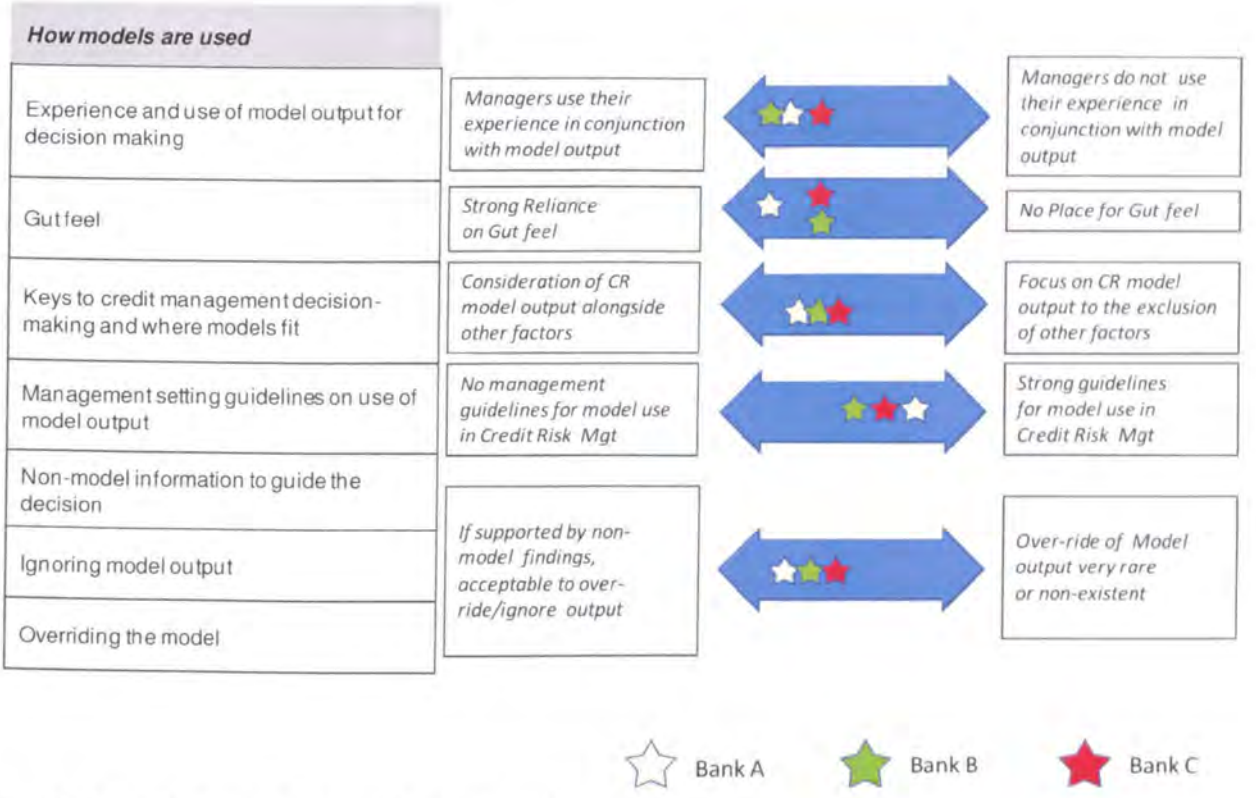


Figure 7.3 How the models are used in the candidate banks

7.2.3.1 Experience and use of models

The amount of experience a risk manager had featured as an important component in the use of the models in all three banks, and was a topic that all the participants had strong views about. Bank B spoke of it most intensively, and this may be due to the fact that they were least advanced in the implementation of models and also to the nature of their business, where in their view the models could only provide limited benefits. Bank A felt experience was especially important in cases where the models did not fully align to their risk strategy and appetite, and where data quality issues in certain geographical regions meant the model output was not always reliable. Bank C spoke about the importance of experience as they did not feel their models captured qualitative factors that the senior managers felt should be part of the credit decision. In all three banks, the managers considered the models' output as just one factor in a multi-faceted process.

Here are listed some of the strong views from each of the banks:

> "I think it's the role of senior management like myself, and like the Chief Executive and what have you, to make sure that we have the right balance between the use of

models and the use of [our staff's] expert judgement, and the weighting for those will change depending on the circumstances." (Code CRO-A11)

"Only experience can actually tell you where the model is slightly off track or where it's not picking up some interesting bits, you know. Experience should be a good thing. You know, it should be a good thing. I don't see why... providing you start with the model as just a starting point, as not the means to an end, it's just... it's not the final kind of solution for a credit rating or a credit exposure calculation. You know, there always has to be a balance to it - experience and model I think. " (Code: HCRI-B6)

"The truth comes with experience. The experience needs input from the Business Users not just the modeller's view which may not be grounded in experience." (Code: HPM-C13)

Balancing the argument that experience was important alongside model use were points made in Bank A and Bank B that experience could also cause resistance to change. With the model implementation being relatively new, staff may be set in the ways that they had been used to doing things and thereby openly or covertly ignoring part or all of the information from the model output. The participants spoke about the right type of experience bring important.

7.2.3.2 Gut feel

One surprising finding of this research was the number of times the words 'gut feel' was raised by the participants in the context of the decision-making process. There is no literature found on this in relation to credit risk models nor in the formal reports published from banks, and as such neither the term nor the use in practice was part of the original design of this research. This was purely an unsolicited term that was introduced by the participants during the interviews.

The lack of published work does not take anything away from the way the risk management teams in the three banks appear to believe that models alone do not provide the only guide to decision making, and that there must be other elements in the decision-making process, one of which is based on gut feel, or intuition. A number of quotes are re-used in this section to help understanding of 'gut feel' from all the candidate banks' points of view, and provides some analysis on why it may have featured so prominently in the interviews.

A good example of the concept of a gut feel decision was provided by a participant in Bank A:

"In a previous job I was at a credit committee in a UK bank and there was a transaction ... and it got around to one of the senior credit guys and he said "I don't know what it is. I can't put my finger on it. You know, the numbers say this and the model says that, but my gut feeling is that we should not be doing this," and the Chairman ... said "I don't know what it is either, but I'm going with your guts and we're not going to do the deal." (Code HCRI-A27)

When pressed for their definition of gut feel, the participants could not fully explain it. Some of them spoke of it as common sense (Bank A), others linked it to a situation not previously encountered but where one could use similar previous experiences (Bank A and C), some looked at it as a "judgement call", where a decision had to be made where there was uncertainty involved (Bank B), and one of the participants (Bank C) explained that gut feel used experience as a reference framework that someone could use to compare against a totally new situation. Gut feel, he said, was the mechanism that was used to interpolate the new situation and experience. Yet another, in Bank A, mentioned gut feeling as an instinct, based on one's own internal back testing (by which he meant previous experience). He called it a sort of undocumented, no-methodology framework, where if you've never seen something happening before, in a particular situation, then you wouldn't expect to see it now.

Also of interest was that the participants also pointed out that gut feel was not restricted to credit risk management, and it was mentioned in the context of seeking front-office views, senior executives and most surprisingly it was also mentioned in relation to regulators.

"The regulators generally have pretty good feel [instinct, understanding] for how much capital they think you should hold and that's the answer they're going to get to, almost regardless of what your models say. Flatten out the amount of capital that they want you to hold anyway. Yeah, so in effect making the capital less sensitive to market movements" (Code HCPM-A 13)

All the responses seem to indicate that gut feel is akin to instinct or intuition where there was an unconscious rational which was grounded in experience. In Carl Jung's theory of the ego and the four psychological types (Jung, 1981), intuition alongside sensation is described as "irrational function", whereas thinking and feelings are "rational functions". In Jung's view an individual whose intuition was dominant, an "intuitive type", acts not on the basis of rational judgment but on sheer intensity of perception (Jung, 1981). Many people hold that Jung's view of intuition shows that intuition is a negative thing, but they misunderstand Jung

who only sees intuition as negative if it is the dominant force in an individual who ignores thinking and feeling. Jung defined intuition as "*perception via the unconscious*" and that in conjunction with sense-perception it could bring forth ideas, images, possibilities and ways out of blocked situations by a process that he finds as mostly unconscious.

Another way at looking at intuition is via the definition used by Abella Arthur "*Intuition is a combination of historical (empirical) data, deep and heightened observation and an ability to cut through the thickness of surface reality. Intuition is like a slow-motion machine that captures data instantaneously and hits you like a ton of bricks. Intuition is a knowing, a sensing that is beyond the conscious understanding — a gut feeling. Intuition is not pseudo-science" Arthur (2010, p1).*

All three banks did surprisingly think 'gut feel' had an important part to play, although the participants in Bank C and one of the participants in Bank B, like Jung (1981), believed that if gut feel was the dominant part of decision making, it would be problematic. It should be a supporting piece on an exception basis in the credit decision, rather than the main driver.

> "Gut feeling and experience is absolutely something which is a necessary added value ... you cannot just do it on that experience or building it up on intuition." (Code: HCR-C1)

The participant in Bank B also pointed out that in his view it was sometimes too easy to claim something as gut feel and (as a result) not to have to explain or rationalise one's position. Therefore the credibility and source of the information also had to be taken into account.

> "It's easy to have gut feelings about simple things. ... But no, I think it's very important to have experience and I think it's important that people have gut feelings, but I think they need to be considered. It's sometimes too easy, you know. So I think when people say they have a gut feeling I think you have to consider the source." (Code: HQRM-B26)

7.2.3.3 Management setting guidelines on use of model output

Both Bank A and Bank B spoke about how ultimately there should be a person that is accountable for model output and to be able to defend or explain the outputs. There should also be quantitative-savvy people that take responsibility for credit decisions rather than just being able to explain that the decision was based on what the models provided. This was felt

to be important as it meant the responsibility for the results could not be delegated to a model or machine. While Bank C did not raise this specific point, of people being ultimately accountable, like the other two banks they felt that the risk team should be able to challenge the model results. As this is an important part of the research, three quotes are used to show this:

> "The most important thing is that sitting on top of each one of those models or across all of them, hopefully, is a human input. What changed management attitude was the combination of Basel 2, which brought in things like stress testing across the board, and the idea that things can go horribly wrong and senior management are accountable". (Code: HMR-B20)

> "There's more of a change to put more confidence in the model, but at the same time I've kind of seen from a management perspective a healthy level of kind of sceptic views and continuous kind of review and assessment of the outputs of those models, because models in themselves are built by individuals or by humans and therefore are fundamentally flawed. So I would say from a management perspective there's the continuous, you know, questioning with regards to "Is the model giving the right thing?" (Code: HSCR-B17)

> "Models will never remove the need for strong governance and credit management and credit involvement and business involvement as well." (Code HCA-A19)

Another area where the research raised the issue of management being able to set guidelines for models was in the area of stress testing. It was felt that an important part of credit risk measurement was to ensure that the results produced were robust and could handle unexpected credit events that impacted the portfolio. There was, though, the question on where to draw the line, especially in relation to where to set the bounds for stress parameters. Setting the stress parameters too conservatively impacts capital and trading activity. In the banks this was a regular source of debate between Front Office and the Risk Management department.

> "So from my perspective I think that stress and scenario testing is going to play an increasing role, but I don't really look at that as being modelling, it's arithmetic rather than mathematics. Credit world mistakes can often not be corrected in any period and, you know, I think that demands that there is an approach that involves considerable expert judgement." (Code: CRO-B11)

Stress testing also was considered an important qualitative check on the models. There is a further discussion on stress testing in section 7.2.6.4 which covers the participants' views on future developments in relation to models and model use.

The concept of collective knowledge and institutional memory was another area that featured in the research where it could provide guidance in the decision-making process. Section 4.6.2.1 of this thesis covered some of the literature on the positive aspects of collective knowledge, as was well as how groupthink can lead the group astray and isolate individuals with different views. Section 5.6.2.1 covered institutional memory and how it helps to preserve knowledge for situations that require experience based on the past, or in providing guidance on a situation not previously seen. How banks have appeared to maximise collective knowledge and institutional memory was via the use of their committee structure and in setting guidelines, policies and procedures. This also safeguarded against groupthink as the clear governance structures avoided strong groups of personalities from hijacking the decision-making processes. Techniques discussed included the chairperson for each of the committees allowing different views to be discussed.

7.2.3.4 Non-model information to guide the decision

A number of the managers mentioned that while credit risk models were a useful tool, it should not be the only source of data. From the replies of all the participants, there seemed to be a significant amount of qualitative information that is used in conjunction with model data to guide the final decision. This seemed to be especially so in times of uncertainty and high volatility.

> "Very often, I believe, the results which are completely almost statistically-based are taken as granted as correct, but it shouldn't be accepted as a rule, the qualitative analysis should be made on top of these calculations which are historical data based, model based information." (Code: HRM-C4)

> "There has been a perception shift in model use [since the credit crunch]. The users are more suspicious. Management will still go on using the models. It is better than nothing. It is ingrained in the culture to use models now but there is more questioning of output though." (Code: HCRL-C19)

Given the recent history of extreme credit events and the atrophy of "normal" market mechanisms, some senior managers seem to have felt little option but to resort to non-model-based factors to inform their decision-making processes. This indicates that the managers believe the models operate less efficiently in periods of high volatility.

> "And those models are based on the past 5 to 7 years. But maybe this cycle is a bit different and is steeper, and certain sectors react to that differently and if I only would base myself on the model, I might miss." (Code HCR-C10).

Banks try and use historic data that covers a credit cycle. However there are debates in the market place on how long a credit cycle lasts. Some believe 5 years, others 7 years and others believe credit cycles vary in length. Part of the issue is also the length of history that banks hold. While this issue may become a smaller problem as time passes and banks hold more data, the question remains that models are backward-looking and base their outputs on information that is provided to the models. Humans, on the other hand, have a range of qualitative data not available to the model. Other than the weakness of models due to the fact that models use historic data, there is also a lag factor on the data coming into the model. The head of Credit Risk in Bank A explains:

> "I guess there's a lag in what the model's going to tell you compared with being in front of people and finding out, so it is important that we get in front of the clients. The model tells you some of the information. Your rating model will tell you something about the organisation, but there's more to it than that." (Code HCRI-A7)

It is worth noting that the participants varied in terms of their assessment of the relative weightings applied to model and non-model-based information when making credit risk management decisions. All acknowledged the need for, and importance of, non-model-based data but there seemed to be some lack of clarity as to whether the model was to be regarded as just one of several equally-weighted inputs to a decision-making process or whether the quantitative models were to be seen as the decision-guides, against which, in certain circumstances, exceptions would be permitted. This study does not cover the weighting for qualitative factors and only provides evidence of the importance that the participants attached to qualitative factors. The weightings for the qualitative factors merits further research.

7.2.3.5 Ignoring and overriding model output

From the cross-case analysis, models results may be overruled for several good reasons, but in general the view across the different cases was that the banks would not just ignore the output. Bank A appeared to have the most critical view on the models and were the most descriptive on when the models would be overruled, with the participants in Bank C least likely to overrule the models (albeit there was a cynical view from their head of QRM that the economic capital data wasn't really acted on, and hence in his view the model output his department produced was in a sense always ignored). The output from models though can be treated with differing levels of credence based on strategy, experience, gut feel, perceived model accuracy and non-model information. It was felt that direct end-users of the models could always over-ride but with reliance on managerial hierarchy to moderate the decision-making process with controls in place, as shown by the following quotes:

> "Well, we never completely ignore it. We certainly have policies in place in terms of the ability of credit managers to over-ride a model output. There's a very strict policy with reference to people who are actually allowed to override model outputs and only within one or two notches [in relation to credit ratings]" (Code HCA-A20)

> "The users of the model should always be allowed to override it. You need to have certain levels of authority to make sure that the person who's doing the overriding is sufficiently knowledgeable and experienced and that there are no conflicts of interest" (Code CAPR-A9)

> "However, that's no substitute for experience and quite often gut feel. So in coming to a decision... you take into account many different inputs, of which the model input just happens to be one. Quite frankly, in the last 12 to 18 months we have on a number of occasions overridden the model [with the necessary controls] and gone with essentially what was gut feel because we didn't really believe what the model was telling us." (Code CRO-A5)

7.2.4 Model improvements and issues

This section looks at themes that were raised in the research covering how often models changed, model issues and what the risk managers felt were steps needed in order to improve the model within the overall credit risk management framework in their bank.

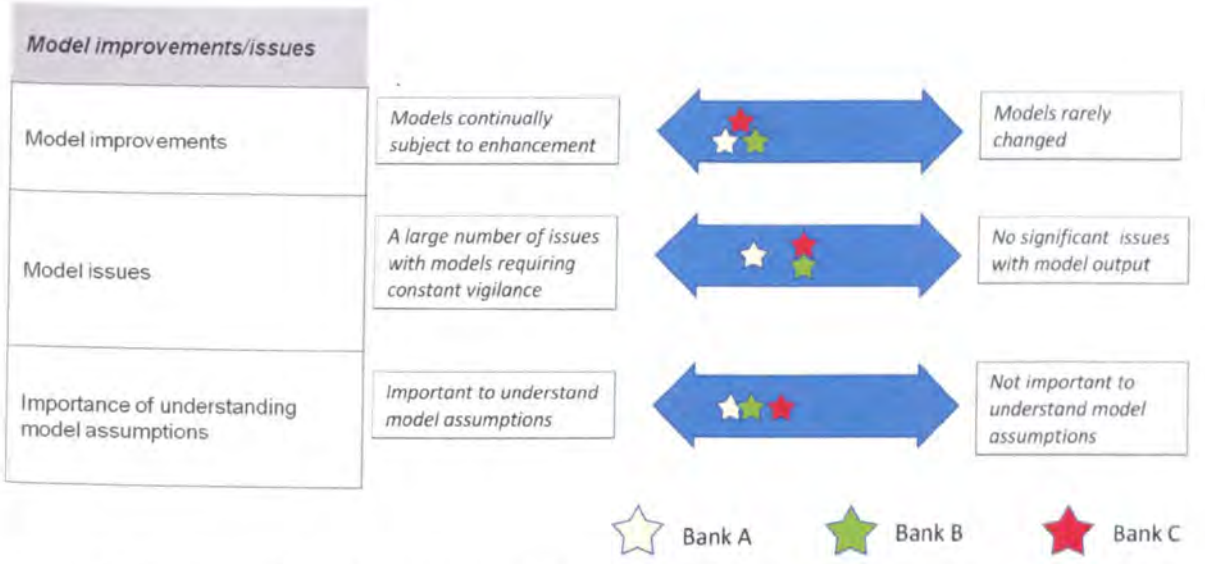


Figure 7.4 Frequency of model improvements and issues found in the models

7.2.4.1 Model improvements

In all three banks, the models were frequently changed (releases happened monthly). Much of this was explained in that the efficacy of the models is assessed regularly in respect to current and future business requirements. There is a more or less a continuous list of items such as newly-traded products, derivatives based on existing products, new traded currencies, fine tuning based on model output and better data sources, to name a few, that get raised and need to be addressed. While this seems to be "business as usual" for the banks, it does also indicate that these models are not mature enough, and fine tuning is still occurring. In Bank A, where information of the model performance was provided, for their LGD models their data indicated there was a 38% failure rate of the model to calculate the LGD values correctly. It is difficult to generalise based on only high-level numbers and without detailed analysis of the different failures, but what is clear is that there are areas for improvements in the model output and there was a continuous process of feedback, validation and improvement.

> "Constantly we have a long list of models and for each of them we have a plan in terms of how often we want to fundamentally review them and potentially re-write the model." (Code HCA-A23)

> "If I had unlimited resources I would say I would expect about half of them to be improved." (Code CAPR-A3)

A number of participants also expressed the view (unsurprisingly) that the models that needed improvements were those designed for mainly exotic, niche or new products. Two participants in Bank C felt the wider use of models should increase operational benefits and over time the standardisation of products would reduce complexity of the models.

> "I'm hoping that in 5 years time we have a finite set of models, that someone will develop their proprietary models and systems offering a multitude of solutions and a multitude of models, you know, to banks / to the financial community." (Code: HCRI-B17)

In a banking operational context, the availability of input data and the sensitivity of the model to data errors or gaps are very important, particularly for an institution such as Banks A and B, which have exposures in emerging market sectors.

There was acceptance that the model for credit risk particularly would only be able to provide so much information as it is based upon historical data and relationships. Since credit can be regarded as a function of future expectations, which may not have any causal relationship with past performance, the models may not always accurately account for upcoming events. Early warning systems were discussed by a number of participants but no clear solution was suggested, except by one participant, of being close to the customer.

The participants also spoke about included improvements to the model infrastructure (hardware and software), improvements that would help with decisions on capital optimisation, and improvements in the models for regulatory risk reporting.

7.2.4.2 Model issues and understanding model assumptions

There was a large amount of variation in the importance the individuals in banks put on basing decisions on an understanding of the exact assumptions made by the model. In looking at the responses from the participants across the banks, the finding is not that the banks held different views but that the participants within each of the banks had different views which were correlated with their role. The participants that were involved in the model design and implementation felt that it was very important to understand the assumptions of the models and to ensure the models were used with an understanding of the assumptions used to build

the models. The inadequacy of model assumptions is covered in the literature by Triana (2009) and Mandelbrot and Hudson (2008) where it shows some of the shortcomings of the model assumptions. As shown in section 4.8.3, the quantitatively aware participants in Bank A felt that without this understanding, the interpretation of results can be flawed. This view was shared by the quantitatively-aware people in Banks B and C.

> "I don't think that the statistics are completely and correctly reflect the actual credit risk of the counterparty. ... First of all, even behind the statistics, as you know, there are assumptions which are made in the model and these assumptions are simplification assumptions." (Code: HRM-C4)

The risk managers and users in all three banks, on the other hand, did not feel that the understanding of model assumptions was as important in decision making. One reason was the fact that they felt there were other factors affecting the model output that had a larger impact. Another reason for the lack of concern from the non-quantitative people could be their lack of knowledge of the assumptions and their impact, or more likely the fact that they probably rely on their quantitative-knowledgeable colleagues to point out the occasions when the model assumptions have a large impact on the model outputs. This reinforces the point made on collective knowledge and institutional memory in section 7.2.3.3

> "The discipline of having my team understand what short-cuts we'll take in the short-term for valuation purposes and how that affects margin and everything else, that is a fantastic discipline. And by the way, I think it's the only discipline that works. It keeps the institutional memory bank." (Code: HQRM-B14)

7.2.5 Regulatory influences on models

A finding of this research is that the regulators have had a very significant part to play in model development in all the candidate banks. This section looks at the findings across the case studies on model issues around calculation of regulatory capital, how regulators influence use of models in banks and how banks view the regulatory capital models against their own internal economic capital models.

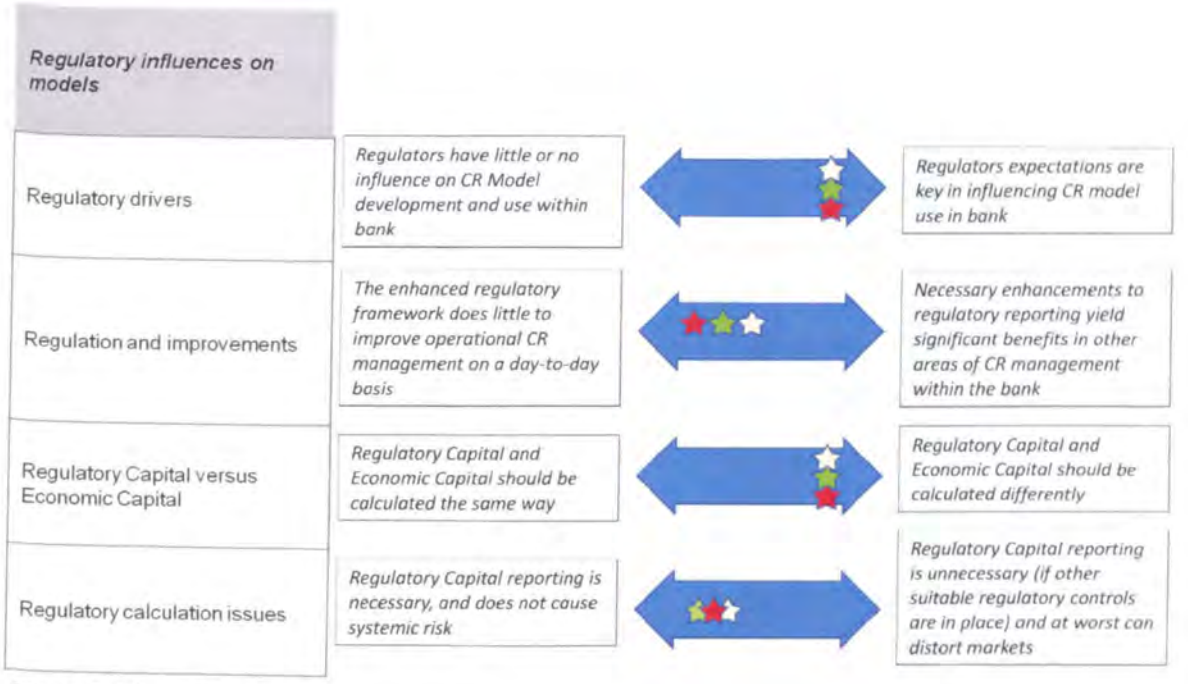


Figure 7.5 Regulatory impacts

7.2.5.1 Regulatory drivers

All the banks in the research felt that regulation was the major factor in driving the development and deployment of credit risk models. However it was also felt that while it was clear to them that the regulators drove the development of models in their banks, the banks themselves have had the opportunity to take it to new levels. This realisation of the opportunity to improve the models is dependent on the banks' own plans and strategy for model development and differs from bank to bank. The part the regulators play in model development is not evident in the current literature for model development (chapter 2 found no literature that evidenced the large part the regulators played in model development in banks). This section will cover the points made by the participants in relation to the regulations and the regulators.

> "Well, the key use of those models is actually to generate the regulatory capital calculation." (Code HCA-A4)

> "I think it's probably true to say that this organisation only developed economic capital models because the regulations effectively forced it to." (Code HCPM-A20)

> "Well, at the beginning yeah, it was something that we needed to do by regulatory pressure, and once you've got the models, you're going to be using them also for other purposes." (Code QRM-C15)

7.2.5.2 Regulation and improvements brought by regulation

All the banks in this research felt that the regulator's part to play in model development was a very positive one but they did refer to a few issues related to the bureaucracy in the need to jump through regulatory hoops, and the dangers of herd mentality if everyone used similar models. It was also pointed out that if the regulatory capital diverged too much from what the banks themselves calculated as economic capital, this would increase costs unnecessarily and provoke regulatory arbitrage (where banks would look at ways to minimise regulatory capital, and models would be developed based on optimising regulatory capital savings rather than prudent risk management). Regulatory arbitrage was common under Basel I.

> "[If] we can gain significant benefit from our own management of our risks from our own understanding of our portfolios by implementing a modelled framework, then we will look at doing that. If there is a regulatory benefit or capital benefit to be gained and it's aligned with that same process, well of course we'll try to get that benefit as well – driving the banks to this is probably not quite the right one." (Code: CRO-B16)

The participants believed that models are guidelines that only get you so far, and that credit decisions needed to be made with the models being one of the sources of information. The other benefit of the models in Bank B was that they enforce a level of rigour and discipline. The head of Quantitative Risk Management believed that this discipline helped to provide institutional memory that helped credit decisions.

> "The discipline of having a proper risk management framework is worth its weight in gold. I don't think there is any question. In terms of institutional memory, in terms of the discipline of forcing people to think about the consequences of products that they want to trade (Code: HQRM-B22)

7.2.5.3 Regulatory Capital versus Economic Capital

From the replies from all the banks, three participants saw a correlation between economic capital and regulatory capital, but the rest believed they should be different based on the way the regulatory rules were applied. All three banks felt economic capital models should better reflect the banks' capital needs although only Bank A had an active capital management process that took into account both economic capital calculations as well as regulatory capital calculations. The other two banks believed that while economic capital models should be

more accurate, their drivers on capital use was mainly based on regulatory capital constraints and economic capital was not used much.

Bank C did develop an overall economic capital framework, but the economic capital models failed to be used widely and stimulated quite a negative response within the organisation at large. The main failing was that the models were complex and the outputs were hard to reconcile against other data that the managers and users had. In contrast, when the regulatory capital models were deployed, the understanding of these models was greater than that of the internally-inspired economic capital models, whose design and structure seemed to be much more opaque, even to managers within the risk management organisation. Another reason that the regulatory models were easily accepted was that the bank had been under severe pressure on regulatory capital which meant that the front office, as well as risk managers, had to actively try and minimise capital use via the use of these models, whereas the economic capital controls were more difficult to enforce. The end result has been that the regulatory capital models have been driving model growth in Bank C. The bank recognised the need for economic capital models, and the participants in all three banks clearly stated the need for economic capital models that would allow the bank to better optimise its capital in line with its strategy. But it was important to make the economic capital models easier to understand, with the ability for managers to relate to, understand and reconcile the results. As the head of Credit Risk mentions:

> "If a model is too complicated for them to really understand what happens, then there is a risk that people are going to just manipulate or ignore completely. ." (Code: HCR-C15)

7.2.5.4 Regulatory calculation issues and future influences of regulators on model development

The participants in all the banks were aware of the newer Basel II amendments coming, as well as the future Basel III regulations for 2013, but mentioned that they needed to fully assess the impact of the new regulations before they could comment. As regulation becomes more sophisticated, a couple of people in Banks A and B felt that there could be a natural convergence there of some sort with regulatory capital and economic capital, although this was felt to be a long way away as the drivers in the two models were different:

> "If you're in a bank, what you're trying to do is maximise your economic profit and maximise your return. To do that you need to maximise your revenue and minimise the amount of capital you consume. I mean if you're a regulator what you want to do first and foremost is to make sure that the industry is insulated from shocks and therefore you require banks not just to carry sufficient capital to cover the risk on the books, but you want to make sure they've got capital plus buffers to cover any shocks. They're just forcing banks to hold higher and higher levels of pure capital." (Code CRO-A21)

It would seem to make sense for the regulatory models to be derivable from exactly the same data that is used to produce the internal economic capital reporting data. There is still some way to go before this objective is achieved. In the case of regulatory capital calculations, Bank C's management saw little point in applying sophisticated mathematical models to produce the numbers. Simplicity and transparency were more beneficial.

> "For the moment, don't think would be expedient for either the bank or for the regulator to use higher maths for regulatory purposes." (Code: HRM-C16)

7.2.6 Smaller themes raised in the case study

This section of the research looks at six smaller themes raised by the participants. While there are some links to previous themes, these merit special mention and cover views on future model development, links between front office and the risk department, risks of models causing herd mentality, importance of stress testing, some insights into the validation process for models and how concentration risk has a part to play in credit risk.

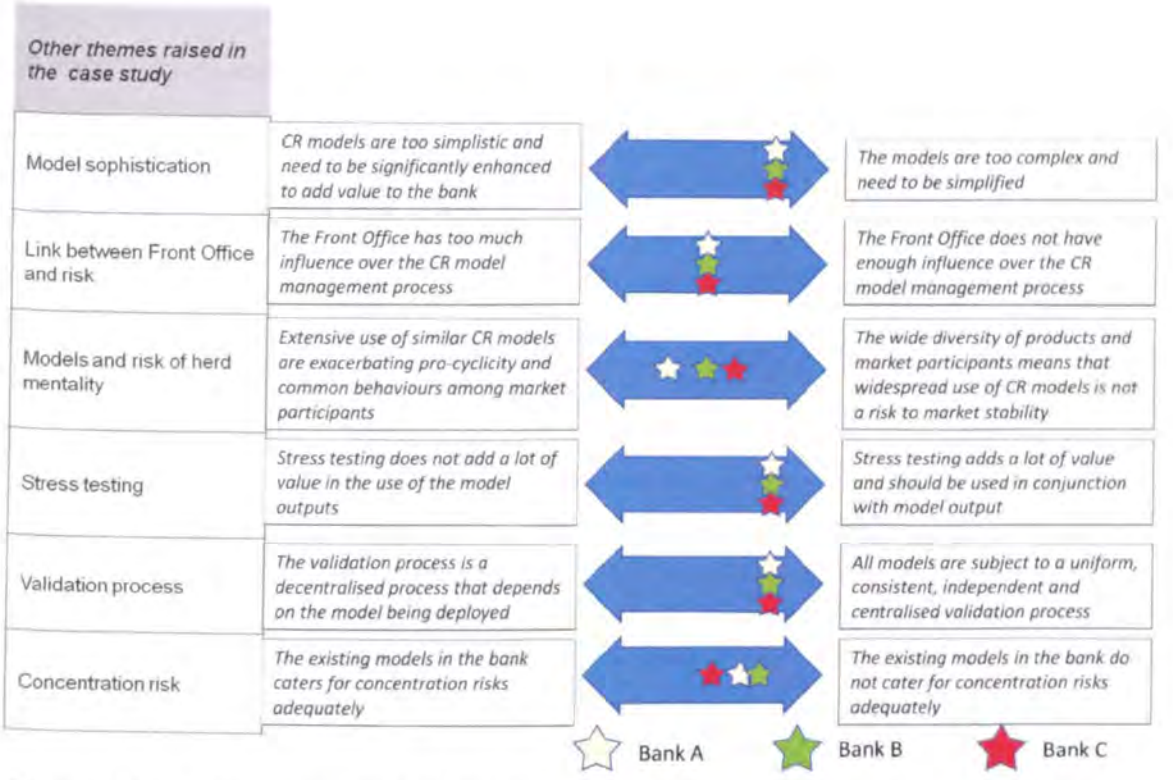


Figure 7.6 Smaller themes raised in the research

7.2.6.1 Model Sophistication

One of the findings of this research is that the participants in the banks felt that the outputs of these models were not always accurate or precise. There is support from the literature in Rebonato (2007), Triana (2009) and Mandelbrot and Hudson (2008). The models still added a lot of value as the discipline of using the model outputs in a consistent form and alongside qualitative information allowed for better credit decisions.

Much of the newer literature as evidenced in chapter 2 proposes highly complex mathematics to allow greater precision in the models. While some of the participants believed models would get more complicated, all the participants felt it was desirable to have less complexity in models. The reasons put forward by the participants for less complex models were that these would be easier to understand, more intuitive to use, allowed the users to be able to reconcile with their own data and it would mean lower costs in developing and implementing these models. Bank B was especially clear that their bank had little to gain from over-reliance on models, whether it be structural, reduced form or otherwise and that the key criteria for a Tier 2 bank, such as Bank B, was the tolerance of the quantitative modelling process to unexpected situations or imperfect data inputs.

Bank C's management voiced the opinion that the reason they believed that models should become less sophisticated was partly as a reaction to the failure in take-up of their own economic models by users in the bank compared to their implementation of regulatory models, and partly in reaction to the inability of their existing models to predict large fluctuations in markets or to protect portfolios adequately from the effects of these extreme outlier events..

> "In our bank, in my department, the approach now is to be more rudimentary. Rudimental means things are now more understandable. I believe estimations will be more common in the industry. I mention we currently risk weight approach, similar to regulator's risk weights populated separately outside the system. This is a more rudimentary application is applied through a cohesive netted exposure set. One of the biggest challenges will be for any bank and our bank in particular is improving system infrastructure for the quantification of risk. I don't believe the challenge will be to improve complexity of models but to improve the delivery of the model results to the users. Yes, it will be to improve of the application of the currently used models and delivery of the results to the users." (Code: HRM-C17)

There is research by Gersbach and Wenzelburger (2007) that provides some evidence that sophistication in models could be a bad thing for the market as it concentrates lending on mainly counterparties with a high credit standing hence increasing the default risks to intermediate-quality credit. "*We have shown that sophistication in risk management which prices in the default risk of entrepreneurs benefits high-quality entrepreneurs by lowering loan rates and reducing cross-subsidization of intermediate-quality entrepreneurs. Sophisticated banks reduce the credit access of entrepreneurs with intermediate-quality levels and attract less equity than simple banks. As a consequence, expected repayments to the simple banking system are higher and its default risk may be lower. We have also shown that an economy with a sophisticated banking system invests its funds more efficiently leading to a higher expected aggregate consumption. This trade-off between efficiency and stability of a banking system may be a serious concern for bank regulation*". Gersbach and Wenzelburger (2007, p 86)

The participants in Bank A, like Banks B and C, also believed models should be less sophisticated. They also specifically mentioned the blurring in the boundaries between credit risk and market risk. In the commonly-found structural and reduced form models, the

estimations of credit risk are directly linked to market prices. Therefore, an expression of credit risk can be regarded as a function of market risk although credit risk and market risk are commonly separated in the market and in banking regulations. Bank B's risk managers appreciated the linkage and relied on a variety of broadly-based techniques to manage this linkage. They felt there was a case for simplification of the way models were used, especially in the overlap of market risk and credit risk, as well as the simplification of regulations in relation to this area.

In isolation, a move towards simpler models is unlikely to yield positive improvements – but if established as part of a more integrated framework, where all risk factors can be evaluated and compared in a coordinated and consistent way, then such simplification is likely to provide a more robust mechanism.

7.2.6.2 Link between Front Office and the Risk department

On the theme of a link between Front Office and the Risk department, three strands of influence emerged with regards how the credit risk management framework in banks was able to moderate trading behaviour.

The first strand was that the bank's Front Office staff were normally included in the model design and development process, so they were able to contribute to decisions on how the risk measures worked (the ultimate decisions were in the credit risk area). In this regard the Front Office has a role to play in imparting real market dynamics to the risk management team, to enable better modelling of risk.

> "I'm sure every bank complains about the models making them uncompetitive in their pricing practices and so on. I think it has fundamentally changed the way in which they (the front office) think about the risk of the counterparties, and it makes them more about the risk of what they're doing prior to actually doing it. So we might actually change the way in which do our business itself. The business wanted a large input into the model development and we actually changed our methodology in terms of model development to actually include them in the workshop, and up-front the message is saying we involve the business at the start and it is part of the development cycle." (Code HCA-A24)

Second, the Risk Management Department applied a more conservative assessment of market behaviours in order to counteract perceived bias to recent history on the part of the Front

Office. Given the now widely-accepted sentiment that so-called "outlier events" had a propensity to occur more frequently than models predicted, this counterbalancing exercise sat comfortably with both risk management and regulatory considerations. An important part of the acceptance by the Front Office of this more conservative view was that it was part of an independent regulatory reporting requirement.

> "risk management has to have a longer view and a more consistent and a steadier view and focus." (Code CAPR-A17)

Third, there was a theme in the recent literature and in the press since the financial crisis of 2008, of the reward that investment banks offer in terms of bonuses where traders and bankers are seen to be rewarded for taking on more risks. Even the credit departments were normally rewarded on the increase of growth and in the profitability of the bank rather than specific management or in the curtailing of risks. The participants felt that the risk team should be rewarded independently from the Front office and could assist in the alignment of Front Office bonuses by independently valuing the risk, and ensuring the correct pay-off profile of the exposures that were being managed by the bank.

7.2.6.3 Models and risk of herd mentality

There was consensus from the banks in the research that poor understanding or application of credit risk models (and, presumably, other risk models) could encourage similar behaviours amongst market participants and therefore affect the dynamics of the markets as a whole. As such it was felt that credit risk models could cause systemic risk. Bank A felt strongest about the risks here. Nevertheless, it was also acknowledged by the participants that models - if properly applied and properly understood - were not likely to accentuate this inherent feature of markets.

> "Herd mentality is, I guess, if a model is in place it negates the need for people to actually know what went into the make-up of that model, and it's very easy then just to kind of use that model without actually questioning is that model giving you a realistic picture of what is the risk that you're looking at. "(Code: HQRM-B10)

Another assumed mitigant mentioned was that by banks using their own economic capital models there would be differences in the models, and the advanced approach in Basel II encouraged banks to build their own model. There could be a weakening of this assumption

due to the fact that, as pointed by the risk managers in Bank A in section 4.7.4, if surveys are to be believed, that 60% of the market uses similar KMV models. However, as also pointed out by Bank A, they do not actually feel banks necessarily follow the herd as they hold that while systems may be similar, individual portfolios would still need to be tailored and in most cases calibration would be done using different data, and there would also be qualitative controls within other banks' risk management teams which would seek to apply the strategic agenda of the bank.

There is also the sense that the shortcomings of the models in certain markets or conditions may influence the types of deals done by banks. Models that return incorrect, but seemingly sensible risk parameters may be favoured over those that don't (even though these may be correct). This is shown in the following example was given by Bank A:

> "If you don't have the top management backing for strategy to actually go into business where the risk is high with a difficulty to measure the true risk, you will have a herd mentality and actually just focus on deals or transactions or counter-parties that come off lightly in the models. So in our case, I mean I can definitely see the potential for that, and in some cases it plays out. ..." (Code HCA-A17)

To help understand the impact of herd mentality caused by models an example would be if regulatory capital penalised lending to poorer grade customers, as this could lead to all banks not lending to certain sectors which could have a very large impact to these areas with very few lenders willing to lend to this market. Another example is if a sovereign (e.g. Greece) had falling credit ratings this could amplify the effects of the impact as the banks would all be led in similar ways by their model output and all divest their Greek exposures at the same time which in turn causes further pressure on the ratings, creating a potential vicious circle.

7.2.6.4 Stress testing

Stress Testing is a term used by regulators for describing the various techniques within banks to gauge their vulnerability to exceptional but plausible events. These events are not meant to simulate worst-case or nightmare events, but instead to check the model output under stressed conditions. In this research most of the participants seemed to believe stress testing was linked to more of a qualitative test although in reality a stress test can be either a qualitative or a quantitative test. All three banks acknowledged the importance of stress-testing over recent years, and saw a significant amount of future work required in both fully integrating the

stress-testing process into the overall credit risk management framework as well as the heightened importance of stress-testing and stress scenarios in credit decision-making.

In the eyes of some, the recent market upheaval has increased the emphasis on the stress-testing of models, at the expense of back-testing against historic data. The models which demonstrated good performance under historic data sets are seen now as less effective, as the major swings experienced recently have little or no precedence in the historical context.

> "I believe that it should be the now considered more carefully how applicable are the risk-based models against other possible or types of risk estimation. I am talking here about stress testing, for example, where it is much, much more important than it was in the past. There was too much emphasis on simulation-based models previously ...even utilised e.g. Historic simulation. Even Monte Carlo has parameters that are backwardly looking. I believe now, stress testing, much more influence or a much bigger say on management decision." (Code: HRM-C10)

Although certain members of Bank C have mentioned that stress testing is somewhat more important than the models themselves, this research does not find they are more important than the existing credit risk models. Instead stress testing is an additional tool and allows for potential extensions of the use of models, rather than potential replacements for the use of the models in banks.

Bank B felt stress testing was an important part of credit risk measurement to ensure that the results produced were robust and could handle credit events that impacted the portfolio. There was the question on where to draw the line, though, especially in relation to where to set the bounds for stress parameters. Setting them too conservatively impacted capital and trading activity. In Bank B it was a regular source of debate between Front Office and the Risk Management department.

> "We redesigned some of our stress tests and we had traders telling us "Actually, that's impossible." We said "Okay, we agree it's less than likely, but actually don't tell me it's impossible because I can give you things that I thought were impossible, but I was wrong by an order of magnitude." (Code: HMR-B20)

Stress testing can be implemented as an ad hoc exercise in the banks, and while this is useful as a flexible tool to look at stressed scenarios it sometimes is done without any estimate of the

probabilities associated with the stress scenarios, and often using modelling approaches that differ from an institution's credit modelling risk-measurement framework. This has the advantage of being an independent check but the disadvantage of it being difficult to reconcile these stand-alone stress test results with their standard credit risk model output. There is probably benefit in integrating some of the quantitative stress tests as part of the normal credit model process.

This research also advocates stress testing on the risk appetite of the bank. While this is a departure from the regulatory stress tests that are more common today, the outputs will allow the board of the bank to be aware of the likelihood of the risk appetite being breached, the scenarios that will cause these breaches and the impacts ensuing. This will allow preventative action and early remediation if a stressed event occurs.

7.2.6.5 Validation process

An area that was spoken about in all three banks was the validation process. Most of the academic literature concentrates on the theoretical framework surrounding a model, i.e. on whether its statistical output yields precise results, rather than the validation process, and as this was an area that was commonly referred to in the interviews, it was felt important to cover this topic.

All three candidate banks had established processes to cover the validation of the models and seemed satisfied by their validation processes (albeit in some cases it was work in progress). The independent validation and verification of the models is needed by banks to meet regulation (Basel Committee on Banking Supervision, 2009). Certain components of the credit risk modelling process were common both to the Regulatory and Economic Capital management and reporting processes and these common components seemed to be subject to the most stringent validation. In all three Banks, the model validation exercises were put through a common review and approval process, subject to moderation by the respective credit risk committees or model approval committees.

7.2.6.6 Concentration risks

Concentration risks are where there are multiple risks all related to a particular area, so that you could be affected drastically if that area is impacted. Bank A spoke about how models could help the bank in better analysing and understanding its concentration risks and, where

the management team could actively change the portfolio make up, it was possible to reduce concentration risks.

> "Where active portfolio management becomes possible, management has to trust better tools or models for some of the decision-making at the portfolio level, but I do think you have the opportunity to see better now where your concentration risks are, what trends are happening in the market, what is happening to the shape of your portfolio and to be able to do something about it – and I think that's the change that's happened." (Code HCRI-A4)

Bank B however felt that one of the larger concentrations of risk for their bank was "wrong-way" risk, where as the exposure goes up there is also a larger separate risk that the client could default. In this regard, they felt that the existing credit risk models only had limited value to them.

> "As I say, it's a very concentrated business, so the majority of our risk has a Russian nexus and it's a very small credit portfolio and so you can probably convince me that in the limitations we see that if you have a geographically diversified portfolio that contains a very large number of, you know, individually insignificant loans, that in reality some form of portfolio modelling is a necessary tool. I would argue to you that for the size of the business that we have right now, we could probably successfully argue that modelling is barely away from, for example, credit scoring because you have to have a consistent basis on which you can compare the strength of different credits. But I think, you know, as foolish as it would be to rely only on models, I also think it's foolish not to look at what models are telling you. You know, at the end of the day the issue's really just what do you place your reliance on and where do you place that reliance." (Code: CRO-B4)

The importance of risk diversification was also recognised by Bank C's management. While concentration risks appeared to be less of a problem for Bank C, the participants felt that these were not fully taken into account by the risk models that they have currently deployed.

7.3 Substantial findings in light of the research questions

7.3.1 Summary of the cross-case analysis

By comparing the three banks, this chapter shows the importance placed on governance, risk appetite and organisational structure in aligning the risk management processes with the strategy of the bank. It also reinforces the fact that the three banks do not follow one particular model philosophy; instead, model use depends on where a particular model is in its

evolution, its lifecycle, how much data the model requires, on the model's fit to the product set and the results of validation that is performed on the model.

An important finding is that while models are an important part of the management decision-making process, it is clear that model output is not the main determinant in management decisions. Bank B especially felt that the models are guidelines that only get you so far, and models were only one source of information. Qualitative factors such as interpretation of the model results against the individual's experiences, the use of collective wisdom, institutional memory, the view of external environmental factors, an understanding of the effects of model assumptions on the outputs and an unexpected "gut feel" factor all have parts to play in the decision-making process.

The cross-case analysis also reinforced the finding that the biggest single driver for the banks for the use of credit models has been regulatory pressures in the past and by the bank wishing to optimise its use of regulatory capital. The banks also recognise the usefulness of these models in day-to-day management of their credit risks, and have tried to develop the models beyond their original regulatory needs.

Finally the cross-case analysis highlighted several lesser themes across the three banks including stress testing, model validation, front office links, the risk of herd mentality and concentration risks. The most important of these, which participants in all three banks raised, was the desire for models to be less complex.

7.3.2 Use of Models (and divergence from the literature)

The Structural model developed by Merton (1974) proposed a new method of calculating and monitoring credit risks. However, the original Merton (1974) model produced discouraging results as shown in section 2.2.2 of this thesis and evidenced by work by Jones, Mason, and Rosenfeld (1984), Ogden (1987), Jarrow, van Deventer and Wang (2003) and Mishra, Kulkarni and Thakker (2008). There has been a lot of research into extending the original Merton model and, in early 1990's, some of the critics of the Structural model proposed an alternate approach called the Reduced Form approach. The academic literature treats these approaches separately and views them as competitive theories (Altman, Brooks, Resti and Sironi, 2002; Giesecke, 2003; Eom, Helwege and Huang, 2003). Academic studies assume that the model outputs are accurate, and while credit risk models are now common in banks

there has not been any empirical studies on what types of models are used in banks and, more importantly, how management actually use the output from these models in decision making. Research into the use of models is important as these models potentially have a significant impact on lending decisions in banks globally.

The surprising finding of this research is that despite the widespread use of models and the large amount of academic work on improvements to the models, the view of the participants in the banks researched is that while models add value to decision making, the models are imperfect and require significant human interaction in order to ensure that the outputs of the models are used correctly. The issues that were raised in this research have been linked to the quality of the available data that are used as inputs into the models, the assumptions that underlie the models mean that they may not work in certain circumstances, the fact that the models do not encapsulate all the information needed for a credit decision, that models use historic data that are backward-looking and do not operate correctly in times of high volatility, and that models do not take into account qualitative information needed to make the right decisions.

The research found that all the candidate banks used more than one type of model, and did not follow one particular model approach. Different types of model approaches were used depending on where a particular model was in its evolution, its lifecycle, how much data the model required, on the model's fit to the product set and on the results of validation that was performed on the model. Models took a lot of effort to implement, to calibrate and to fine tune to the particular portfolio of the bank. None of the model approaches were found to be implementable straight out of the box.

7.3.3 Expert judgement has a larger role to play within credit risk model use than formally recognised

Extensive evidence was uncovered regarding the moderation of model results based upon a number of judgemental factors, including gut feel, detailed knowledge of credit or transaction circumstances, information from the Front Office and market, known cyclical factors and strategic considerations. Bank B especially felt that the models are guidelines that only get you so far, and models were only one source of information. The participants stated that while model output was never ignored, the outputs could be treated with differing levels of credence based on strategy, experience, gut feel, perceived model accuracy and non-model

information (examples given were, considerations on the risk of damage to their reputation, information on a borrowing company's management changes and information on competitors and suppliers of a company in potential distress). It was felt that direct end-users of the models could always over-ride the model outputs so long as there was an effective managerial hierarchy to moderate the decision-making process, with strong controls in place.

How these models are used in decision-making is a complex process involving a high level of qualitative factors not found in the literature, as well as regulatory influences that impact capital usage. Qualitative factors also include interpretation of the model results against the individual's experiences, the use of collective wisdom, institutional memory, the view of external environmental factors, an understanding of the effects of a model's assumptions on its outputs; all have parts to play in the decision-making process. This research did not look into the weighting for qualitative and expert judgement factors and only provides evidence of the importance that the participants attached to these factors. Section 7.6 suggests the relative weightings of these factors as an area of future research.

7.3.4 Regulatory influence on the use of models is a double-edged sword

From the findings it is clear that regulatory pressures have been the main driver for the use of credit risk models in the banks researched. However it was also felt that while the regulators drove the development of models in their banks, the banks acknowledged that they have opportunity to take it to new levels. This realisation of the opportunity to improve the models is dependent on the banks' own plans and strategy for model development and differed from bank to bank.

All the banks in this research felt that the regulator's part to play in model development was a very positive one on the whole, but they did refer to a few issues related to red tape on the need to jump through regulatory hoops, and a real danger of herd mentality if everyone used similar models. It was also pointed out that if the regulatory capital diverged too much from what the banks themselves calculated as economic capital, this would increase costs unnecessarily and provoke regulatory arbitrage (where banks would look at ways to minimise regulatory capital, and models would be developed based on optimising regulatory capital savings rather than for the purposes of prudent risk management). This distortion of the necessary alignment between business decision-making and regulatory supervision could drive a wedge between regulatory reporting and business-decision-making.

The other area of regulation spoken about was that as part of Basel II there was a push for more sophistication in modelling. This point is covered in more detail in section 7.2.6.1 including showing where sophistication could bring negative results in lending practices, and it should be noted that most of the participants did not believe it expedient for either the bank or the regulator to use higher maths for regulatory purposes.

7.3.5 The weakness of link between the governance and model use in banks

A significant finding from the cross-case analysis was that model use was linked to the strategy. More specifically, from the banks researched, strategy, risk appetite, governance structure and organisational structure were all felt to be important factors for the successful implementation and use of credit risk models. This viewpoint from the interviews was reinforced by references made in the financial accounts of the banks researched, as well as in documentation relating to credit committee minutes and in their regulatory reporting.

While governance structure and organisational structure seemed to be well embedded in the organisations, strategy - especially as expressed in the form of risk appetite - appeared to not be taken fully into account in the development of the models, in the implementation of these models or in the decision-making process except where qualitative judgements were used by individuals to account for the risk appetite.

Two factors were found to be at work here. First, there seemed to be a lack of clarity around the definition of risk appetite and, second, there did not seem to be a mechanism for the use of credit risk models as a tool for understanding, interpreting, exposing and measurement of exposures against the risk appetite (the exception to this was where the risk appetite was expressed as a regulatory capital target).

The next section of this thesis, 7.4, looks at how the risk appetite framework could be extended to factor the findings of this research on risk models.

7.4 Incorporating the findings of this research into a risk appetite framework

One of the key findings of this research, as shown in section 7.2.1.2, was the importance of ensuring there is a clear understanding of the risk appetite across a bank, as well as the disclosure of the risk appetite to the market. Section 2.7 of the literature review showed that there was support found for this in the literature as shown in FSA (2006), Walker Report (2009) and Institute of Risk Management (2011).

Existing risk appetite frameworks do not fully take into account the use of credit risk models and this section of the thesis incorporates some of the findings of this research to extend the Institute of Risk Management framework (based on British Standards Institute's BS3110). The goal is to add to the body of knowledge on risk appetite as well as provide a practical way for risk departments to ensure that their use of credit risk models is aligned to the risk appetite of the bank.

The following section uses BS3110 paragraph numbers a guide and the original British Standards Institute's text in italics (taken from Institute of Risk Management, 2011)

Paragraph 3.1 *The risk management framework should have defined parameters around the level of risk that is acceptable to the organisation, and thresholds which trigger escalation, review and approval by an authorised person/body.*

Bank A had the clearest description of their risk appetite and of their parameters. The use of specific parameters will vary from bank to bank depending on their strategy and monitoring capabilities. As an example the following are a range of parameters that are found in the researched banks and in the literature:

- Maintenance of a target credit rating for the bank (or bank's own credit spreads)
- Acceptance of a certain level of earnings volatility
- Maintenance of a level of capital adequacy (as measured by Bank A's regulatory calculations)
- Maintenance of a level of capital adequacy as measured by the ratio of available financial resources to economic capital consumption (broken down by risk type, product, sector and geography)
- Maintenance of liquidity ratios and survival horizons

- Maintenance of VaR limits and risk sensitivity limits
- Maintenance of risk concentrations by internal and/or external credit ratings
- Maintenance of asset growth ceilings by business line or exposure type
- Monitoring of performance of internal audit ratings
- Monitoring of value based measures (based on probability of ruin or default and including share price target)
- Maintenance of post-stress-test targets for capital, liquidity, and earnings
- Monitoring of qualitative statements and measures (e.g. growth of certain home markets, ethical stances, reputational risk, zero tolerance for regulatory breaches)

Paragraph 3.3.2 *Content of the risk management policy has explicit reference to risk appetite saying that this should be included in the policy and should outline the organisation's risk appetite, thresholds and escalation procedures.*

As an example Bank C uses its Risk Committee to address matters of risk governance, maintaining risk policies and the setting of the risk appetite for the bank. The risk committee is a key part of the governance structure that the banks use to escalate issues.

In addition to policy updates mentioned in Paragraph 3.3.2, this research recommends that the risk appetite should also be incorporated into the risk methodology documentation for the bank. Risk methodology documentation defines the risks calculations. By incorporating the risk appetite into risk methodology documentation, it will allow the respective model teams to take into account risk appetite factors in model development, model implementation and model validation.

Paragraph 3.8 (i) *Considering and setting a risk appetite enables an organisation to increase its rewards by optimizing risk taking and accepting calculated risks within an appropriate level of authority.*

This research holds that qualitative factors should also be incorporated into the terms of reference of the relevant committees, along with explicit recognition of non-model information including the role that experience and gut fee may play in a decision that is aligned to the risk appetite, hence optimising decisions made in respect to risk.

Paragraph 3.8 (ii) *The organisation's risk appetite should be established and/or approved by the board (or equivalent) and effectively communicated throughout the organisation.*

The results of this research provided a different view to the top-down versus bottom-up debate found in the risk appetite literature in section 2.7.1.1, where a top-down approach appeared to be preferred. The participants believed that both a top-down "and" a bottom-up approach should be used. Strategy should come from the board but feedback should be received from the different units of the bank (bottom) on the viability of the strategy, ability to monitor the appetite and the ability to take correcting action in the event of a breach. Bank C for example had integrated its risk management team into the annual strategic planning process and it helped define the bank's risk appetite for the coming year. The process should include qualitative and quantitative assessment by the business units of the risks involved in the plans. Involving the business units in the plans allows buy-in from these business units. Also, at each level, strategies and metrics can be identified to measure success in achieving objectives and to assure adherence to the strategic plan. In Bank C, based on the business unit and line of business plans, the Executive Board then formulates Bank C's actual strategic plan and risk appetite which is submitted to the Supervisory Board for approval. The Supervisory Board has the opportunity to incorporate other stakeholder views that may not have been considered (e.g. the bank's customers or regulators)

Paragraph 3.8 (iii) *The organisation should prepare a risk appetite statement, which may consider the context of the organisation's understanding of value, cost-effectiveness of management, rigour of controls and assurance process*

To provide some further insight into considering the context of the organisation the following quotation during the interview on risk appetite from Bank A provides a good example on how they look at risk appetite from the organisational context, *"...and obviously in articulating a risk appetite for the bank, you've got to take into account both the financial risk side and the non-financial risk side and be able to demonstrate first of all you have sufficient capital to cover any down-side on the financial risk, but also that you understand how the non-financial risk may impact the viability of your franchise and your ability to meet your non-financial objectives and have the appropriate mitigants around that" (Code CRO A12)*

Paragraph 3.8 (iv) *Define the control, permissions and sanctions environment, including the delegation of authority in relation to approving the organisation's risk acceptance,*

***highlighting** of escalation points, and identifying the escalation process for risk outside the acceptance criteria, capability or capacity.*

The banks in the research had strong governance structures and sections 4.3.1, 5.3.1, 6.3.1 and 7.2.1.3 provide examples on how authority was delegated, how things were escalated and the high-level processes which handled exceptions. To add to the points made previously and to also extend them, Bank C mentioned that as part of the actions taken based on its internal risk reporting, there were also a number of upgrades to their methodologies as part of the correcting mechanism (the example they gave was in new efforts to implement stress testing). Stress testing was also introduced as part of the planning purposes. As a result of Bank C's actions, the economic capital model for credit risk was being updated to bring it more in line with the regulatory capital framework and importantly the risk appetite framework was revised as well and better aligned with the capital management targets for the capital ratios.

***Paragraph 3.8** (vi) Include quantitative statements, described as limits, thresholds or key risk indicators, which set out how certain risks and their rewards are to be judged and/or how the aggregate consequences of risks are to be assessed and monitored.*

The researcher believes there should also be qualitative statements describing non-model information that may be relevant for monitoring and decision-making purposes. Also, to provide insight on how qualitative statements on risk appetite can steer decisions, the following was mentioned in the research *"the bank's portfolio committee steers the portfolio in the direction they want it to go and that might be putting on more risk in total, it might be having less risk in total, it might be having more or less in particular sectors or particular countries, but it's generally around managing concentrations and managing the overall direction and whether we want to take more or less risk. That does actually map into our overall risk appetite statement to the bank so, you know, there is a sort of constraint on the internal number but it's actually the analysis and then the trend is the other big thing. So the way these things are moving and what is causing them to move are the things that we look at. But as an organisation with various committees, yeah, we believe very strongly in that. I mean particularly in emerging markets and some of the places where we do business, you know, knowing the client and having a good relationship with the client is essential in (1) making the right decisions and (2), you know, taking mitigating action when things start to go wrong." (Code HCPM-A4)*

***Paragraph** 3.8 (vii) The risk appetite should be monitored by the Board (or equivalent) and formally reviewed as part of the organisation's strategy and planning process. This should consider whether the organisation's risk appetite remains appropriate to deliver the organisation's objectives in light of internal and external drivers and constraints.*

Once a year seemed to be the norm for setting the risk appetite although it is important to point out that Bank C felt that in periods of volatility, the risk appetite may actually need to change more frequently.

Finally, as part of improvements to risk appetite, this research believes that banks should explicitly reveal their risk appetite via annual accounts and via Pillar 2 disclosures for Basel II. As discussed in section 7.2.1.2, the reason that not all banks reveal their risk appetite may be due to the fact that they may feel they could lose competitive advantage by disclosing their risk appetite (and by implication part of their strategy) to their competition. However if the competition was also to reveal their risk appetite, it would mean a level playing field. By encouraging and compelling banks to reveal their risk appetite it would force banks to improve their internal and external risk appetite governance processes. This would allow transparency to the bank's shareholders, bondholders, regulators and customers of the bank's risk appetite (and the controls that are in place).

7.5 Contribution of the thesis

This research provides a contribution to the academic understanding of the use of credit risk models not found in any of the studies to date. These findings are significant as they open up commonly-hidden processes on how these models are used in practice and why these processes are used. This research is believed to be the first study of risk models that has used only qualitative techniques, and the research's perspective on the use of models as a social construction is a new addition to the academic domain. The research findings show the merits in examining the social, organisational and cultural constructions as well as the role of individuals in this process. This evidences the usefulness of interpretive research, which thrives on diversity of meanings as opposed to attempting to generalise based on mathematics, as commonly found in the credit risk modelling literature (much without observations and empirical evidence to support them).

As well as offering new insights, section 7.4 of this thesis extends existing frameworks for risk appetite to cover model development, model implementation and model use. This is done by incorporating the findings of this research into existing knowledge on risk appetite.

The research informs academic discussion on three levels, first as an insight on how banks use these models in reality, second in the recognition of the qualitative factors that are key parts of their decision-making process and finally in the extension of the risk appetite frameworks to include the findings of this thesis. The research opens up new areas of study and the next section, 7.6, suggests areas for further research.

7.6 Limitations of this research and future research

The research is based on three case studies, and while the research uses analytical generalisation (Yin, 1989 p. 38) to help improve understanding of the use of these models not found in other studies to date, the research does not attempt to generalise the findings across the universe of all banks. This research is the first research that looked at the use of qualitative factors in credit risk modelling. It opens up new areas of research and the use of models should be a fertile field where new research could add a lot to the understanding of models and improvements to the models. All the participants acknowledged the need for, and importance of, expert judgement and non-model-based data but there seemed to be some lack of agreement on whether the model was to be regarded as just one of several equally-weighted inputs to a decision-making process or whether the quantitative models were to be seen as the decision-guides, against which, in certain circumstances, exceptions would be permitted. This study provides evidence of the importance that the participants attached to qualitative factors but does not cover the exact weighting for qualitative factors to the decision-making process. The relative weighting of the quantitative outputs and weightings for the different qualitative factors merit further research.

One of the areas touched on in this thesis is resistance to the use of the models' outputs and the potential link to the experience of older and younger members of staff. It is not an area that the research provides any conclusive evidence on, and merits further research.

Risk appetite is also an area where research is needed into how organisations can go about translating higher-level qualitative and quantitative expressions of their risk appetite into

specific and measurable quantities, as well as on the effective communication of the risk appetite, both within organisations (to its departments and employees) and externally to shareholders, bondholders, regulators and customers. Frameworks for stress testing of the risk appetite are another area for future research.

7.7 Practitioner relevance and implication of research on banks

An element of the doctorate of business administration is contribution to practitioner use and this section of the thesis covers the research contribution to banks as well as to the regulators. The research may also assist other financial institutions that use risk models such as the insurance industry where there is greater use of risk models as part of the Solvency II regulations (Solvency II is the insurance industry's version of Basel II)

7.7.1 Implications for the banks

For risk departments, this research helps provide new insight into the use of qualitative data and expert judgement and the links to risk appetite; the participants' views of model sophistication would be useful to developers working on the design of models, banks that are looking to implement these models or that are reviewing their decision-making process based around model output.

The research also guides smaller banks that are looking to implement credit risk models on the importance of understanding the data needed for the models, the models' assumptions and the models' limitations; the choice of time slice in model data (the different results depending on use of a 'point of time' or 'through the cycle' view, as well as the differences in trading view, shareholders' view and rating agency view); and the importance of ensuring models and processes are in line with the bank's risk appetite.

This research also provides extensions to the risk appetite frameworks that should be of benefit in model development and use. The recommendations on risk appetite may also benefit governance structures by helping to better align the use of risk models to the strategy in the bank.

7.7.2 Implications for Regulators

This research should allow regulators to better understand how credit risk models are used in the banks and some of the challenges in risk modelling. This should also allow the regulators to better monitor and design the regulations for the use of credit risk models. An interesting challenge for regulators may be in how to incorporate qualitative information into regulatory reporting.

The views on future models from this research should also guide regulators on the banks' views on complexity in modelling as well as potential conflicts of regulatory capital versus the banks' own calculations and strategy. As evidenced by this research, regulators have a significant influence on model development and a large impact on the banks' lending decisions.

8 References

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9 Appendix A – Approach used to build the cross case analysis graphs

This appendix provides an example of how data in the research was coded. As described in Section 3.8, analysis was done on the transcripts to find the emerging themes. These themes were based on the analysis of the interviews and informed by the research questions and literature. The relevant text was highlighted in the transcripts and was given a code. These codes were grouped to relevant themes using Microsoft Excel as the tool to capture the information and link the themes back to the original text. Theme names were used were used to uniquely identify the themes (e.g. "Experience and use of models" was the code used to identify this theme). A link is maintained from the theme to the page and line number in the candidate's original transcript. An example showing the list of themes in Bank A is as follows:

Theme	Chief Risk Officer (CRO-A)	Head of Regulatory Capital and Portfolio Management (HCPM-	Head of Credit Risk (HCRI-A)	Global Head of Credit Analytics (HCA-A)	Head of Credit Analytics and Portfolio Management (CAPR-A)
What models are in use and where are they used					
Model type/underlying school/preference		HCPM-A1		HCA-A1	
None for different models	CRO-A1, CRO-A22			HCA-A2	CAPR-A1
Where models in an organisation	CRO-A3		HCRI-A1		
How models are used					
Experience and use of models	CRO-A6, CRO-A8, CRO-A11, CRO-A16, CRO-A17	HCPM-A5, HCPM-A8, HCPM-A10, HCPM-A14, HCPM-A15	HCRI-A2, HCRI-A3, HCRI-A9, HCRI-A12, HCRI-A16, HCRI-A21	HCA-A6, HCA-A14	
How models information brigade the decision	CRO-A9, CRO-A12	HCPM-A6	HCRI-A5, HCRI-A6	HCA-A13	CAPR-A4
"Gut feel"	CRO-A5	HCPM-A19	HCRI-A8, HCRI-A10	HCA-A12	CAPR-A2
Generator of "gut feel"	CRO-A10		HCRI-A11		CAPR-A3
Link to good credit management and where models fit	CRO-A2		HCRI-A13, HCRI-A14, HCRI-A15	HCA-A19	
Management setting guidelines on use of model output		HCPM-A4, HCPM-A7		HCA-A7, HCA-A8	
Ignoring Model Output			HCRI-A19	HCA-A20, HCA-A21	
Overriding the model				HCA-A5	CAPR-A9
Management Queries				HCA-A16	
Strategic View and Model Output within decision making				HCA-A17	
Model improvements/issues					
Model improvements	CRO-A15		HCRI-A18, HCRI-A25	HCA-A23	CAPR-A21
Model issues	CRO-A4	HCPM-A9, HCPM-A11	HCRI-A7, HCRI-A3		CAPR-A6, CAPR-A10, CAPR-A12,
Understanding model assumptions			HCRI-A20		CAPR-A7, CAPR-A8, CAPR-A11, CAPR-A13, CAPR-A14
Model lack of data				HCA-A18	
Regulatory influences on models					
Regulatory drivers	CRO-A19			HCA-A25, HCA-A26	
Regulation and improvements		HCPM-A20		HCA-A4	CAPR-A19
Regulatory Capital versus Economic Capital	CRO-A21	HCPM-A2, HCPM-A3, HCPM-A16, HCPM-A17	HCRI-A23, HCRI-A24		
Regulatory Calculation issues	CRO-A13	HCPM-A13			CAPR-A15,CAPR-A16
Smaller themes raised in the case study					
Validation Process		HCPM-A18	HCRI-A22	HCA-A22	
Link Between From Office and Risk			HCRI-A26	HCA-A24	CAPR-A17, CAPR-A18
Models and risk of herd mentality		HCPM-A12, HCPM-A13	HCRI-A17		CAPR-A5
Stress Testing	CRO-A7			HCA-A28	
Concentration Risks			HCRI-A4	HCA-A3	
Governance				HCA-A15	
Early Warning systems				HCA-A9	
Fraud Events				HCA-A11	
CVA	CRO-A14				
Interdepartmental needs and resource constraints				HCA-A29	
Viewpoint on the future					
Sophistication of models		HCPM-A22		HCA-A27	CAPR-A20
Blurring in the edges between Credit Risk an Market Risk	CRO-A23		HCRI-A20		
Likely to be a more holistic view of risk		HCPM-A21			

Figure 12.1 The analysis of Bank A showing the themes that the participants that spoke about with codes allowing a link back to original text in the transcripts

There is a linked Excel worksheet which that shows the text relating to the theme as well as exactly where it appears on the relevant transcript. If we take CRO-A in Bank A as an example and drill down on what comments he made on "Need for different models", the excel file is used to store the relevant text as well as the page and line number from the transcript.

Theme	Chief Risk Officer (CRO-A)	Text	Where in Transcript
What models are in use and where are they used			
Model type/underlying school/preference			
Need for different models	CRO-A1, CRO-A22	From my perspective we don't have a specific choice. We've quite smart, quite a few models that are expert judgement models. My point is that whatever type of model we use, it has to go through a process of initial validation and then independent validation thereafter to confirm that the model is fit for purpose	p2 L9
		My preference [for economic capitan and regulatory capital purposes] is to use through the cycle because what you don't want is the volatility that point in time introduces into your capital numbers	p10 L6
		Both approaches [through the cycle and point in time] are valid. They just have different uses, but you need to have both views.	p10 L24

Figure 12.2 Data from the Excel sheet showing the link from the code back to original text

It is then possible to go to the transcripts to find the original quote. If we use CRO-A as an example, on page 10 of the transcript we see text related to the theme highlighted on line number 6 and line number 24.

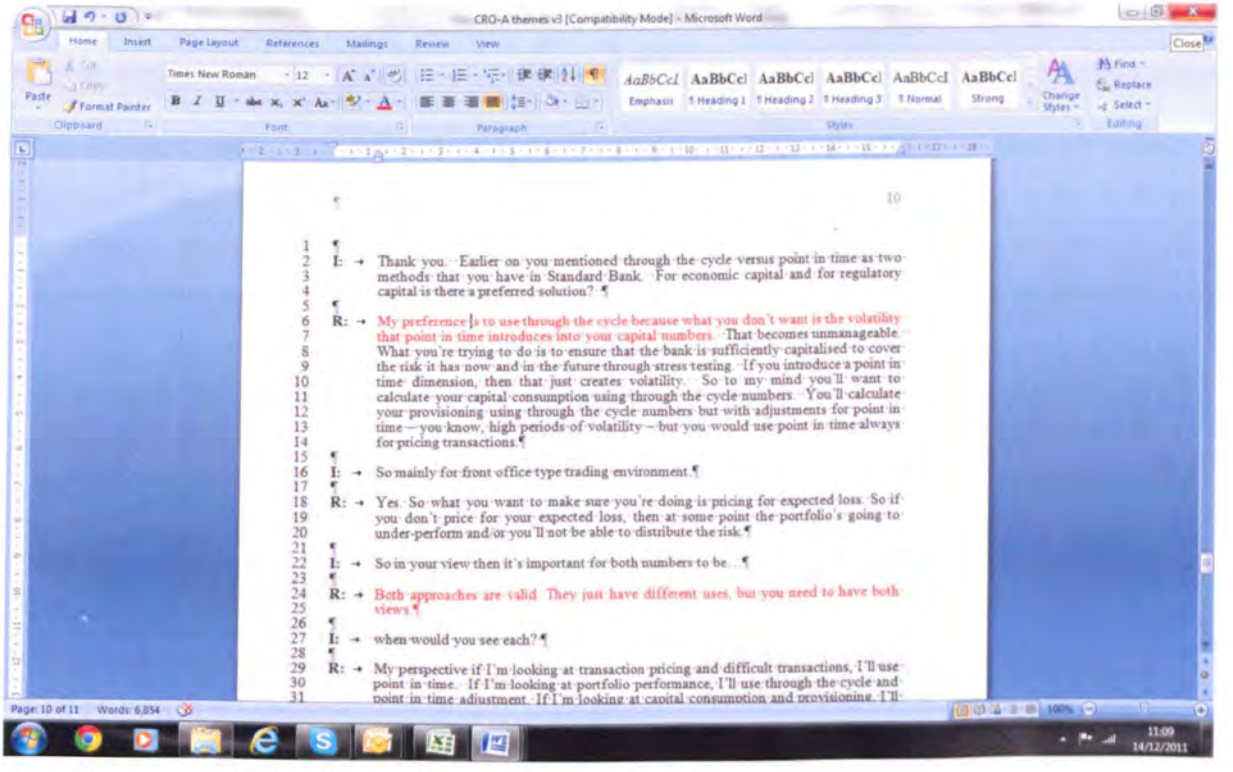


Figure 12.3 Screen showing the example from the original text

The coding allows there to be an easy and transparent link between the themes and the original text. The analysis and coding followed the recommendations of Yin (2003), Remenyi (2000) and Charmaz (1995) as described in greater detail in section 3.8 of the thesis.

10 Appendix B – Approach used to build the cross case analysis graphs

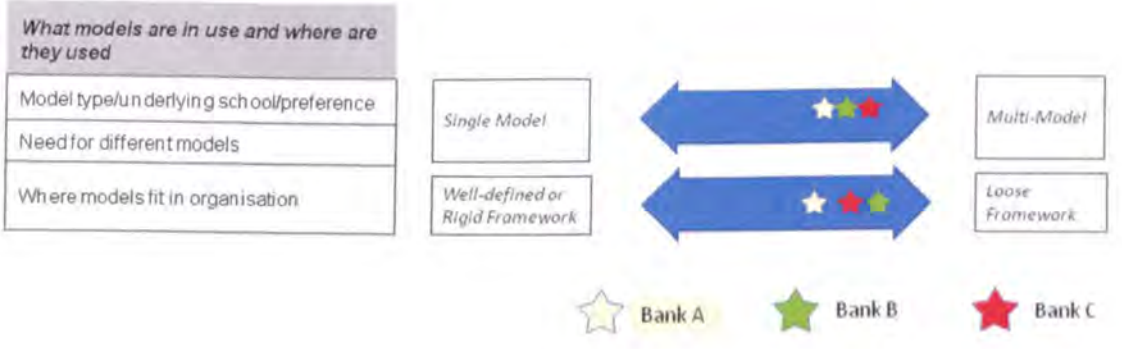
This appendix provides more detail as to the methodology for the cross-case analysis in Chapter 4 of this thesis. In particular, it describes the rationale behind some of the graphics in this chapter.

In adopting the Case Study approach to this research, it was necessary to facilitate the formal interview sessions with a high-level structured and topic-based questionnaire that led the participants through a number of pertinent areas for discussion. The questionnaire was used by the interviewer as a framework from which he could explore a number of different themes.

The participants, depending on their job function, seniority and perception of the subject matter were able to respond more fully to some topic areas than others. However, since a broad sample covering function and seniority was available for each organisation, the research was able to highlight a number of areas where more opinion and comment was offered. Each of the major themes yielded a satisfactory level of responses although some sub-themes were more popular than others. Those sub-themes which yielded a total of more than six comments or responses across all participants were subject to comparative analysis between Banks A, B and C.

The graphical representations of the cross-case comparisons are intended to indicate the relative position of each of the banks within the case study for the given sub-themes. This is based on the researcher's review of the comments made by participants within the banks. It is necessarily partially subjective but is intended to remain faithful to what was said by the participants in the interviews.

For example, the graphic below is taken from the section dealing with the Cross Case Analysis of Use of Models in Chapter 4.



The use of models was still being formulated in all three banks, and none of the three banks had an all-encompassing, rigid, fully-defined framework for model development nor had clear processes that prescribed a list of actions to be taken based on model output. Instead, most of the banks operated along much more flexible frameworks. Bank A had the most structured approach with Bank C having a fairly flexible framework, as they were still in the process of deciding and implementing their models.

Moreover, the interviews suggested that the review and decision-making framework was more comprehensive within Bank A than the others.

The above graphic is therefore intended to summarise in broad terms what was said by the participants of each bank regarding the particular sub-theme.