INTEGRATING ENVIRONMENTAL RISK INTO BANK CREDIT PROCESSES: A SOUTH AFRICAN BANKING CONTEXT

by

Alfred Bimha

submitted in accordance with the requirements

for the degree of

DOCTOR OF PHILOSOPHY

in the subject

MANAGEMENT STUDIES

at the

UNIVERSITY OF SOUTH AFRICA

Supervisor: Prof Johan Marx

September 2020

DECLARATION

Name: Alfred Bimha

Student Number: 49095986

Degree: Doctor of Philosophy in Management Studies (Financial Management)

Integrating environmental risk into bank credit processes: a South African banking context

I declare that the above thesis is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I submitted the thesis to originality checking software and that it falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at Unisa for another qualification or at any other higher education institution.

30 September 2020

Mr A Bimha Date

ACKNOWLEDGEMENTS

Firstly, I would like to thank God for being omniscient and empowering me with the wisdom to complete this thesis. Glory and honour to His Name.

My special thanks go to my promoter, Professor Johan Marx, for continuous support, valuable guidance and comments throughout the dissertation-writing process.

I am thankful to Professor Godwell Nhamo for introducing me to the field of Environmental Finance and holding my hand in research writing. I am also grateful for his invaluable contribution and advice in tackling this thesis.

I am also grateful to Professor Joseph Chisasa, Professor Athenia Sibindi, Professor Ashley Mutezo and Professor Godfrey Marozva. To Professor Godfrey Marozva, thank you for proofreading my thesis and contributing to the conceptualisation and thinking.

I am also grateful and indebted to colleague and friend, Dr Tapiwa Muzata, for walking with me and motivating every tiny issue that was bothering me during the thesis writing. Thank you for helping me put my ideas across. Not forgetting the family fellowship – Dr Tapiwa, Tapera Gilbert, Thandi Muzata, Barbara Muzata, Sipho Guvi and Victoria Guvi – thank you for the prayers and the encouragement.

A special mention goes to my wife, Pamela, and my children, Azriela, Amanda and Alfreda, my siblings, and the whole clan at large - The House of Aaron. Thank you all for your prayers, your motivation, your support and your patience with me in this time of writing the thesis.

To my mother, Sukoluhle (MaNkala), may God richly bless you for sacrificing your all to ensure I get to this point. The informal education tutoring you did since I was young has finally paid off. This dissertation is dedicated to the memory of my father, Pastor Amon Nhamoinesu Bimha. It would have been a delight for him to see this day in which the seed he planted has become a big tree.

.

ABSTRACT

The impact of climate change on the financial performance of companies is of concern to bank credit processes. The main objective of this research was to develop a South African contextualised credit process that incorporates environmental risk. The research methodology comprised of a mixed-method being content analysis – the qualitative portion and the Probability of Default prediction using a Merton Model and the Hoffmann and Busch (2008) carbon risk analysis model - the quantitative portion.

A content analysis of the banks' Annual Reports, Integrated Reports and Sustainability Reports showed that, while South African banks follow a qualitative approach to embedding environmental risk into their credit process, none of the four banks that formed part of the study divulged their quantitative approach to embedding environmental risk. The study used a proximity matrix method to examine the level of embedding.

The second part of the study, which used prior studies as the benchmark, adopted the following: (1) a simulated carbon tax regime as a proxy for an environmental risk, and (2) the Hoffmann and Busch (2008) carbon risk analysis tool and the Merton Model (1974) as the bank credit process proxies. The second part of the study used a sample of 33 JSE-listed Carbon Disclosure Project reporting companies out of a population of 107.

The carbon risk analysis showed that the companies in the materials and energy sector have a high carbon risk. However, the results from the Merton Model showed that the companies have enough profit to cushion the additional carbon tax liability, given the insignificant shift in probability of default between the three scenarios, where financial data had (1) no carbon tax, (2) was adjusted for a carbon tax with incentives, and (3) adjusted for carbon tax without incentives.

Triangulation of the results from the content analysis, carbon risk analysis and the probability of default analysis confirms that South African banks do not fully integrate environmental risk across the credit value chain or process in the 2010 to 2017 period. However, the carbon risk analysis shows a heavy dependency on carbon sources for critical inputs into the South African companies' production processes, which if not checked, will affect the credit portfolios of banks.

Keywords: environmental risk, climate change, carbon risk analysis, credit process, lending process, carbon tax, climate change risk, probability of default, credit rating, Merton Model, environmental liability, financed emissions.

TABLE OF CONTENTS

DECLARATION i

ACKNOWLEDGEMENTS ii

ABSTRACT iii

TABLE OF CONTENTS v

LIST OF FIGURES viii

LIST OF TABLES ix

LIST OF ABBREVIATIONS AND ACRONYMS x

CHAPTER 1: INTRODUCTION 1

1.1 BACKGROUND TO THE STUDY 1

1.2 CLIMATE CHANGE AND THE BANKING SECTOR 5

1.3 CLIMATE CHANGE ISSUES IN THE SOUTH AFRICAN BANKING SECTOR 6

1.4 RESEARCH PROBLEM/CONTEXT 7

1.5 RESEARCH QUESTIONS 8

1.6 RESEARCH OBJECTIVES 9

1.6.1 Primary research objective 9

1.6.2 Secondary research objectives 9

1.7 METHODOLOGY AND METHODS 9

1.8 SCOPE AND LIMITATIONS 11

1.8.1 Scope 11

1.8.2 Limitations 12

1.9 ASSUMPTIONS 12

1.10 JUSTIFICATION OF THE STUDY 13

1.11 STRUCTURE OF THE THESIS 15

CHAPTER 2: FINANCIAL INTERMEDIATION, BANK CREDIT PROCESSES & ENVIRONMENTAL RISK 18

2.1 INTRODUCTION 18

2.2 THE CONCEPT OF ENVIRONMENTAL RISK 18

2.2.1 General perspective on environmental risk 18

2.2.2 Defining environmental risk in the bank lending context 21

2.2.3 Defining environmental risk from a business perspective 23

2.2.4 The relationship between environmental risk, climate risk and carbon risk 26

2.3 EFFECT OF CLIMATE CHANGE IMPACT ON FINANCIAL INTERMEDIATION THEORIES 35

2.3.1 Functions of financial intermediaries 36

2.3.2 The Arrow-Debreu theory 37

2.3.3 Modern financial intermediation theory 40

2.4 BANK CREDIT PROCESSES AND INCORPORATION OF ENVIRONMENTAL RISK 41

2.4.1 Theoretical perspective on bank credit processes ... 41
2.4.2 Environmental risk and bank lending ... 46
2.5 SUMMARY ... 57
CHAPTER 3: EMBEDDING OF ENVIRONMENTAL RISK IN CREDIT RISK MANAGEMENT ... 61
3.1 INTRODUCTION ... 61
3.2 INTERNATIONAL PERSPECTIVES- EMPIRICAL STUDIES ... 61
3.3 FINANCED EMISSIONS ... 76
3.3.1 Review of the methodologies ... 77
3.4 SOUTH AFRICAN PERSPECTIVES ... 79
3.4.1 Carbon tax: proposed policy for climate change mitigation ... 82
3.4.2 South African financial sector and environmental risk ... 83
3.5 FINANCIAL PREDICTION MODELS THAT INCORPORATE ENVIRONMENTAL RISKS ... 85
3.6 BRIEF OVERVIEW OF EMBEDDING METHODS AND MODELS ... 95
3.6.1 Dimensions of embedding ... 95
3.6.2 Locating the embedding level ... 102
3.6.3 Financed emissions ... 103
3.6.4 Carbon risk analysis ... 106
3.6.5 Environmental stress analysis ... 108
3.7 SUMMARY ... 114
CHAPTER 4: RESEARCH METHODOLOGY ... 116
4.1 INTRODUCTION ... 116
4.2 METHODOLOGICAL FRAMEWORK FOR THIS STUDY ... 116
4.3 RESEARCH DESIGN ... 118
4.4 DATA, POPULATION AND SAMPLE ... 120
4.5 CONTENT ANALYSIS METHODOLOGY ... 122
4.5.1 Validity, reliability and credibility of data from sustainability and integrated reports ... 123
4.5.2 Content analysis procedures ... 124
4.5.3 A methodological review of the proximity matrix analysis ... 128
4.6 CREDIT RATING METHODOLOGY PROCESS ... 132
4.6.1 Carbon tax policy framework ... 133
4.6.2 Adjusting equity and liability values for carbon tax ... 136
4.6.3 Accounting for carbon credit or offsets ... 137
4.6.4 Credit rating model ... 138
4.6.5 The Merton Model construct ... 139
4.6.6 The iterative approach ... 142
4.6.7 Using equity values and equity volatilities ... 144
4.7 SUMMARY ... 145

CHAPTER 5: DATA ANALYSIS AND DISCUSSION 146
5.1 INTRODUCTION 146
5.2 QUALITATIVE STUDY: CONTENT ANALYSIS RESULTS 146
5.3 QUANTITATIVE METHODS: CARBON RISK ANALYSIS AND PROBABILITY OF DEFAULT RESULTS 154
5.4 TRIANGULATION OF RESULTS 173
5.5 SUMMARY 177
CHAPTER 6: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS 179
6.1 INTRODUCTION 179
6.2 SYNTHESIS OF LITERATURE REVIEW 179
6.3 RESEARCH METHODOLOGY 183
6.4 RESEARCH FINDINGS 184
6.5 IMPLICATIONS AND CONTRIBUTIONS OF THE RESEARCH 187
6.6 THEORETICAL AND PRACTICAL CONTRIBUTIONS OF THE RESEARCH 189
6.7 PROPOSED ENVIRONMENTAL CREDIT-RISK PROCESS FRAMEWORK 190
6.8 LIMITATIONS OF THIS STUDY 192
6.9 FUTURE RESEARCH 194
6.10 SUMMARY 195
LIST OF REFERENCES 197
APPENDIX A: ETHICAL CLEARANCE CERTIFICATE 213
APPENDIX B: PROXIMITY MATRICE RESULTS 215
APPENDIX C: CARBON TAX AMOUNTS DERIVED FROM A SIMULATION OF THE CARBON TAX INCENTIVE REGIME 223
APPENDIX D: CARBON TAX CALCULATION FRAMEWORK AS PER CARBON TAX ACT 225
APPENDIX E: CARBON RISK ANALYSIS RESULTS 227
APPENDIX F: PROBABILITY OF DEFAULT VALUES PER COMPANY & PER SECTOR (2010 TO 2017) 244
APPENDIX G: DECLARATION OF PROFESSIONAL EDIT 248

LIST OF FIGURES

Figure 1.1: Mixed methods: Exploratory sequential methods 10
Figure 2.1: Components of environmental risk 19
Figure 2.2: Definition of risk in relation to natural hazard.. 21
Figure 2.3: Climate risk from a Portfolio Theory-View 30
Figure 2.4: Illustration of Operator carbon risk and Carbon asset risk 33
Figure 2.5: Lending decision-making structure incorporating environmental risk.............. 50
Figure 2.6: Redefining and contextualising environmental risk – broader view................. 57
Figure 3.1: Categorisation of environmental risk tools.. 96
Figure 3.2: Levels of embedding environmental risk into bank processes 102
Figure 3.3: ICBC Stress-testing Model.. 113
Figure 4.1: High-level summary of the research methodology....................................... 116
Figure 4.2: Schematic view of methodological framework 118
Figure 4.3: Synopsis of data required for the embedding model 122
Figure 4.4: Conventional wisdom on the choice of proximity measures 130
Figure 4.5: Credit rating methodology process... 133
Figure 4.6: Carbon tax calculation flow 136
Figure 5.1: Banks content analysis results plotted on radar charts (2010 to 2017)......... 148
Figure 5.2: Comparison of levels of embedding between ABSA, FNB, Nedbank and SBSA 175
Figure 6.1: Environmental risk stress-testing model... 191

LIST OF TABLES

Table 2.1: Definition of sub-categories of climate risk 31
Table 2.2 Definition of carbon risk: Fulton and Weber view 32
Table 2.3: Definition of climate-related financial risks 35
Table 2.4: Checklist for evaluating the environmental credit risk management (ECRM) performance of banks 52
Table 3.1: The 10 Equator Principles 62
Table 3.2: Changes in the Equator Principles versions I, II and III 65
Table 3.3: Empirical studies on environmental performance and credit risk 69
Table 3.4: Examples of emissions pricing, regulatory and pricing scenarios used in financial risk assessment of climate risk 89
Table 3.5: Examples of individual asset analysis assessed by the GFSG in 2016 98
Table 3.6: Categories of disclosing climate progress by financial intermediaries 100
Table 3.7: Explanation of carbon performance metrics 106
Table 3.8: Summary of stress-testing models: International survey studies 109
Table 3.9: Summary of stress-testing models: International survey studies 110
Table 4.1: Comparison of the Jeucken Sustainable Banking Model and Kauefer Sustainable Banking Model 126
Table 4.2: Framework of categorising levels of embedding environmental risk 127
Table 4.3: Description of variables, codes and levels used in content analysis 128
Table 4.4: Payoffs for bondholder and equity holder 140
Table 5.1: Content analysis results of embedding environment risk by SA banks 147
Table 5.2: Environmental words against the embedding levels & EP number of deals ... 151
Table 5.3: Environmental credit words against the embedding levels & EP No. of deals 153
Table 5.4: Average carbon emissions per each JSE sector – (Ton CO_2e) 000s 156
Table 5.5: Average carbon tax amounts – R millions 158
Table 5.6: Combined analysis of carbon intensity: JSE CDP sample by sector 160
Table 5.7: Combined analysis of carbon dependency: JSE CDP sample by sector 163
Table 5.8: Combined analysis of carbon exposure of the JSE CDP sample by sector 167
Table 5.9: Combined analysis of carbon risk of the JSE CDP sample by sector 169
Table 5.10: Probability of default values per sector (2010 to 2017) 171
Table 6.1: Summary of research objectives, research questions and research findings . 185

LIST OF ABBREVIATIONS AND ACRONYMS

The following abbreviations are used throughout the study:

2^{o}ii	2 Degrees Investing Initiative
ABSA	Amalgamated Banks of South Africa
ADEME	French Environment and Energy Management Agency
ADFIAP	Association of Development Financing Institutions in Asia and the Pacific
AFD	French Development Bank (*Agence Française de Développement)*
AFOLU	Industrial Processes and Other Product Use
BIG	Business Innovation Group
BMZ	Federal Ministry for Economic Cooperation and Development (*Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung*)
CAMCO	Carbon Asset Management Company
CCS	Carbon Capture Storage
CDP	Carbon Disclosure Project
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CH_4	Methane
CO_2	Carbon Dioxide
CRE	Commercial Real Estate
CSR	Corporate Social Responsibility
DCF	Discount Cash Flow
DNB	De Nederlandsche Bank
DTIC	Department of Trade, Industry and Competition
EBA	Environmental Banking Association
ECRM	Environmental Credit Risk Management
EEIO	Environmentally Extended Input-Output model

EP	Equator Principles
EPA	Environmental Protection Agency
EPFI	Environmental Principle Financial Institution
ERA	Environmental Risk Analysis
ESG	Environmental, Social and Governance
ETS	Emissions Trading System
FEBRABAN	Brazilian Federation of Banks
FI	Financial Intermediation
FNB	First National Bank
FRAT	Financial Risk Assessment Tools
G20 GFSG	Group of 20 Nations - Green Finance Study Group
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GIZ	*Deutsche Gesellschaft für Internationale Zusammenarbeit* (German Development Agency)
ICBC	Industrial and Commercial Bank of China
IEA	International Energy Agency
IPCC	International Panel on Climate Change
IPPU	Agriculture Forestry and Other Land Use
JSE	Johannesburg Stock Exchange
KLD	Kinder, Lydenburg and Domini Research and Analytics
N_2O	Nitrogen
NIPF	National Industry Policy Framework
OECD	Organisation for Economic Cooperation and Development
PAGE	Policy Analysis of the Greenhouse Effect
PCAF	Platform Carbon Accounting Financials
PD	Probability of Default

PFC	Perfluorocarbons
POS	Point-of-sale
PRI	Principles for Responsible Investment
PRP	Potential Responsible Parties
RAN	Rainforest Action Network
REFIT	Renewable Energy Feed-in Tariff
S&P	Standards and Poor
SA	South Africa
SEC	Securities and Exchange Commission
SIC	Sector Industrial Codes
SME	Small Medium Enterprise
SRI	Sustainability Research Institute
SwissRe	Swiss Reinsurance Company Ltd
TCO_2e	tonnes carbon emissions equivalent
TIPS	Trade and Industrial Policy Strategies
TRI	Toxic Release Inventory
UBS	Union Bank of Switzerland
UNEP FI	United Nations Environment Programme Finance Initiative
US/USA	United States of America
VfU	Association for environmental management and sustainability in financial institutions
WEF	World Economic Forum
WIAGEM	World Integrated Assessment General Equilibrium Model

CHAPTER 1:
INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Two critical concepts underpin the study of climate-related risks in the financial sector. These are the transition to a low-carbon economy and the creation of a climate-change resilient economy (Huang, Punzi & Wu, 2019). These two concepts hinge on the financial sector's intermediary role between borrowers and depositors, which also involves risk amelioration (Herbohn, Gao & Clarkson, 2019). Climate-change risk, a subdivision of environmental risk, emanates from the sources of carbon that are mainly used to generate energy. For example, 74% of the electricity generated by South Africa emanates from coal that is one of the major sources of carbon emissions which cause climate change (International Energy Association, 2019). Furthermore, in terms of electricity consumption trends in South Africa, the industry sector is the most substantial, consuming 53% of the electricity generated, followed by the residential sector which consumes 24%. The commerce and public services sector is the third largest, consuming 18% of generated electricity.

If the industry sector electricity consumption is disaggregated, the following sub-sectors are found to be the largest consumers of electricity: (1) Mining and Quarrying (29%), Iron and Steel (18%), Non-Ferrous Metals (14%) and, Chemical and Petroleum (8%) (Department of Energy South Africa, 2018). These large electricity consumption percentages also translate into an immense contribution to the South African total carbon emissions (Carbon Disclosure Report, 2019).

According to StatsSA's Annual Financial Statements survey (2018), the largest electricity-consuming sectors discussed above make up 46% of the loans and advances from South African Banks. This situation suggests a severe threat by climate change to South Africa's financial stability (Nieto, 2019; Lamperti, Bosetti, Roventini & Tavoni, 2019). Therefore, it is important to arrive at a definition of climate change from the view of its threat to financial intermediation, which is central to the economic system and its sub-sectors discussed above.

The Stern Review Report (Stern, 2007) indicates that climate change is the result of greenhouse gas emissions that originate from economic activities such as energy, land-use, transportation, and industry. Although these economic activities are quite broad, the industrial sectors that primarily and extensively use fossil fuels in their production activities are the major emitters of carbon dioxide and other associated toxic gases, termed herewith collectively as greenhouse gases (GHG). The increase in GHG has impacted weather and climate patterns through the raising of temperatures globally, known as global warming. Global warming has led to extreme weather patterns that occur more frequently and that have a disastrous effect on reasonable livelihood through the occurrence of droughts, landslides, heatwaves, floods and hurricanes, amongst a host of intense weather patterns (Cox, Betts, Jones, Spall & Totterdell, 2000; Houghton *et al.*, 2001; Gore *et al.*, 2006). This leads to the question: How will climate change impose an induced risk to corporate sustainability that is critical to a company's financial health?

These three factors, namely, climate change, sustainability and risk management, are charting new frontiers for doing business, and are redefining business operations (ElAlfy & Weber, 2019). Sustainability is concerned with the imperative of doing business in a way that ensures that harmony exists between the economic, social, and environmental status of the society in which a company operates (Garcia, Mendes-Da-Silva & Orsato, 2019). Furthermore, sustainability pertains to behavioural change in terms of the way of doing business, that is, shifting from business practices that are harmful to people (social), the planet (ecological) and that do not yield adequate profits (economic), to those that harmoniously balance the three 'P's, namely, people, planet, and profits (Wilson & Post, 2013).

There are four distinct categories of corporate sustainability (Russell, Haigh & Griffiths, 2007). The first category is when a corporation, in the long term, wants to achieve economic performance (economic sustainability). The second category involves a corporation working towards positive outcomes for the natural environment (environmental sustainability). The third category refers to a corporation that supports people and social issues (social sustainability). The fourth category is related to a corporation with a holistic approach (total or corporate sustainability). According to Dyllick and Hockerts (2002), sustainability can be regarded as a panacea for climate-change effects. However, this has led to the need to re-examine the current risk management tools in the light of the imminent climate change-related risk.

The scholars, Turner, O'Riordan and Kemp (1991) acknowledge that the unfamiliar characteristics of climate change present serious difficulties for risk management. They further note that there are inadequate risk management techniques, and also a lack of risk professionals to deal with the peculiarities that climate change casts on risk management processes. A complicated climate-change system drives the climate change peculiarities related to risk management processes, and this is underpinned by unpredictable socio-political and economic forces. A further pressing issue that needs to be addressed is to establish the probability of the impact of the expected climate change, given the current evidence of the disruptive changes caused by unabated greenhouse gas emissions (Mabey, Gulledge, Finel & Silverthorne, 2011).

Kousky and Cooke (2009) concur with Turner *et al.* (1991) that climate change is altering the current risks. However, Kousky and Cooke (2009) observe that climate change is creating new risks that require proper conceptualisation, measurement and management. Therefore, there is a need to investigate the link between risk management and climate change.

In their efforts to connect risk management and climate change, Kunreuther, Heal, Allen, Edenhofer, Field and Yohe (2013) observed the failure of climate change impact studies to yield common ground on the distribution of its exposure, vulnerability or possible outcomes. Thus, Kunreuther *et al.* (2013) proposed a broader risk management approach to enhance the range of potential issues. The same thinking has prompted this study to advocate for the broadening of the bank's credit process to incorporate climate change-related risk. For their part, Goldstein, Turner, Gladstone and Hole (2019) examined 1 600 corporate adaption strategies and found significant gaps in the assessment of climate change impacts and the strategies that were developed to manage them. Such a finding is material to the banking sector that requires the elimination of any potential business failure that might render a corporate borrower unable to repay a loan. Therefore, it is important to determine how risk manifests itself in the form of climate change, or in other words, to find out how climate change risk emanates.

Risk is the product of physically defined hazards interacting with exposed systems, while taking into consideration the properties of the systems, such as their sensitivity or social vulnerability. Risk also can be considered as the combination of an event, its likelihood, and its consequences (Brooks, 2003; Füssel 2007)).

Climate risk equals the probability of a climate hazard multiplied by a given system's vulnerability. It emanates from variables in the climate and weather systems reaching levels that adversely affect human life. The International Panel on Climate Change (IPCC, 2012) defines the threats that emanate from climate change by measuring the impact of weather and climate events using three variables, namely, (1) nature and severity of event, (2) vulnerability, and (3) exposure. The question that needs to be asked is: How does this impact the formulation of a climate risk management framework?

Travis (2014) defines climate risk management as the process of incorporating knowledge and information about climate-related events, trends, forecasts and projections into decision-making to increase or maintain benefits, and reduce potential harm or losses. This definition clarifies the risk management framework required to tackle the issues that emanate from climate change for any area of exposure to climate risk. However, a further problem that needs clarification is how to determine the range and causes of uncertainty in the projections of future climate change. For example, Yohe (2010) mostly investigated the risk management of climate change at a policy level. Of interest from the study by Yohe is the notion of not being able to quantify all risks from climate change in monetary terms. Jones (2003) and Hillerbrand (2012) concur with Yohe with regards to not being able to quantify climate risk in numerical terms since there are a host of issues in climate change that are difficult to enumerate. This aspect poses a further complication to the management of climate risk.

This section has established four aspects. The first issue is the global phenomenon of climate change and its sources, mainly human anthropogenic activities that cause carbon emissions. The second issue is how climate change is related to the concept of financial intermediation. The touchpoint for climate change and financial intermediation is risk amelioration or management, for example, not embarking on banking transactions with a company that has a high climate change risk. The third point is involved with defining the risk arising from climate change that can affect financial institutions. It is conclusive that a company affected by climate change ceases to be economically efficient (profit-making), socially efficient (relevant to its stakeholders) and ecologically efficient (depleted resources essential to its operations). The fourth and last aspect pertains to the creation of a climate change risk management framework for the banking sector.

To continue with the last or fourth point, the next section provides an overview of how banks are currently dealing with climate change.

1.2 CLIMATE CHANGE AND THE BANKING SECTOR

The banking sector has not been the focus of studies on factors exacerbating the production of carbon emissions (Furrer, Hamprecht & Hoffmann, 2012; Diaz-Rainey, Robertson & Wilson, 2017). For now, banks are at the low end of causing climate change through anthropogenic activities, especially if compared to the carbon-intensive industries of mining, agriculture, transport and heavy manufacturing (Chenet, 2019). However, banking institutions could use their lending and investment products to facilitate change in countries that are high carbon emitters to encourage them to become low carbon emitters (Jeucken & Booma, 2001).

Bowman (2010) contextualises the relationship between the banking sector and climate change through three essential banking functions, which are risk assessment, financing and profiteering. Although Brimble, Stewart and De Zwaan (2010) agree with Bowman, they maintain that regulation will be essential to foster the role of financial institutions as key to combating climate change. However, uncertainties related to the global and national climate change regulations are stalling the banking institutions' effectiveness in that regard.

A considerable amount of scholarly work covers the role of banks in combating climate change (Doherty, 1997; McCarthy, Canziani, Leary, Dokken & White, 2001; Bouwer & Aerts, 2006). The literature mainly discusses emission trading systems, carbon markets (Hamilton, Sjardin, Shapiro & Marcello, 2009; Kossoy & Ambrossi, 2010; Yamin, 2005) and climate finance (Ballestoros, Nakhooda, Werksman & Hurlburt, 2010; Buchner *et al.,* 2011). However, less work has been done with regards to incorporating environmental risk into the lending decisions of banks, given the impact of this activity in funding projects that exacerbate climate change (Scholtens, 2017).

Climate change will transform the manner in which institutions operate, specifically due to physical risks, anticipated government regulations, changing market conditions, and new sources of competition (Lorenz, 2008). The biggest concerns have been expressed by environmental NGOs (such as Banktrack, Friends of the Earth, World Wide Fund, Rainforest Alliance) that have been at the forefront of criticising the banking sector's continued funding of environmentally damaging and high carbon-emitting projects. Therefore, it can be concluded that banks are mostly passive or mildly participative in initiatives to combat climate change.

The next section presents a brief discussion of the South Africa banking sector's involvement in initiatives to mitigate the impact of climate change.

1.3 CLIMATE CHANGE ISSUES IN THE SOUTH AFRICAN BANKING SECTOR

The South African National Industry Policy Framework (Department of Trade & Industry - Republic of South Africa, 2007) illustrates the crucial and multi-faceted intermediary role of the South African financial sector. The Carbon Asset Management Company (CAMCO) and Trade and Industrial Policy Strategies (TIPS) indicate that the South African financial sector is exposed to the secondary impacts of climate change (CAMCO & TIPS, 2010; Montmasson-Clair, 2012).

The most pertinent issues for this sector are reporting requirements, energy efficiency targets, and increased electricity prices through carbon pricing. The 2010 report by CAMCO and TIPS recommends compelling portfolio and project screening, and the embedding of climate factors within the risk management processes of financial institutions. The significant risks identified in the aforementioned report (CAMCO & TIPS, 2010) include regulatory risk and investor risk, as follows:

- Regulatory risk would mainly emanate from electricity emissions, carbon pricing, and the introduction of emission reduction limits, which would put the financial institutions at risk.
- Investor risk would emanate from current and anticipated investments projects, as well as project-related screening activities.

Thus, regulatory risk would drive the need to incorporate climate risk in the form of carbon-pricing implications on the risk management processes and project evaluation procedures of financial institutions.

In the National Climate Change Response White Paper (Republic of South Africa, 2010:45), the South African government articulates the role of the financial sector in providing risk management to mitigate the impacts of climate change through its operating activities in section 11.1.4.d, as follows:

> *"Identify opportunities in the existing financial regulations governing the domestic financial sector to enhance the financial sector's capacity to mainstream climate change in risk and investment decisions."*

Based on the above assertion, this research study investigates how banks can properly incorporate environmental risk, specifically in the form of climate (carbon) risk, into their lending decisions in light of the transition to low carbon economies. This should be seen against the background of the basic need to move to low or zero carbon-emission economies, while the dilemmas that simultaneously need to be faced are economic growth and job losses that might be affected by this transition (Foxon, 2011; Fuller, Portis & Kammen, 2009).

The damage caused by carbon emissions can be reduced or reversed by retrofit, adaptation, resilience, green jobs, green supply chains, green buildings, renewable energy, electric cars and numerous other green solutions (Fankhauser, 2010; Makower & Pike, 2009;). This leads to the question: How can all these aspects be modelled into the loan decision-making processes of banking institutions in South Africa?

1.4 RESEARCH PROBLEM/CONTEXT

The research problem stems mostly from the Carbon Disclosure Project (CDP) Report of 2008 (NBI, 2008), which identified the financial services sector's ability to disclose risks and opportunities through their available expertise at identifying, assessing and managing the risks to combat the effects of climate change. The report advocates the need for the financial services industry to integrate climate change risks and opportunities into their daily investment, lending, and contract decisions to achieve sustainable and efficient business operations.

The CDP report of 2013 (NBI, 2013) also acknowledged the need to develop accurate risk-pricing models to tackle climate as a significant challenge. In the same report it was asserted that the financial sector is affected by the overall economy and the wellbeing of its clients, both of which may be adversely affected by tightening regulations, climate change mitigation policies, and by increasing energy and materials costs.

Further, Hart (2007) confirms that there is no adequate common framework for systematically analysing climate risks in the financial services sector. Particularly notable in the CDP report of 2008 (NBI, 2008), was the acknowledgement by the financial services sector respondents that climate change has had an impact on the investment and loan portfolios. Credit risks and other financial exposures reside in a vast and complex domain which makes it difficult to evaluate them. Nevertheless, this begs the question: How far can that complexity be unravelled?

According to the current knowledge, there is no concrete framework that financial institutions can use to incorporate climate risk into the lending decision-making processes in South Africa. The only survey that has been done indicates that only three South African Banks include environmental criteria in their lending practice, and this is not applied across their products (Department of Environmental Affairs, 2011).

Currently, South African banks adhere to the reporting requirements offered by voluntary institutions such as the Carbon Disclosure Project, Equator Principles and Dow Jones Sustainability Index, amongst a host of climate change and corporate sustainability projects (Maubane, Prinsloo & van Rooyen, 2014; Clayton, Rogerson & Rampedi, 2015). There are guiding policies that banks have implemented to manage their operations with regards to climate change. However, there are no integrated and industry-wide accepted guidelines with regards to the incorporation of the risk that emanates from climate change into their overall risk framework and particularly credit risk assessment or policy (Hart, 2007).

The current situation in the South African financial sector that is characterised by a non-existent bank credit climate framework is attributed, in no small degree, to the lack of a national, coherent climate change policy, which is also slow in being developed. Therefore, this research will attempt to formulate a framework that can be used by banks in South Africa to incorporate environmental and climate risk in their lending decisions.

1.5 RESEARCH QUESTIONS

The following research questions were formulated for the current research study:

- What are the issues that emanate from the adverse conditions of climate change that are of concern to the banking sector?
- Why is environmental and climate risk of significance to the banking sector?
- What are the current trends in the South African banking sector related to climate change mitigation in their lending or credit processes?
- How should environmental and climate risk be incorporated into the credit appraisal models of banks, given economic sectors, government policy on climate change, financial sector regulation and international standards on environmental and climate risk management?

1.6 RESEARCH OBJECTIVES

The following primary research objective and secondary research objectives were formulated for the current research study.

1.6.1 Primary research objective

The primary research objective of the current study is: To formulate a credit appraisal model that incorporates environmental and climate risk for South African banks.

1.6.2 Secondary research objectives

The secondary research objectives of the study are:

- To establish theoretical concepts related to environmental risk and climate risk in bank lending.
- To investigate the state of environmental and climate risk incorporation by banks into their lending decisions.
- To investigate the overall engagement of banks in South Africa with regards to mitigating climate change risks through lending.

1.7 METHODOLOGY AND METHODS

Through determination, empirical observation, measurement and theory verification, the research approach adopted the pragmatism paradigm world view. This paradigm was adopted, given that the current research study adopted a mixed research method.

According to Brierley (2017), the pragmatism paradigm is suitable for mixed research methods research in behavioural accounting.

The current study investigates the behaviour change imposed by the South African government's climate change regulations. The carbon tax law in South Africa is intended to drive behaviour change in South African companies, and to encourage them to adopt green energy. Therefore, the research design adopted for this study determined a credit-risk model that incorporates environmental risk. The study also took the form of empirical measurement by testing the following factor, namely, environmental risks' contribution to exacerbating the credit risk of a borrowing company.

The research design adopted for this study was a mixed-method qualitative-quantitative study. The research took a subset mixed-method design called exploratory sequential design, as shown in Figure 1.1. The research design is deemed suitable to answer the research problem detailed in Section 1.4, the outlined research questions in Section 1.5, and to fulfil the research objectives stated in Section 1.6.

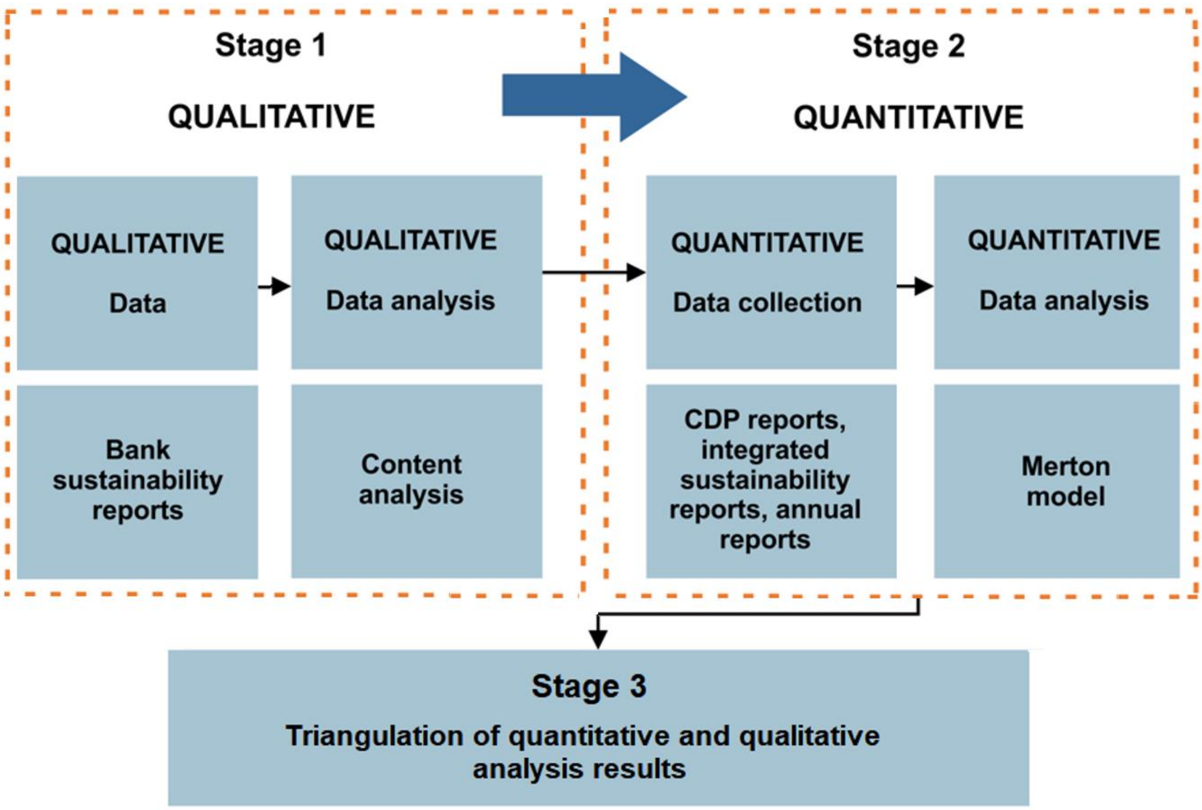


Figure 1.1: Mixed methods: Exploratory sequential methods

Source: Author's own compilation

As shown in Figure 1.1, the research design started with Stage 1 that involved qualitative data collection and analysis, and which produced the qualitative results in the form of determining the level of embedding of environmental factors in credit processes. Stage 1 employed the content analysis technique to determine the embedding levels of the banks in the sample.

The next stage, Stage 2, used the results obtained from the qualitative study to justify the results of the quantitative analysis. In this case, the quantitative portion of the study resulted in the creation of a default predicting credit-risk model that has environmental risk or factors embedded. Also, in Stage 2, quantitative data were collected and analysed based on variables, instruments and interventions created from the qualitative results.

Phase 3 of the quantitative study triangulated the results obtained from Stages 1 and 2 to determine trends and answer the research questions. Chapter 4 presents the detailed research methodology employed in this study.

1.8 SCOPE AND LIMITATIONS

This section briefly discusses the scope and limitations of the current study.

1.8.1 Scope

This study is limited to South Africa, based on its level of industrialisation and data availability compared to other African countries. More so, most of its financial institutions and leading companies have a broad footprint on the African continent; therefore, the results of this study embody the implications of climate change risk applicable to the African continent.

South Africa’s energy sources are mainly thermal coal-fired power stations that emit high levels of carbon emissions into the atmosphere, which contribute to global warming and therefore making this study appropriate. The study categorised the JSE100 (Johannesburg Stock Exchange Top 100 companies), based on the Carbon Disclosure Project sample of 2017 (NBI, 2017), and measured by their carbon emissions, into high carbon emitters and low carbon emitters. Furthermore, the JSE100 were categorised into seven sections by type of industry, namely, Consumer Staples, Consumer Discretionary, Energy and Materials, Financials, Health Care, Industrials, and I.T. and Telecommunications. This ensured a proper analysis and appropriate identification of the South African industrial sectors that are susceptible to bankruptcy or financial distress due to their carbon emissions output.

Another delineation considered in this study was the relationship between the measured carbon emissions of the JSE100 companies and the loans acquired from banks in general. Most of the companies have a wide footprint of operations across Africa, and most loans are acquired locally to finance subsidiary operations. As it was challenging to obtain the carbon emissions output in some of the countries in which the JSE100 companies have subsidiaries, the current study focused only on carbon emissions measured in South African operations, and the loans acquired to finance local operations only.

1.8.2 Limitations

At the best of times, it will be difficult to access detailed information on the lending amounts and conditions posed by South African banks, given the confidentiality clause of such transactions. More so, the issue of environmental sustainability has become a competitive edge, and therefore, obtaining full disclosure from companies was deemed almost impossible. Therefore, this study was based on disclosed information found in annual reports, specifically, the environmental performance data, and the loan and debt amounts granted to companies that were targeted for this study.

The outcomes of the study are not solely based on all companies in South Africa, but the outcomes are based solely on those that have given full disclosure of borrowings from South African banks and have supplied environmental performance data.

1.9 ASSUMPTIONS

To simplify the complex nature of environmental risk, as discussed in this chapter, and more extensively in Chapter 2, the proxy for environmental risk is the risk caused by the carbon emissions of a company. By deduction, as explained in Chapter 2, environmental risks are meant to embed all risk that emanates from climate change. The assumption is that there are qualitative and quantitative aspects to be considered in the incorporation of environmental risk in bank credit appraisal systems.

The study concentrated on the quantitative aspect of incorporating environmental risk into bank credit processes, and particularly, on the credit measurement process. The qualitative aspects were not considered extensively due to the study concentrating more on the scantily researched quantitative side. More so, the qualitative aspects of embedding environmental risk have been widely researched and extensively used, as shown in Chapter 3. The use of Equator Principles (discussed intensively in Chapter 3) by banks to appraise the qualitative aspects of environmental risk in credit granting by banks was considered as the first method in the banking sector.

The other assumption considered in this study was that the initiation of credit processes deals mainly with quantitative aspects and is involved less in the monitoring and closing process of the credit relationship. Thus, the study has been premised on the credit initiation process, and particularly, the credit scoring models.

The study did not consider the whole spectrum of bank credit process because it would have complicated the study. The cost of studying the incorporation of environmental risk into the whole bank credit process outweighs the benefit of doing so at the source of credit granting. The study of the infusion of environmental risk into the bank credit process, even in part, will prove to be more fruitful and comprehensive.

1.10 JUSTIFICATION OF THE STUDY

The rising phenomena of corporate sustainability, corporate governance and the relevance of environmental sustainability to business corporations motivated this study. More so, climate change is currently a continuous issue of discussion on almost all corporate boards worldwide (Wiedmann & Minx, 2007). The increased interest in climate change stems from the rationale that human-induced activities and corporate operations are the leading cause of global warming that has resulted in adverse changes in climate patterns (Pearce *et al.*, 1996; Verweij *et al.*, 2006; Stern, 2007).

There are various ways to combat the impact of climate change through corporate behavioural change. Currently, the most popular methods to solve climate change include measuring and disclosing the carbon emissions of business operations, and adapting or innovating to carbon emissions-free production processes (Dietz, Gardner, Gilligan, Stern & Vandenbergh, 2009; Sims, Rogner & Gregory, 2003). These are of interest to financial institutions that are proactive in promoting the green economy. Therefore, the imperative is to promote green financing to ensure green economic development that guarantees the reduction of environmental risk through reduced climate change impacts.

The mantra of growing green economies and industries has made it imperative to study the status quo of companies' production processes and the ongoing change from high carbon production processes to lower ones (Pearce, Markandya & Barbier, 1989; Fankhauser, 2010; Stern, 2007; Makower & Pike, 2009). However, the transition from high to low carbon production processes presents the challenge of revamping production processes and the assets used for production (Stern, 2007; Winkler & Marquard, 2009). Therefore, an understanding of the impact of climate change on company profitability and cost structures will be critical for financial institutions loan underwriting processes and decision-making while granting loans to high carbon-emitting business.

The South African National Treasury announced the intention to introduce a carbon tax in 2019 (National Treasury, 2018). Hence, it has become imperative to measure the amount of carbon emissions concerning the asset size of a firm and its operating costs to determine its vulnerability to the increased costs of the carbon tax. The carbon tax will affect the cost of doing business in South Africa, and this study determined the extent of the impact that the carbon tax will have on the current operations of the JSE100 companies. Though based on historical information, it provided a valuable benchmarking tool for future decisions on borrowings, by providing a variety of anticipated scenarios in the implementation of the carbon tax. More so, the South African National Development Plan insists on delinking economic activity from environmental degradation, and to cease the use of carbon-intensive energy (National Planning Commission, 2011).

The United Nations Environment Programme Finance Initiative and Sustainable Business Institute study (UNEP FI & SBI, 2011) found that only four out of 35 institutions investigated integrated climate change in their due diligence and risk management processes. About eight of the participants indicated that they always systematically integrate climate change into their due diligence processes. However, in the study conducted among South African financial institutions, there were no clear answers in terms of embedding climate issues into credit risk assessments. Only three of the targeted 10 financial institutions conceded that they do apply environmental criteria into their lending practices, and this is not done consistently across their products.

A significant issue that was highlighted as an impediment to embedding climate change issues into credit risk assessment was predominantly of a regulatory origin. Another reason cited was the delay in making alternative sources of energy profitable through REFIT (Renewable Energy Feed-in Tariff) subsidies from the government. Extensive regulatory interventions, in the shape of tax incentives, could encourage participation in the low carbon economic sector, and it would encourage banks to embed environmental issues into their lending processes. In addition, funding is needed for innovation, or financial guarantees and subsidies are needed for the promotion of technology that generates clean energy that is GHG emission-free.

The process of companies transitioning from dependence on high carbon materials to low carbon materials will result in company delinquency. There are bound to be companies that will resist the transition to renewable energy sources, and thus will render their production processes susceptible to high carbon tax charges and environmental pollution penalties. Therefore, bankruptcy studies in light of the consequences of carbon emissions will assist firms in acting assertively while crafting production processes that limit the impacts of climate change.

The current study makes a significant contribution to the incorporation of environmental risk and climate risk into the credit appraisal process of banks. This contribution augurs well for the intention of the South African government to move to a low carbon economy. Furthermore, this study adds to the body of knowledge with regards to the theory of lending decision-making in the context of environmental risk. A further contribution is the opening up of corporate delinquency studies caused by environmental risk in a South African context, which, to the best of the researcher's knowledge, has not been extensively researched.

1.11 STRUCTURE OF THE THESIS

This section provides a layout of the chapters in the thesis.

Chapter 1: This chapter embodies the introduction to the research topic. The introduction elaborated on the rationale for the study, the problem statement, the research questions and research objectives. This chapter provided a brief background to how climate change has evolved into a risk management issue that was discussed in three sections, from climate change as a risk, to how it affects the financial intermediation role of banks.

Chapter 2: This chapter discusses the concept of environmental risk and bank credit processes. The chapter lays the foundation to understanding the underpinning theories that drive banks' credit processes, while simultaneously reviewing current literature that discusses the incorporation of climate and environmental risk into bank credit process. The chapter shows that environmental risk can be broadly divided into carbon risk and climate risk. However, in the banking context, this can be further subdivided into (1) the combined environmental sub-types of regulatory or policy risk, reputational risk, competitive risk, transitional risk, legal risk and financial markets' risk, and (2) physical risk. This chapter also presents a discussion of the relevant financial intermediation theories, namely, delegated monitoring theory and the information asymmetry theory.

Chapter 3: This chapter provides a literature review of the various methods being used to embed climate and environmental risk into the bank credit processes at an international and South Africa level. This chapter uses empirical studies to test the theories that were discussed in Chapter 2. The chapter, through the empirical studies, also investigates the state of embedding environmental risk by banks at an international level and establishes the current methods of embedding. The chapter proposes various ways that environmental risk can be embedded in the South African context.

Chapter 4: This chapter explains the methodology used to conduct the research. In a nutshell, Chapter 4 provides a discussion of the methodological framework, research design, data sources, data-collection methods, as well as the method of analysis of the proposed credit appraisal model to this study. The study employed a mixed-method approach, consisting of a qualitative stage that used content analysis and a quantitative stage that used the Merton Model and the Carbon Risk Analysis Model proposed by Hoffman and Busch (2008). The triangulation process between the qualitative and quantitative research design is explained. The qualitative stage conducted a content analysis of the four big banks to ascertain the level of embedding of environmental risk in bank credit processes. The quantitative stage studied the

JSE100 companies that consistently report to the Carbon Disclosure Project as a test case for the proposed environmental credit-risk model.

Chapter 5: The results of the content analysis and the proposed Environmental Credit-risk model of the sampled JSE 100 companies are presented in this chapter. This chapter presents the findings of the qualitative and the quantitative study. The chapter concludes with the triangulation of the findings from the quantitative and qualitative research.

Chapter 6: This chapter presents the implications, drawbacks and conclusions of the research findings. Future research areas, limitations of this study, the extent of achieving the research objectives and the summary of the study's results are also detailed.

CHAPTER 2:
FINANCIAL INTERMEDIATION, BANK CREDIT PROCESSES AND ENVIRONMENTAL RISK

2.1 INTRODUCTION

The central theoretical concept relevant to this study is the interaction between financial intermediation (FI), bank credit processes and environmental risk. The concept of FI explains how banks are relevant to the functioning of financial markets and economic systems. Chapter 1 showed that the main objective of this research is to link environmental risk to the credit-decision processes of banks. However, before linking the two, this chapter will endeavour to clarify how the theoretical concepts relevant to FI drive the bank credit processes, and then further annotate the current known bank credit process standards.

This chapter firstly discusses the main aspects regarding FI as found in the literature. Thereafter, the study investigates how FI affects bank credit process, and how FI is impacted by climate change. This chapter has three sections. The first section explores the theories behind financial intermediation and climate change. The second section discusses the concept of environmental risk and the definition of bank lending. The third section explores how environmental risk is embedded in bank credit processes, and discusses the relevant current theories. The chapter concludes with a set framework or generic embedding of environmental risk into the structures of a bank credit process.

2.2 THE CONCEPT OF ENVIRONMENTAL RISK

This section firstly presents a general perspective on environmental risk. Thereafter, definitions of environmental risk in the bank lending context and from a business perspective are provided. The section ends with a discussion of the relationship between environmental risk, climate risk and carbon risk.

2.2.1 General perspective on environmental risk

In the general context, environmental risk can be described as the risk to human health and ecosystems. Broadly speaking, this risk can be measured as environmental quality relevant to the economy, human health and ecosystems. In terms of ecosystems, this refers to fauna and flora, or rather the natural plant-life and animal life (Jones, 2001; Cardenas, 1999).

Jones (2001) describes environmental risk as that which emanates from climate change that is caused by the greenhouse effect. The following two views are suggested by Jones with regards to environmental risk, namely: (1) the environment we live in as being directly exposed to risk from climate change, and (2) environmental change that is the result of climate change directly affecting human activities. Cardenas (1999) concurs with Jones (2001), and breaks down environmental risk into human health risk and ecological risk. Figure 2.1 graphically illustrates the components of environmental risk.

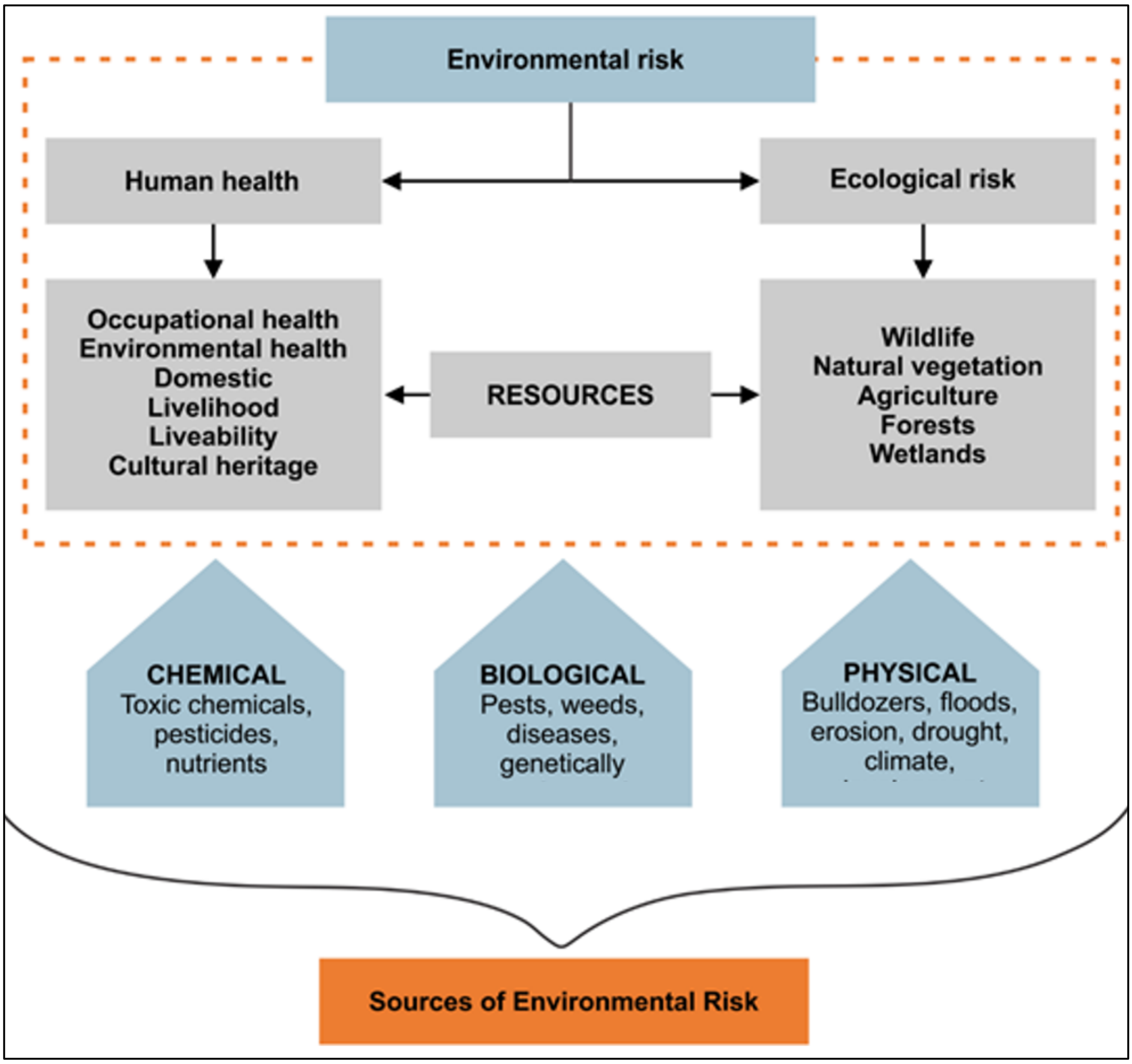


Figure 2.1: Components of environmental risk

Source: Author's own compilation

As shown in Figure 2.1, the sources of environmental risk are threefold; namely, chemical, biological and physical, explained as follows:

- **Chemicals:** the impact of mishandling toxic chemicals, overuse of pesticides and deficiency in nutrients has an impact on both humans and the environment.
- **Biological:** the menace of pests, weeds, plant and animal diseases and the shortcomings of genetically modified organisms affect the wellbeing of both humans and the environment.
- **Physical:** the physical view pertains to the impact of human machinery, natural floods, soil erosion, droughts, climate change, urbanisation, and its impact on humans and the environment.

Assessing these and allocating probability and likelihood measures gives an extent of the environmental risk. Whyte and Burton (1980) indicate that environmental risk arises from the air, water, soil or natural food chains (ecosystems) to man.

Environmental risk is also premised on the concept of risk, as defined in financial risk, as to the probability of loss multiplied by the amount of loss in monetary terms. Hollenstein (2005) defines risk in simple terms, as the frequency of an event occurring multiplied by the damage. Therefore, Hollenstein asserts that risk is the expected amount of damage for a given time. Algebraically, it can be expressed as risk is equal to the probability of the disruption event multiplied by the loss connected to the event's occurrence.

However, Hollenstein contextualises the concept of risk concerning natural hazards as having four elements. These four elements are in two groups, with the first group being hazard-related and comprises of (1) probability of hazard occurrence, and (2) hazard intensity, which relates to the probability that is the magnitude and or duration of hazard. The second group is target-related and comprises of (3) physical exposure to hazard, which relates to the extent of resistance to the impact of a hazardous event of the targeted objects, and (4) human vulnerability to disaster. These variables can also be explained in the form of a diagram, as shown in Figure 2.2.

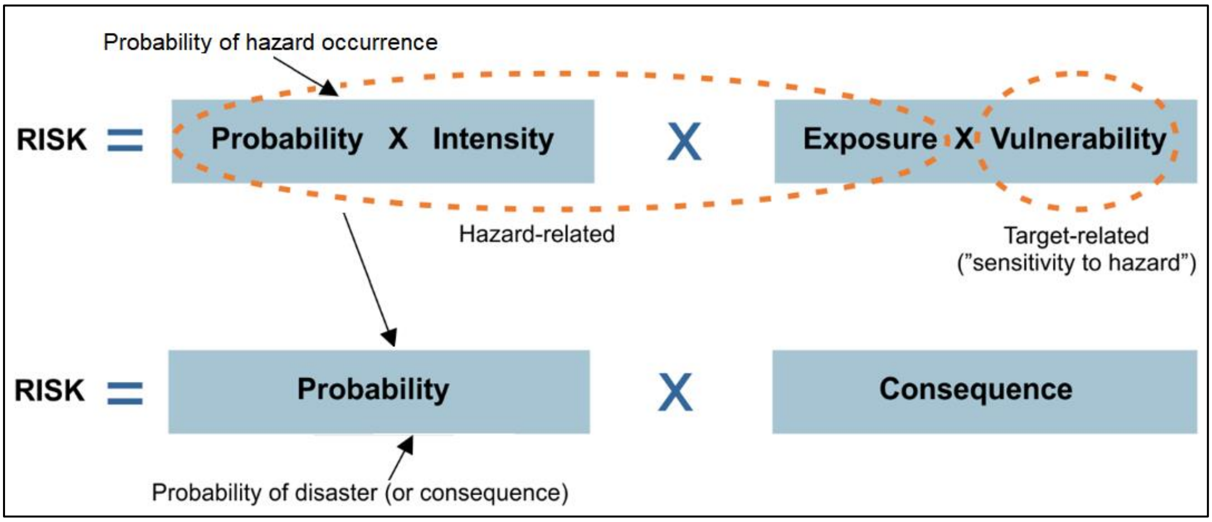


Figure 2.2: Definition of risk in relation to natural hazard

The next two sub-sections provide definitions related to environment risk.

2.2.2 Defining environmental risk in the bank lending context

The literature details two separate views on the way that environmental risk has affected bank lending. The first view originated in the period when environmental risk was regarded as the cost of pollution through environmental clean-ups. It stemmed from the regulation that caused banks to be liable for the clean-up costs of any pollution damage caused by companies they had financed (Boyer & Laffont, 1996).

This notion of banker liability for environmental damage was more pronounced in the 1980 Comprehensive Environmental Response Compensation Liability Act (CERCLA) of the United States of America (US). Through this law, the banker's liability arises when the bank was part of the monitoring of the firm's activities. Thus, the bank is an operator, and hence, this makes the bank liable for cleaning up the environmental damage. This factor emphasised the need for lenders to be knowledgeable about environmental laws, given the extensive liability of banks that lend, which augurs well for the notion of banks being monitors and managers of firms, (Klotz & Siakotos, 1987; Al-Tawil, 2017; Mitchell, 2018; Patton & Gable, 2018).

The second view found in the literature is that environmental risk is the risk that corporate activities exert on the environment through the carbon emissions that they produce, and how they contribute to climate change. However, a collaboration between the Association of Development Financing Institutions in Asia and the Pacific (ADFIAP), the Sustainability Research Institute, the University of Leeds, and the

Wuppertal Institute of Climate, Environment and Energy examined environmental risk, based on the reason that the exact impact of climate change in environmental and economic terms is not well known (ADFIAP, 2005). They further argued that since most lenders focus on economic losses due to environmental aspects, they would instead not call this an environmental risk but an economic risk that is caused by environmental aspects. Figge (1998) also regards the environmental effects brought about by climate change in financial terms as 'environmentally-induced economic risks'. Figge goes on to emphasise that the composition of environmental risks is more important than its scale or probability of occurrence.

Bowman (2010) indicates how climate risk encompasses credit, investment, reputation and legal risks. Bowman classifies the corporate world into two segments in terms of the risk they pose to banking institutions. The first segment is that of organisations that are climate-vulnerable, which are real estate, agriculture, forestry and tourism. These are affected by extreme weather. The second segment contains corporations that cause climate risk by being the highest emitters of GHG. These are the oil, gas, coal, heavy manufacturing and transport firms that are profoundly affected by government policies that price carbon emissions through a carbon tax, and thus increase their production costs, and in turn, their earnings.

Thompson (1998), Case (1996) and Wanless (1995) agree on the three categories of environmental risk that are faced by bank lenders, namely, direct risk, indirect risk and reputational risk. Thompson argues that lenders face environmental risk through the financial risk management concepts used in bank lending principles. The principle of risk-return and trade-off on loans determines the loan decision of granting the loan or not.

Direct risk pertains to the bank's liability for cleaning up contamination caused by a project they have financed. Environmental laws like the CERCLA in the US are also found in South Africa, for example, Section 28 of National Environment Management Act (NEMA) and section 19 of the National Water Act (NWA) hold banks partially or fully liable for financed projects that contaminate the environmental elements (soil, water and air).

Indirect risk is when projects funded by the bank cause significant environmental damage, and this consequently results in, for example, fines and penalties for non-compliance to environmental regulations, and the clean-up costs of the contamination that was caused. This increase in costs will result in considerable damage to a project's revenue, resulting in the borrower being unable to repay the loan.

Reputational risk is faced by banks when they finance companies that have environmentally-unfriendly products. Protests from environmental pressure groups have made the customers of banks aware of the consequences of using banks that finance companies with environmentally-unfriendly products and processes. Thompson (1998) argues that reputational risk is the most challenging sub-risk of environmental risk to identify and quantify. More so, it is different from the other two environmental risk sub-types, direct and indirect risks, in that it affects the potential generation of future revenues. In contrast, the former risks affect the present value of the loan portfolio.

From the derived definitions above, environmental risk is derived from the effects of climate change, with carbon emissions being a proxy of this. A further aspect is an earlier held view of connecting environmental risk to the banks' liability for the pollution caused by a firm that they have financed. The difference between these two views is that the earlier view is confined to pollution affecting natural resources directly, while the latter view is confined to how firms' carbon emissions indirectly affect the natural resources through the effects of climate change.

Latham (2009), however, bridges this contrast by showing how the dynamic evolution of climate change issues have vastly changed environmental legislation to include the issues of abating greenhouse gas emissions (another synonym for carbon emissions). Latham indicated how, in the US, disclosures of environmental risk by the Securities Exchange Commission had an impact on the operations of publicly listed companies. For example, one of the impacts is related to the material issue of environmental risk disclosure to potential lenders.

2.2.3 Defining environmental risk from a business perspective

For a business, environmental risk is multi-faceted. Aspects of environmental risk are explainable from a global view, and these range from local pollution problems to global warming. From a business perspective, environmental risk varies widely, depending on a company's industry, location, customer base, regulatory regime, and even its shareholders' expectations. The scholars, Sinclair-Desgagne and Gozlan (2003) define environmental risk as industrial risks that affect human health and the environment. Their studies have mainly focused on how industrial activities endanger human health standards and disrupt the balance of nature.

Bray, Colley and Connell (2007) support the idea of climate change being caused by anthropogenic activities that emit greenhouse gases, and they illustrate how some businesses will be negatively affected by climate change. They reiterate the need to identify and understand these risks and opportunities related to climate change faced by the business. In their study, they identify generic climate risk management measures that will help businesses 'acclimatise' their strategies and activities to the unavoidable climate change. Some of these generic measures include the addressing of climate risks to incorporate risk management systems by way of identification, assessment and management. These are more of the qualitative characteristics of a company that is implementing climate adaptation strategies.

A study commissioned by the United Nations Environment Programme Finance Initiative (UNEP FI) and Principles for Responsible Investment (PRI) (Trucost, 2011), defines environmental risk in the form of environmental externalities. This study (Trucost, 2011) quantified the cost of global environmental damage. The main aim was to assess the financial implications of unsustainable natural resource use and pollution by the business. The study discovered the following significant environmental impacts:

- greenhouse gas emissions,
- water abstraction,
- pollution,
- general waste, and
- natural resources, mainly focusing on timber and fish.

Trucost's (2011) study argues that one can quantify environmental damage or costs in monetary terms, and therefore, easily integrate it into financial analysis. The study defines environmental externalities as the costs of environmental damage caused by business activities that are primarily external to their financial accounts. The inadequacy of information about these external costs has led to financial and credit markets failing to accurately account for the extent of business activities affecting or promoting a stable climate and access to water.

The study by Trucost (2011) provides two points that outline the scope of environmental risk. The first point is that of inadequate capital allocation to highly polluting activities that result in a decrease of shareholder value. Environmental costs will be embedded in institutional investors' portfolios as insurance premiums against environmental liability, environmental taxes, inflated input prices, and the physical costs associated with disasters. The implication of these costs is the reduction of future cash flows and dividends. There is also a systemic risk in this phenomenon in that one company or several companies in an institutional investor's portfolio can affect the portfolio return, and the same applies to a portfolio of loans within a lending institution. Having many companies that have high environmental costs can affect the loan quality of that portfolio.

The second point is the issue of environmental damage costs being generally higher than the cost of preventing or limiting pollution or resource depletion. Many business incident examples show that the costs of addressing environmental damage after it has occurred are usually higher than the costs of preventing the pollution or using natural resources in a more sustainable way (Jaffe, Newell and Stavins, 2005). Therefore, it is crucial in the credit appraisal process to see what a borrowing company has put in place to manage its anticipated environmental risks and their impacts.

Latham (2009) identified three categories of environmental risks in the form of environmental liabilities or costs that business face. The first category is deemed the most significant portion of environmental costs, and involves the obligation to maintain legal compliance, and the implementation of various environmental laws and regulations. Examples under this category include the compliance costs of the proper storage, treatment or recycling of hazardous waste so that it does not endanger human health or the natural environment. Various other compliance costs included in this category are capital expenditure on pollution-control infrastructure and labour costs for employing and training staff to implement environmental compliance procedures.

The second category of environmental liabilities is related to environmental penalties for non-compliance with environmental laws and regulations. This involves, for example, the legal costs of hiring lawyers to act in civil suits regarding allegations of non-compliance to environmental laws and regulations. Reputational risk causes enormous and unpredictable costs which stem from accusations by environmental pressure groups that the business applies environmentally-unfriendly business policies and operations. If the business does not take heed, it might face a loss of market share and revenue, and therefore, there is a need to produce environmentally-friendly products.

The third category of environmental liabilities that businesses are likely to face is related to the substantial costs required to clean up contaminated environmental elements, such as soil, water, groundwater or sediments, as a result of the improper disposal of toxic chemicals or substances.

The discussions above have provided a conundrum of synonyms or sub-types of environmental risk. There is a need to rationalise and discuss the differences and relationships amongst these types of environmental risk, as in the next section.

2.2.4 The relationship between environmental risk, climate risk and carbon risk

In the literature, the evolving nature of environmental risk is visible but not apparent. From 1970 to around 1999, environmental risk is described as the contamination of the environment by toxic wastes in the form of liquid hazardous wastes from industrial processes (Labatt & White, 2007:53). This contamination was mainly focused on the land and water and not the air. Improvements in toxic waste reduction in the industrial processes have re-contextualised the definition of environmental risk to focus on air contamination or pollution. The extent of the effects of air pollution has wider geographical consequences if compared to land and water pollution. Hence, the terms ‘carbon risk’ and ‘climate risk’ gained prominence in the period starting 2000 up to the current time.

Latham (2009) indicates that climate risk and carbon risk are sub-components of environmental risk. Latham further divides climate risk (termed climate change-related risks) into physical risk, regulatory risk and litigation (reputation or legal) risk. Climate risk stems from the impact of climate change caused by adverse weather (Onischka, 2008), while the environmental risk is derived from how business, through its operations, faces litigation from contaminating the natural environment (Romilly, 2007).

Onischka (2008) postulates that climate risk, in the context of a financial institution, demonstrates physical risk, regulatory risk, liability risk and reputational risk to their operations. According to Romilly (2007), environmental risk is a broad concept, and is mostly associated with environmental events such as oil spills, while climate change-related risk is part of environmental risk. Hoffmann and Busch (2008) describe carbon risk as a change in the company's monetary carbon over a given period. In other words, the company's production of carbon emissions is measurable in the monetary terms related to carbon taxes, and the prices of carbon credits through the emissions trading system.

A study by Innovest Strategic Value Advisors (2007) shows that carbon risk should go beyond the level of carbon disclosure and the overall quantity of measured carbon emissions. They amplify this notion of carbon risk by postulating four variables that carbon risk should include, namely:

- Firstly, a company's overall carbon footprint (total measured carbon emissions from operations);
- Secondly, the measured ability to manage and reduce carbon risk exposure;
- Thirdly, the ability to perceive and take advantage of climate change opportunities; and
- Fourthly, the rate of improvement or deterioration in managing carbon risk.

An interlink between climate risk and environmental risk is observable, as defined in the economic and financial fields, while carbon risk is more related to exposure measurement.

Environmental risk is being redefined in the form of carbon risk and climate risk, with its impact on financial assets. A working paper by 2 Degrees Investing Initiative (2ºii) (2ºii, 2013) illustrated the characteristics of carbon risk as related to financial risk. The study defined carbon risk as a family of risks correlated with the GHG emissions associated with an asset. However, the 2ºii study (2013) excluded the impacts of the following as being a consequence of carbon risk: physical climate change impacts and macroeconomic consequences, such as variation in temperature, the rise of the sea level and the impacts on national economies.

The study by 2ºii (2013) further annotated the impact of carbon risk through time dimensions, nature or characteristics and source. The aspect of time dimensions includes defining carbon risk as a point-in-time risk in which carbon risk is highly predictable and extremely likely to occur at one point in time, causing the owner of the affected asset to go bankrupt. Although it can be deemed to have systematic effects, they are not so material in the short term. The same study by 2ºii (2013) identified climate policies which are used to mitigate climate change impacts through the efforts of reducing greenhouse gases as sources of carbon risk. These climate policies include climate regulatory standards, carbon tax schemes, market prices of carbon-containing products and changes in the consumption of carbon-emitting products.

From a financial perspective, being proactive in going low carbon in production processes when the government has not implemented any relevant policies can jeopardise the financial position of a company. Carbon emissions correlate with other impacts, such as resources depletion, local air pollution, the local environmental impact of extractive activities, water consumption and pollution, and so forth. Carbon intensity can, therefore, be a proxy for risk exposure to other environmental and energy-efficiency policies (for example, air quality standards for cars), contested operation licenses (for example, for fracking), and increasing market prices (for example, energy). Equally, it cannot alone cover the whole scope of risks (for example, large hydro and biofuels).

The 2ºii study (2013) maintains that the carbon risk associated with banks emanate from the direct relations that lenders have with a borrowing company that is an emitter of greenhouse gases. They argue that this risk is transferred partially or wholly to the lender since a drop in asset value creditworthiness translates into losses in their loan books. Therefore, the implication is that the lending bank is involved in the risk of GHG-emitting of the borrowing company and assets. This further implies that carbon risk is transferrable through the loan that the lending bank has provided to the borrowing company (2ºii, 2013).

The investment company, 2ºii (2013) suggests three definitions of carbon risk. These are:

1. Narrow definition: the financial risks faced by lenders and investors are credit and market risks linked with assets held during the holding period, as well as regulatory and litigation risks related to the investment framework.
2. Broader definition: this includes the risks for the ultimate asset owner, if lending banks have to assess these risks and inform the next investor of these, or the regulator, when considering the moral hazard.
3. Extended definition: this includes the social cost of emissions, assuming that someone will pay this ‘off-balance sheet (statement of financial position)’ liability at the end of the day and that governments might sooner or later try to shift the burden to asset-owners by all possible means.

Kim, An and Kim (2015) use the word climate change-related risk for carbon risk. They define carbon risk as representing future potential losses, or current, mostly off-balance sheet (statement of financial position) debts due to increasingly severe regulations related to the emission of GHGs across the globe. They further identify the sources of carbon risk as emanating from the Kyoto Protocol which was promulgated in 2007 and required all Annex I countries to reduce their GHG emissions to an average of 5.2% below 1990 levels by 2012.

Another source of carbon risk is the emissions trading system, which facilitates that companies that are high on carbon emissions can contribute through energy-efficient credits to offset their over-the-limit GHG emissions. The high costs and pricing structures in the ETS (Emissions Trading System) bring a heightened sense of carbon risk for less energy-efficient companies. Kim *et al.* (2015) also cite regional and country-level regulations in the form of carbon taxes and penalties as a source of carbon risk.

The IPCC (2007) indicates six types of carbon risk which are a physical risk, regulation risk, litigation risk, competition risk, production risk and reputation risk.

Figure 2.3 below presents an illustration of climate risk from the Portfolio Theory view.

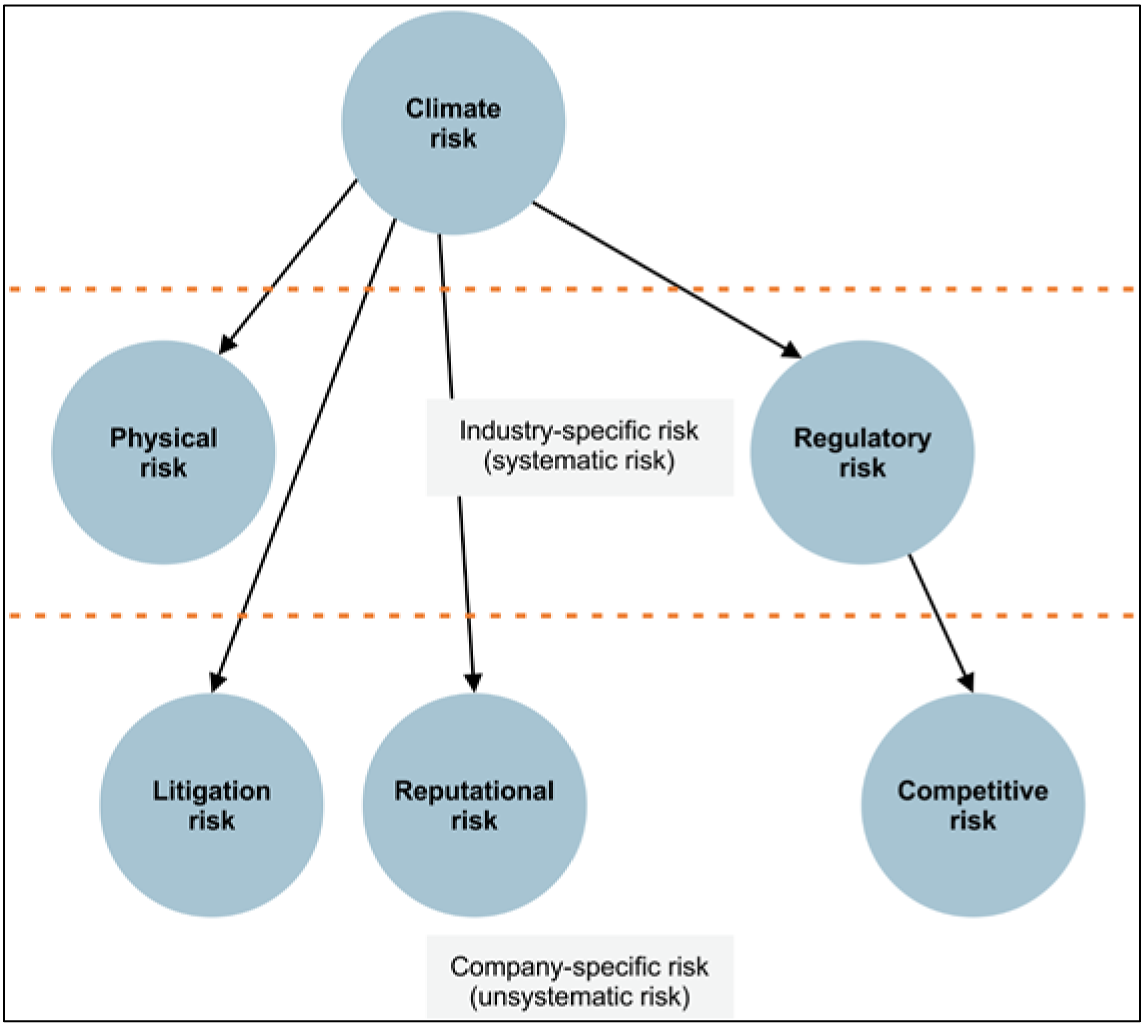


Figure 2.3: Climate risk from a Portfolio Theory-View

Source: Sauer & Wellington (2005)

As seen in Figure 2.3, Sauer and Wellington (2005) define climate risk from a portfolio theory perspective which divides climate risk into systematic risk and unsystematic risk. Though it is biased towards portfolio investments, the underlying principles apply to loan and bond portfolios. In their view, systematic risk consists of the overall economic and market risks which are caused by policies put in place to manage the impacts of climate change. These climate change policies will result in systematic risk across the economy, affecting energy prices, national income, health and agriculture. Therefore, eventually, this systematic risk will affect energy production and consumption. Their view of unsystematic climate risk is the risk to investment security issued, and to a bond issued or loan made.

Figure 2.3 shows how climate risk is split into industry-specific risk, which consists of physical risk and regulatory risk, and company-specific risk that is comprised of litigation, reputational and competition risk. Table 2.1 details the definitions of these risks.

Table 2.1: Definition of sub-categories of climate risk

Type of carbon risk	Sub-type of carbon risk	Definition
Sector-specific risk	Regulatory risk	International, national, regional, and state regulation of greenhouse gases (GHGs), depending on the stringency, is likely to have a financially material effect on most GHG-intensive sectors, because it will create a cost for carbon dioxide (CO_2) and other GHG emissions.
	Physical risk	Some sectors of the economy will be directly affected by the physical effects of climate change, such as droughts, floods, storms, and rising sea levels. Agriculture, fisheries, forestry, health care, insurance, real estate, tourism, and water may be particularly exposed because of their dependence on the physical environment. Human health, water, and the weather are all directly affected by climate change.
Company-specific risk	Competitive risk	Within any climate regulatory framework, some companies will fare better than others. Individual companies could win or lose, depending on the policy framework. In portfolio management, this dynamic is most important in determining the effects of GHG constraints on investment valuation.
	Litigation risk	High GHG-emitting companies could face risk in the form of lawsuits similar to those in the tobacco, pharmaceutical and asbestos industries.
	Reputational risk	Companies viewed negatively in terms of climate change (for their politics, products, or processes) could run into consumer or shareholder backlash in environmentally sensitive markets. This is especially relevant in highly competitive sectors, such as motor vehicles and fuel service stations, where brand loyalty is an essential attribute of company value. As with other reputational issues, costs or benefits are difficult to project accurately into security valuations.

Source: Adapted from Sauer & Wellington (2005)

Fulton and Weber (2014) propose a framework for assessing carbon risk, which they call carbon asset risk. To them, carbon risk is a subset of the risks related to climate change and is distinguishable from physical climate risks. They assert that physical climate risks are risks associated with the physical impacts of climate change that influence carbon assets and operating companies. These impacts include the physical damage accompanied by the capital expenditures used to mitigate extreme weather patterns, such as severe storms, floods and drought, and 'slow onset' impacts such as sea-level rise and desertification.

According to Fulton and Weber (2014), carbon risk is a non-physical climate change-related factor facing assets and companies. They place carbon risk into three primary types or categories, namely: (1) policy and legal, (2) technology, and (3) market and economic. Table 2.2 briefly defines these categories of carbon risk. They argue that depending on their nature and severity, carbon risks may translate to carbon asset risk to financial intermediaries.

Table 2.2 Definition of carbon risk: Fulton and Weber view

Category of risk	Definition	Nature of impact	Examples
Policy and legal	Policies or regulations that could impact the operational and financial viability of carbon assets	Impacts physical carbon assets and companies that own/ operate assets	Fuel-efficiency standards for personal vehicles; emissions trading systems; US EPA regulations targeting air pollution and GHGs from power plants
Technology	Developments in the commercial availability and cost of alternative and low-carbon technologies	Impacts technology choices, deployment and costs and demand profiles	Energy storage technologies; advances in renewable energy technologies, carbon capture and storage; alternative fuels
Market and economic	Changes in the market or economic conditions that would negatively impact carbon assets	Impacts physical carbon assets and companies that own/ operate assets	Changes in fossil fuel prices; changes in consumer preferences

Source: Fulton & Weber (2014)

In Figure 2.4, Fulton and Weber (2014) present a conceptual framework that explains how carbon risk translates to carbon asset risk, which eventually affects financial intermediaries and investors. The conceptual framework uses the example of a power generation company that has several coal-fired power plants. This company is deemed to face a range of carbon-related policies and other technological and market risks which directly affect it. For example, the company would reduce the amount of energy it is selling to the market, or there might be a threat to the operator's ability to continue power generation in the future. Therefore, the banking institution and investors who have financed the operation would be indirectly affected by these impacts through increased credit risk or even loss of revenue, depending on the severity of the impacts. Fulton and Weber refer to the direct risk to the company as ‘operator carbon risk’, while the corresponding financial risk to financial intermediaries and investors is referred to as ‘carbon asset risk’.

Operator carbon risk: risk of financial loss to an operator of a physical asset due to non-physical climate change-related factors (predominantly policy, market and technology).

Operator carbon strategy: the strategy by which an operator of carbon assets minimises its operator carbon risk by positioning itself to adapt to a carbon-constrained world.

Carbon asset risk: the potential for a financial intermediary or investor to experience financial loss due to unmanaged operator carbon risk in its clients or investee companies.

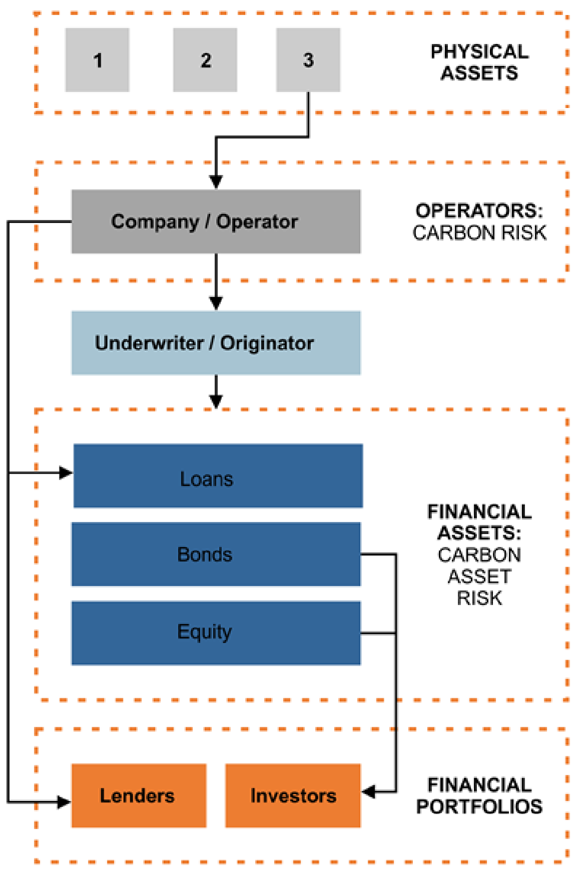


Figure 2.4: Illustration of Operator carbon risk and Carbon asset risk

Source: Fulton & Weber (2014)

Figure 2.4 condenses the above analysis of that which constitutes environmental risk and its relation to carbon risk and climate risk. It is important to keep in mind that environmental risk encompasses carbon risk and climate risk.

The explanation of environmental risk will assist in understanding which aspects to embed and empirically measure, or it may assist in finding the right proxy for an identified climate issue or concept. The next chapter defines the various dimensions of environmental risk. However, in this section, the discussion focuses on the financial aspects, as Chapter 3 does not exhaustively pinpoint the appropriate types of environmental risks for embedding in the credit process.

The Bank of England‘s Prudential Regulation Authority (2015) groups climate change-related financial risks into the following three groups: (1) physical, (2) transition, and (3) liability risks.

- Physical risks are those risks that could arise from climate and weather-related events which can damage a company's fundamental property and its operating activities.
- Transition risks relate to the process of a company adjusting to production processes, policies, regulations and technologies that lower, and eventually eradicate carbon emissions.
- Liability risks could arise from ignoring and non-adherence to mandatory environmental and climate mitigations policies and regulations.

Table 2.3 presents a detailed description of the three categories of climate-related risk.

The United Kingdom (UK) Task Force on Climate-Related Financial Disclosure -Financial Stability Board (2017) shows how physical risks can range from acute (event-driven) to chronic (long-term in nature). The mission is to locate these risks in the South African context and apply them to this research, which is the identified research gap for this study.

Table 2.3: Definition of climate-related financial risks

Type of risks	Sub-types	Sub-types definition
Transition risk	Policy and legal	▪ Increased pricing of GHG emissions ▪ Enhanced emissions-reporting obligations ▪ Mandates on and regulation of existing products and services ▪ Exposure to litigation
	Technology	▪ Substitution of existing products and services with lower emission options ▪ Unsuccessful investment in new technologies ▪ Upfront costs to transition to lower emissions technology
	Markets	▪ Changing customer behaviour ▪ Uncertainty in market signals ▪ The increased cost of raw materials
	Reputation	▪ The shift in consumer preferences ▪ Stigmatisation of sector ▪ Increased stakeholder concern or negative stakeholder feedback
Physical risk	Acute	▪ Increase severity of extreme weather events such as cyclones and floods (causing damages on facilities, reduction or disruption in production capacity)
	Chronic	▪ Changes in precipitation patterns and extreme variability in weather patterns ▪ Rising mean temperatures ▪ Rising sea levels (causing damages to facilities, increased operating costs, impacts on workforce management and planning)
Liability risk	None	These are the uncertain financial impacts resulting from litigation stemming from either contributing to climate change or from the failure to take into account physical or transitional climatic risks.

Source: Adapted from the Task Force on Climate-Related Financial Disclosure -Financial Stability Board (2017)

2.3 EFFECT OF CLIMATE CHANGE IMPACT ON FINANCIAL INTERMEDIATION THEORIES

Merton (1993) illustrates the concept of financial intermediation through two frames of references, namely, the institutional perspective and the functional perspective, which concurs with Hasman, Samartín and Van Bommel’s (2014) categorisation of the functions of financial intermediaries.

Merton posits that the institutional perspective on financial intermediation stems from the existing financial institutions or the prevailing public policy that shapes the intermediary's structure, survival and success.

The functional perspective on financial intermediation guides the economic functions performed by the financial intermediaries. It determines the best institutional structure for the financial intermediary to perform these functions.

The same frame of reference infers in this study how the function of credit risk management within the banking sector shapes the handling of environmental risk. Most of the public policies at the global level and national level with regards to environmental risk and climate change threaten bank operational processes and bank regulatory systems (Ryan-Collins, 2019). Chapter 3 presents the details of these threats.

2.3.1 Functions of financial intermediaries

Allen and Santomero (1997) delineate the functions or roles of financial intermediaries by describing the services they offer, instead of their functions, although they generally concur with Merton (1995) and Hasman *et al.* (2014). They indicate the following as the services offered by financial intermediaries to the financial system:

- transmission of the monetary policy,
- reduction of information, transaction and agency costs,
- mitigation of adverse selection and moral hazard problems,
- creation of economies of scale and scope,
- credit allocation (residential mortgages, business loans),
- intergenerational wealth transfer (time brokering), and
- payments service (for example, electronic transfer, POS (point-of-sales) and mobile payments).

According to Allen and Santomero (1997), this is the traditional financial intermediation theory. Most of these functions were ignored in the complete markets paradigm theory of financial intermediation as proposed by Arrow and Debreu (1954).

2.3.2 The Arrow-Debreu theory

The Arrow-Debreu theory presents a utopian financial system or financial markets interactions. The assumptions are too unreasonable to exist and ignore rational and irrational human behaviours. For instance, the issue under study gives rise to incomplete financial markets, where there are no contingent markets to hedge against the environmental risk that rises out of the volatile climate change phenomena. More so, the disruptive nature of climate change will influence the following functions: credit allocation and reduction of information costs, transaction and agency costs (Chenet, 2019). Chapter 3 explores how the banking sector is avoiding the full adoption of climate change issues into their business or service operational models.

The Arrow Debreu FI model (1954) presents a perfect financial market where there would be no need for financial intermediaries in the process of lending. Therefore, there are no transaction costs, one can purchase securities in any denomination, and there is complete information about the quality of financial instruments. However, the same FI model provides the reasons for having financial intermediations.

The first reason comes from the fact that there is a cost of bringing the lender and borrower together. These costs include (1) search costs (search for potential transactors), (2) verifications costs (costs in evaluating investment proposals), (3) monitoring costs (costs of monitoring the actions of borrowing), and (4) enforcement costs (costs of enforcing contracts). Using a FI reduces these costs, and this reduction is relevant to small lenders and borrowers. The transaction costs of borrowing under climate change conditions need to be reviewed to establish whether lending or borrowing costs will increase. Currently, the costs of environmental due diligence in the financial markets make investment transactions expensive (Nizam, Ng, Dewandaru, Nagayev & Nkoba, 2019).

The second reason for FI is to achieve portfolios that are able to diversify risks away. The spreading of investments or loanable funds (deposits) over a large number of securities or loans reduces the risk of exposure. However, this option is not available to small investors with limited funds. In other words, their pool of funds limits them from diversifying away from their identified risk exposure. Similarly, it is imperative to ask if there are enough funds to diversify away environmental risk or climate change-induced risks (Nieto, 2019).

The third reason for FI is the ability of financial intermediaries to specialise in gathering information, evaluating credit risks and acting as specialists in the production of information. Chapter 3 reviews how banks have begun structuring their credit value chains to incorporate the management of climate change-induced risks in the credit portfolios and investments.

The fourth reason for the need of FI is to address asymmetric information which leads to adverse selection and moral hazards. Asymmetric Information is related to a state where buyers and sellers in a market are not equally informed about a product. As Mishkin (2004) puts it, asymmetric information is a state of one party having inadequate knowledge about the other party in the transaction to allow them to make accurate decisions. A similar situation might be where the borrower knows more than the lender about the borrower's future performance or a situation, and where the borrower understates the risk. With big corporates, asymmetric information is much less of a problem, given that there is more publicly available information. Environmental risk can pose asymmetric information, given that climate change risks are continually evolving and are not fully understood (Trouw, Weiler & Silverstein, 2020).

2.3.2.1 Adverse selection

Mishkin (2004) recommends at least four solutions to the adverse selection problem; however, only two are relevant to this study. The first is the private production and sale of information to solve the information asymmetry that causes adverse selection, preventing the free-rider problem. This solution augurs well for the impact of climate change information on a business that will help in the due diligence of a business's environmental risk or climate change-induced risk. On the contrary, the climate change impact information of a business is critical to the UN Sustainable development goals, and making this information public and free should be paramount.

Mishkin's (2004) second solution is related to government regulations to increase information availability. This solution puts pressure on listed companies to declare or disclose full information about their operations. This solution is also critical to this study, as the following chapter reveals more detail about the initiatives promulgated for companies to disclose climate change impacts. However, the contrary side of this solution is that it is challenging to coerce companies to disclose adverse information, especially with regards to environmental issues.

2.3.2.2 Moral hazards

Moral hazard occurs in a situation that takes place after the loan disbursement. Moral hazard is a phenomenon explained from the borrower's view or the view of the business owner who is borrowing from a bank. The borrower may take risky decisions that may work to their advantage, and which may prompt the borrower to take riskier than rational decisions. While business owners or borrowers may reap great rewards from the riskier than regular decisions, this may cause losses for the banks. From the business owner’s perspective, a moderate loss is the same as a considerable loss.

Mishkin (2004) indicates how this problem arises out of the principal-agent problem, where the agents are managers of the company and the principals are the shareholders or owners of the company. The managers usually act in their best interest and not those of the shareholders. This principal-agent problem even extends to agents (managers) taking risky decisions that cause climate change, and thus, impact on the principal’s company value (Brunner & Enting, 2014; Basak, 2017).

Under conditions of complete information, the principal-agent problem can be eliminated (Mishkin, 2004). Mishkin suggests a couple of tools to solve the principal-agent problem that may be causing a moral hazard. Firstly, there is a need for a monitoring mechanism to monitor the firm’s activities through the production of information by regular audit checking, in this case, Carbon Verification Standards. Monitoring is expensive from a time and money point of view, and can lead to the phenomenon of costly state verification, and therefore, this makes equity contracts less desirable compared to debt contracts. However, in this instance, there are a number of institutions providing environmental verification and audits at a cost.

The second tool is government regulation that increases information disclosure through legislation. In the case of South Africa, companies have to pay a carbon tax and be participative in carbon budgets to benefit from carbon tax incentives (National Treasury, 2018). The pursuance of accounting principles that make profit verification easier and the enforcement of criminal penalties for fraud leads to a reduction in moral hazard, for example, Green House Gas Protocol, Sustainability Accounting Standards Board (SASB), and Task Force on Climate Related Financial Disclosures (TCFD) are leading carbon accounting standards. Therefore, it is imperative to explore how moral hazard connects to decisions regarding the financing of projects that result in either increased or decreased climate change impact (Schwarcz, 2017).

2.3.3 Modern financial intermediation theory

The modern financial intermediation theory stems from the traditional financial intermediation theory's shortcomings of overestimating market frictions (Allen & Santomero, 2001). Therefore, the modern theory of financial intermediation emphasises the importance of financial intermediaries in the financial system in doing the following: (1) risk transformation, (2) risk management, and (3) facilitation of participation in financial markets. All this results in financial innovation and financial engineering. It is important to note how the environmental risk ensuing from climate change is presenting the need to transform this risk. Environmental risk also presents new risk management processes that create a whole new market to mitigate environmental risks and the risks emanating from climate change.

The discussion so far justifies the existence of financial intermediaries and why they are unique to economic and financial systems. More so, the discussions explored how theories surrounding the concept of financial intermediaries relate to the impact of climate change. The issue at hand is that the impacts of climate change present unique characteristics that are relevant to the information asymmetries explored here. Therefore, according to Scholten and Van Wensveen (2003), banks do not exist for the mere reasons of ameliorating information asymmetries presented in the form of adverse selection and moral hazard but to transform risk. The discussion has concluded that environmental risk can be transformed from threat to opportunity through the various existing financial intermediation functions. But the adequacy of the financial intermediation functions needs to be explored further since logic inference was being made.

In theory, environmental risk financial impact can be quantified through the financial intermediation functions, but there is a need for empirical evidence to prove this. So this discussion has outlined a theoretical framework which comprises the financial intermediation process and its relation to climate change. The next step is to juxtapose this theoretical framework in the bank lending process. Therefore, the next section discusses the current frameworks of integrating climate change impacts into bank credit processes.

2.4 BANK CREDIT PROCESSES AND INCORPORATION OF ENVIRONMENTAL RISK

This section discusses the theoretical perspective on banks' credit processes and environmental risk and bank lending.

2.4.1 Theoretical perspective on bank credit processes

The concept of delegated monitoring as applicable to banks is the focus of the current study. It is widely used as an underpinning theory to explain why banks should incorporate environmental risk into their credit processes. Goss and Roberts (2011) explain the unique intermediation role of banks in private debt markets where the banks are provided with information by borrowing companies that is not available to other outsiders. The banks use this information in their credit processes to determine if the borrowing company will be able to honour its loan obligation. After concluding the loan agreement, they can then monitor its repayment capacity.

Banks are also able to mitigate loan defaults by requesting collateral from the borrowing company, or by reducing the loan term and adding loan covenants to the loan agreement. Thus, Goss and Roberts (2011) conclusively argue that this monitoring role provides information efficiency to the loan market. They base this assertion on the study of Altman, Gande and Saunders (2006) that shows how syndicated loan markets predict loan defaults before the bond markets are able to. Drawing from this analogy, banks are well suited to assess the value of a borrowing company's environmental performance and to incorporate its environment performance into the loan contract terms.

Boyer and Laffont (1996) use the banking theories of agency problems, moral hazard and adverse selection in attempting to explain how a bank should handle environmental risk in the bank lending process. They base their explanation on the CERCLA of the US, which holds banks liable to pay for the reparations to environmental damage caused by a borrowing company. They theoretically analyse the impact of lender liability under the provisions of the CERCLA, based on a bank being either fully liable or partially liable for environmental damage.

Boyer and Laffont (1996) assert that even if the bank has complete information about the borrowing company, full liability on the bank's side means that rationally the borrowing company will have an excessive investment in high-risk environmental projects. This case of moral hazard may lead to the failure of the project, since the company might fail to recognise environmental issues in their pursuit of returns. Pitchford (1995) concurs that by adopting full liability, banks increase the frequency of environmental damages or accidents.

Therefore, under full liability, from the notion of adverse selection discussed in Section 2.3.2.1, the banks will tend to under-lend to such risky projects. However, Boyer and Laffont (1996) argue that making the bank fully liable for any environmental damage, forces the bank to appropriately internalise environmental risk into the bank credit processes. The above authors further argue that, under partial liability, the cases of moral hazard are reduced, since the bank and the borrowing company are equally liable for the environmental damage. Pitchford (1995) confirms that partial lender liability enhances efficiency and reduces environmental damage.

However, the conceptualisations by Boyer and Laffont (1996) stem from the insurance of this liability. Thus, they emphasise how the insurance company investigates the behaviour of both the lending bank and the borrowing company in matters of environmental liability.

Dionne and Spaeter (2003) conceptualised a situation where a company requires a loan from a bank while simultaneously investing in production and environmental damage prevention. They consider the amount invested by the company, which is comprised of debt and equity, where the debt is paid back by the company if it remains solvent after going through an environmental disaster. They also theorise that in order to sustain the environmental risk-reduction activities, under moral hazard, the company will privately choose environmental damage-prevention mechanisms that are higher than the social expectations.

Therefore, Dionne and Spaeter (2003) intimate that the company should apply the marginal costs and marginal benefits to a limited range of situations. For example, if the company goes bankrupt, they will not have anything, and they cannot pay back anything more than their net asset value. The abovementioned authors further conceptualised production and prevention activities as perfect substitutes. Therefore, they assert that a firm will gain more benefits from a higher level of environmental risk prevention when an increase in this prevention generates more benefits than it costs in terms of expected operating income.

Dionne and Spaeter (2003) also agree with Boyer and Laffont (1996) and Pitchford (1995) that partial lender liability to the bank in an environmental clean-up offers the optimal solution. Their reason is that extended liability to a company can be useful in environmental risk prevention but can also increase the value of debt, hence, increasing the probability of bankruptcy. They focus on the ramifications of extended liability on improving social welfare.

Schmitt and Spaeter (2005) rationalise how convertible bonds or debt can be used by a lender to control the borrower's behaviour by increasing environmental risk prevention, and the company's expected profitability and optimum operating state. They assert that the bond conversion right gives the lending bank the right to benefit from high levels of environmental risk prevention and future capital appreciation, therefore reducing the underinvestment problem. Therefore, they conclude that convertible bonds are an excellent instrument for risk management in situations where it is difficult to fully understand an asset's risk exposure. More so, the lender will actively monitor the borrowing company's operating expenses. With this iteration, Schmitt and Spaeter (2005) extend the assertions made by Boyer and Laffont (1996) and Pitchford (1995) related to the optimal level of extended liability in their conceptualisations of the convertible bond contracts. According to Schmitt and Spaeter (2005), a debt contract, with or without a conversion option, and with no extended liability will always be optimal, especially to yield maximum the level of social welfare.

Groth (1994) disintegrates environmental risk into two categories with the lender in mind: (1) the actual environmental risk, and (2) the perceived risk, and the behaviour, responses and actions related to environmental risk. Using the analogy of the characteristics of risk, Groth elaborates on the second segment of environmental risk that is determined by the following factors:

- Firstly, perceptions of environmental risk determine behaviour and not the real impact, and often, this risk is not predictable.

- Secondly, it is challenging to determine the range of potential adverse outcomes related to environmental risk.
- Thirdly, the perceptions of environmental risk may differ from the actual facts related to the environmental risk to be faced.
- Fourthly, reaction and actions in terms of environmental risk may not be rational.
- Lastly, the forces and behaviour of environmental risk can be overwhelming and uncontrollable; as an example, political forces can dominate issues in environmental incidents.

Groth (1994) provides further clarification on the consequences of environmental risk as it applies to property lending, but that can be generically applied to bank lending in other sectors. In terms of property lending, the following are defined as essential factors related to environmental risk.

- Firstly, there is a disruption of the cash-generating capacity, or a decrease in the market value of the financed property, due to environmental issues that impact the natural resource-based business.
- Secondly, the bank's efforts of limiting environmental damage might affect the borrower's repayment capacity.
- Thirdly, mandatory environmental compliance as a result of the new standards will impact repayment cash flows.
- Fourthly, there will be a reduction or elimination of the collateral, residual, or liquidation property value in the event of default as per the loan contract.
- Fifthly, forcing the lender to institute legal proceedings due to an environmental breach by the borrower will cause the incurring of unnecessary costs to recover the loan.

A novel argument raised by Groth (1994) in terms of the source of environmental risk, is the theory of rational behaviour. Groth states that it is rational to correct past damage done to the environment because this protects property values; however, he maintains that it is irrational to presently damage the environment since this will result in diminishing property values. With this in mind, Groth (1994:21) argues that a significant portion of environmental risk originates more from political and special interest groups than from factual, knowledge-based, cost-benefit and conscious social-benefit analysis. Groth (1994) cites an example of how the environmental superfund in the US is not being used to protect and clean the environment, but that approximately 85% of this fund has gone to settling environmental legal disputes and contestations. Groth also shows how the political and actual response to oil spills is a source of environmental risk by giving an example of the oil spill in the Komi republic in 1994, where Russia did little to respond to this spill.

Groth lists some pointers to rational behaviour for lenders that are applicable to environmental risk, using the theory of agency conflict and costs between lender and employee. Using the reward-penalty function as the source of agency costs, Groth explains how an employee who approves a highly environmentally-risky loan should have to face high personal costs. These costs come from being fired, and possible failure to gain similar employment in the industry. On the lender's side, an environmentally-risky loan can have dire consequences, financially and reputation-wise. Groth extends the consequences of environmental risk by focusing on the concept of loan securitisation, where someone originates and packages the loans and sells them to investors. If the property or mortgage loans have properties that are deemed highly environmentally contaminated, this will come back to haunt the loan originator, since the purchaser of these securitised mortgage-based loans will sue the loan originator for environmental damages.

Heyes (1996) maintains that if lenders are made liable for all or part of any environmental damage caused by their borrowers, it will increase the cost of capital, which will then affect the rates of investments and economic growth. Thompson (1998), however, confirms the need for the bank credit process to incorporate environmental risk aspects, especially in the loan pricing structures. Heyes investigated the incorporation of loan pricing using the regulatory reform clause in the European Community's (now the European Union) Green Paper of 1993. The clause proposed a penalty for lenders, which is also in the form of extended lender liability under CERCLA, in the financing of environmentally risky projects. There was strong opposition to this clause because it was felt that it would cause high interest rates in key growth areas such as biotechnology, advanced chemicals and plastics. Heyes' (1996) conceptual model produced positive results that penalising lenders for environmental damage done by their borrowers will increase interest rates.

From a lender's point of view, an increase in interest rates is slow to mitigate (partially) a class of adverse selection problems, but it exacerbates the moral hazard issues. Heyes admits that the results of his study differ from that of Stiglitz and Weiss's (1981) earlier study which indicated that a rise in interest rates solves both the moral hazard and adverse selection issues. Moreover, Heyes highlights how the extended lender liability clause would cause 'investment blight' which in effect, increases the extent of credit rationing. Heyes' (1996) research found that the exclusion of a higher proportion of prospective borrowers from attaining loans at any interest rate will co-exist with a decrease in the interest rates charged to those borrowers who are not excluded.

2.4.2 Environmental risk and bank lending

The incorporation of environmental risk into bank lending is evolving. Coulson and Monks' (1999) study highlighted how banks were incorporating environmental information into their bank credit processes. One of the adverse environmental decisions often cited is the financing of a borrowing company that contaminates a piece of land and resells it without cleaning it up. The purchaser then investigates the environmental state of that land and realises that it is contaminated and is not environmentally safe. The purchaser can then press charges, where the law allows, against the seller and the bank that financed the seller.

Therefore, Coulson and Monk listed the steps banks should take to protect themselves against this type of environmental risk:

- Firstly, banks should assess the environmental policy and management practices of the prospective borrower as part of the lending evaluation.
- Secondly, to foster good lending relations with borrowers, banks should avoid being viewed as environmental regulators or being responsible for the environmental liabilities of their borrowers.
- Thirdly, there is a need to do a thorough investigation of collateral or security in the form of property, to ensure that it is not on land that is contaminated.
- Fourthly, banks should foster the behaviour of companies first addressing their environmental issues before looking for finance.

- Lastly, banks can use the environmental tag as a valuable service to their corporate borrowers, and the borrower will benefit through expedited loan provision, reduced costs of loan negotiations and more favourable loan conditions.

Research by Elsakit and Worthington (2012) emphasises the use of environmental information in lending decisions. Furthermore, in tandem with Coulson and Monks (1999), Gray and Bebbington (2001) agree that banks can use their middleman role to influence the environmental behaviour of borrowing companies. In the UK, US and Europe, there are robust laws that have encouraged and allowed banks to influence their borrowing customers to adopt environmentally-friendly practices in the operations. However, in developing countries, there is a lack of such laws.

Elsakit and Worthington (2012) elaborate on the importance (the why) of environmental information for bank lending. Although they do not venture into the practicality of embedding environmental information in bank lending (the how), they cite some good reasons of embedding environmental information into bank lending that addresses the reputation risk, regulatory risk and financial risk discussed earlier. However, they emphasise that the lack of information and accounting standards that do not adequately disclose financial and environmental information in developing countries are a hindrance for banks to foster environmental stewardship amongst their borrowing companies.

A study by Campbell and Slack (2011) concluded that UK sell-side bank analysts did not consider environmental issues in their loan decisions. The main reason for that, as from the interviews conducted, was that the environmental information in the annual reports of the borrowing entities was immaterial and of no use in making loan decisions. Campbell and Slack's (2011) study found that this attitude was justified by the participants because they felt that the bank analysts might not be well equipped to use this environmental information in lending evaluations. More so, the analysts' technical skills tend to allow them to focus on the short to medium-term measurable metrics, due to the incentives attached to them, and they ignore the long-term effects of environmental information.

However, as in Elsakit and Worthington's (2012) study, Campbell and Slack (2011) address the 'why' and not the 'how'. Furthermore, Thompson (1998) addresses the 'what', that is, the situation of environmental exposure applicable to UK banks at the time of Thompson's study, which, although it might not be current enough, gives an indication of the rising concern related to how the impacts of environmental risk are increasingly bombarding banks.

The scholars, Weber, Fenchel and Scholz (2008) investigated where banks have embedded environmental risks into the whole credit risk management process, namely, the credit rating, loan costing, loan pricing, loan monitoring and loan workouts. Their results show that banks have only embedded environmental risk at the credit rating stage (loan appraisal or evaluation stage) and not in the other phases. The sample was mostly European banks. Weber *et al.* (2008) also conducted research on the 'where' but did not investigate the 'how' part. They also emphasised the need for banks to not only rate or evaluate the environmental risk exposure of the borrower but to include the estimated cost of the environmental risk in the loan price.

Weber *et al.* (2008) used the United Nations Environmental Program Statement by Banks on the Environment and Sustainable Business to conduct a qualitative study on which banks that are signatories and those that are not, are embedding environmental risk in all their credit risk management phases. However, they cited a lack of standard methods of embedding environmental risk in the loan-rating and loan-costing phases.

Weber (2012) investigated Canadian banks to determine how they integrate environmental risk in the credit risk management process. Weber also included a benchmarking study of how the Canadian banks compare with their global peers in terms of embedding environmental risk into bank credit processes. Similarly, Weber, Scholz and Michalik (2010) did a study which showed that by incorporating sustainability criteria into the credit risk process, banks would likely improve the credit default predictions by 7.7%.

Weber's (2012) study was a mixed-method study where the qualitative part looked at the reporting on the integration of environmental risks into the credit risk management processes. The following were the indicators considered in discovering how a bank incorporates environmental risk in the credit process: general reporting, economic importance reported, quantitative indicator reported, trend analysis reported, and benchmark reported.

The qualitative part of the study showed that the nine banks that comprised the study mostly reported at a general level on the embedding of environmental risk in the credit process. The other indicators (quantitative indicators reporting, economic importance reported, trend analysis reported, and benchmark reported) were used less by the banks. However, four of the nine banks reported the number of loans analysed per year, showing a trend of reporting more facts and figures than policies in place.

Weber emphasises the ‘why’ rather than the ‘how’ in this study. Weber maintains that by reporting the embedding, and the facts and figures of how the bank is embedding environmental risk into bank credit processes, this provides evidence to show if their environmental risk management policies are working.

The quantitative part of Weber’s (2012) study shows that Canadian banks are better than their global peers in integrating environmental risk into bank credit processes. However, the gap left by Weber, is the need to look at the models used to embed environmental risk into bank credit process, which the literature does not adequately address.

Erina and Lace (2012) conducted a study that focused on a qualitative analysis of the scientific literature on environmental risks that are applicable to lending transactions. They used information from the Latvian commercial banks to construct a sectorial analysis of environmental risks. They further identified the lending workflow that needs to be considered by Latvian banks when dealing with environmental risk. They made an ex-ante identification of the sectors that affect the environment and those that do not affect the environment. These sectoral classifications were determined using a focus group.

Figure 2.5 shows the new lending decision-making structure Erina and Lace proposed in which the banks would need to incorporate the borrowing client’s corporate social responsibility aspects in the loan decision-making.

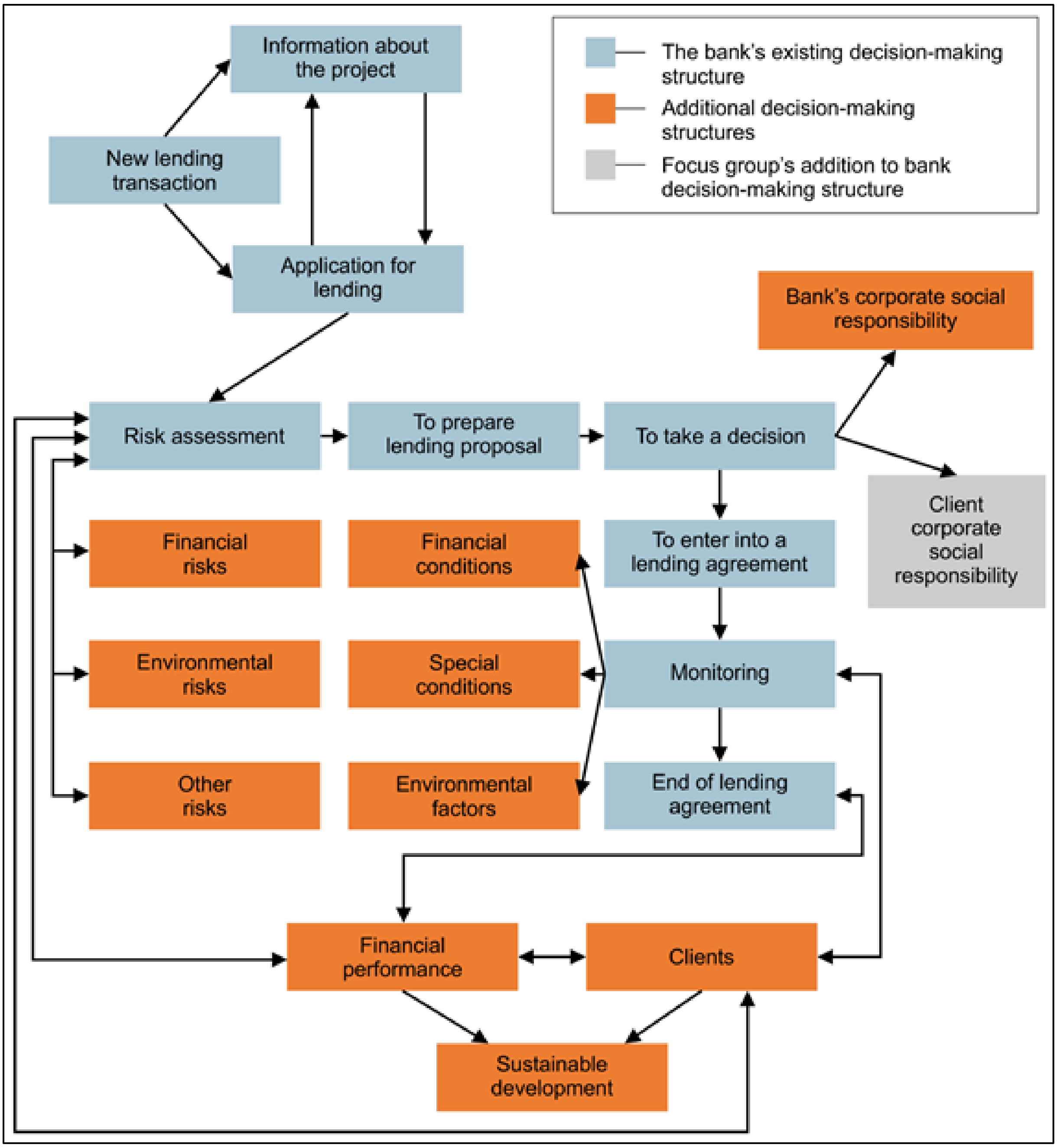


Figure 2.5: Lending decision-making structure incorporating environmental risk

Source: Erina & Lace (2012)

Erina and Lace's (2012) study emphasises the need for, and where, to embed environmental risk into credit processes but does not further provide any technical details of how to do so. They also show the 'who', that is, the different types of borrowing customers that are affected by environmental risk but do not show the degree of impact.

In order to introduce loan pricing models that incorporate environmental risk, Erin and Lace reclassified the sectors into three groups as follows: A1 – low-risk sectors, B1 – medium risk sectors, and C1 – high-risk sectors. This classification is derived from the sub-sectors created by the Central Statistical Bureau of Latvia. Therefore, they created a simple loan-pricing model for each group, which was derived from the inputs by the banks participating in the focus groups.

Although Erina and Lace (2012) provide a useful and simplified approach to incorporating environmental risk into bank credit processes, the simplification falls short when complex structures are considered by the lending bank. There is no scientific or methodological justification of how the proposed loan-pricing model calculates the risk premiums. More so, how these risk premiums compensate for the environmental risk identified, is not shown.

The strength of Erina and Lace's study is the provision of a framework to work from, despite the lack of details about embedding environmental risk into the bank credit process. Their study can also be commended for the classification of borrowing entities into industrial classifications that are of low, medium and high environmental risk exposure. However, this classification could have been more robust if there were elaboration and justification of the classification factors.

Mengze and Wei (2015) conducted a study on the Environmental Credit Risk Management (ECRM) of commercial banks in the Asia Pacific region. Their study revealed 32 indicators of ECRM performance that have been tabulated in Table 2.4 (on the next page). These ECRM performance indicators are used to do a comparative study to determine the level of embedding of environmental risk into the credit processes.

Table 2.4: Checklist for evaluating the environmental credit risk management (ECRM) performance of banks

Sections	Sub-sections	Indicators	References
A. Policy framework for ECRM	A1. Policy approach	A11. General environmental management policy applicable across all of the bank's activities. A12. Functional policy embedded in other policies for specific activities such as credit assessment.	Coulson (2002); Lundgren & Catasús (2000); Jeucken (2004); UNEP FI (2007a)
	A2. Organisation structure	A21. The department or committee considers environmental risks for the environment or sustainable development. A22. Environmental risks consideration by risk committee or lending officer.	
	A3. Product coverage	A31. ECRM policy is applied to project loan. A32. ECRM policy is applied to the corporate loan. A33. ECRM policy is applied to personal and small and medium-sized business (SME) loans.	UNEP FI (2007a); UNEP FI (2007b)
	A4. Influential issues	A41. ECRM policy takes account of environmental impacts associated with products and services. A42. ECRM policy takes account of climate change issues such as, for example, carbon emission, and energy efficiency. A43. ECRM policy takes account of biodiversity and ecosystem service issues, such as vital goods and resources, and cultural services.	Coulson (2009) UNEP FI (2002) Mulder (2007); NEP FI (2011a); PCLPP- Pricewaterhouse Coopers (2010); Rubino (2000)

Sections	Sub-sections	Indicators	References
B. Method of implementation of ECRM	B1. Assessment priorities	B11. Bank cited sector classification as a factor triggering environmental assessment. B12. Bank cited the geographic location of the borrower as a factor triggering environmental assessment. B13. Bank cited the influence of legislation as a factor triggering environmental assessment.	Coulson (2002); UNEP FI (2007a)
	B2. Implementation tools	B21. Application flow chart to guide implementation of ECRM. B22. Application of own tools, such as a checklist or questionnaire, to implement ECRM. B23. Application of own tools such as risk matrix to implement ECRM.	
	B3. Assessment Process	B31. **Identification:** bank conducts a comprehensive investigation of potential environmental risks associated with client and client's undertakings. B32. **Analysis:** bank analyses how real the potential risks are and how they might impact the bank. B33. **Categorisation**: bank places the transaction into a category based on analysis results. B34. **Mitigation**: bank requires environmental risk mitigation measures in their transactions. B35. **Monitoring:** bank adds mitigation measures to financial terms and ensures measures are enacted effectively.	Coulson (2002); Weber *et al.* (2008); UNEP FI (2011b)

Sections	Sub-sections	Indicators	References
C. Embedding ECRM	C1. Managing ECRM policies	C11. Bank has a centralised environmental credit risk support service team to help and advise on ECRM policy implementation. C12. Bank relies on external consultants to help inform the environmental assessment process. C13. Bank trains employees in ECRM work.	FORGE (2002); Coulson (2002); UNEP FI (2007a)
	C2. Monitoring ECRM policies	C21. Bank audits ECRM policy system periodically. C22. Bank formally tracks its performance concerning ECRM.	
	C3. Reporting of ECRM	C31. Bank reports on the environmental examination of credit risk at the general reporting level. C32. Bank reports on the environmental examination of credit risk at the financial importance reporting level. C33. Bank reports on the environmental examination of credit risk at the quantitative indicator reporting level. C34. Bank reports on the environmental examination of credit risk at trend analysis reporting level. C35. Bank reports on the environmental examination of credit risk at the benchmark reporting level.	GRI (2008); Weber (2012)
	C4. Communication of ECRM	C41. Bank establishes structures or procedures for consultation or feedback regarding continuous improvement.	Coulson (2002); UNEP FI (2007a)

Sections	Sub-sections	Indicators	References
D. Influence factors on the ECRM performance of the bank	D1. Signatory of voluntary code	D11. Bank as a signatory of UNEP FI. D12. Bank as a signatory of EPs.	Cowton & Thompson (2000); Wright & Rwabizambuga (2006); Scholtens & Dam (2007)
	D2. Green income incentive	D21. Bank provides specific financial products and services for environmental purposes. D22. The bank sets green development as its new strategy.	Jeucken (2004); Weber (2005); Porter & Kramer (2006)

Source: Mengze & Wei (2015)

Mengze and Wei (2015) drew a sample of 120 banks from 12 countries out of 19 member states of the Asia-Pacific Economic Cooperation to test the ECRM performance using the checklist provided in Table 2.5.

Columns B and C are relevant to this study since they focus on how banks are embedding environmental risk into their credit processes. It should be noted that Mengze and Wei considered the ‘how’, though not the details thereof. Their focus is on the performance of embedding ECRM, which also has no standards, such as the average credit risk management system. Therefore, this draws attention to the need to standardise the embedding of environmental risk into bank credit process to have a common yardstick.

This study resulted in the classification of the performance of the banks into the following three levels: systematic management (higher scores), preliminary management (medium scores) and no management (low scores). The study showed that 49 banks do not conduct any environmental credit risk management, 31 banks fall within the level of preliminary management, and 40 banks are at the level of systematic management.

Also of importance to note is the decrease in mean and standard deviation values as one moves from section A to C, meaning that policy implementation was poor amongst the sample of banks. Relative to this study, on sub-section B1 (assessment priorities), fewer banks did declare their assessment priorities. In other words, not many banks provided details about specific policy or guidelines about certain kinds of environmental risk by sector or geographic location.

The illustrated schematic view in Figure 2.6 summarises the discussion done in this chapter of how the current study views environmental risk. The task at hand, therefore, involves the process of quantifying the proposed scope of environmental risk. However, as noted in some definitions and studies discussed earlier in this thesis, carbon risk seems to be a plausible proxy for environmental risk, given its wide-ranging impact on climate change and its global effect as well. Therefore, its link to the physical damage risk makes it a suitable proxy for the heightened perception of environmental risk.

As observed in the previous discussions, the lender-liability phenomenon has been overtaken by climate change as a source of environmental risk. Climate change has broadened the scope of environmental risk in terms of quantified damage and the impact from local to global.

Figure 2.6 illustrates the types of environmental risks from the bank lending perspective.

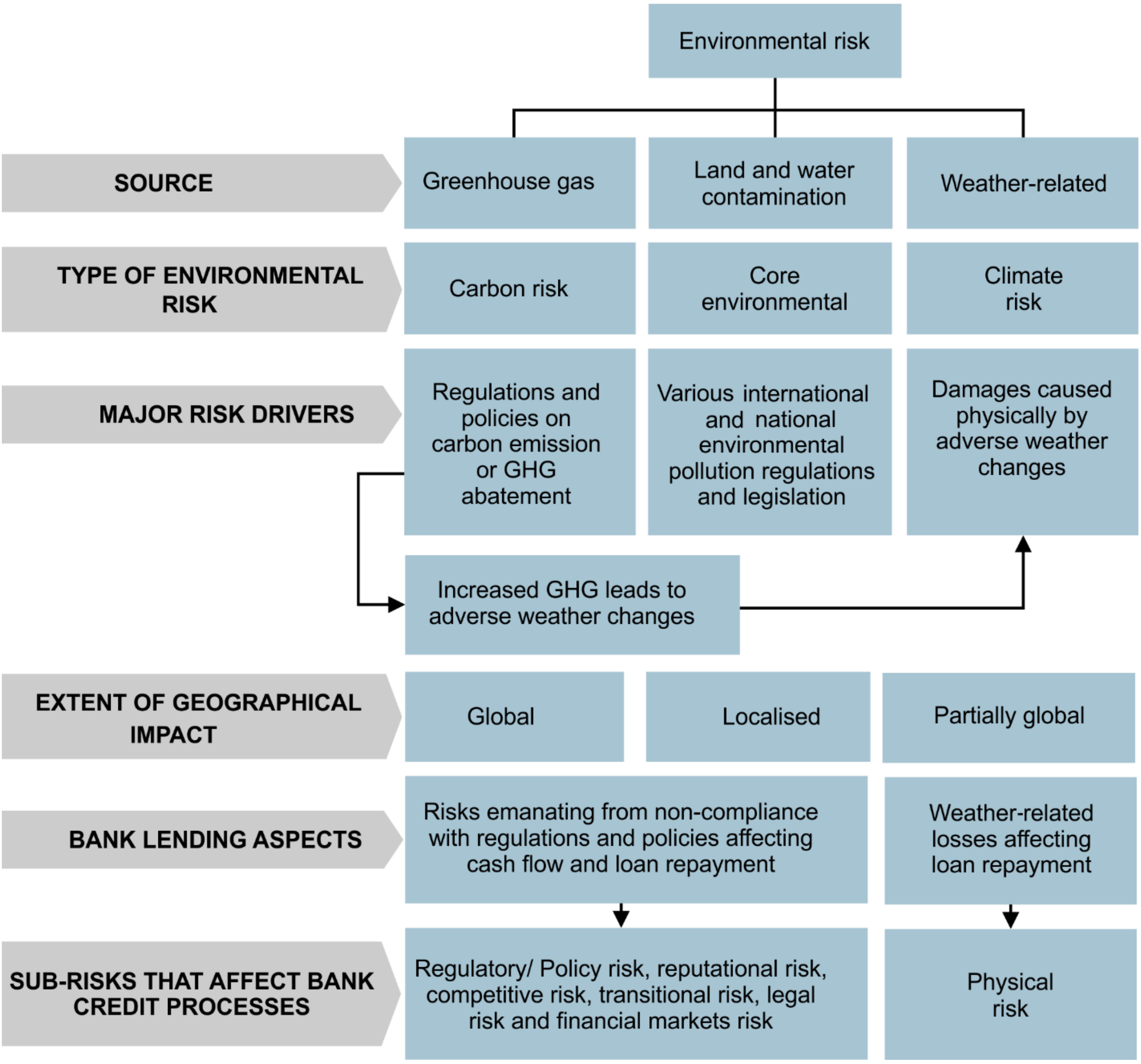


Figure 2.6: Redefining and contextualising environmental risk – a broader view

Source: Author's own compilation

2.5 SUMMARY

This chapter discussed two main issues: (1) the definition of environmental risk and its subsets, and (2) the implications of climate change-related risk to financial intermediation theories. Firstly climate change-related risk was defined to place it in the context of its relationship with environmental risk. It has been proven that environmental risk is a broad term, with climate risk and carbon risk being a subset of environmental risk. However, there are various angles related to defining these types of environmental risk, for example, as related to: (1) source, (2) risk driver, (3) extent of geographical impact, and (4) the bank lending aspects of each risk.

It has been established that environmental risk can be split into carbon risk caused by greenhouse gases, core environmental risk emanating from land and water contamination, and climate risk emanating from extreme weather patterns. However, the policies to control these risks also exacerbate the risks. These aspects are summarised in Figure 2.6. Most importantly, the discussion managed to differentiate environmental risk in the context of a non-financial institution or a business and a financial institution.

The discussion narrowed down to environmental risk and its impact on bank lending. Environmental risk affects bank lending on two fronts, that is, through (1) the combined environmental sub-types of regulatory or policy risk, reputational risk, competitive risk, transitional risk, legal risk & financial markets risk, and (2) physical risk.

The combined environmental risk sub-types have a transmissional effect that affects mainly the cash flows of a given business, firstly, by non-compliance to environmental regulations or policies related to environmental legislation. In this case, the business can take either of the two routes, for example, the business may face reputational risk in that its stakeholders will withdraw from it fearing the negative effect on their own reputation and loss in any investments in that business. Secondly, not adhering to new environmental regulation exposes the business to competitive risk if its peers or competitors are either first-movers or quickly turn the adherence into a competitive edge. From here, the business can face transitional risk if they don’t have the resources and capital needed to make their business operations comply with new environmental regulation. By not complying with these environmental regulations, businesses face legal risk through penalties and legal prosecutions. With regards to physical risk, the business would have its operations disrupted, leading to reduced financial income or losses.

The business perspective on environmental risk is mainly in the form of environmental liabilities that emanate from flouting regulations and policies around the sub-types of environmental risk, as shown in Figure 2.6. A taxonomy has been established, which shows how environmental risk fits into the existing business risk taxonomy (see Table 2.2 and Figure 2.3).

By disintegrating environmental risk into carbon risk and climate risk, one can understand environmental risk from a business perspective. The Fulton and Weber view of carbon risk adopts a carbon asset risk, in that, if a business has assets that produce carbon emissions, that will be operator carbon risk. The corresponding financial risk to financial intermediaries will be carbon asset risk. However, the conclusion is that there is synonymity between carbon risk and climate risk, since both stem from the impact of climate change.

Finally, climate-related financial risks can be divided into transition risk (with the sub-types: policy and legal, technology, markets and reputation), physical risks (with sub-types: acute and chronic), and lastly, liability risk (see Table 2.3 for full definitions). For the purpose of this study, carbon tax is regarded as transition risk, and carbon tax will be used as a proxy for environmental risk. Therefore, the review has put environmental risk into perspective in the context of this study.

The second aspect that this chapter has established is how banks are embedding climate change, or environmental risk, into the bank credit process, and how financial intermediation theory is affected by the impacts of climate change. The delegated monitoring theory and the information asymmetry theory are particularly relevant, in that banks can monitor environmental risk on behalf of depositors address moral hazard and adverse selection issues. Inferring from the complete information analogy, it is realised that if there is complete environmental risk information, moral hazard and adverse selection issues can be solved. Therefore, these theories infer that depositors or investors would not like to see funds given to entities that have environmental risk, and they would not give their funds to financial intermediaries who do not have environmental risk-screening processes in place. This analysis provides a basis for how the credit allocation function (in the ambit of financial intermediation) is necessary for environmental risk amelioration.

Having established the nexus between the financial intermediation theory, bank credit process, and environmental risk, the next chapter explores the empirical evidence related to the embedding of environmental risk into bank credit processes. Chapter 3 will look at current inroads of environmental risk into bank general processes, and then whittle the discussion down to bank credit processes.

CHAPTER 3:
EMBEDDING OF ENVIRONMENTAL RISK IN CREDIT RISK MANAGEMENT

3.1 INTRODUCTION

This chapter establishes the link between bank credit processes and environmental risk and explores the embedding of environmental risk at an international and South African level. Furthermore, this chapter presents the analysis of the exploration of methods of embedding environmental risk into bank credit processes. The aim is to establish the width and breadth of how bank credit processes are embedding environmental risk. In other words, the chapter explores parts of the bank credit processes where environmental risk is embedded. The exploration pursues the qualitative and quantitative methods and particular aspects of embedding environmental risk into bank credit processes. The chapter ends with a discussion that shows the lack of full embedding of environmental risk into the financial prediction models used in bank credit processes.

3.2 INTERNATIONAL PERSPECTIVES- EMPIRICAL STUDIES

Cogan (2008), in a report compiled for Ceres Inc., indicates the initiatives implemented by global banks to embed environmental risk into their bank lending processes. Cogan surveyed 40 global banks to find out if they had an environment risk policy in place that embeds environmental risk into their credit processes. Only 30 of the 40 banks had a general environmental risk assessment policy in place. In contrast, some banks had specialised environmental risk management teams or had integrated the environmental issues into their mainstream risk assessment processes.

Cogan argued that the risk assessments done by the global banks with regards to environmental impacts are confined to the traditional environmental risks, which are site contamination, or the assessment of the high polluting sector and how they impact the creditworthiness of a borrowing client. Cogan (2008) further argues that such an approach will not adequately address emerging environmental risks, such as climate change, or involve any public disclosure.

The Equator Principles (EP) is a risk management framework that is a popular tool for embedding environmental risk into the bank lending process. The Equator Principles that were promulgated in 2003 was the brainchild of various financial institutions, such as ABN AMRO, Barclays, City Group and WestLB, in collaboration with the International Finance Corporation.

The EP is a tool that banks use to help assess, mitigate, document and monitor the credit risk and reputation risk associated with financing development projects. Although the EP does not address climate change mitigation, as per Cogan (2008), it provides the first step in integrating environmental considerations into project finance for most banks. As part of an annual review process, banks should report on development projects they have financed, and rank the extent of social and environmental impact the projects might have. They should also indicate the number of projects they declined to finance due to their adverse environmental and social impact.

The EP mainly covers four financial products, namely, project finance advisory services, project finance, project-related corporate loans and bridge loans. Table 3.1 summarises the 10 principles that make up the EP. There have been three phases of the EP: when launched in 2003, the EP I consisted of the original principles. Thereafter, EP II appeared that consisted of the revised EP I that incorporated the new IFC performance standards on environmental and social risks of project finance in 2006.

Table 3.1: The 10 Equator Principles

Principle	Explanation
1. Review and categorisation:	EPs describe three risk categories (A, B and C) as categorised in the IFC's social and environmental screening criteria. Category A projects have potential for, or significant or adverse social and environmental impacts that are diverse, irreversible or unprecedented. Category B projects have potentially limited adverse social and environmental impacts that are few, generally site-specific, largely reversible and can be readily addressed through mitigation measures. Category C projects have minimal or no social or environmental impacts.

Principle	Explanation
2. Environmental and social assessment:	A mandatory prerequisite for the client seeking financing is a requirement to the satisfaction of an EPFI (Environmental Principle Financial Institution).
3. Applicable environmental and social standards:	Following EP II, the social and environmental assessment should be in tune with the socio-environmental standards relevant to the country or jurisdiction of the project. Differences exist between standards in non-Organisation for Economic Co-Operation and Development (OECD) high-income and OECD countries ('designated countries' as per EP III). For projects located in non-OECD countries, and those not designated as high-income, the assessment will refer to the applicable IFC performance standards and the applicable industry-specific EHS guidelines.
4. Environmental and social management system and EPs action plan:	Drawing upon results of EP III and conclusions thereof, the client/borrower must prepare action plans describing and prioritising between mitigation measures, monitoring and corrective actions, the relevant details of which align with the potential severity of the anticipated risks.
5. Stakeholder engagement:	Stakeholder engagement is required for category A and B projects. It requires the client, host country or third party expert to engage with affected communities in a culturally appropriate manner, seeking their free, informed and prior consent about the project.
6. Grievance mechanism:	The EPs require that the client should establish a grievance mechanism appropriate to the level of risks and adverse impacts of the projects, and the affected communities should be made aware.
7. Independent review:	The EPs require an 'independent expert', independent of the borrower, to review documents on social and environmental assessment, environmental and social management systems, and environmental performance assessment procedures to inform on the due diligence process.
8. Covenants:	Refers to covenants with the host country, compliance with the assessment procedure, periodic reports, and, where appropriate and necessary, a decommissioning plan.
9. Independent monitoring and reporting (IM & R):	A client will retain an IM & R expert for category A and B projects were 'appropriate'.
10. Reporting and transparency:	The Environmental Principle Financial Institutions (EPFIs) will annually report on their implementation outcomes, or report frequently or scaled to the severity of potential risks. For example, EP III requires online reporting (The EPs, 2013).

Source: Adapted from Weber & Acheta (2014)

The current EP III has expanded the EP II to include project-related loans and bridging loans. Weber and Acheta (2014) maintain that the addition of these modes of financing is because the continuous aggregation of relatively short, maturity-sized financing could contribute significantly to unsustainable social and environmental project finance activities.

Furthermore, EP III requires not only implementation but also the structure and staffing personnel involved. The information should include mandatory training information of staff with regards to the first year of EP implementation. Also addressed in the EP III is the client's public reporting, which was not included in EP I and II. So, organisations are expected to report Environmental and Social Impact Assessment, as well as Greenhouse Gas (GHG) emission levels for projects emitting over 100 000 tons of CO_2 annually during the operation phase.

Table 3.2 summarises the changes from EP I to EP II, and then from EPII to EP III.

Table 3.2: Changes in the Equator Principles versions I, II and III

Topics	Version I	Version II	Version III
	Changes reflecting priorities and recommendations from the EP strategic review		
Scope	Lending	Lending, project finance advisory	Project finance, advisory, project-related corporate loans, bridge loans.
	No format required.	High-level reporting: number of transactions screened and closed	Reporting minimum requirements: number of projects closed, including categorisation, sector, region, and whether an independent review has taken place. Project names for project finance deals (subject to client consent). An online summary of environmental and social impact assessment.
	Changes to align with updated IFC standards		
Sustainability issues	Environmental assessment (no social risks, climate change not mandatory.	Social risks' due diligence, free prior informed consultation. Climate change as part of World Bank guidelines, and general due diligence.	Social and relevant human rights due diligence. Free prior informed consent. Addressing human rights. Guiding principles on business and human rights and UN Protect Respect and Remedy Framework. Climate change: Attention in due diligence for high emitting projects.
	Changes to address consistency and support implementation		
Information sharing		Informally	A formalised approach to share information related to environmental and social matters with other mandated financial institutions.

Topics	Version I	Version II	Version III
Country designation	Assessment in high-income OECD countries equivalent to IFC standards.	Assessment in high-income OECD countries a substitute for IFC standards.	The assessment process in designated countries (EP list) equivalent to IFC standards.
Glossary of terms			Glossary of terms for loan documentation.
Implementation notes	Best practice – As per internal EPFI procedures and policy.	For loan documentation.	For loan documentation. Under development - implementation notes for climate change reporting requirements, and questions and answers on scope.

Source: Adapted from Weber and Acheta (2014)

A study by Bauer and Hann (2010) investigated the impact of corporate environmental management credit risk on bond investors. They propose that environmental practices influence the solvency of borrowing firms by impacting their exposure to legal, reputational and regulatory risks. They further argue that a borrowing company that engages in environmental misconduct can incur costly penalties (regulatory risk) and educe strong negative responses (reputational risk) from financial and non- financial stakeholders. Hence, this affects the value of its default risk or ability to repay, and therefore, deteriorates the value of a borrowing company's fixed-income security.

Bauer and Hann also state that bond investors wanting to protect themselves against environmental performance-related payment losses should fully understand the interaction between credit risk and various corporate environmental activities before making their decision to lend. The empirical study done by Bauer and Hann indicates an economically meaningful and statistically significant relationship between the environmental performance measures, and both the cost of borrowings and credit ratings of borrowings.

Gao (2011) conducted a study on the impact of environmental capital expenditure on electrical utility companies' market value in the US between 2005 to 2007. The study was done at a time when the Environmental Protection Agency introduced various regulations to limit the emission of sulphur dioxide, nitrogen dioxide and mercury into the air from coal-fired electric generating stations. The primary outcome of this study is that environmental capital expenditure has a positive impact on the market value of companies with superior environmental performance. However, it has a negative impact on the market value of weaker environmental performers. Gao's (2011) study also confirms the assertions of previous studies that compliance drives environmental capital expenditure, as, for example, some companies intentionally spend on environmental capital to obtain a strategic competitive advantage (Johnston, 2005).

Gao (2011) argues that compliance through environmental capital expenditure results in more investments in innovative technologies that remarkably reduce pollution and improve the production process. The result is that companies become environmentally compliant and avoid environmental penalties. Similarly, Porter and Van der Linde (2001), Epstein (1996) and Reinhardt (1999), argue that environmental capital expenditure will benefit the companies in terms of improving their reputational risk from environmental liabilities and lawsuits.

Therefore, these arguments highlight new aspects that banks should consider when incorporating environmental risk into their bank credit processes. The most relevant aspect for the lender will be to determine how environmental capital expenditure is related to the growth in the market value of a firm. The only problem is that Gao's (2011) study was done over a short period of time and only focused on electric utility companies. It, therefore gives us a limited view on the relationship between environmental spending, environmental performance and revenue generation.

Table 3.3 presents a compilation of studies that investigated how banks are quantitatively embedding environmental risk into their lending processes. The studies underline the key factor that a connection exists between credit risk and environmental risk. Most of the studies use environmental liability as a proxy for environmental risk, and bond issue or ratings as a proxy for credit risk.

The studies by Graham, Maher and Northcut (2001), Billiot and Daughtrey (2001), Ulph and Valentini (2004), and Graham and Maher (2006) connect environmental liabilities with bond ratings. The main outcome of these studies is that environmental liabilities have a significant impact on bond ratings. This literally means that environmental liabilities (environmental risk) directly impacts bond ratings (credit risk). The implication from these studies is that as environmental liabilities increase so does the bond ratings, which means that a company's credit risk deteriorates as its environmental liabilities increase. This is the phenomenon the current study aimed to explore in relation to the JSE100 companies that have been reporting their carbon emissions from 2010 to 2017. These studies give a base to the possibility of testing the connection between environmental risk and credit risk.

The studies by Chava (2010), Schneider (2011), and Bauer and Hann (2010) mainly focused on how environmental risk affects the credit pricing or interest rate charged on a company. In this case, the studies examined the link between environmental liabilities and interest rate or credit pricing and some with the cost of debt. The overall outcome from the abovementioned studies was that there is a positive correlation between environmental risk and bond pricing or cost of debt.

Therefore, it is clear that the theory that drives all studies compiled in Table 3.3 is that environmental risk has a direct positive relationship with credit risk.

Table 3.3: Empirical studies on environmental performance and credit risk

Authors & study year	Country and method of study	Variables for credit risk	Variables for environmental performance	Major outcomes
Graham *et al.* (2001)	USA Company-specific data, Logistic Regression, Bond rating model, Classification accuracy	Status of a bond issue, Total assets, Long-term debt to total assets, Share Beta, Net income from operations to total assets, Net pension liability of the company, Dummy variables to control for industry type.	The variables for this study: ▪ Notice letter received from the Environmental Protection Agency. ▪ Total capital. ▪ Monitoring and operating costs for all sites of a company are identifiable as a PRP (Potential Responsible Party) on a site. ▪ Total of a company's equal share from all sites it is identifiable as a PRP. ▪ Costs allocated on an equal basis but the company being registered on COMPUSTAT and Settlement costs.	Environmental liability is a significant factor in explaining bond ratings. Value relevance of environmental information to debt markets.
Billiot and Daughtrey (2001)	The USA, Agribusiness companies, 1993 -1996, logit analysis and OLS	Loan variables: Interest rate risk premium charged to agribusiness borrowers, Loan amount, and loan term. Macro-economic variables: Base interest rate and consumer confidence index. Borrower variables: deviation in interest coverage, interest coverage ratio, leverage, total assets.	Environmental variables: air pollution violations, emergency response notifications, pesticide violations, properties named potentially responsible parties, underground tanks, potential oil and petroleum release, potential liability for spills of hazardous materials in transit for companies with specific industry affiliation and potential releases of other types of pollutants, adjusted for industry affiliation.	Significant environmental liability is considered as a source of financial risk to Agribusiness and is priced in loan terms by lenders through increased interest risk.

Authors & study year	Country and method of study	Variables for credit risk	Variables for environmental performance	Major outcomes
Ulph and Valentini (2004)	USA Industry-level data, Regression analysis.	Interest rate, Monetary base, Profitability (retained income over sales), Shareholder equity over total assets, Fixed Assets over total assets, current assets/total assets, working capital over total assets, growth of total assets, growth of capital stock and depreciation over total assets, the standard deviation of profitability over 12 periods.	Exposure of different industries to clean-up costs under CERCLA, Use of dummy variables to capture the different environmental liability regimes: – value 0 if from 1973 to 1980, – value one if the company falls within 1981 to 1991 and – value 0 after that. Dummy variables capture Fleet factors where both company and bank are jointly liable.	Imposing environmental liability on companies only would lead to highly inefficient use of bank borrowing as well as an inefficiently low-level effort to reduce environmental damage. However, imposing liability jointly on banks and companies would lead to lower bank borrowings than when liability is imposed only on companies. The empirical study showed that by imposing environmental liabilities on companies, only the bank borrowing would increase by 15% to 20%. However, when liability extended to banks, borrowing fell back almost to the level expected without any environmental liabilities.
Graham and Maher (2006)	The USA, 1995 -1998, Modified logistic regression model (Kaplan and Urwitz (1979), panel data analysis	Bond yield, treasury yield, relative risk premium, bond size, year to bond call divided by the years to maturity, years to put divided by the years to maturity, dummy variable for make whole-provision,	Company's environmental liability accrual, net pension obligation divided by total assets, number of times a company has been issued with a PRP notice letter, costs of remediation for a site summed across all sites at which the firm has been named as a PRP, divided by the average total assets, costs of remediation for a site divided evenly	The higher the estimated environmental liability, the larger or riskier the company's bond rating. EPA – generated environmental liability estimates are positively related to bond yields for new debt issues.

Authors & study year	Country and method of study	Variables for credit risk	Variables for environmental performance	Major outcomes
		Moody's bond rating, bond issue subordination, company's beta, total assets, long-term debt divided by total assets, interest expense divided by income before taxes and interest, net income divided by total assets	among the Compustat PRPs named at the site, then summed across all sites at which the firm has been named as a PRP, divided by average of total assets, costs of remediation for a site divided evenly among all PRPs at the site, then summed across all sites at which the firm has been named as a PRP, divided by the average of total assets.	
Sharfman and Fernando (2008)	S&P 500 Dataset of United States firms. Causality Model or Multivariable Regression Models between Environmental Risk Variables and Cost of Capital Variables.	WACC (Weighted Average Cost of Capital). Company control variables: – Financial Leverage, – Industry Sector, – Company Size	USA Environmental Protection Agency (EPA) TRI data and from KLD social and environmental performance dataset.- Total TRI emissions, Total TRI emissions treated on-site to reduce toxicity, total TRI emissions reused or recycled on-site for energy generation and total waste generation, including TRI emissions. Standardised the first three measures by the waste generation variable to see what percentage of the company's waste generation is closely monitored. Also, what percentage of the firm's discharges were being treated to reduce their toxicity Used KLD environmental strengths and	There is a significant positive relationship between the cost of debt capital and environmental risk management. Companies with better environmental risk management benefit by being able to carry a higher level of debt. Companies with a higher level of environmental risk management reap higher tax benefits arising from debt financing. Cost of debt increases with environmental risk management but offset by higher levels of tax reduction associated with environmental

Authors & study year	Country and method of study	Variables for credit risk	Variables for environmental performance	Major outcomes
			concerns to come up with an environmental score.	risk management driven by a combination of higher leverage and higher cost of debt. Environmental risk leads to a lower beta also leading to a lower cost of capital.
Chava (2010)	MSCI KLD 400 social index, Panel Data Analysis, Sample study period: 1992 to 2007	(1) Bank loan data, - Dealscan database – loan spread (interest rate variable), all-in-spread-drawn (amount paid by borrower in basis points over LIBOR), Control variables at company level: – company's total assets, – operating income before depreciation to the total company assets, – leverage (debt to equity), – modified Z-Score (based on Graham, Lemmon and Schalleim (1998), – public debt rating (binary), – public rated investment grade from S&P (binary), – Loan maturity, – loan performance-price feature (binary), – loan term (binary). Macro variables:– Treasury notes yields, Corporate bond yields	KLD Stats on Environmental profile of companies used in the study – environmental concerns (hazardous waste, legal emissions of toxic waste, binary variable if company sells carbon linked products or not) and environmental strengths, (sale environmental beneficial products, pollution prevention products, use renewable energy and clean fuel, signatory to the CERES principle, environmental disclosure report).	Lenders charge a significantly higher interest rate on the bank loans issued to companies with environmental concerns. Observed positive relation between expected stock returns and spread on the bank loans and a company's environmental concerns are partly driven by socially responsible investors and environmentally sensitive lenders screening out companies with environmental concerns.

Authors & study year	Country and method of study	Variables for credit risk	Variables for environmental performance	Major outcomes
		(2) Implied cost of capital calculations (from I/B/E/S database, KLD, CRSP, COMPUSTAT) – company size (book assets), market to book ratio, book leverage, stock volatility return over the year and accounting and market data.		
Schneider (2011)	Univariate & Multivariate Analysis, USA Pulp, Paper and Chemical Industries 1994 -2004	Bond trades – spread basis between yield to maturity of a company in the sample and the comparable US Treasury Bill yield of similar maturity traded on the same day. Firm-Specific Control – Z-Score, Leverage, Share price volatility, Company Size. Bond Specific controls: – bond rating, bond time to maturity, spread between the average Moody's Aaa corporate bond yield and the 10-year Treasury bond yield on the day of bond trade, original offering amount of the bond issue, callable bond, number of covenants associated with a bond.	Toxic Release Inventory (TRI), Mandatory and Voluntary disclosure of information. To create a comparable measure between firms, TRI is divided by sales (sales being a proxy of production).	The univariate analysis results show a strong correlation between environmental performance variables and yield spread. The multivariate analysis shows that there is no association between environmental performance and yield spread. However, a firm's environmental performance is reflected in its bond pricing. Nevertheless, as bond quality increases, there is the likelihood that the environmental costs will lead to insolvency decreases.

Authors & study year	Country and method of study	Variables for credit risk	Variables for environmental performance	Major outcomes
Bauer and Hann (2010)	USA, Multivariate Regression Analysis	Cost of debt financing (bond spread), bond ratings and long term issuer ratings, issuer-specific controls (Leverage, size, capital intensity, interest coverage, Return on Assets, Loss) and issue-specific controls (subordinated, Time to maturity (in years), issue Size (in MM$) and speculative).	Used data from Kinder, Lydenburg and Domini Research and Analytics (KLD) and grouped the environmental management performance into two (1) Performance strength indicators – beneficial products, pollution prevention, recycling, clean energy, other strength (2) Performance concern indicators – hazardous waste, regulatory problems, substantial emissions, agricultural chemicals, climate change and other concerns.	Environmental practices affect the solvency of companies through possible legal, reputational and regulatory costs. Firms with high Environmental concerns from KLD scores pay a premium on the cost of debt financing and also have lower credit ratings. Firms with proactive environmental engagement are charged a lower cost of debt.
Ge and Liu (2015)	Univariate regression analysis 1992 to 2009	STATS database for variables of credit risk. Firm-level control variables: Bond Issuer size, Return on Assets, Leverage, Audit quality or earnings quality, Z-score. Bond-level control variables: bond rating, bond maturity, bond covenant restrictions, bond issue size, business cycle, bond call feature, bond put feature,	RiskMetrics Group KLD. CSR performance, strengths and concerns scores.	Higher CSR (Corporate Social Responsibility) results in better credit ratings. Higher overall CSR is positively linked to lower bond yield spreads. CSR dimensions of environment, community and governance are significantly associated with lower bond yield spreads.

Authors & study year	Country and method of study	Variables for credit risk	Variables for environmental performance	Major outcomes
		convertible bond feature, US SEC (Securities and Exchange Commission) rule 415, US SEC rule 144a. Industry and year indicator variables: Fama and French's 48 industry indicators and year indicators.		

Source: Author's own compilation

The studies summarised in Table 3.3 prove that the causal relationship of environmental risk with credit pricing confirms that high risk is consistent with high-interest rate or credit price or bond price. Bond price or credit price or interest risk is linked to the major outcome of the credit process, namely, credit rating or credit risk status. Therefore, these studies confirm the need to investigate the link between environmental risk and credit risk. The studies further provide a base from where to start. However, these studies have used mainly environmental violations compiled by companies and have not used carbon pricing, which links directly to the climate change impact of a company's activities. Therefore, there remains a chasm of not linking all the company's activities that emit carbon emissions to its credit rating.

3.3 FINANCED EMISSIONS

The concept of financed emissions is derived from the carbon footprinting concept. Weidmann (2009) asserts that the term 'carbon footprint' originated from the concept of ecological footprint that was formulated in the 1990s, and it is linked to the work of Rees and Wackernagel (1996). For their part, Plassman *et al.* (2010:393) define carbon footprint as an "estimate of the total amount of greenhouse gas (GHGs) emitted during the life cycle of goods and service, that is, from the extraction of raw materials, production, transportation, storage and use to waste disposal". Plassman *et al.*'s definition captures the whole process of carbon footprinting and makes it generic to any business, whatever industry it operates in.

Weber (2014) defines financed emissions as emissions caused by the bank's clients. Therefore financed emissions are the Green House Gas emissions emitted by companies in which a financial institution has invested through either debt or equity. There are two notable studies in the literature that deal with the measurement of financed emissions. The first is the study by Nielsen, Luttmer and Van der Hoek (2009) that put together a compilation of the methods used to carbon footprint financed emissions. The second study involved a compilation of financed emissions methodologies by 2°ii (2°ii, 2013) in partnership with ADEME (French Environment and Energy Management Agency), Caisse des Depots and AFD (French Development Bank).

Nielsen *et al.*'s (2009) compilation shows that most of the organisations developed methodologies to measure financed emissions in financial products, ranging from investment banking products, asset management and banking products (corporate loans, project finance, bonds and transactional banking products). Nielsen *et al.* mention the following as the leading financed emissions methodologies: Profundo, Utopies, CenSA and EcoFys are methods that measure the financed emissions in loans given out by banks. The EcoFys financed emissions methodology seems to have been more thoroughly researched if compared to the other methodologies that were analysed, and it also relates to the objective of the current study.

The compilation put together by 2ºii (2013) involves models that were developed to measure financed emissions, and they focus on measuring investments, while Nielsen *et al.*'s (2009) compilation investigated a broad spectrum of banking products. The methodologies compiled by 2ºii, however, provide a general view that can be used to measure the financed emissions of any financial product, even though they may be biased toward investment. The main emphasis of 2ºii's compilation is to measure the portfolio risk of investments held by investors to carbon risk. As an example, it answers the question: How is a portfolio of investments of equities impacted by carbon risk? Some organisations developed methodologies that appear on both the compilations; these are TruCost, Profundo, EcoFys and Utopies. A brief review of the methodologies will be ideal at this juncture.

3.3.1 Review of the methodologies

TruCost's model used the carbon data reported by companies. Emissions for non-reporting companies are estimated based on the US statistical model (environmentally extended input-output) to extend coverage to +4 500 listed companies for cradle-to-gate emissions (direct, electricity + third-tier suppliers). Trucost data are available to clients via proprietary online tools, allowing them to screen companies, access company briefings and perform portfolio analysis, as well as allowing access to Factset's terminals. Trucost also uses its data to publish funds rankings, company rankings, and research papers.

Inrate's model uses the same US statistical model, enhanced with life-cycle data to cover the sold products emissions of the investees. Inrate covers more than 2 800 listed companies for cradle-to-cradle emissions (including emissions from sold products use). This method has then be used by Utopies to assess savings products and to publish bank rankings.

The CrossLAsset Footprint model was developed in 2012 for the AFD (the French Development Bank) by a start-up company called Money Footprint Software. It is based on Inrate's model and Caisse d'Epargne's methodology. The model blends bottom-up and top-down approaches to cover all listed non-financial companies and financial institutions (including financed emissions), sovereign bonds, loans to SMEs and households, mortgages, and green projects, for cradle-to-cradle emissions.

The P9XCA methodology was developed in 2011 by Antoine Rose, a PhD student at the Paris-based Sustainability Chair for Crédit Agricole CIB. It covers commitments to non-financial companies and sovereign issuers. The main goal of the methodology is to avoid multiple counting so that it is able to provide an order of magnitude for a bank's financed emissions, rather than informing client selection or industry-allocation. It is based exclusively on open-access public statistics (for example, national GHG inventories, public accounts from UNO and OECD).

The South Pole Carbon model is a mathematical model that extrapolates reported carbon data to provide carbon footprints for every listed company. The data has been made available on Bloomberg terminals since 2012. The methodology is used to calculate the GHG footprints of private equity portfolios in partnership with ESG (Environmental, Social and Governance) analytics. South Pole Carbon has also developed a screening tool for real estate portfolios.

In 2012, Bank of America Merrill Lynch developed another mathematical approach to extrapolate reported data (Asset 4) to non-reporting listed companies. Since 2013, Camradata, which is a firm specialising in institutional investment data and analysis, has been selling the related financed emissions data. The approach is based on CDP data (direct + electricity), and it covers about 8 000 listed companies.

Profundo produces bank rankings based on the amount of financing provided to, for example, fossil-fuel extraction and coal-powered electricity. Their approach is exclusively bottom-up. The approach inventories fossil-fuel companies, both listed and private, and tracks the transactions (loans, equities and bonds issuance) between banks and the companies, as well as equity holdings (asset management and on-balance sheet (statement of financial position) based on data from Bloomberg and public sources.

Carbon tracker uses external data to raise awareness about the carbon bubble issue. The data they use is based on the carbon content of fossil fuels reserves (oil, gas, coal) allocated to the owners; that is, the shareholders of energy companies.

The Dutch ASN Bank developed a cross-assets framework to assess its Statement of Financial Position, and to track carbon performance. They also are measuring financed emissions for equity portfolios, Trucost framework and data. ASN also commissioned Ecofys to build a methodology for them. Ecofys built a methodology similar to the framework developed by Caisse d'Epargne that could calculate emission factors based on a mix of reported data and national statistics, and that was related to sovereign and municipal bonds, mortgages, and real estate. Finally, for emissions that are avoided on project finance, ASN relies on the GHG Protocol. The goal is to balance avoided and financed emissions by 2030 in order to reach carbon neutrality.

3.4 SOUTH AFRICAN PERSPECTIVES

In 2009, at the Copenhagen Accord, South Africa pledged to reduce GHG emissions by 34% below business-as-usual levels by 2020, which equates to a 4% cut in emissions from the levels as at 2005. One of the climate policies proposed was called a feed-in tariff, where the prices paid to the generators of renewable electricity are higher than those paid to fossil fuel-based suppliers. Some of the climate policies in lieu include a carbon tax and fuel efficiency standards (Department of Trade, Industry and Competition: NIPF, 2014).

The financial sector in South Africa is a crucial cross-cutting intermediary that is able to facilitate, among others, the effective allocation of capital resources for industrial upgrading, productive investment, and the reduction of capital costs for small and medium enterprises (Department of Trade, Industry and Competition: NIPF, 2014).

South Africa is the sixteenth largest emitter of GHGs in the world, despite its relatively small population and economy, if compared to developed countries Ritchie and Roser (2017). Montmasson-Clair (2012) further claims that financial institutions, including banks, insurers, venture capital, private equity and hedge funds, have been increasingly active in the low-carbon project and company development in South Africa. This assertion is based on the emergence and development of new climate change-related technologies, notably in the fields of renewable energy and energy efficiency, coupled with the introduction of appropriate incentive and support governmental schemes, which have increased green investment opportunities (CAMCO & TIPS 2010).

Montmasson-Clair (2012) also alludes to a growing body of banks and investors in South Africa that are increasingly concerned about the climate change liabilities associated with companies' activities and investments. There are also a growing number of South African companies that are participating in the Carbon Disclosure Project, led by the National Business Initiative (NBI), which actively promotes investments in climate change mitigation and adaption. For example, in 2016, 71% of the 100 most significant South African companies by market capitalisation reported on their GHG emissions (NBI, 2017).

Naidoo, in a report (2011) commissioned by the Department of Environmental Affairs, concurs with Montmasson-Clair that there has been considerable progress in South Africa, and South African companies are beginning to embed climate change mitigation into their strategies and governance practices. Naidoo (2011) confirms that financial institutions are integrating environmental and climate considerations into their financing decisions, however, she also asserts that there is a lack of comprehensive mainstreaming of these considerations into their risk and investment processes. This assertion is true to an extent, and this situation has persisted up to the current times, since there have been no studies done in South African financial institutions on how they are embedding environmental issues into their risk and investment processes. In addition, policy uncertainties have contributed to the lack of full embedding of environmental issues into the risk and investment processes of financial institutions.

Based on a survey conducted by BIG (Business Innovations Group), there are varying degrees of acceptance across different stakeholders in the financial sector in terms of their role in financing climate interventions (BIG, 2011). There is broad acknowledgement that there are investment and economic growth opportunities in financing climate response strategies. However, limited investment has occurred within South Africa, primarily due to policy uncertainties. The survey results indicated that the insurance sector is ahead of other financial sector players in developing new products and services to combat the impact of climate change. However, other financial sector participants, such as banks, are more concerned with policy decisions around GHG emissions.

According to the results of the BIG (2011) survey, there seems to be a lack of awareness amongst the microfinance institutions in South Africa with regards to creating financial products that promote sensitivity to the environment and that combat the impacts of climate change. The survey respondents stated the following as necessary conditions the government should put in place to create an environment that promotes investment and crafting of products and services of that address climate change mitigation and adaptation:

- Providing political and regulatory certainty over the long term on the government's national position.
- Public finance commitment to leverage private capital.
- Integrating climate change into development planning.
- Enhancing government's capacity to transition to a green economy and climate resilience.
- New financial incentives and improved processes for emerging technologies.
- Expanding consultations on solutions, partnerships and cooperation opportunities.
- Harmonising and aligning complementary policies.
- Improved access to information to assist in risk modelling and predictions.

One of the most important outcomes from the survey by BIG (2011) is the acknowledgement of how several South African financial institutions are integrating environmental and climate issues into their financing decisions. However, not all financial institutions are in the mainstream of embedding environmental and climate issues into their products and services. An example is that of the asset management industry. In order for them to embed environmental and climate issues they would require the following: the pricing of climate risk within an investment portfolio, access to quality climate information that enables investment portfolio decisions, and the willingness of trustees to extend mandates towards climate change-related investments.

The National GHG inventory for South Africa is not up to date, and the implementation of a carbon tax has been stalled for quite some time, creating uncertainty in financial institutions on how to deal with climate issues in their daily activities.

The sub-section below discusses the South African carbon tax as the proposed policy for the mitigation of climate change.

3.4.1 Carbon tax: proposed policy for climate change mitigation

The National Treasury of South Africa initiated the process of environmental fiscal reform in 2003, by researching the feasibility of a carbon tax as a climate change tool. A framework was promulgated in 2006 proposing market-based instruments, such as carbon trading systems, as tools to be used for climate mitigation in South Africa.

In 2010, following the Copenhagen Accord, a discussion document was released for public comment (National Treasury, 2010). After the adoption of the climate policy in 2011, a carbon tax policy was issued by the National Treasury (National Treasury, 2013). The carbon tax policy's primary goal is to reduce GHG emissions in three ways. The first way involves changing producer and consumer behaviour. The second way involves contributing to mitigation, and adaption being taken into account in investment decisions (including infrastructure). This second way of implementing a carbon tax is essential to this study. The third way involves creating incentives for low carbon technologies.

The 2010 carbon tax discussion document (National Treasury, 2010) proposed three options for implementing a comprehensive carbon price through the carbon tax. The options are for applying carbon tax in the following tax bases:

1. The monetary value of tax measured on direct GHG emissions;
2. The determination of carbon content in coal, crude oil and natural gas, and charged as fossil fuel input tax; and
3. The energy outputs of electricity and transport fuels measured, and the carbon content taxed as well.

The proposed carbon price to be used for taxing is a nominal rate of R120 / t CO_2-eq. However, tax-free thresholds have been proposed, increases in the tax rate and carbon offsets will be considered, and other adjustments are in the pipeline to incentivise good practice within industrial sectors.

The tax is to be charged as a fuel input tax (the base is coal, crude oil and natural gas inputs) on six gases, which in principle, but effectively, includes the three major GHGs: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_20), and the three less prevalent, but equally powerful GHGs: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) (Winkler, Jooste & Marquard, 2010).

The proposed carbon tax is meant to be an economy-wide tax, but agriculture, forestry and land use (AFOLU) and waste will get 100% exemption in the first phase. The first phase was expected to run from 2016 to 2020, but it has been postponed. The tax rate is proposed to increase by 10% per year. There will be revisions to the design for future five-year periods, including the rate of increase to be announced in February of the final year of the previous period.

Adeleke, Kiragu and Murombo (2014) argue that the proposed South African carbon tax policy will reprice existing goods and services that generate excessive levels of anthropogenic GHG emissions in order to reflect the social costs of such emissions. Current carbon tax designs proposed the levying of the carbon tax through product prices, such as electricity, petroleum, and energy-intensive goods, such as steel, cement and aluminium. Adeleke *et al.* (2014) therefore, argue that a carbon tax will affect the broader policies on energy access and affordability, as well as industrial competitiveness.

For the lending fraternity, this is of concern, since the carbon tax will increase the financial risk of most borrowing companies, and therefore, it necessitates a relook at the credit process systems to incorporate the carbon tax risk and its repercussions.

3.4.2 South African financial sector and environmental risk

Camco (2010) compiled a synopsis of the likely emerging risks from climate change that the financial sector in South Africa might face. They noted that several financial services companies have significant emissions, and cited companies such as Bidvest Group, Old Mutual, FirstRand and the Absa Group. However, they focus mainly on the carbon emissions emanating from internal operations, in which they note that most of the carbon emissions come from electricity consumption. However, they indicated that due to the emergence of a national climate policy, most financial institutions might face mandatory reporting of emissions and stipulated energy efficiency targets. The regulatory risk will affect those financial institutions that have subsidiaries in other regions and continents, depending on the scope and scale of their operations.

With regards to the external impact of the financial institutions' products and services, the emphasis was on the current and anticipated investments, and the projected related screening activities (Camco, 2010). Camco acknowledged the impact of climate change on the investment and loan portfolios of most South African financial services companies, and recommended a detailed assessment of the risks and opportunities which accompany this impact.

Furthermore, the pricing of carbon, through a carbon tax within the economy, is under scrutiny. This implies there is a need to scrutinise company level shadow prices for carbon, and banks should intensify the loan screening of companies that damage the climate. Camco also iterated the importance of embedding climate change concerns, which include: inserting carbon pricing into existing risk management systems, and project evaluation procedures to aid investment-related decision making. An aspect that required immediate action was to scrutinise investments made into long-term fossil fuel infrastructure, especially coal-fired power stations.

However, there is no scope or detail on how to embed climate change issues into the risk systems of financial institutions. To the best of the researcher's knowledge, no detailed technical research has been done to demonstrate how South African financial institutions can embed the emerging national climate policy into their lending and investment operations. Therefore, the more reason this study is undertaken to recommend a solution to that effect. Chapter 5 provides an outline of the initiatives South African banks are embarking on to embed climate change in the banking activities.

The previously mentioned BIG survey (2011) did manage to benchmark the extent to which the financial sector in South Africa is embedding climate change issues into its bank credit processes. The survey compared the results from the survey with a similar study done by the United Nations Environmental Program, Financial Institutions and Sustainability Business Institute (UNEP FI/SBI, 2011). The survey comprised of commercial banks, investment banks, international financial institutions, asset management, development financial institutions, reinsurance and insurance companies, private equity and venture capital companies, and microfinance institutions. Though the survey response rate was low, considerable analysis could be made from the results.

One of the primary outcomes from the BIG survey was the realisation that banks in South Africa are not incorporating climate change-related issues into their credit risk assessment and due diligence processes. It was cited, as well, that credit risk is exacerbated by policies that are enacted to cut emissions by creating costs for carbon-intensive sectors and companies. Moreover, in South Africa, most lending banks rely on insurers to accept these risks on their behalf.

Compared to the research done by UNFEPFI/SBI, 12 out of the 35 lending institutions that were targeted in the BIG survey felt that their credit transactions are affected by the direct physical effects of climate change. Also noted in this study, was confusion between the direct risks of climate change and carbon-related issues, and an indication of how lenders are preoccupied with emission's policy, rather than the impacts of climate change. However, most companies felt that there was a need to incorporate climate issues into their credit risk assessment processes.

3.5 FINANCIAL PREDICTION MODELS THAT INCORPORATE ENVIRONMENTAL RISKS

To the best of the knowledge available, there are no existing studies that have directly recommended prediction models to embed environmental risk. However, some studies in the literature insinuate the embedding of environmental risk by proxies into bank prediction models. Onischka (2008) asserts that it is insufficient to just apply the conventional methods and procedures to measure the impact of climate and environmental risks in investment and lending activities. This reasoning stems from the problem of the debasement of historical data in the light of climate change.

Onischka (2008) further supports this assertion by maintaining that climate change has a direct influence on the financial performance of companies because, in part, external effects will be embeddable in its internal operations. Therefore, the damages and costs caused by a company will, if not considered, lead to increased use of resources, which exacerbate the pollution of the environment. Onischka argues that the normal company valuation process is based on historical data to derive the value of a company. However, with climate risk, the issue of historical data of weather or weather extremes can make the data quality unreliable for use in measuring the impact of climate change on the company's cash flows. Existing historical data of weather or weather extremes are mainly for predicting weather forecasts and are inadequate for those types of climate risk forecasts. More so, Fischer,Kumke, Lohmann, Miller and Negendank (2013). argue that most climate models in use prove that in the past, currently, and in the future, there will be non-linear, time-delayed and even erratic changes in the direct and indirect climate effects.

Onischka (2008) posits that it will be difficult to reach fair conclusions from historical climate exposure, which is the monetary price impact of climate risk since they are based on unclear weather data estimations. Onischka argues that it would be better to use the impact of future regulations and changing reputation in measuring the impact of climate change on companies' cash flows. However, Onischka cautions that there may be problems in using data from climate-related regulations since there are a few relevant and comparable regulations.

Since Onischka's work was first published in 2008, a vast array of climate-related regulations have been promulgated, which facilitate comparisons. Onischka maintains that regulations can affect probit and logit models. In terms of the current study, the carbon tax policy that is used in predicting business failure is now being vastly applied in many countries. Although Onischka's solution is over-theorised and has no empirical evidence to back it up, Onischka does provide us with a base and presents the issues to consider when doing financial analysis or valuation, and explains when and where to consider environmental and climate risk. One of the essential aspects noted by Onschika is the classification of climate risk into qualitative states expressible as: highly likely, likely, not likely, and so forth. However, in calculating the financial impact of a risk factor, one would prefer a numerical probability and not a quantitative probability. Jones, Boer, Magezi and Mearns (2004) indicate that it is possible to use highly advanced numerical techniques which include calculations of probabilities using statistical and modelling techniques.

To predict the impact of climate change on the lending process, it is plausible to find models that quantify and analyse climate change financial risk. A study by David Gardiner & Associates, Coalition For Environmentally Responsible Economies, Pew Charitable Trusts, & Surdna Foundation. (2006) investigated the best practice of climate change risk analysis in the electric power sector. Amongst other aspects, they looked at emissions disclosure, climate change corporate governance and management systems, and financial analysis of climate risk. Similarly, the financial analysis of climate risk is of interest to the current research, and two essential best practices have been identified, which are: (1) comparison of emissions pricing, and (2) comparison of regulatory and pricing scenarios.

In a study by David Gardiner and Associates (2006), emissions pricing involved determining a price to reduce carbon dioxide in electricity-producing companies at a state level, in an attempt by regulators and companies to capture a future cost of carbon in their power planning and procurement decisions. Therefore, the pricing of carbon acts as a financial risk to carbon dioxide emissions reduction, and this financial risk needs to be quantified. The regulatory and pricing scenarios were developed using sophisticated tools that compare several plausible regulatory or carbon pricing scenarios and their impacts on electricity-generating companies.

David Gardiner and Associates (2006) indicated that power companies use more robust financial tools to understand internal climate risks, to assess business opportunities and to allocate capital to a range of policy and carbon allowance pricing scenarios. Moreover, companies want to show potential investors, lenders, regulators and customers how their business strategy, market conditions and other relevant factors impact their climate risk and management strategies. Investors want simple and comparable models of corporate and facility emissions and the potential financial liabilities of different regulatory scenarios. However, complex models are needed to understand the full exposure of a power company and its strategy to mitigate the risk. David Gardiner and Associates give an example of how the company's unique regulatory environment and its ability to recover expenses are crucial aspects to consider. For example, David Gardiner and Associates outlined the advantages and disadvantages of using financial risk assessment tools (FRAT) to measure the impact of climate risk, as below.

According to David Gardiner and Associates (2006), the following are advantages of financial risk assessment tools:

- Allow the measure of climate risk under a range of potential outcomes;
- Facilitate the comparison of climate risk of companies, projects or other potential investments;
- Allow for prices and regulatory scenarios to be used as inputs for financial modelling, even with market and regulatory uncertainties;

- Gauge how seriously senior managers view climate risk;
- Facilitate the assessment of the extent of disclosing of absolute and normalised emissions; and
- Allow for the comprehension of programmes in place to manage climate risk.

According to David Gardiner and Associates (2006), the disadvantages of financial risk assessment tools are the following:

- They are static and mostly based on historical data that may no longer be accurate;
- They need detailed and real-time knowledge of the current and future assets and power generation or use of the companies being evaluated, especially in the power sector in light of frequent changes in asset ownership; and
- FRAT does not include strategic business changes, corporate risk or environmental management initiatives.

The last or third disadvantage listed above is vital to the current study since this current research aimed to combined the quantitative and qualitative measures of environmental risk to predict its impact on the cash flows of a company.

David Gardiner and Associates compiled a list illustrating the use of emissions pricing and regulatory and pricing scenarios that are being used in analysing climate risk on the financial performance of companies. This is illustrated in Table 3.4.

Table 3.4: Examples of emissions pricing, regulatory and pricing scenarios used in financial risk assessment of climate risk

Analysing emissions pricing (Simplified approach)			
Organisation	**Name of financial risk assessment tool**	**Reason for evaluation**	**Method of evaluation**
Wisconsin Public Service Commission	Climate change sensitivity run (Quantitative tool).	Differentiate among potential power generation projects.	Price expected carbon dioxide emissions from potential projects at USD15 per ton.
California Public Utility Commission	Greenhouse gas adder (Quantitative Tool).	Evaluation of competitive bids to supply energy. So the greenhouse adder captures the financial risk to investor-owned utilities and rate payers of emitting GHGs and recognises the likelihood that these emissions will be limited by regulation in the future.	Green gas adder of USD8 per ton of carbon dioxide emissions produced by potential energy production bid.
Colorado Public Utility Commission and Xcel Energy	Least Cost Planning for Project evaluation.	New power plant being built.	Cost of USD9 per ton of carbon dioxide.
Pacificorp (electric power company)	-	Consideration of bids to provide energy.	Cost of USD8 per ton of carbon dioxide emitted.
PSEG (electric power company)	Internal Emissions Pricing Model	Estimated allowance prices for NOx, SO_2, Mercury, and CO_2 over 20 years to guide investment decisions, in light of climate change and other regulatory risks.	The pricing plan uses point estimates and ranges and incorporates allowance prices in modelling new and existing plants

Analysing regulatory and pricing scenarios (Complex approach)			
Organisation	**Reason for assessment**	**Methodology**	**Research outcomes**
Bernstein Research Call (2006)	To estimate the effect that CO_2 emission limits may have on power prices and generators' gross margins in unregulated markets.	Bernstein adopted the following methodology: ▪ Using EPA data on power plants' CO_2 emissions, calculated the average CO_2 emissions per MWh produced by coal and gas-fired generators in the various unregulated power markets of the US. ▪ Multiplied these average CO_2 emission rates by a range of assumed prices for CO_2 emission allowances to estimate the increased cost to utilities of generating a MWh of electricity at their coal and gas-fired plants. ▪ Estimated the number of hours per year during which power prices in these markets reflect the operating costs of coal-fired and gas-fired generators, respectively. ▪ Assumed that power prices in unregulated power markets will rise to reflect the incremental cost to the marginal or price-setting generators of purchasing CO_2 emission allowances. ▪ Calculated the impact that the price and cost increases resulting from the imposition of CO_2 emission limits will have on the gross margins of nuclear, coal-fired and gas-fired generators in the various unregulated power markets.	▪ Utilities that will benefit most from national CO_2 emission limits will be those with the largest unregulated sales of nuclear generation, with particular benefits accruing to those nuclear generators whose fleets are situated in regions where coal-fired generators are the marginal or price-setting suppliers. These companies could see gains of 4%–139% of EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortisation). ▪ Most adversely affected in this study were unregulated coal-fired generators supplying markets where gas is the predominant price-setting fuel. These companies could see losses of 24%–83% of EBITDA.

Analysing regulatory and pricing scenarios (Complex approach)			
Organisation	**Reason for assessment**	**Methodology**	**Research outcomes**
Citigroup Equity Research (2006)	The impact of greenhouse gas regulation on corporate profits.	Modelling low, medium and high-cost scenarios of greenhouse gas regulation with varying assumptions of allocation of allowances and 'safety valve' allowances.	▪ Nuclear power generators experience a significant increase in revenue, even under low-cost scenarios. ▪ Gas-fired generated would probably have less financial benefits compared to nuclear operations. ▪ Coal-fired generators operating in gas-driven markets would be greatly exposed but with a distinct variation based on the company. A given scenario and the percentage of allowances auctioned. ▪ Regulated markets with greenhouse gas regulation will have increased electricity rates in the short run but decreasing over time due to the commercial availability of carbon reduction technologies.
JPMorgan North America Corporate Research (2006)	Potential impacts of state and regional and federal climate regulations.	This was more of a qualitative study and did not have a company-specific analysis. The reason for not doing a detailed company-specific study was attributed to considerable uncertainties in policies.	▪ The ad-hoc requirements of carbon emissions regulation at the state level present a high risk to companies. The current state regulations will eventually align to federal regulations of carbon emissions, thus reducing this risk exposure. ▪ In deregulated markets of carbon emissions, coal-fired generators of electricity will face increased risks. ▪ Given the regulatory scenario, renewable energy and nuclear will yield

Analysing regulatory and pricing scenarios (Complex approach)			
Organisation	**Reason for assessment**	**Methodology**	**Research outcomes**
			better financial benefits compared to wind and solar which have limited ability to provide baseload power due to problems of dispatchable power and cost. ▪ Carbon emissions are effectively reduced through energy conservation and efficiency, and electronic metering has reduced energy demand by 10% in many programmes surveyed in the research.
European Financial Models	The presence of an advanced climate policy and carbon trading markets makes financial analysis tools more advanced in Europe. A number of studies proposing financial models that assess the financial impacts of the EU emission trading programme on individual companies and groups of companies in the power sector were done.	Models by ABN Ambro, Standard & Poor's and UBS. Assumptions used in financial modelling are proprietary, and thus, evaluating the financial risk analysis used by these banks was a challenge The results were impacted by: ▪ Projected price of an emissions permit (the 'allowance price') ▪ Method of allocating allowances ▪ Forecasted price of electricity ▪ Pace of technology innovation ▪ Degree to which power companies switch to cleaner fuels ▪ Allowance allocation decisions' impact on the compliance cost of companies and the sector as a whole.	▪ ABN Ambro found the EU emission trading programme to have a minimal impact on company valuations. ▪ Standard & Poor's indicated that compliance cost will be crucial for power companies' financial performance, particularly those in the coal and oil facilities. ▪ UBS estimated from their analysis an increase in profits of European Electric Companies to the tune of USD33.1 billion. ▪ UBS used projected national allocation decisions to create four scenarios: disaster, black sky, central and blue sky. ▪ Under the central scenario: the model found a positive impact on equity valuations.

Analysing regulatory and pricing scenarios (Complex approach)			
Organisation	**Reason for assessment**	**Methodology**	**Research outcomes**
			▪ Under the disaster scenario: equity values fell for eight out of the 10 firms evaluated. Under all four models, there was no significant impact on most companies.
WWF Power Switch Study	Analysis of complex scenarios and models incorporating shifts in fuel prices and a range of regulatory scenarios	The Power Switch model included 14 power generating companies that were analysed on how they would operate within three policy scenarios with distinct carbon prices. The power switch model included: ▪ Regional market differences ▪ Changes in each company's power generation mix (at different permit prices) The power switch model modelled the allocation methods of permits and natural gas price volatility, and the impact on a company's exposure	▪ Policies to reduce GHG emissions are posed to increase electric power companies' costs by as much as 10% of 2002 earnings. ▪ The cost burden for each company is primarily affected by the allocation method for the GHG permits and the ability of the power company to pass on costs to consumers. ▪ Limits on GHGs have a fundamental impact on the prices of the fuels used to generate electricity ▪ Even modest price changes as a result of the greenhouse gas limits could increase demand for cleaner fuels, such as natural gas.

Source: David Gardiner & Associates (2006)

Though direct financial prediction models could not be found in literature, the models listed in Table 3.4 indicate a good measure of how financial distress caused by climate change factors is being analysed. It should be observed that at the centre of most of these models, the following factors are dominant, namely, price of carbon emissions, regulatory policy of carbon emissions, and carbon trading systems for carbon emissions. Therefore, the transmission mechanism of most of the models has the following generic order:

- **Inputs:** types of fuel used in the generation of power, the proportional mix of the types of fuel, cost of fuel before adding the regulation price of emissions, GHGs/ carbon emissions emitted;
- **Model of analysis:** scenario analysis of the prices of carbon emissions (either through carbon taxes, penalties of carbon emissions, carbon trading prices) and their impact on fuel prices; and
- The **output** is the financial quantitative impact of the price of GHG or carbon emissions on the cost of electricity generated and overall profits.

This generic model gives credence to the essence of why the current study was carried out. The same table showed that a range of international banks have also initiated a system of quantifying the impact of the cost of carbon emissions on credit risk in some of the projects they are financing that are deemed to be carbon-intensive. The only detriment is the proprietary limitations on some of the models where the intricacies of model structure could not be analysed and studied to understand more beyond the generic model. However, the glimpse presented in Table 3.4 provided a guided hint into the intricacies of the various financial prediction models. It was envisaged that these would provide a better foundation in the formulating of a model for this study.

Referring back to the disadvantages identified by David Gardiner and Associates (listed earlier in this section). The last or third disadvantage point is vital to the current study, since it combined the quantitative and qualitative measures of environmental risk to predict its impact on the cash flows of a company. David Gardiner and Associates (2006) show the emissions pricing, regulatory and pricing scenarios used in analysing climate risk on the financial performance of companies.

3.6 BRIEF OVERVIEW OF EMBEDDING METHODS AND MODELS

This section reviews the current methods being used in the embedding of environmental risk and how to find the type of data to do so. The implication of the outcome will help to identify the data to be used for this study since it is contextualised in South Africa.

There are three main methods of embedding, namely: (1) financed emissions, (2) carbon risk analysis, and (3) environmental stress testing.

Weber, Thoma, Dupre, Fischer, Cummis and Patel (2015) describe financed emissions as the general portfolio level aggregation of GHG emissions associated with a portfolio's underlying entities or projects, allocated proportionally based on the financial stake in the underlying entity or project, and this is usually cross-sector and cross-asset class approach.

Carbon risk analysis involves three areas: risk to physical assets; risk to financial assets, equities and credit, and risk to financial institutions. The first and third areas will be challenging to analyse in South Africa. The last national carbon emissions data that is economic sector-specific was done in 2010, and the only carbon emission data available is company-specific. Therefore, carbon risk analysis will be focused on company level embedding.

With regards to environmental stress testing, this can be done at the company, portfolio, and financial or economic system level. However, in South Africa, the same predicament of non-availability of data at an economic sectorial and broad national level is encountered. However, each method will be looked at in detail to determine how suitable it is to find the required data for use in this study.

3.6.1 Dimensions of embedding

Research by the G20 Green Finance Study Group (GFSG) (2017) indicates that physical and transitional factors (including environmental externalities, trends and events) can result in a range of financial risks. These financial risks have significant implications for both financial institutions and financial institution supervisors. Therefore, the G20 GFSG (2017) has recommended environmental risk analysis (ERA), which is a portfolio of tools and methodologies that will enable the embedding of environmental data into the decision-making process from a risk management and asset allocation perspective.

For the current study, the interest is on embedding environmental risk into the credit risk management process. Therefore, the focus is on how environmental risk is embeddable into the credit risk process. The G20 - GFSG study has a categorisation of recommended environmental risk tools, as shown in Figure 3.1.

In Figure 3.1, under credit risk, it can be seen that the embedding of environmental risk into bank credit processes in general, is particularly focused on credit rating models.

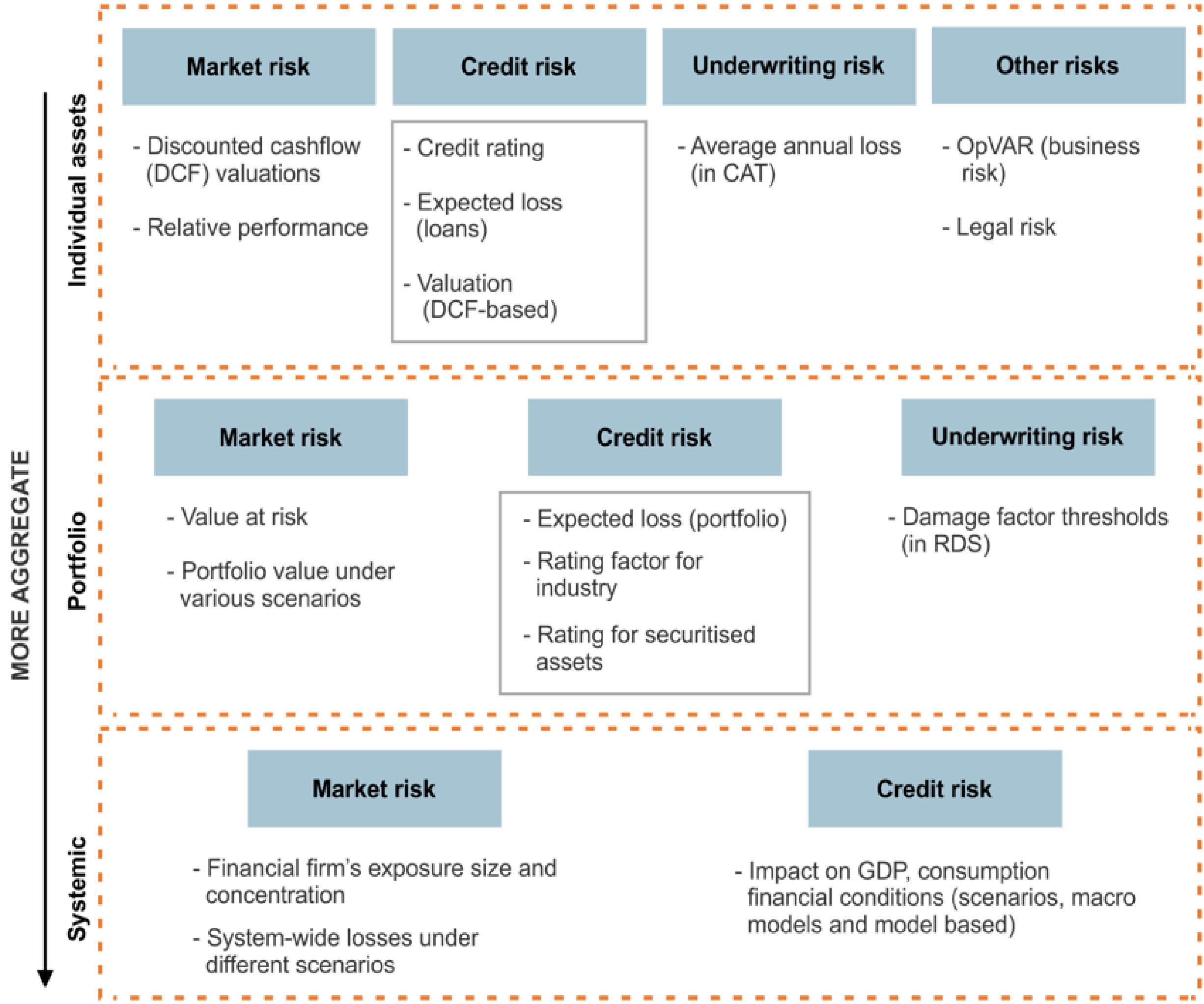


Figure 3.1: Categorisation of environmental risk tools

Source: GFSG (2017)

Table 3.5 shows the G20 - GFSG Benchmarking study on embedding as performed by selected International Financial Institutions. This GFSG study provides a 'chief cornerstone' view on building a framework contextualised to the South African banking context.

Table 3.5 also presents examples of embedding at the individual, portfolio and system levels. The embedding is mainly concerned with externalities affecting the credit rating of an individual loan, or a portfolio of loans held by the Banks surveyed in the study by GFSG and at a financial system level.

The G20-GFSG study is a benchmark of best practice in embedding environmental risk into bank credit process. However, for the purposes of the current study that this thesis is reporting on, the data requirements for embedding risk at portfolio and system-level from a South African context seemed futile due to the unavailability of the data required to perform such. South Africa has not been consistent in reporting national climate change risk data consistently. The current data required for the period under study, 2010 to 2017, is unavailable. More so, obtaining granular loan portfolio data from banks proved futile as banks have propriety information on portfolio structures that they are unwilling to divulge. Therefore, it was imperative for the researcher to look at the data available and structure the study around data availability.

Although, as explained above, physical climate risk data at the portfolio level, economic sector level and national level is scarce and lagging in time updates in South Africa, there is an abundance of granular individual company data on climate change available in South Africa.

Table 3.5 provides more detail about the environmental risk embedding tools highlighted in Figure 3.1.

Table 3.5: Examples of individual asset analysis assessed by the GFSG in 2016

Asset type	Market Risk	Credit Risk (bonds)	Credit Risk (loans)
Example	Allianz Global Investors	S&P/SwissRe	Moody's
Environmental factor	Transition: Climate regulation and introduction of the carbon price	Physical: Cyclones and floods	Physical: exposure to a range of physical climate risks and economic resilience to them
Financial risk metric	Reduced profit, DCF-based valuation	Impact on the sovereign rating	Adjust credit ratings of sovereigns that are highly exposed
Examples of portfolio-level analysis assessed by the GFSG in 2016			
Example	Mercer	ICBC	Lloyds
Environmental Factor	Identify high-risk factor	Three scenarios of stricter regulation of air and water pollution	Physical: Shock to global food production
Financial risk metric	Relative performance against alternative portfolio	impact on the credit quality of commercial banks' portfolio	RDS: losses based on expert judgement

Examples of system-level analysis assessed by the GFSG in 2016

Feedback module	Financial system	Economy-wide
Example	DNB	UBS
Environmental factor	Identify key transition risk sectors	Physical risk: flooding in critical coastal cities, followed by transition risk: including global carbon pricing agreement
Financial risk metric	The total exposure of financial institutions	Effect of regulation and physical damages on the financial market and GDP

Source: GFSG, 2017

As seen in Table 3.5, at the individual and portfolio level, the environmental factors used to determine the impact of climate change on credit risk in banks are mainly physical components. For example, S&P and SwissRe studying how cyclones and floods affect sovereign ratings and Moody's studying the impact of a range of physical climate risk affecting credit ratings of sovereigns that are highly exposed. However, the ICBC (2018) study is unusual in that it uses air and water pollution as proxies for the stress testing of their loan portfolios.

A more in-depth look at this study (ICBC, 2018) reveals that there are aspects that are similar to the data available in South Africa which can be used by the current study to craft an embedding framework (this process is detailed in Section 3.6.2). Climate performance or progress metrics are essential when selecting the level to embed at.

Weber *et al.* (2015) define the climate progress metrics for banks and assess the relative merits of these different metrics. Weber *et al.* (2015) identify three main categories by which financial intermediaries are disclosing climate progress. Table 3.6 outlines the pros and cons of using climate performance or progress metrics.

Table 3.6: Categories of disclosing climate progress by financial intermediaries

	Description & examples	Application	Advantages	Disadvantages
GHG Accounting Approaches	Cross-sector portfolio-level assessment of investees' exposure to GHG emissions, such as financed emissions (a bank's scope three emissions)	▪ Connecting the dots between portfolios and GHG emissions in the real economy, ▪ Project finance screens (lifetime GHG emissions > 50 Metric tons), ▪ Public communication and reporting, particularly for assets with known use of proceeds.	▪ Broad information on carbon emissions of sectors and portfolios, ▪ Directly measures the contribution of each transaction (if proportional, for financed emissions), ▪ Metric works across sectors and asset classes, thus enabling portfolio-level reporting.	▪ Emissions data availability, ▪ Inability to track 'green' activities directly (except through avoided emissions accounting), ▪ Lack of accounting standards and agreement on some measurement issues, ▪ Data availability and confidentiality issues outside listed companies and projects, ▪ Difficult to apply to off-balance sheet (statement of financial position) services.
Sector – specific Energy/Carbon Metrics	Sector-specific physical unit metrics expressed in absolute units (kWh generated) or intensity units (kWh/ ft^2 or m^2)	▪ Measuring sector-level climate performance. ▪ Comparing portfolio performance to economy-wide averages.	▪ Sector- and asset-specific indicators can provide nuance and context. ▪ Benchmarks possible for transition (2°C scenarios).	▪ Only applicable to several vital sectors. ▪ No obvious way to aggregate data across sectors or assets and transactions.
Green / Brown Metrics	Taxonomies distinguishing between activities and technologies that are climate solutions	▪ Tracking both 'green' and 'brown' financing in the context of portfolios	▪ Ability to track both 'green' and 'brown.' ▪ Exposure metrics easy to track.	▪ Controversial technologies and taxonomies (for example, are natural gas,

	Description & examples	Application	Advantages	Disadvantages
	(‘green’) and climate problems (‘brown’).	▪ Tracking and reporting for any transaction or asset type, including services.	▪ Applicable to off-balance sheet (statement of financial position) services and on-balance sheet (statement of financial position) assets.	nuclear, CCS, biofuels ‘green’ or ‘brown’?). ▪ Lack of standard taxonomy.

Source: Weber *et al.*, 2015

3.6.2 Locating the embedding level

Battiston *et al.* (2017) provide a framework for risk assessment, ranging from the asset to systems levels, and this will assist in the framing of a contextualised South Africa environmental risk embedding model. The framework consists of eight levels, as shown in Figure 3.2. The beauty of this framework is that it guides by giving the concepts or principles to consider when crafting the embedding method or model.

As a point of departure, the framework will help to identify the available data at each level to consider in the embedding. It starts on the first level with loan assets, second-level: firm-specific data, third level: sector-specific data or organisation (Sectorial Industrial Codes (SIC), fourth level: loan portfolios, fifth level: types of financial institutions, sixth level: the make or structure of the financial sector, seventh level: the financial system organisation, and lastly, eighth level: the macro-economy.

The next aspect is to determine how to consider these levels when embedding environmental risk.

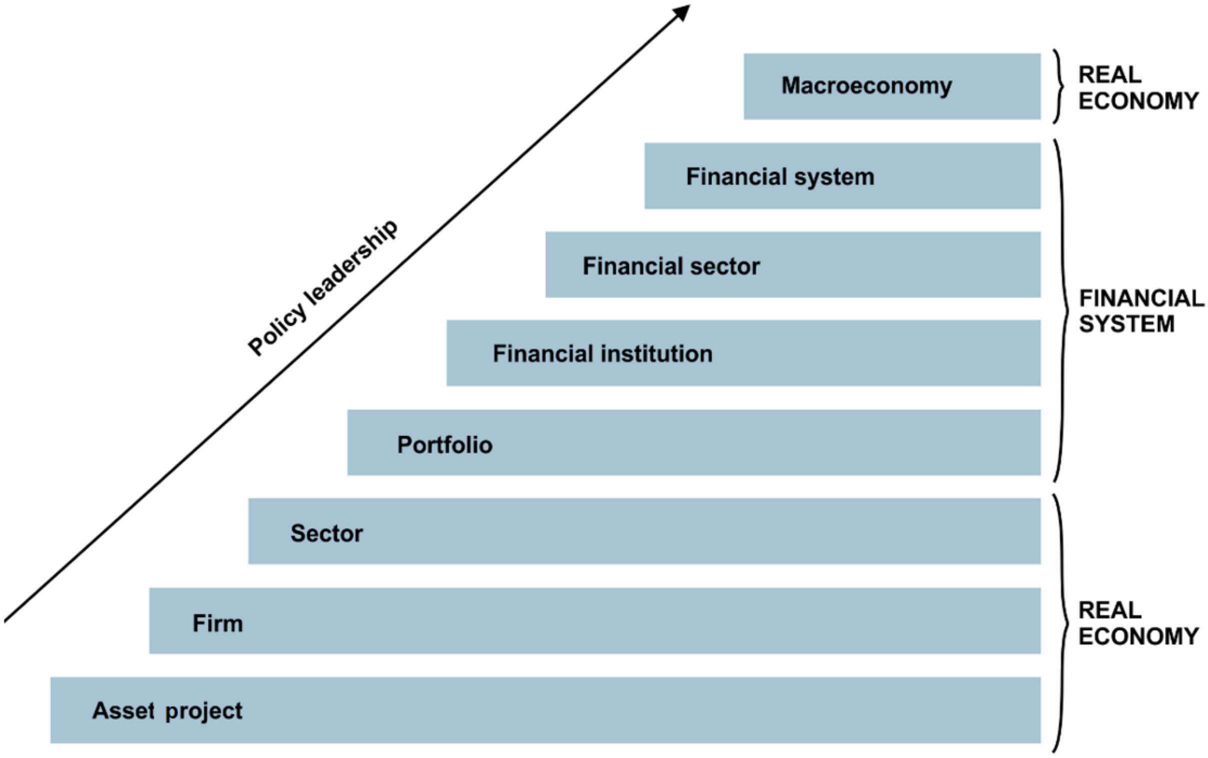


Figure 3.2: Levels of embedding environmental risk into bank processes

Source: GFSG (2017)

According to the G20 GFSG (GFSG, 2017), a lack of robust assessment of environmental risks could lead to the mispricing of assets, exposure to ‘stranded assets’, and flawed capital allocation, which may result in excessive investment in polluting sectors and underinvestment in green sectors. They further indicate that the process of identifying, assessing and managing environmental risks will require relevant information from market participants and other sources that can be processed coherently and comparably.

The range of issues that are prominent in the literature to be considered in terms of building solid frameworks for embedding environmental risk into bank credit process are: (1) air pollution, (2) decarbonisation pathways, (3) natural hazards and (4) water stress. Therefore, these are the data sources to consider for building a proper methodology of embedding environmental risk into bank credit process.

There is a need to determine the available data for each level for the South African context. In other words, is there adequate data at the (1) individual asset level, (2) portfolio level risk level, and (3) macroeconomic or systemic level for the South African banking context? Therefore, the research framework adopted has to determine at which level the embedding can happen in a South African context.

3.6.3 Financed emissions

The concept of financed emissions is the process of carbon footprinting the impact of financing done to borrowers or customers by financial institutions. The annual GHG emissions of each company in the lending book of a financial institution are determined and related to the financed amount or investment to the company. To place it in context and allow for comparability over time, the financial institution will take the loan value of a company and divide it over the total loan amount or value of the financial institution. This ratio is then multiplied by the established emissions of the company to give the amount of financed emission into the company by the financial institutions.

The same is doable at the sectoral, geographical or regional level. In this study, the carbon emissions are done at a sectorial or Standard Industry Code (SIC) level for South Africa stock listed countries. This approach allows for the carbon risk of the loan book or portfolio to be expressible in absolute and relative terms. Furthermore, the direct association and quantification of carbon emissions per company or industrial sector allows for the comparison of climate or environment risk intensity per company or sector.

The study by Rainforest Action Network (RAN) and BankTrack (2012) suggested the following three formulas for calculating the financed emissions by banks at a portfolio-level for project-specific lending, project finance, general corporate lending and debt underwriting:

1. Annual financed emissions from a bank's general corporate lending = ∑ for all outstanding loans, (that is, annual emissions of investee x percentage of total debt and equity capital of investee held by the bank);
2. Annual financed emissions from a bank's project finance = ∑ for all underwriting transactions, (that is, annual emissions of project x bank's percentage share of the project's financing);
3. Annual financed emissions from a bank's debt underwriting = ∑ for all underwriting transactions, (that is, annual emissions of underwriting client x percentage of the client's total debt and equity capital underwritten by the bank).

These calculations involve the Scope 3 emissions of the bank. In the GHG protocol, Scope 1 and 2 mainly look at the direct emissions caused by a company, and Scope 3 is the category for emissions caused indirectly by the firm.

Platform Carbon Accounting Financials (PCAF) (2018) propose a way of calculated emissions for corporate and SME loans, amongst a host of other banks asset class, such as government bonds, listed equity, project finance, mortgages, commercial real estate and corporate debt (comprising of bonds and SME loans.

With regards to corporate debt, which is of importance to this study, PCAF advises how to treat it when measuring financed emissions. By proposing that corporate loans be split into ring-fenced and not ring-fenced, they propose how to treat or measure the financed emissions. Ring-fenced corporate loans are those for targeted projects defined as project finance or project loan. Therefore, they recommend a project finance approach. For the 'not ring-fenced' portion, if it is a small loan, use a region/sector average approximation. If the loan is a large one, use a company-specific approach.

For corporate/SME loans, a twofold approach involves estimating and accounting for emissions and carbon intensity. The first approach is region/sector-specific average emissions data, using public data sources or data from third-party data providers for market and emissions data. The second approach builds on company-specific source data provided by the borrower. When reporting aggregated GHG data, the percentage of the reported emissions data use methods 1 and 2.

When the borrower does not report on GHG emissions, and the transaction does not involve detailed due diligence and monitoring, use the region/sector average approach. This is typically the case with small exposures and smaller (SME) companies. This approach is not preferable for high-emission industry sectors (such as extractive industries, heavy industries and large-scale thermal power generation). Only use it if all the other criteria for using this approach have been met, and if the total exposure to such sectors is below a certain percentage of the total corporate/SME debt exposure.

The second approach makes use of company-specific data provided by the borrower, which is either GHG emission data or other source data to calculate financed emissions. This approach uses an appropriate calculation methodology/tool, issued or approved by a credible independent institution. This approach is preferable from a data quality perspective but not always realistic or practical. It is most suited for more substantial loans to more prominent companies, as these are usually involved in detailed diligence and monitoring, and target companies that have useful GHG emissions data available. If this is the case and the emissions of the activity to be financed are significant, company-specific data, provided by the borrower should be used, rather than region/sector averages.

As explained in the previous section, this approach should also be applicable for exposure to high emission industry sectors (such as extractive industries, heavy industries and large-scale thermal power generation), regardless of the other criteria are being triggered, if the total exposure to such sectors exceeds the minimum percentage of the portfolio

3.6.4 Carbon risk analysis

This thesis utilises the carbon performance indicators as presented by Hoffmann and Busch (2008) in constructing a Carbon Risk Index to obtain a score to validate the PD results of the companies in the sample, simulated for embedding environmental risk.

Table 3.7 displays the proposed business metrics by Hoffmann and Busch that are relevant for measuring carbon performance indicators to be used in constructing a Carbon Risk Index.

Table 3.7: Explanation of carbon performance metrics

Business Metric	Description
Unit of production	Business output in physical units; no consideration of monetary units
Long-term loans	Loans used are for more than one year, are interest-bearing and contribute to the emissions accruing to the company
Short-term loans	Loans used are for less than one year, are interest-bearing and contribute to the emissions accruing to the company

In order to derive at the required carbon risk score for companies from the JSE100 companies, the current study used the following base model for corporate carbon performance indicators, as proposed by Hoffmann and Busch (2008):

	Static approach	Dynamic approach
Physical units	Carbon intensity	Carbon dependency
Monetary units	Carbon exposure	Carbon risk

Carbon intensity is a company's physical carbon performance. It describes the extent to which its business activities produce carbon emissions for a defined scope and fiscal year. Therefore, carbon intensity measures the ratio of a company's gross carbon fuel usage to a business metric.

Carbon usage is the measured carbon emissions by the company in a defined scope, as per the GHG protocol measure and the financial year. The business metric can be a financial performance measure for the company, like sales or cost of sales in our case.

This study will do a combined carbon input intensity and carbon output intensity. The carbon output intensity formula to be used is:

$$\mathbf{C_{I-O}In_{i,t}} = \frac{\sum_{k=1}^{K_{I-O}} \mathbf{K_{I-O_{k},t}}}{\mathbf{BM}}$$ **Equation 3.1**

Where:

$C_{I\text{-}O}$ is the carbon inputs and outputs in tons of carbon for inputs and GHG emissions for the output

k =1, … , $K_{I\text{-}O}$ is the index for the $K_{I\text{-}O}$ different inputs and outputs of carbon sources

t is the physical year of analysis

'i' is the scope 1,2 and 3 emissions

Carbon dependency is the change in the company's physical carbon performance within a given time. Carbon dependency measures the company's physical relative performance change from the current state to the projected carbon intensity. A company's carbon dependency specifies what percentage of the current state (t_o) carbon intensity will remain if the company continues to operate under the conditions that will give the projected carbon intensity at (t_1). Therefore, carbon dependency is the degree to which the company can reduce its carbon intensity.

Given the same scope, i = 1,2,3 emissions for both carbon intensities (t_o and t_1), the carbon dependency CD_e is stated as a percentage of the t_o carbon intensity for the time $\Delta t = t_1 - t_0$.

$$\mathbf{C_{I-O}D_{ei,\Delta t}} = \frac{\mathbf{C_{I-O}In_{i,t_1}}}{\mathbf{C_{I-O}In_{i,t_0}}} \times \mathbf{100}$$ **Equation 3.2**

Carbon exposure is a company's carbon performance in financial terms. Carbon exposure expresses the financial implications of the business activities due to carbon usage for a defined scope and fiscal year. The exposure is determined using a ratio which relates the carbon usage in financial terms to a defined or chosen business metric.

Through the use of prices, the carbon input intensity and carbon output intensity ratios are combined into one financial figure, which is the carbon exposure.

Based on equation (1), a company's carbon exposure (CEx) can be derived for a financial year t:

$$\mathbf{CEx_{i,t}} = \frac{\sum_{k=1}^{K_{I-O}} \mathbf{C_{I-O_k,t}} \times \mathbf{p_{I-O_k,t}}}{\mathbf{BM}} \qquad \textbf{Equation 3.3}$$

Where:

$C_{I-O_k,t}$ is the combined input and output unit of carbon emission

$p_{I-O_k,t}$ is the combined price of the input and output price of each unit of combine emissions

Carbon risk defines the change in a company's financial performance within a given time. The indicator is measured as the relative performance change from the current state to the projected carbon exposure, in the case of the present study, from one year to another.

A company's carbon risk will show the percentage change from this year (t_o) of carbon exposure to the coming year (t_1). The assumption is that the scope of carbon emission i= 1,2,3 of carbon exposures (t_o and t_1), the resulting carbon risk (CRi) is derived for the time $\Delta t = t_1 - t_0$.

$$\mathbf{CR_{i,\Delta t}} = \left(\frac{\mathbf{CEx_{i,t_1}}}{\mathbf{CEx_{i,t_0}}} - \mathbf{1}\right) \times \mathbf{100} \qquad \textbf{Equation 3.4}$$

3.6.5 Environmental stress analysis

Stress testing is the most prominent method of embedding environmental risk into bank credit process. In Table 3.8, is a compilation of the studies on environmental stress testing by banks, and it shows the varied ways banks globally have stress-tested environmental risk in their bank credit process.

From this compilation, the embedding of environmental risk into credit process of banks is gaining prominence, and there is a need to contextualise the embedding to South Africa since no relevant study has been done yet.

Table 3.8: Summary of stress-testing models: International survey studies

Country	Sector	Focus
Brazil	Banking	Measuring the exposure of the Brazilian banking system to environmental risks.
China	Banking	Stress testing the impact of environmental factors on a Chinese commercial bank's credit risk.
India	Banking	Measuring and managing an Indian bank's exposure to natural capital risks.
International	Ratings	Integrating the impacts of climate change into sovereign debt ratings.
Italy	Banking	Using stress-testing and ratings models to align risk analysis with a 2^{O}C climate scenario.
Netherlands	Financial sector	The Dutch Central Bank's review of sectoral exposure to energy transition risks.
Switzerland	Banking	Stress-testing statement of financial position and client vulnerability to climate change risks.
United Arab Emirates	Banking	Integrating environmental risk, including technology change, into credit approval processes in the Gulf.
United Kingdom	Banking	A scorecard approach to integrating environmental performance into pricing decisions for real estate.
United States	Banking	Stress testing a US bank's energy clients against regulation and incentives driving the energy transition.

Source: GFSG, Cambridge Centre for Sustainable Finance (2016)

However, in Table 3.9, the studies are fully detailed and show the various tools used to stress test a company's financial state for environmental risk by banks. The main objective of these stress tests is to see how environmental risk affects the financial viability of the companies loans are being granted to.

Some of these companies are highly sensitive to climate change or environmental risk. Therefore, following the research framework of these studies, the carbon risk analysis explained in this chapter, can be used to calculate the carbon risk of every company in the sample.

Table 3.9: Summary of stress-testing models: International survey studies

Organisation	Year	Geography	Financial sector	Environmental source of risk	Tools or approach used	Motivation
Brazilian Federation of Banks (‘FEBRABAN’)	2014	Brazil	Banking	Physical, Transition and Liability	Industry-wide data survey of risk exposure.	Analysis of sectoral risk exposure.
Industrial and Commercial Bank of China (ICBC)	2015	China	Banking	Transition	Stress test	Impact of environmental factors on credit risk.
YES BANK	2015	India	Investment	Physical and Transition	Trucost’s environmentally extended input-output model (EEIO) and the India Natural Capital Model, commissioned by GIZ and BMZ.	Assess potential new and emerging credit risks.
S&P Global Ratings and Swiss Re	2015	Expertise from across Europe applied globally	Insurance and credit rating agencies	Physical	Probabilistic modelling, with sovereign credit risk analysis.	Investigation of possible credit and market risk.
Financial institutions from Colombia, Mexico, Switzerland and the US, led by GIZ (then the German development agency), the Natural Capital Declaration and VfU	2015	Global	Banking and Investment	Physical	Stress test	Understanding credit and market risks from water stress.

Organisation	Year	Geography	Financial sector	Environmental source of risk	Tools or approach used	Motivation
UniCredit SpA	2013	Italy	Banking	Transition	Stress-testing and rating models.	Aligning risk analysis with the transition to a 2°C economy.
Dutch Central Bank: De Nederlandsche Bank ('DNB')	2016	Netherlands	Banking, Investment and Insurance	Transition	The strategic regulatory review supported by industry exposure data.	Analysis of sector-wide vulnerability to transition risks.
UBS	2015	Switzerland, global application	Banking	Physical and Transition	Top-down balance sheet (statement of financial position) stress testing, as well as bottom-up stressing of targeted sectors.	Management of climate-related risks, on behalf of the bank and its clients, as part of a broader climate change strategy.
National Bank of Abu Dhabi	2015	United Arab Emirates	Banking	Transition	Technology change scenario analysis and integration of environmental and social risk into the credit approval process.	Impact of unmanaged environmental and social risks on reputational and credit risk in the context of growing market focus on such issues.
Lloyds Banking Group	2016	United Kingdom	Banking	Transition risks, specifically exposure to sustainability and regulatory risks, across Corporate Real Estate (CRE) lending activities	A scorecard approach to integrating environmental performance into pricing decisions for real estate.	Part of the bank-wide initiative to integrate sustainability across its client and product mix to mitigate its risk exposure.

Organisation	Year	Geography	Financial sector	Environmental source of risk	Tools or approach used	Motivation
Withheld		The US, global application	Banking	Transition	Stress testing of specific industry sector client portfolios to determine relative lending client. Exposure to (i) increased carbon regulation and (ii) market responses to low-carbon transition incentives.	Investigation of potential new credit risk factors, responding to increasing disclosure expectations.

Source: GFSG, Cambridge Centre for Sustainable Finance (2016)

In the studies, the ICBC environmental risk stress-testing modelling (2018) is of interest, given that earlier discussions indicated the climate change data disparity and time-lag. The framework in this study fits the company-level data that is readily available in South Africa. The model stress tests change in Revenue, Cost of Goods Sold and Profit of companies in sectors that are highly sensitive to climate change. In this study, the companies are mainly in the cement and thermal power sectors. So, there is the imposition of changes in environmental protection standards on the statement of financial position (balance sheet) and statement of financial performance (income statement) of these companies. Parameters and scenarios of change are then worked at simulated on the statement of financial position (balance sheet) and statement of financial performance (income statement). The financial indicators, coupled with qualitative indicators, will stress test the change in the credit rating of these companies.

Figure 3.3 summarises the components of the environment risk stress-testing framework.

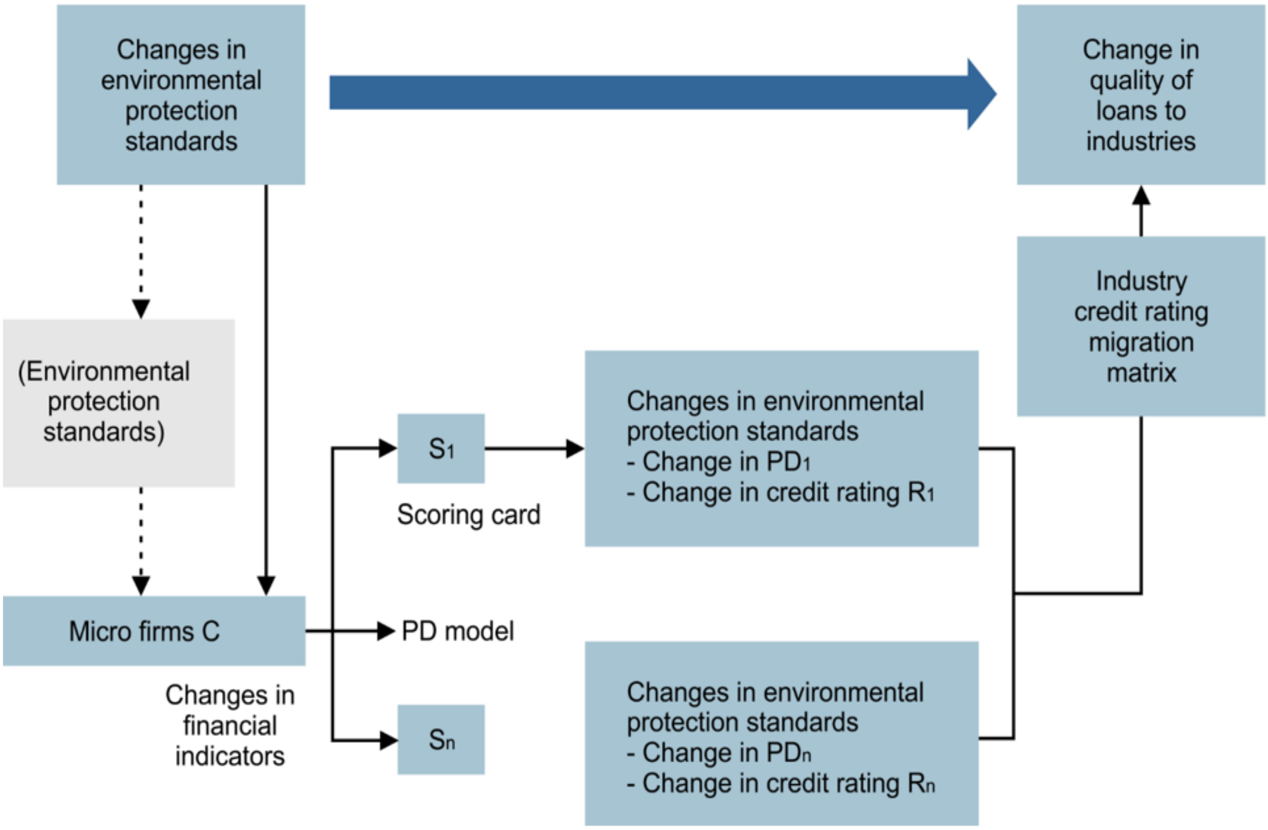


Figure 3.3: ICBC Stress-testing Model

3.7 SUMMARY

This chapter tied up the theory between financial intermediation theory, bank credit process and environmental risk discussed in Chapter 2, and aligned it with empirical evidence. However, in the process as well, the methodological framework suitable for use in South Africa was investigated and established. Data availability and methods of analysis were critical in constructing this methodological framework.

In Chapter 2, it was established that environmental risk broadly covers climate change-related risk, and it is subsumed in carbon risk and climate risk. Further, it was also established that carbon risk arises when a company fails to adhere to emissions abatement policies and regulations through financial penalties and lawsuits that affect its cash flows directly and indirectly. However, climate risk is the resultant physical damage to the companies' operations. With regards to South Africa, carbon risk will come in the form of non-compliance to the carbon tax policy and its nuances. This non-compliance provides an excellent basis for the creation of a variable that will represent an environmental risk in the 'to be' proposed credit risk analysis model. More so, there is convincing motivation to use carbon risk as a proxy for the heightened state of environmental risk. The reason for this has been its far-reaching scrutiny through issues of climate change driven by the Kyoto Protocol under the IPCC. More so, the global climate change impact of GHG or carbon emissions has exacerbated this.

The discussion in Chapter 2 illustrated how the bank's intermediary role is crucial in incorporating environmental risk into the bank processes in general. The current methods of embedding environmental risk into general financial analysis processes, specifically bank investment and due diligence processes, were explored in this chapter to reconcile with the postulated theories in Chapter 2. Overall, there is a set foundation to the studies reviewed in this chapter on how the process of embedding environmental risk into credit analysis can be undertaken. These studies indicated that emission pricing and climate policy scenarios are two critical factors in embedding environmental risk in financial analysis. It has been envisaged as well that currently, no evident quantitative models are being used to embed environmental risk in the bank credit process, as those reviewed are used by non-financial institutions.

It seems that there is an established pre-embedding process and a post-embedding process. The pre-embedding process is more of qualitative embedding, which is a screening process with a set checklist of environmental criteria; the Equator Principles is an example. The post-embedding process involves the stress testing of the loan portfolios for environmental risk scenarios. The financed emissions and carbon risk analysis are two methods that can be used in tandem with the credit process, whilst the environmental stress test can be used as a post-embedding process tool. Hence, the need for the current study to incorporate carbon risk analysis in the methodology for this study and to contextualise it to South Africa.

A closer look at South Africa shows a lack of studies that indicate how banks are embedding environmental risk or climate change impacts in the bank credit process, whether qualitatively or quantitatively. Also, overall (both internationally and in South Africa) there is qualitative embedding and limited or shallow quantitative embedding of environmental risk in their bank credit process. For example, the ESG ratings and the Equator Principles are merely a checklist of how environmental and stakeholder issues have been considered in bank loan and investment decisions. More so, at an international level, environmental risk cannot be financially quantified through all economic sectors. The outcome from this discussion is that given the South Africa company data availability, it will be wise to embed at a company level. Furthermore, the embedding methods emerging from current research were investigated, and the environmental stress analysis was deemed appropriate for use in this research.

Thus, the study continues to Chapter 4 that details how the research problem was investigated and solved.

CHAPTER 4:
RESEARCH METHODOLOGY

4.1 INTRODUCTION

This chapter discusses the research methodology adopted for the study. The study adopted a mixed-method approach, which consisted of three stages, as shown in Figure 4.1. This chapter further details the data-collection process, data sources and justification of the research methodology. The chapter first discusses the methodological framework, which is followed by the overall research design for this study. Under the research design, the mixed research methods pursued in this study are explained.

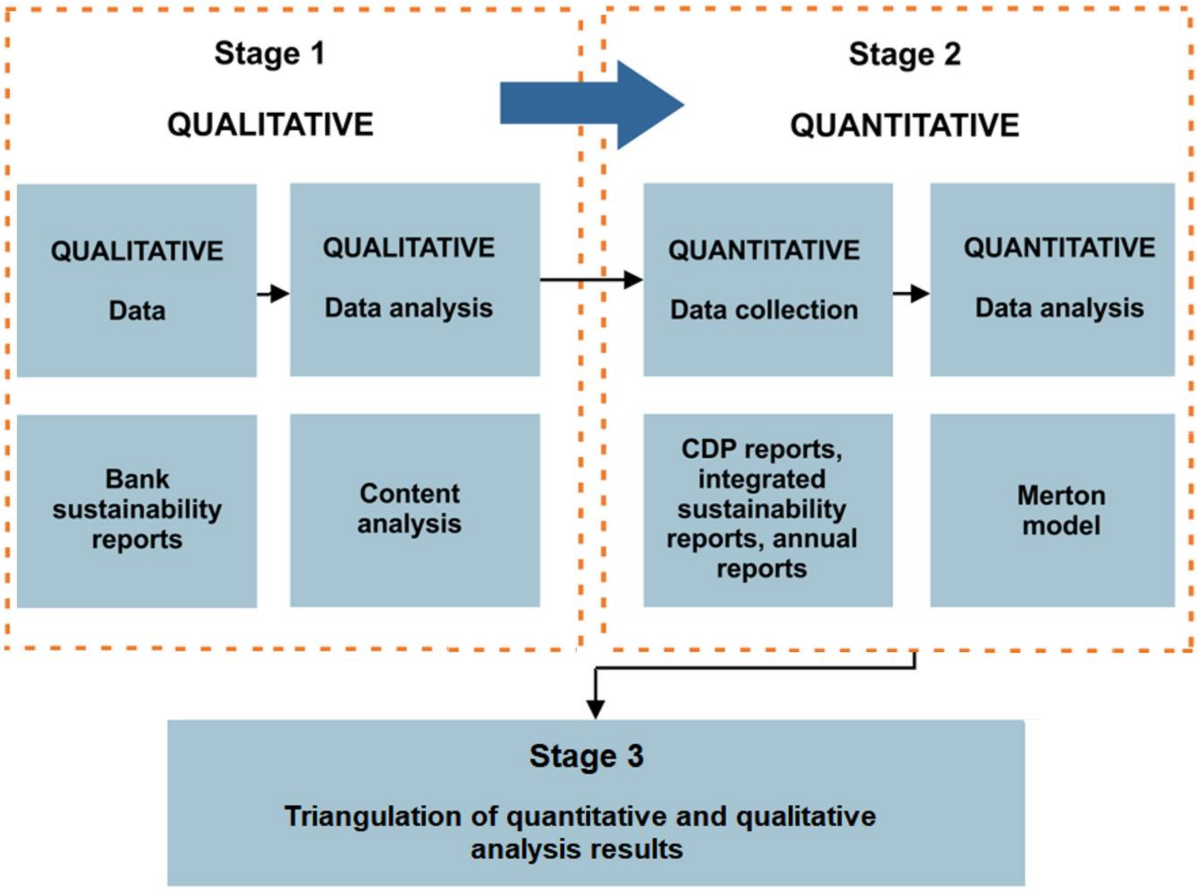


Figure 4.1: High-level summary of the research methodology

4.2 METHODOLOGICAL FRAMEWORK FOR THIS STUDY

This research study adopted a mixed-methodology framework consisting of qualitative and quantitative methods to answer the research questions.

The first stage of the study employed a qualitative research methodology, namely, the content analysis method to achieve the objective of benchmarking the level of embedding of environmental risk into bank credit processes by exploring whether there was evidence of embedding or not. If the content analysis found evidence of embedding, the embedding was classified and benchmarked against best practice observed in the literature.

If the content analysis found no evidence of embedding by the South African bank, the research moved onto the quantitative aspects of the research (Stage 2). (Section 4.5 discusses the content analysis method).

Stage 2 (the quantitative part) of the research involved taking a sample of the JSE100 CDP reporting companies and using the consistency of the reporting of carbon emissions for the period under study, selecting the companies to be modelled for the carbon tax impact. The carbon tax is the proxy for environmental risk. (Section 4.6 details the quantitative part of the research.)

Figure 4.2 presents a schematic view of the methodology, which amplifies Figure 4.1.

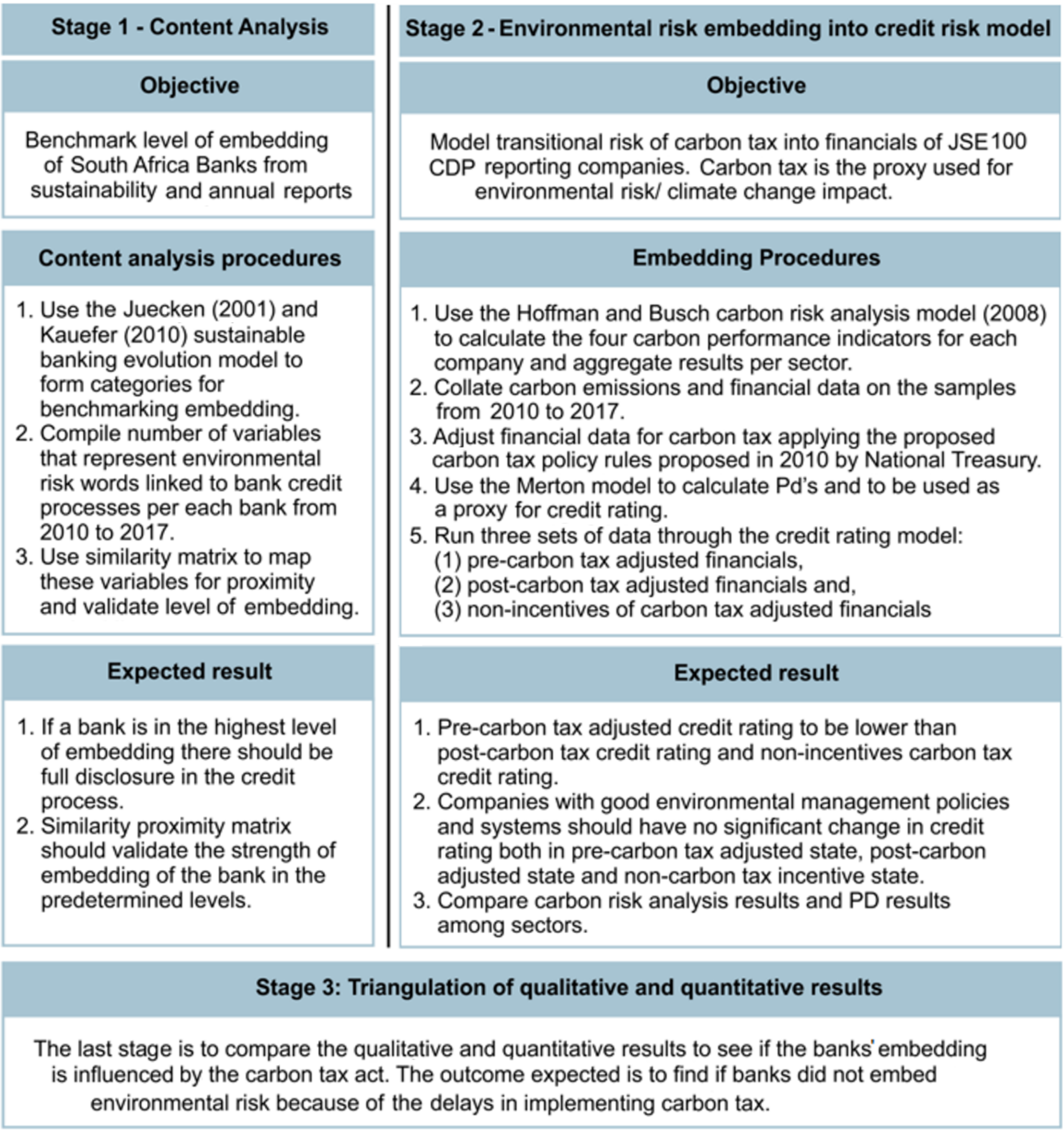


Figure 4.2: Schematic view of the methodological framework

4.3 RESEARCH DESIGN

Exploratory research looks for patterns, ideas or hypotheses, rather than being research that tries to test or confirm a hypothesis. Davies (2011) explains exploratory research as a methodological approach that is mainly concerned with discovery and generating theory.

The research being reported on in this thesis, adopted the grounded theory approach developed by Glaser and Strauss (1967, 2017). Grounded theory is a design approach that allows the researcher to build systematic theoretical statements inductively from the coding and analysis of observed data. The process of content analysis built a theoretical exposé of how banks in South Africa embed environmental data into their credit processes.

The research design chosen was an exploratory study because the main research question was exploratory: How to embed environmental risk into the current credit processes of banks of South Africa. More so, this approach allows for the subsequent development and refinement of conceptual categories which can be tested and re-tested with continual data collection.

In this research, the content analysis tool collected secondary data to formulate a model or conceptualised modified credit analysis model that is able to incorporate environmental risk. As new data appears, the proposed model will be used to test and re-test the proposed model for increased validity and reliability. In accordance with Davies' (2011) assertion that exploratory research is an exploration-for-discovery, this research is deemed a feasibility study to determine the impact of carbon tax implementation on the credit rating of companies.

Exploratory research relies on either one or all three techniques of collecting data. The first technique is secondary research, such as reviewing the available literature or data. The second technique is informal qualitative approaches, such as discussions with research subjects (for example, customers, employees, management). The third technique is the formal qualitative research through in-depth interviews, focus groups, case studies or pilot studies.

For this study, the first method, which involves the analysis of secondary research data, was chosen. However, the banks were not willing to divulge sensitive information that could have been useful in doing a more thorough analysis, and that could have provided answers to the research questions. This information about the individual firm's loans and their environmental data over the years was deemed too sensitive to share, specifically due to their role in the competitive intellectual edge of both banks and companies. The public information that was used by the study was found in the Annual Reports and Sustainability reports of companies and banks; therefore, a tool for textual analysis was used to extract and ascertain the data required for the proposed embedding model.

One of the significant drawbacks of the exploratory research design is the factor of not being able to generalise the research results to the general population. In addition, the limited number of companies with published environmental data prevented a broader analysis of all companies in South Africa.

The three types of data that were important in crafting the embedding model were environmental data, loans data and credit rating data. The dimensions of the required data proved a barrier to extracting the required data to embed in the model. Figure 4.3 illustrates the complexity of collecting data at different levels of analysis in the proposed embedding model. However, drawing from the rationale done in Sections 3.6.1 and 3.6.2, counteractive measures were found that would solve this problem of finding the appropriate data for the analysis. The next section explains the data that was collected for the study.

4.4 DATA, POPULATION AND SAMPLE

Stage 1 of the study (the qualitative research method) selected four South African banks for the content analysis: ABSA, Standard Bank, Nedbank and First National Bank (FNB) by virtue of the fact that in the period under review, 2010 to 2017, they held 80% of loans and advances in the South African banking sector.

For Stage 2 of the study (the quantitative research method), which involved the study of the embedding environmental risk into the credit-risk model, the population was all the companies that voluntarily participated in the answering of Carbon Disclosure Project questionnaires for the period under review: 2010 to 2017.

A stepwise sampling method was used to determine the companies that were consistent in providing answers to the CDP questionnaire from 2010 to 2017. The inconsistent companies were left out of the sample. It was difficult to apply a sampling method that balanced the companies per sector, or asset wise, or to apply any other sampling factor, due to companies not providing any data in one or more years between 2010 and 2017. The years 2010 to 2017 were chosen for the study because the CDP data started gaining consistency in 2010.

The qualitative and quantitative research methods had separate data requirements. The qualitative research method utilised the South African banking institution’s Annual and Sustainability reports dataset. The data was used to ascertain the level of embedding of environment risk into bank credit processes for the banks as reflected in their annual or sustainability reports. The data required for the quantitative study for each company depended on the components of the qualitative research method.

The quantitative research investigated three components, namely, carbon risk analysis, carbon tax calculation and the probability of default calculation.

- The data required for the carbon risk analysis consisted of the eight aspects of the primary business data that was obtained from the financial statements (as explained in Section 3.6.4) and the carbon emission per each year of the study period. The business data used in the study were: Sales, Total Expenses, Current Assets, Non-Current Assets, Current Liabilities, Non-Current Liabilities, Long term Loan, and Short Term Loan.
- The Carbon tax calculation required the following data for each company: net income, carbon emissions, carbon offsets, sales, and sales exports.
- The probability of default calculation required the following data for each company: Asset Value, Equity Value, Number of Ordinary Shares in Issue, Share price and Liabilities or Total Debt Value.

With regards to the reliability and validity of the data used for calculation, the JSE100 companies have been reporting their carbon emissions data since 2000 and have been doing so involuntary. The data is deemed credible, given that all carbon emissions reported are measured using the GHG Protocol, one of the leading standards in measuring corporate carbon emissions. More so, companies should have the carbon emission measuring, and reporting process audited and verified by competent environmental auditors, which makes this data credible, valid and reliable.

Figure 4.3 provides an overview of the data required for the study.

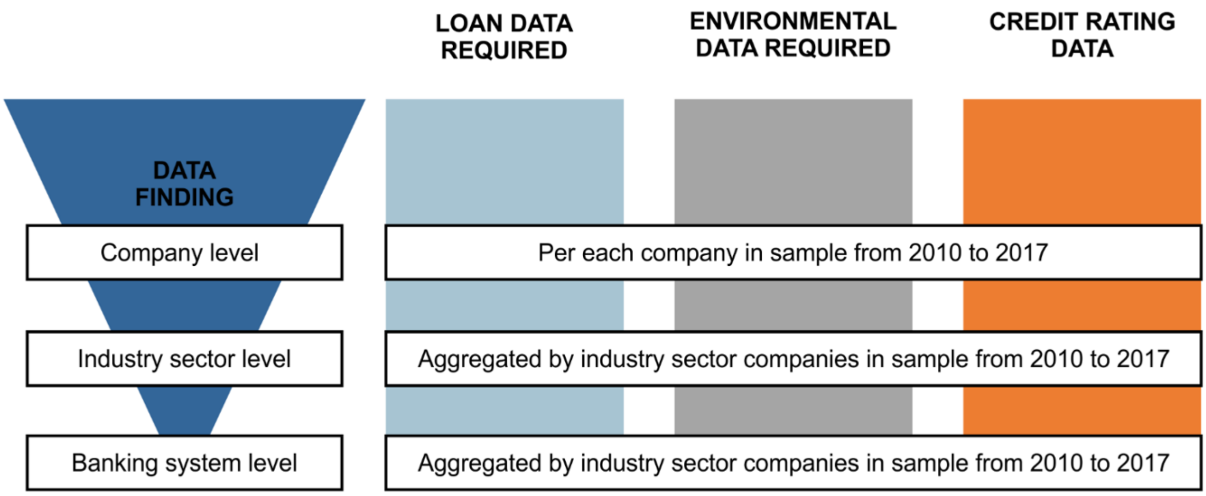


Figure 4.3: Synopsis of data required for the embedding model

There was a need to determine the data required for the quantitative research that was available in South Africa at company, sector and national level. It can be observed from Figure 4.3 that company and industrial sector-level data, loan data, environmental data and credit rating data were available for the period under review. However, obtaining aggregate data (loan, environmental and credit rating) for the industrial sector and banking system level proved to be difficult in South Africa due to confidentiality, and hence, the rationale for the study to work at a company level.

4.5 CONTENT ANALYSIS METHODOLOGY

The current study used the content analysis method to analyse how banks were embedding environmental issues into their bank credit processes. The content analysis explored the methods or procedures disclosed in the banks' publicly available annual reports.

According to Parker (2005), researchers in the field of social-environmental accounting have used content analysis as the dominant research method for collecting empirical evidence. Parker deduced this from a literature review of social-environmental accounting studies from the periods 1988 to 2003. Parker also found that over the study period, 48% of the papers published were empirical studies, with 19% using content analysis. According to Neuendorf (2017), content analysis is the systematic, objective quantitative analysis of message characteristics. It includes both rational and computer-aided text analysis.

For content analysis to be credible, the study should comply with specific technical requirements; of specific importance is the unit of analysis (Guthrie & Abeysekera, 2006). According to Babbie (2015), the unit of analysis is the subject of study, namely, the 'what' or 'who' that is under study. Babbie further distinguishes the unit of analysis from the unit of data collection, where the unit of data collection is the element of each variable that is measured. The unit of analysis is the element of data analysis and is used to report findings.

Gray, Kouhy and Lavers (1995) indicated that in accounting literature where content analysis is used, researchers either count the number of disclosures or examine the extent or volume of disclosures. This study explored how South African banks disclose their methods of embedding environmental or climate change issues into bank credit processes. The unit of analysis for the current study that was explored through content analysis was the disclosure of the embedding of environmental risk into bank credit processes. This was proxied by some environmental risk-related words, for example, by searching for the following terms: equator principles, environmental risk criteria, environmental lending criteria, carbon risk, climate risk, financial risk related to climate change, environment credit-risk model, that were mentioned in or near bank credit processes disclosure in the publicly available annual and sustainability reports.

Surveys and questionnaires could have been used as a method of collecting data; however, these annual reports are a thoroughly audited (independently verified and assured) source of information that is accessible. Moreover, annual reports are the primary source of obtaining data for analysis in the accounting literature, with most studies that use content analysis in account research using annual reports (see Gamble, Hsu, Kite & Radtke, 1995; Bae & Sami, 2004).

4.5.1 Validity, reliability and credibility of data from sustainability and integrated reports

The study needed clarity to prove the reliability, validity and credibility of the integrated reports being used for content analysis. The main question that needed to be answered was whether the data being sought, namely, the data related to whether the banks were embedding environmental risk in the banking credit process, was compulsory for banks to disclose. This was important, because the information is not required legislatively but is supplied voluntarily with a persuasion that enhances the banks' investment grade. This means that the more a bank adopts reporting standards that disclose environmental, social and governance issues, the more it attains a higher investment grade.

The banks in the sample subscribe to the Global Reporting Initiative (GRI) which requires sustainability reporting on the following categories: economic, social, environment and governance. The GRI FSSS (Global Reporting Initiative – Financial Services Sector Specific disclosure (2013) is a compilation of financial services reporting standards. One of the standards requires financial institutions to disclose data that shows their efforts to integrate environmental risk assessment into their standard processes for developing and delivering product and services. The GRI FSSS FS4 specifically mandates banks to disclose their procedures for assessing and screening environmental and social risks in their business lines.

The voluntary reporting might dilute the efficacy of these reports as a source of data able to answer the research questions. However, the King III reporting is a compulsory South African Company Reporting Standard for JSE-listed companies that was implemented in 2010. The King III was replaced by the King IV reporting standards in 2017, which insisted on the integrating of ESG issues in annual reporting.

Solomon and Maroun (2012) indicate that the adoption of the King III by JSE-listed companies increased the discourse of social, environmental and ethical issues. The sustainability reports are deemed adequate to provide the required information to answer the research questions, based on the fact that the banks in the sample are JSE-listed and adhere to the ESG integrated reporting required by both the King III and King IV codes.

4.5.2 Content analysis procedures

The process involved the collection of all the annual reports, integrated reports and sustainability reports of the big four banks in South Africa that were selected for the study, namely, Nedbank, Standard Bank, ABSA and FNB.

Categories were created using Jeucken's Sustainable Banking Model (2010) and Kaeufer's Four Phases of Sustainable Banking Model (2010). Table 4.1 discusses these two models, and Table 4.2 shows the categories and indexing that were used. The current study used the conceptual analysis content analysis method, which involves choosing certain concepts for examination and analysis and then tallying their presence in the chosen texts. To make the research more robust, credible and dependable, the presence of environmental issues (terms) and climate change issues (terms) around common bank credit process terms were also incorporated. A priori coding method which requires a strong theoretical foundation for the coding categories was used to code the data.

The qualitative research method analysed the South African banks' data, as identified in Section 4.4, using the content analysis software ATLAS.ti to code the words and do the number tallying. The annual, integrated and sustainability reports for the four banks were loaded into ATLAS.ti software. First, the number count of the following words was done: environmental risk in general, and environmental risk lending, or environmental risk financing, and environmental risk credit. Secondly, there was a noting and numbering of the following words: credit, loan, credit process, credit-risk model, due diligence, specifically in terms of their closeness to the discussion of either the environmental risk or climate risk or carbon risk.

The construct concept for using content analysis to determine the level of embedding environmental risk into credit processes was presented first in this thesis. The motivation for using content analysis started with the expected outcome was two-pronged: (1) the state of disclosing environmental risk in credit processes, and (2) the disclosure of the level of embedding. If disclosed, could it be benchmarked to the Jeucken (2001) and Kaeufer (2010) bank sustainability models?

The second step was determining the source of the data for content analysis. The data was collected from the Annual CDP reports, Sustainability Reports, and Integrated or Annual Reports of companies from 2010 to 2017.

The third step was the derivation of coding categories, Table 4.1 shows the framework of creating categories, while Table 4.2 presents the actual codes used for categorising the data related to South African Banks into levels of embedding.

It should be noted that the Jeucken Sustainable Banking Model and the Kaeufer Sustainable banking Model where chosen because they reflect the time-evolutionary view of sustainable banking. In this part of the research, the aim is to trace that time evolutionary view of sustainable banking within their bank credit process amongst the South African banks.

Table 4.1: Comparison of the Jeucken Sustainable Banking Model and Kauefer Sustainable Banking Model

Jeucken (2010): **Four phases of sustainable banking**	**Comparison of the two methods of categorising level of embedding**	**Kauefer (2010):** **Five levels of sustainable banking**
Phase 1: Defensive	Jeucken indicates this stage as when the bank does not participate in activities that support environmental legislation. Kaeufer, on the other hand, talks of the bank only being a sponsor of various environmental events and not internalising them into its activities.	Level 1: Unfocused corporate activities
Phase 2: Preventative	At this stage, Jeucken indicates that the bank starts incorporating environmental responsibility into the banking operations, mainly targeting internal operations of environment cost-savings on internal energy, water use and waste. Kaeufer shows that, at this stage, banks start to introduce unique products or services with regards to environmental risk as part of their conventional services	Level 2: Isolated business projects or business practices
Phase 3: Offensive	Kaeufer indicates that, at this stage, the majority of the banks' financial products and services have social and environmental principles infused in them. Jeucken agrees with Kaeufer on this stage of sustainable banking, where banks begin to realise the opportunities present in sustainable development, both in their internal and external banking operations.	Level 3: Systemic business practices
Phase 4: Sustainable	Kauefer has a fourth level that Jeucken does not have. However, on close observation, Kaeufer's 4th and 5th level is a broadened 4th phase of Jeucken's sustainable banking model. Both agree that at this level bank sustainability is no longer regular. However, there is more innovation and deepened embedding of sustainability principles in internal and external operations of a bank. Jeucken states that banking products at this level influence and stimulate sustainability among customers and other entities in society. Both indicate that, at this level, the lending and investment business bear the hallmarks of sustainability principles from a social, economic and environmental perspective.	Level 4: Strategic ecosystem innovation stage Level 5: Intentional (purpose-driven) eco-system innovation stage

Table 4.2: Framework of categorising levels of embedding environmental risk

Item	Description	Categorisation rule
Level 1: Defensive embedding	**No** mention of rules, policies or procedures being in place to consider climate change issues in bank credit processes	Count frequency of pre-determined phrases with regards to embedding. Determine frequency on a priori terms per year
Level 2: Preventative embedding	Annual reports **begin** mentioning the embedding of climate change issues into bank credit processes with little to **no detail on the process.**	The first step is to enumerate the presence and mention of environmental and climate issues in the bank credit process. Secondly, measure the detailing by frequency of pre-determined terms. Thirdly, measure word presence between climate change and environment issues to bank credit process in each paragraph. Tally word presence and correlate them with frequency. Fourthly, after looking at all results, pre-determine cut-offs and categorise these results into level 2, 3 or 4.
Level 3: Offensive embedding	Annual reports **show limited** embedding of climate change issues into bank credit processes and credit products	
Level 4: Sustainable embedding	Annual reports **show full disclosure** of processes of how they embed environmental and climate change issues into bank credit process and credit products.	

The process proceeded to group the results of this analysis into the embedding level of banks using the pre-determined four codes that automatically classified the data into the level of embedding. In the analysis part, the research employed the proximity matrix by using the rescaled Euclidian distance.

The analysis utilised the following data from each bank:

- Four levels of embedding;
- Number of projects reported under Equator Principles;
- Non-project finance credit deals analysed for environmental risk;
- Number of environmental words; and
- Environmental words connected to credit processes or lending processes.

Table 4.3 provides a more detailed description of these variables.

Table 4.3: Description of variables, codes and levels used in content analysis

Code variable	Description of code variable
L1 - EP (w)	Level 1 is the implementation of Equator Principles, without the number of deals subjected to EP disclosed
L2 - EP ProjFin (w)	Level 2 is the implementation of Equator Principles in Project Finance with number of deals subject to EP deals disclosed
L3 - EP - ERA (w)	Level 3 is the implementation of EP Beyond Project Finance, and the bank has its own or extended Environmental Risk Analysis Tool
L4-ERA-CreEnv (w)	Level 4 is when a bank has a credit system the incorporates environmental issues along the whole credit value chain
EP - A	Credit deals classified as Equator Principle group A
EP - B	Credit deals classified as Equator Principle group B
EP - C	Credit deals classified as Equator Principle group C
EP -Total	Total of Equator Principles deals assessed
Non-ProjFin	Number of Non-Project Finance deals assessed for environmental risk
Number of Enviro Words	Number of environmental words
Enviro -Words Cr	Number of environmental words close to or associated with credit processes

The expected outcome from the analysis was to first obtain the level of embedding for each bank for the period under study. Secondly, to find a single view of embedding by using the similarity and dissimilarity results from the proximity matrix, namely, the rescaled Euclidian distance between the variables (Please see Appendix B for the full results).

4.5.3 A methodological review of the proximity matrix analysis

Proximity is a measurement of the similarity or dissimilarity, broadly defined, of a pair of objects. If measured for all pairs of objects in a set (distances between the level of embedding, number of environmental risk words and number of environmental risk words included in credit processes), an object-by-object proximity matrix represents the proximities.

Proximity is thought of as a *similarity,* if the more significant the value for a pair of objects, the closer or more alike it is assumed to be. Examples of similarities are co-occurrences, interactions, statistical correlations and associations, social relations, and reciprocals of distances. Proximity is a *dissimilarity,* if the smaller the value for a pair of objects, the closer or more like it is assumed to be. Examples are distances, differences, and reciprocals of similarities.

Proximities are generally symmetric so that the proximity of object *a* to object *b* is the same as the proximity of object *b* to object *a*. However, in the case of one-way streets, distances can be non-symmetric. There are two basic ways of obtaining proximity: directly (or *dyadically*) and indirectly (or *monadically*).

Direct measures are found in an obvious way. For example, a direct measure of the distance between cities is obtainable by driving from one city to the other. In the context of this study, a direct measure of the interaction between these eleven variables is obtained by counting the number of times that they interact with each other over a given period (2010 to 2017). So, for instance, the interaction between the level of embedding to the number of words (environmental risk) in credit processes and the number of Equator Principles deals reported. The interactions are complexed to measure how each level of embedding separately interacts with the number of words identified (counted) in the credit process, and in general, also to the number of Equator Principles deals reported. This is done for each bank and aggregated for the period 2010 to 2017.

Indirect measures are obtained by first measuring the objects on one or more attributes and is recorded as a 2-way, 2-mode object-by-attribute matrix. The set of scores associated with an object or an attribute (that is, a row or a column of the data matrix) is called a *profile*. Then, a statistical measure of the similarity or dissimilarity of a profile is computed for each pair of objects or attributes (that is, each pair of rows or columns of the data matrix). In many situations, the objects are thought of as *cases,* and the attributes are seen as *variables*.

Figure 4.4 presents a diagram illustrating the conventional wisdom related to the choice of proximity measures.

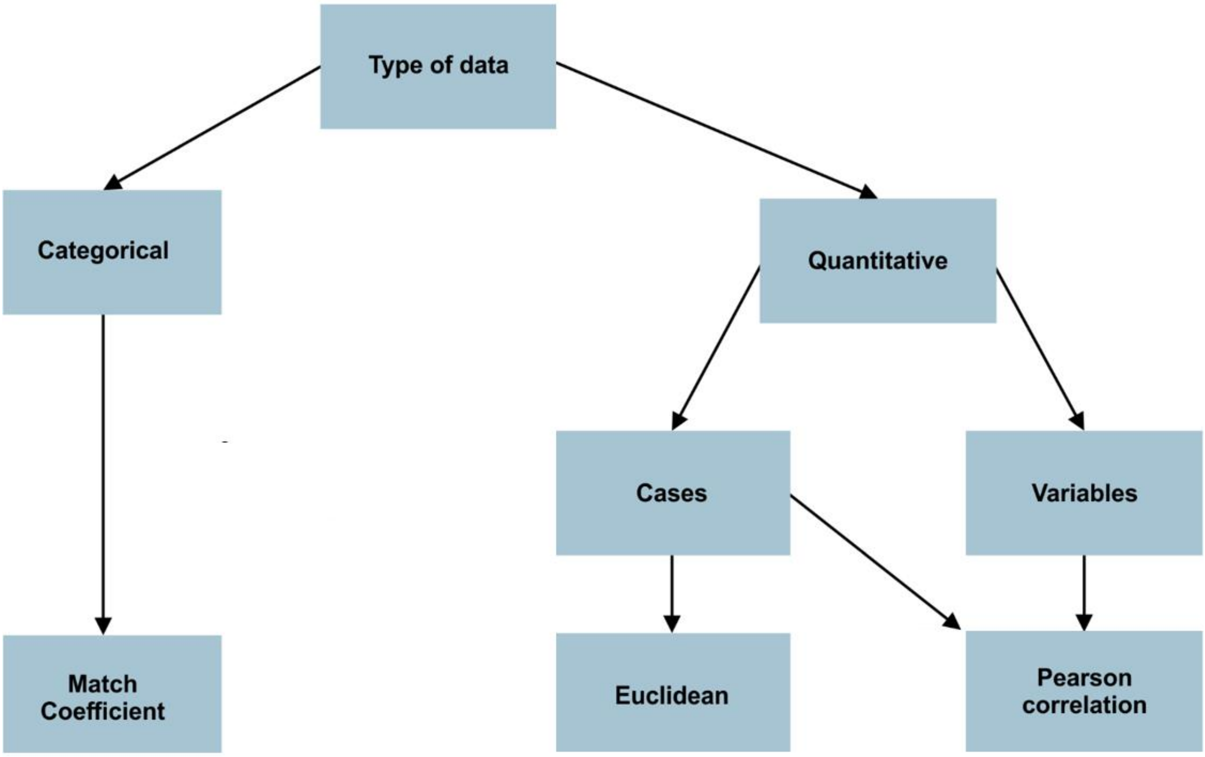


Figure 4.4: Conventional wisdom on the choice of proximity measures

Source: Adapted from Borgatti, 1987

The choice of measure is determined in part by the type of data (see Figure 4.4). For categorical data, the standard measure is the matching coefficient, which, for a given pair of objects, is simply the count of the number of times (attributes/columns) that one object has the same value as the other object. Typically, this count is divided by the maximum possible, which is usually the total number of attributes/columns in the data (that both objects have non-missing values for).

For quantitative data, two measures are commonly used, namely, a similarity measure (correlation) and the other a dissimilarity measure (Euclidean distance). Typically, the Euclidean distance is only used to measure proximities among cases (generally, respondents), whereas, correlation tends to be used to measure proximities among variables (general attributes of the respondents).

The critical issue in choosing a measure of proximity for quantitative data is determining what aspects of profiles the measure should demonstrate. Every profile can be said to possess the following three aspects: level, amplitude (or scatter), and pattern.

- Level refers to the overall size of the numbers, and is measured by the mean of all the values.
- Amplitude refers to the extremeness or variability of the numbers, and is measured by the standard deviation.
- Pattern refers to the sequence of ups and downs in the values from case to case. It is not measurable in isolation. It should be assessed whether two profiles have the same pattern, and even how different they are from each other, but there is no monadic measurement of pattern.

Therefore, in the context of this research, variables are profiles ranging from 2010 to 2017. The Euclidean distance between two profiles is a function of differences in mean, differences in amplitude, and differences in pattern, all taken together. Only if two profiles are the same across all three aspects will the Euclidean distance say they are the same. In contrast, correlation ignores differences in level and amplitude, and focuses only on differences in pattern. For example, if the count of frequency per bank measures all the variables of embedding, the units of frequency are rescaled to between 0 and 1 (so that 200 becomes 0.2). The amplitude of the variable would be reduced by a factor of 1000 in this case, but the correlation between the two versions of income would be a perfect 1.0.

The reason why the Euclidean distance is typically not used for comparing variables is that variables often have different units of measurement. If the carbon emissions (CO_2e tons) of each bank are compared to the number (count) of environmental risk words mentioned in the annual and sustainability reports, there would be a massive Euclidean distance between the variables. Even if their patterns are identical, that is, when one variable (carbon emissions) is relatively higher than other cases (for example, ABSA Bank), the other variable (environmental risk words) may be high relative to other cases (for example, in relation to Nedbank), and vice-versa.

Therefore, the only time Euclidean distances are used is when differences in scale (that is, level and amplitude) are meaningful. For example, suppose our data consists of carbon emissions on a sample of banks, arranged as a bank-by-variable matrix. Each row of the matrix is a profile of *m* numbers, where *m* is the number of variables. The proximity of the variable can be evaluated (in this case, the distance) between any pair of rows. Now, consider what it means, for a moment, that the variables are the columns. A variable records the results of a measurement. For this study, it is useful to think of the variable as the measuring device itself. This means that it has its scale, which determines the size and type of numbers it can have. For instance, the carbon emissions measurer might yield numbers between 0 and 100 million, while another variable, the environmental risk words, might yield numbers from 0 to 500. The fact that carbon emission numbers are more substantial in general than the environmental risk words numbers are not meaningful because the variables are measured on different scales.

In order to compare columns, there is a need to adjust for or take account of differences in scale. But the row vectors are different. If one case has larger numbers in general than another case, this is because that case has more environmental risk words, than the other case. It is not an object of differences in scale, because rows do not have scales: they are not even variables. In computing similarities or dissimilarities among rows, there is no need to try to adjust for differences in scale. Hence, the Euclidean distance is usually the right measure for comparing cases. Hence, for this study, the Statistical Package for the Social Sciences (SPSS) was used in calculating the Euclidean distance.

4.6 CREDIT RATING METHODOLOGY PROCESS

Having ascertained the level of embedding by South African Banks, the research went on to craft a simulation of the embedding of environmental risk into the bank credit processes. From the previous discussion, it has been ascertained that embedding is at company (individual) level. Also, in terms of the credit terminology, the impact of environmental risk on the credit rating on the company's financial wellbeing is the basis of crafting this model. The precedence of this is based on the frameworks done in the study by ICBC (2018) when it stress-tested the environmental impact on the credit rating of companies, in particular, climate change sensitive sectors.

Figure 4.5 summarises the methodology process flow.

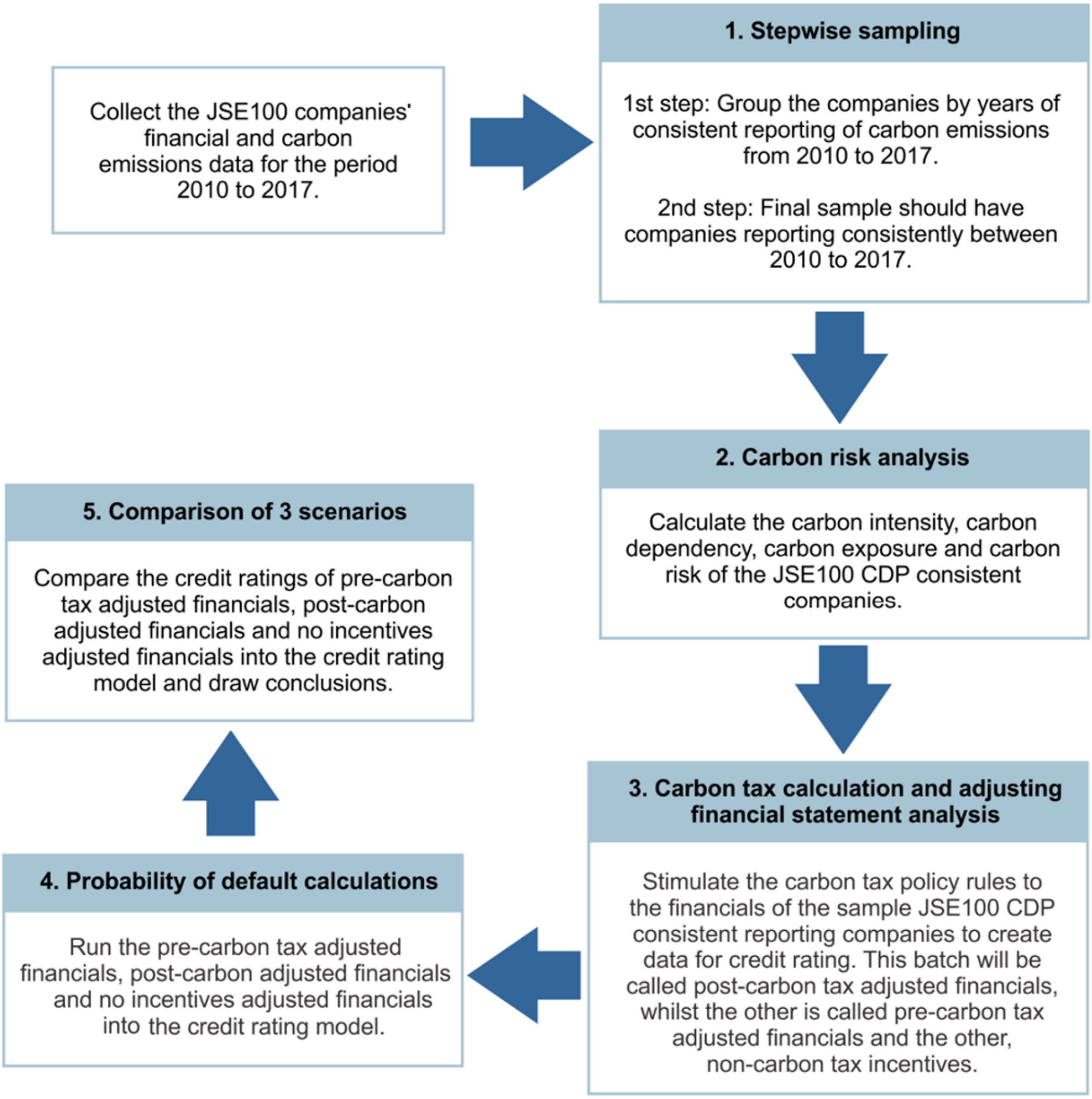


Figure 4.5: Credit rating methodology process

Three tools underpin this portion of the research, and these are: (1) the South African Carbon Tax policy, (2) Adjusting financials for Carbon tax, and (3) the Credit Rating Model. Below is an explanation of these three tools, and a discussion of how they have been used in this research.

4.6.1 Carbon tax policy framework

A carbon tax was chosen in accordance with the ICBC (2018) framework of environmental stress testing of its loans (Section 3.6.5). For South Africa, a carbon tax is the perfect proxy for the impact of environmental risk and climate change. As per the discussions in Chapter 3, specifically Section 3.4.1, the carbon tax policy is being used as a tool to help South Africa move to a green, or a low carbon economy. The aim is to make sure that companies are penalised for engaging in activities that emit an excess of carbon emissions. Therefore, this phenomenon is classified as transition risk, as discussed in Section 2.2.4 and Table 2.3.

As previously explained, the South African carbon tax policy has undergone all the necessary processes to have it legalised and implemented. Initially, it was supposed to have been implemented in the following two phases:

- Phase 1: January 2017 to December 2020, and
- Phase 2: January 2010 to December 2025.

However, the design of the carbon tax in Phase 2 was going to be reviewed. Therefore in this study, the timeline was realigned, in retrospect, to see the impact of the carbon tax policy on the credit ratings of companies as follows:

	Actual Implementation timeline	**Simulated retrospective timeline**
Phase 1:	January 2017 to December 2020	January 2010 to December 2013
Phase 2:	January 2010 to December 2025	January 2014 to December 2017

In the detailed features of the carbon tax, the main concern was related to the carbon tax design features and the calculation of carbon tax. The administration and other features were not of much concern to the purpose of this study.

Therefore, the carbon tax is applied to all direct (scope 1) GHG emissions (CO_2, CH_4, N_2O, Perfluorocarbons (PFC) based on emissions provided in the Carbon Tax Bill. The scope one emissions include energy combustion factors, fugitive emission factors and industrial process and product use emission factors, which are all based on inputs to the production process of companies.

Carbon emissions from stationary sources are also taxable; however, transport fuels, such as petrol and diesel will be taxed via the existing fuel levy regime. Most of the taxable emissions will be determined by a Notice in respect of the Declaration of Greenhouse Gases as priority air pollutants under the Air Quality Act. However, agriculture, forestry and land use, and emissions from waste are exempted from tax during Phase 1, although transport fuel use in these sectors is not exempt.

The tax rate was initially pegged at R120/tCO_2e starting from 2019; however, it is expected to increase by 10% per annum over the first five years, to reach R172.69 in 2020. There are a couple of allowances or incentives to the carbon tax that will be granted. These are:

- a 60% basic tax-free allowance will be applied to all sectors during the first five years,
- a tax-free allowance of up to 10% is available to firms in 'trade-exposed' sectors;
- a further 10% tax-free allowance will be provided to firms in sectors where there is a structural or technical inability to make reductions (process emissions);
- firms will be able to use domestic offsets in relation to 5% or 10% of their gross tax liability, that is, before the impact of exemptions;
- full exemption during the initial five-year period has been proposed for the agriculture, forestry and other land use activities, as well as the waste management sectors;
- a 'Z-factor' will be introduced which will reward firms that have lower emissions relative to others in the same sector, with a further tax-free allowance of up to 5%;
- an additional 5% tax-free allowance will be available to companies participating in the carbon budget process.

Revenue from the tax will be recycled to support the transition to a low-carbon economy and to protect poorer households and vulnerable sectors from the impact of energy price increases.

Figure 4.6 illustrates the carbon tax calculation and the details of the additional tax allowances. These are enunciated more in Appendix D.

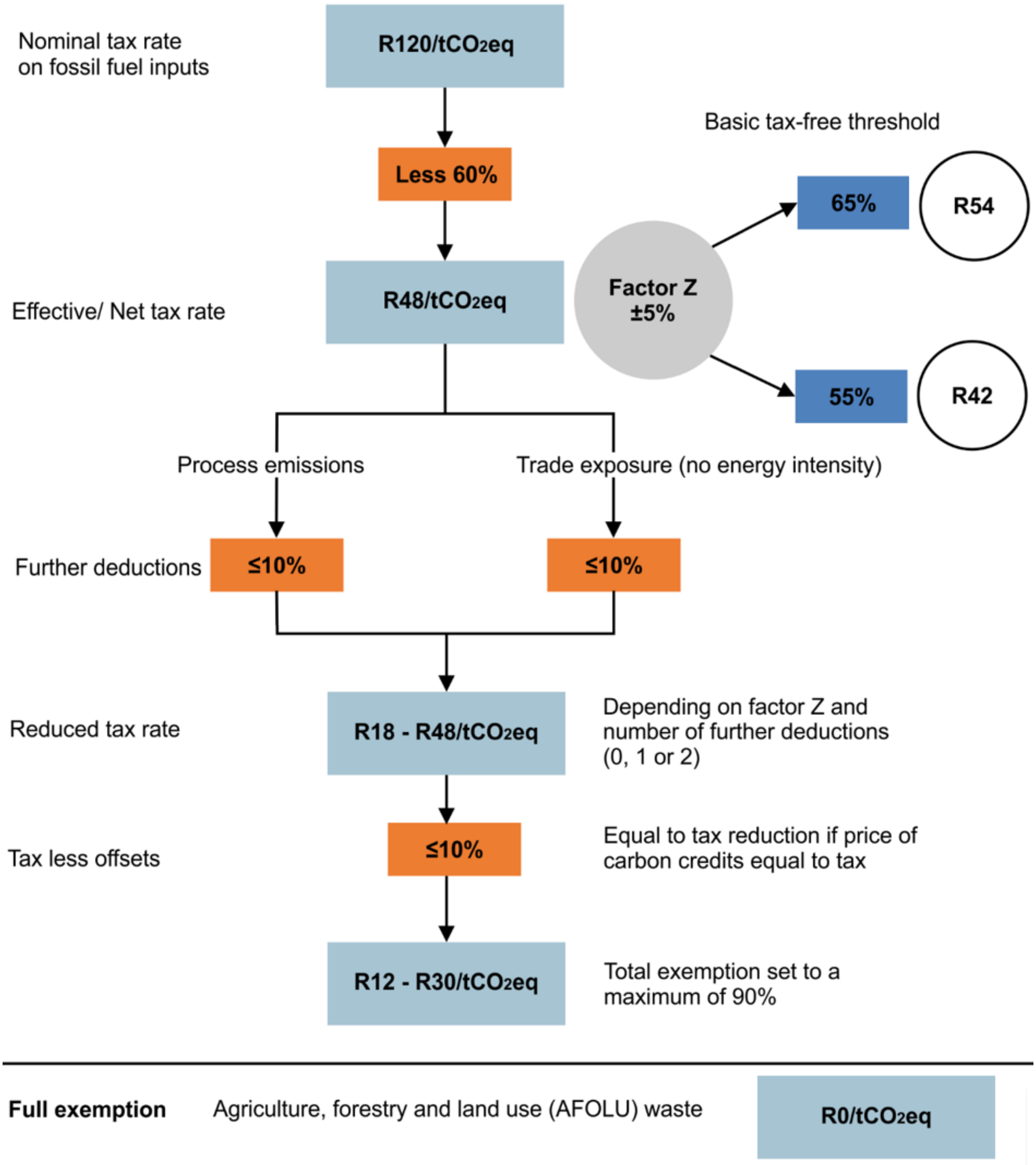


Figure 4.6: Carbon tax calculation flow

Source: Adapted from Energy Research Centre (UCT), 2013

4.6.2 Adjusting equity and liability values for carbon tax

The Merton Model (1974) was adopted for the calculation of the probability of default values. Therefore, the probability of default is calculated on three data sets to ascertain the impact of the carbon tax on company credit rating. The three data sets are:

1. The typical financial data set that is unadjusted (Pre-Carbon Tax) for the carbon tax;
2. The financial data set that is adjusted for a carbon tax (Post Carbon Tax) as per Section 4.6.1 (carbon tax calculations); and
3. The financial data set is adjusted for a carbon tax (Post Carbon Tax) with no allowances and incentives.

The third financial data set represents the stress test as per the ICBC environmental risk stress test described in Section 3.6.5. So, for the second data set, the study adjusts the equity value of a company by subtracting the carbon tax value. Carbon tax reduces income tax, and therefore the retained income that is added to capital, or equity value, reduces the equity value of the company. The carbon tax is treated as a liability to balance the accounting equation of ‘Asset Value’ is equal to ‘Equity Value’ plus ‘Liabilities Value’.

4.6.3 Accounting for carbon credit or offsets

Carbon credit or offset (as per the South African Carbon Tax design framework) is an instrument which bears non-environmental polluting characteristics that can be used to reduce the carbon emissions of a given entity. Based on the South Africa Carbon Tax Design Framework, companies can use between 5% and 10% to reduce the carbon emissions liable for tax (National Treasury, 2018).

In literature, however, these carbon credits or offsets are of material importance on the financial statements of companies (Riley, 2007; Kouskey & Cook, 2009; MacKenzie, 2009; Warwick & Ng, 2012; Ayaz, 2017). According to Oker and Adiguezel (2017), carbon accounting remains an area in which there is no consensus amongst the various international accounting bodies, such as the International Accounting Standards Board, International Financial Reporting Standards, International Accounting Standards and Financial Accounting Standards Board. To complicate matters even further, there are two distinct issues in terms of carbon accounting, namely, (1) accounting for the trading of carbon credits through any emission trading platform, and (2) accounting for owning or the development of carbon credits. However, a study by Lovell, Sales De Aguiar, Bebbington and Larrinaga-Gonzalez (2010) indicates that most of the large emitters participating in the EU-ETS (European

Union Emissions Trading System) use a variety of accounting practices for the accounting of emission allowances.

Given the non-existence of a carbon offset trading system in South Africa, it will be challenging to model the carbon credits or offsets declared by companies in the annual financial statements. Therefore, the carbon offsets are only utilised in the calculation of carbon tax and are not used in readjusting the balance sheet (statement of financial position) to give a fair value of the company.

Since most companies have been participating voluntarily in the carbon offset markets, it is also imperative to check retrospectively if they have incorporated carbon credits or offsets on their financial statements. It is essential to recognise these as either assets or inventory on the balance sheets (statement of financial position) of companies in the sample. Attention will be paid to the materiality of these, given the small percentage of carbon offset allowances in the carbon tax bill.

It is believed that the results of the study will not be biased, given that the carbon offset system has not been fully developed yet. Therefore, accounting for carbon credits or offsets was ignored in the case of the current study, since such data sporadically occurred amongst the sampled companies. Given this, the data structuring for credit-risk modelling was deemed to proxy well for the outcome that was observed, namely, the adverse effect of the carbon tax on the credit rating of the sampled JSE100 CDP companies.

4.6.4 Credit rating model

The study intended to determine if there was a significant degree or magnitude of change in the probability of default with the adjustment of the carbon tax on the JSE100 CDP reporting sample companies. The JSE100 CDP sample data that was collected dated from 1 January 2010 to 31 December 2017.

To simplify matters, the Merton Model was used to calculate the probability of default. The Merton Model is the first-order structural form model for predicting credit deterioration. The research used data obtained from the INET BFA database, now called IRESS, which is a South African supplier of quality of financial data. The IRESS database was used to source the equity prices, equity volatilities, market capitalisation and company debt levels as applicable to the study. The South African Reserve Bank's website was used to source the 90-day Treasury Bills for the period covered in this study.

4.6.5 The Merton Model construct

This section provides a brief overview of the Merton Model construct. Merton (1974) proposed a model for assessing the structural credit risk of a company by modelling the company's equity as a call option on its assets. This method was amplified by the use of the Black-Scholes-Merton option pricing methods. The Merton Model is structural because it provides a relationship between the default risk and the asset (capital) structure of the firm.

From an accounting point of view, the book value of a firm's equity (E), total assets (V) and total liabilities (D) are defined by the equation below:

Assets	Liabilities
V_t	$E_t + D_t$

Where V_t represents the company's assets

E_t is equity

D_t is senior zero-coupon debt

These book values for *E*, V, and *D* are all observable, since they are recorded on the balance sheet (statement of financial position). Although the book values are infrequently reported, the equity's market value is observable, as it is derived from the company's share price times the number of outstanding shares. However, the market value of the firm's assets and total liabilities are unobservable.

Therefore, Merton's Model relates to the market value of assets, equity and liabilities in an option pricing framework. The Merton Model assumes a single liability *D* with maturity *T*, usually within one year. At time *T*, the firm's value to the shareholders equals the difference *V*–D, when the value of the assets *V* is greater than the liabilities *D*. However, if the debt *D* exceeds the asset value *V*, then the shareholders will make a loss.

The value of the equity E_T at time *T* is related to the value of the assets and liabilities. In other words, the payoff of equity holders is equivalent to a European call option on the assets of the company with a strike price D_T and maturity T, as shown by the following formula:

$$\mathbf{E_T} = \boldsymbol{max}(\mathbf{V_T} - \mathbf{D_T}, \mathbf{0}) \qquad \textbf{Equation 4.1}$$

However, the payoff structure of debt holders is equivalent to a portfolio, which consists of a European put option and debt. The strike price of the European put option is D_T with maturity T, and underwritten on the assets of the company. So, its value at time T is $min(V_T, D_T)$, which is equal to $D_T - max(D_T - V_T, 0)$.

Table 4.4 shows the payoffs of equity holder, and debt holders are summarised:

Table 4.4: Payoffs for bondholder and equity holder

	At time 0	**At time T**	
		$V_T < D_T$	$V_T \geq D_T$
Equity holders	European call option	Not exercised	V_T - D_T
Debt holders	European put option + Debt	D_T-V_T	Not exercised + D_T

In the above discussion, a rationale for the Merton Model has been set. Pursuant, the estimation of default probabilities and valuation of the company's debt (liabilities) values is shown.

The following identity holds:

Asset Value = Value of Equity + Value of liabilities

Therefore, the following scenario is considered:

$$if\ V_t < D_t \Rightarrow E_t < 0$$

The above scenario is the point of departure for the Merton Model, where the value of the company (V_t) at time t is less than its debt (D_t) at time t; therefore it follows that the equity of this company at time t is less than 0.

In such a scenario, three conditions may hold: (1) equity holders of the company may walk away, (2) the company's creditors' claims will not be fully recovered, and (3) the company is in default. Therefore, equity holders will wait until time T, which is the maturity date of debt or the payment date of debt, before the company defaults which algebraically can be presented as follows:

$$\mathbf{PD} = \mathbf{P}(\mathbf{V_T} < \mathbf{D_T})$$ **Equation 4.2**

The following items are required to determine the default probability for a given company. These are: (1) the company's liability from the balance sheet (statement of financial position), and (2) specification of the probability distribution of the asset value at maturity *T*.

Coupled with this, it is assumed the value of financial assets (V_t) follows a log-normal distribution, that is, the logarithm of asset value is normally distributed. The per annum variance of the log asset changes by σ^2 and the expected per annum change in log asset values are represented by $\mu - \sigma^2/2$, where μ is the drift parameter.

With *t* today or current, the log asset value in *T* will follow a normal distribution with the following parameters (Löeffler & Posch, 2011):

$$\mathbf{InV_T} \sim \mathbf{N}\left(\mathbf{InV_t} + \left(\boldsymbol{\mu} - \frac{\boldsymbol{\sigma}^2}{2}\right)(\mathbf{T} - \mathbf{t}), \boldsymbol{\sigma}^2(\mathbf{T} - \mathbf{t})\right)$$ **Equation 4.3**

If *D, V_t*, μ and σ^2 are known, it will be easy to determine the probability of default using elementary statistics (Löeffler & Posch, 2011). Therefore, since Φ gives the probability that a normally distributed variable x falls between z$[(z - E[x])/\sigma(x)]$, with Φ cumulative standard normal distribution, it holds:

$$\mathbf{P}(\mathbf{V_T} < \mathbf{D_T}) = \boldsymbol{\Phi}\left(\frac{\mathbf{D_T} - \mathbf{E}(\mathbf{V_T})}{\boldsymbol{\sigma}(\mathbf{V_T})}\right)$$ **Equation 4.4**

Moreover, applying this result to our case, the following is derived:

$$\mathbf{Prob\ (Default)} = \boldsymbol{\Phi}\left(\frac{\mathbf{InD_T} - \mathbf{InV_T} - (\boldsymbol{\mu} - \frac{\boldsymbol{\sigma}^2}{2})(\mathbf{T} - \mathbf{t})}{\boldsymbol{\sigma}\sqrt{\mathbf{T} - \mathbf{t}}}\right)$$ **Equation 4.5**

$$= \boldsymbol{\Phi}\left(\frac{\mathbf{In}(\mathbf{D}/\mathbf{V_T}) - (\boldsymbol{\mu} - \frac{\boldsymbol{\sigma}^2}{2})(\mathbf{T} - \mathbf{t})}{\boldsymbol{\sigma}\sqrt{\mathbf{T} - \mathbf{t}}}\right)$$ **Equation 4.6**

Literature alternatively uses the term distance to default (Avellanada & Zhu, 2001; Bharath & Shumway, 2008; Duan & Wang, 2012; Kovacova & Kollar, 2018; Suto & Takehara, 2018). Distance to default is derived by measuring the number of standard deviations the expected asset value V_T is away from the default. Therefore, distance to default can be expressed as:

$$\mathbf{DD} = \frac{\mathbf{InV_t} + \left(\mu - \frac{\sigma^2}{2}\right)(\mathbf{T}-\mathbf{t}) - \mathbf{InD_T}}{\sigma\sqrt{\mathbf{T}-\mathbf{t}}}$$ **Equation 4.7**

It follows that:

$$\mathbf{PD} = \boldsymbol{\Phi}(-\mathbf{DD})$$ **Equation 4.8**

Therefore, the Probability of Default (PD) of a company is determined if the following are known:

$$V_t, D_T, \mu, \sigma^2$$

According to Löeffler and Posch (2011), there is no theoretical reason to justify the determination of default probabilities. However, as practically the market value of assets is observable, it is justifiable to do so. Therefore, the book values of assets are observable, although the book value can diverge from the market value for various reasons.

It should be noted that if asset values are not observed, and the asset value today, V_t is not known, then Equation 4.9 cannot be calculated. Further, observed asset values cannot be used to derive an estimate of asset volatility σ. So, in the Merton problem, V_t cannot be observed, therefore, the solution is to use the option pricing theory of Black-Scholes to determine V_t.

Assuming no dividends are paid, the Black-Scholes call option formula is used:

$$\mathbf{E_t} = \mathbf{V_t}\boldsymbol{\Phi}(\mathbf{d_1}) - \mathbf{D_T}\mathbf{e}^{-\mathbf{r}(\mathbf{T}-\mathbf{t})}\boldsymbol{\Phi}(\mathbf{d_2})$$ **Equation 4.9**

Where:

$$\mathbf{d_1} = \frac{\mathbf{In}(\mathbf{V_T}/\mathbf{D_T}) + \left(\mathbf{r} + \frac{\sigma^2}{2}\right)(\mathbf{T}-\mathbf{t})}{\sigma\sqrt{\mathbf{T}-\mathbf{t}}}$$ **Equation 4.10**

$$\mathbf{d_2} = \mathbf{d_1} - \sigma\sqrt{\mathbf{T}-\mathbf{t}}$$ **Equation 4.11**

and r is a logarithmic risk-free rate of return. Given the problem of determining asset value V_t and the asset volatility σ, Equation 4.9 links these two to the observable value (the equity value - E_t). However, this is one equation with two variables, so the (1) iterative approach, and (2) using the equity values and equity volatilities are the methods used to solve for the two unknowns.

4.6.6 The iterative approach

Rearranging the Black-Scholes formula, the following equation is deduced:

$$\mathbf{V_t} = \left[\mathbf{E_t} + \mathbf{D_T}\mathbf{e}^{-\mathbf{r}(\mathbf{T}-\mathbf{t})}\boldsymbol{\Phi}(\mathbf{d_2})\right]/\boldsymbol{\Phi}(\mathbf{d_1})$$ **Equation 4.12**

Going back in time for 260 trading days, the following systems of equations are derived:

$$\mathbf{V_t} = [\mathbf{E_t} + \mathbf{D_t}\mathbf{e}^{-\mathbf{r_t}}\boldsymbol{\Phi}(\mathbf{d_2})]/\boldsymbol{\Phi}(\mathbf{d_1})$$ **Equation 4.13**

$$\mathbf{V_{t-1}} = [\mathbf{E_{t-1}} + \mathbf{D_{t-1}}\mathbf{e}^{-\mathbf{r_{t-1}}}\boldsymbol{\Phi}(\mathbf{d_2})]/\boldsymbol{\Phi}(\mathbf{d_1})$$ **Equation 4.14**

$$\vdots$$

$$\mathbf{V_{t-260}} = [\mathbf{E_{t-260}} + \mathbf{D_{t-260}}\mathbf{e}^{-\mathbf{r_{t-260}}}\boldsymbol{\Phi}(\mathbf{d_2})]/\boldsymbol{\Phi}(\mathbf{d_1})$$ **Equation 4.15**

Interest rates and liabilities are kept constant in the Merton Model; and the same is done in this iteration. It is envisaged that this approach will bring the company value closer to market valuations, given that the information from the market at any particular day is being used (Löeffler & Posch, 2011).

It should be observed that the system (Equation 4.14) contains 261 equations in 261 unknowns (the asset values). Though an additional unknown variable – σ asset volatility, is also there, it is estimated through a time series of *V*s, making this system of equations solvable. However, since a company has debt or liabilities maturing at different points in time, all debt is assumed to be maturing in one year. This is because structural models often produce one default probability (Löeffler & Posch, 2011).

As per Löeffler and Posch (2011), the system of equations can be solved through the following iterative procedure:

> *Iteration 0: Set starting values V_{t-a} for each a = 0, 1, 2, … 260. A sensible choice is to set the V_{t-a} equal to the sum of the market value of equity E_{t-a} and the book value of debt D_{t-a}. Set σ equal to the standard deviation of the log asset returns computed with the V_{t-a}*

For any further iteration k = 1, …, end

Iteration k: Insert V_{t-a} and σ into the formula from the previous iteration into the Black-Scholes formulae d_1 and d_2 into Equation 4.15 to compute the new V_{t-a}. Once more, use V_{t-a} to compute asset volatility. This is repeated until the procedure converges. Convergence is checked by examining the change in the asset values from one iteration to the next. Typically, if the sum of squared differences between consecutive asset values is below some small value (such as 10^{-10}), the iterations are stopped.

To implement these procedures in the study, the debt or liabilities from IBNET for a given JSE100 CDP sample company are collected from IBNET. A one-year Treasury Bill is collected from the South African Reserve Bank website and used as the risk-free rate of return, while the market value of equity is obtained mainly from the JSE website. The practical calculations from here, follow the recommended Microsoft Excel and VBA procedures, as demonstrated by Löeffler and Posch (2011:32-34).

4.6.7 Using equity values and equity volatilities

In the iteration, the following equation was used to find a solution:

$$\mathbf{E_t = V_t \Phi(d_1) - D_T e^{-r(T-t)} \Phi(d_2)}$$ **Equation 4.16**

Löeffler and Posch (2011) recommend the following equation for current date *t* only by introducing an equation with two unknowns. The rationale is that equity is a call on the asset value, and its riskiness depends on the riskiness of the asset value. Therefore, it can be shown that equity volatility $\sigma_E$is related to the asset value V_t and the asset volatility σ in the following way:

$$\boldsymbol{\sigma_E = \sigma \cdot \Phi(d_1) \frac{V_t}{E_t}}$$ **Equation 4.17**

Where d_1 is the standard Black-Scholes d_1 as given in Equation 4.10. Since the equity value E_t is known and the estimate of the equity volatility $\sigma_E$has been derived, Equations 4.16 and 4.17 are equations with two unknowns. According to Löeffler and Posch (2011), this system of equations has no closed-form solution and can be solved using numerical routines.

Thus, on using this method the horizon *T-t* is set to one year, equity value E_t from the stock market, set debt or liabilities *D* equal to debt or liabilities book, and the one year yield on South African treasuries is used as the risk-free rate of return. The only new parameter that is needed is an estimate of the equity volatility σ_E. The base of the estimate on the historical volatility is measured over the preceding 260 days. Data and computations are then done as per Löeffler and Posch (2011:35-37).

It is expected that for a relatively large default probability, it will be able to obrain a spread that is typical of relatively risky debt. The Microsoft Excel and VBA procedures of Löeffler and Posch (2011:42, 43) are utilised for this study.

4.7 SUMMARY

This chapter detailed the research design undertaken for this study. Figure 4.1 presented an illustrated summary of the research design, whilst Figure 4.2 gave more detail. The study adopted a mixed-method research approach, where the qualitative part utilised a content analysis tool to identify the state of embedding by the four major South African banks into their credit processes. The envisaged outcome was a classification of the level of embedding on four levels using the Jeucken (2010) and Kauefer (2010) Sustainable Banking Evolution Models. Level one is when there is no embedding of environmental risk into bank credit processes, and level two is mention of embedding without details, on level three there is embedding with scant mention of the details of embedding, and level four is embedding with full details.

The quantitative part of the research used a stepwise sampling of the JSE100 companies that voluntarily participate in the annual CDP reporting questionnaire to choose the companies that are consistent in emissions reporting between 2010 and 2017. This chapter also detailed all the tools used in the quantitative part of the research, starting with the carbon risk analysis tool from Hofmann and Busch (2008), Carbon Tax Policy and the Merton Model for credit rating. A carbon tax re-adjustment of key financial values was done to prepare the simulation process of the South African carbon tax framework to stress test the impact of the carbon tax. So, the Merton Model was used in the credit risk analysis on three sets of financial values: (1) Pre-Carbon Tax or financials not adjusted for carbon tax, (2) Post-Carbon Tax or adjusted for a carbon tax and (3) Adjusted for Carbon Tax but with No Incentives from the Carbon Tax Policy. The next chapter presents the results and discussion of findings.

CHAPTER 5:
DATA ANALYSIS AND DISCUSSION

5.1 INTRODUCTION

This chapter presents the results of applying the research techniques discussed in Chapter 4. The primary objective of the study was to determine how banks in South Africa embed environmental risk into their bank credit processes. The first section, Section 5.2, shows the results of the qualitative part of the study, and then the results of the quantitative part of the study follow in Section 5.3. The next section, Section 5.4 triangulates the results from these two studies. Overall the research findings are collaborated to show the achievement of the research objective.

5.2 QUALITATIVE STUDY: CONTENT ANALYSIS RESULTS

As explained in the methodology chapter, the content analysis embarked on measuring the embedding of environmental risk by banks using a constructed disclosure index model based on the two existing models of Jeucken (2001) and Kaeufer (2010). These models only test for the environmental leg of sustainable banking. Sustainable banking embodies three legs: Environmental, Social and Governance. The model had three strands of testing of embedding and scoring. These are: (1) the number of environmental risk words in general, (2) the number of environmental risk words connected to lending or credit process, and (3) the statistics of the Equator Principles.

Atlas.ti software coded the four levels of embedding, and the detailed results are shown in Appendix B and are also visually illustrated in Figure 5.1. In Figure 5.1 Gr stands for Groundedness of Codes (number of quotations coded) or Documents (quotations created for a document), and GS stands for Number of documents in a document group or number of codes in a code group.

Table 5.1 presents a summary of the content analysis. The summary is the summation of the count or frequencies from 2010 to 2017 per bank per each variable that was analysed. Standard Bank South Africa (SBSA) leads in terms of the level of embedding, FNB is second, Nedbank ranks third, and ABSA came last.

In terms of embedding at level four, Nedbank leads, FNB is second, with SBSA ranked third, and ABSA ranked fourth with a zero count. However, on closer analysis, Nedbank is ranked third at embedding at level three. Standard bank leads at embedding in level three, followed by FNB.

Table 5.1: Content analysis results of embedding environment risk by SA banks

Company	L1 - EP (w)	L2 - EP ProjFin (w)	L3 - EP - ERA (w)	L4-ERA-CreEnv (w)	EP-A	EP - B	EP- C	EP -Total	Non-ProjFin	# of Enviro Words	Enviro -Words Cr
FNB	0	4343	4 526	134	10	17	37	64	16 140	488	112
SBSA	0	631	5 610	45	4	14	4	71	501	501	120
NEDBANK	0	614	3 751	1 166	11	35	3	49	0	990	72
ABSA	0	456	1 659	0	11	14	0	73	613	185	75

Level three of embedding is dominant amongst the banks. Conclusively, most of the banks are implementing the Equator Principles in their project finance, and have an environmental risk analysis process that goes beyond analysing project finance deals.

FNB leads in terms of the disclosure of non-project finance deals screened for environmental risk. FNB and Standard bank also disclose the process they use to assess environmental risk in their annual reports. Interestingly, Nedbank has fewer words that are linked to credit processes, though they lead in embedding environmental risk at level four, and have the highest count for the environmental words. Also, of interest is that Nedbank does not disclose their non-project finance credit deals and the system or process thereof.

This conundrum of results led to the researcher interrogating these results further, and thus, each bank's results were plotted on a radar chart, as shown in Figure 5.1.

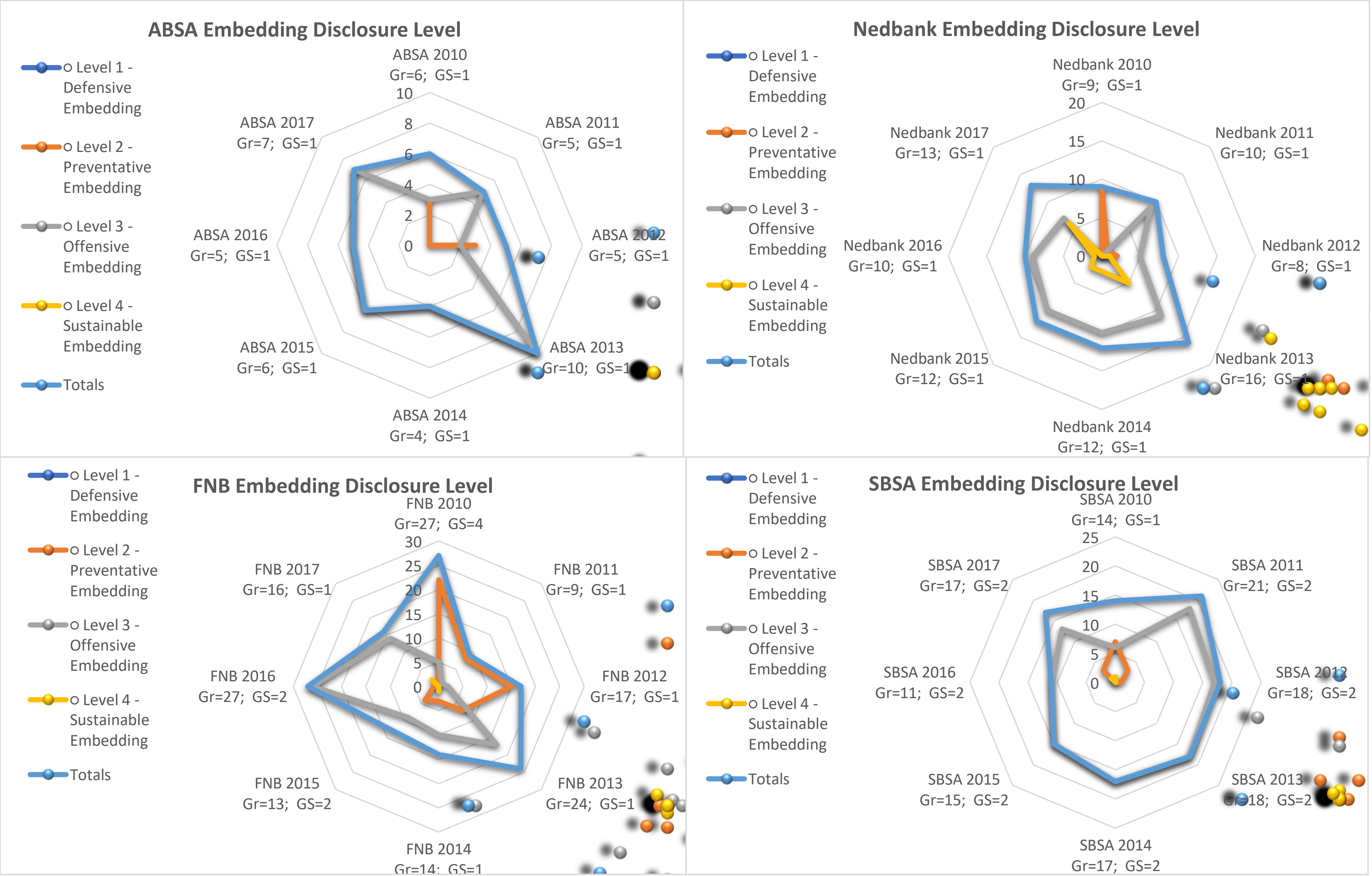


Figure 5.1: Banks content analysis results plotted on radar charts (2010 to 2017)

From the radar charts, level four of embedding is more prominent in Nedbank, especially in 2017. However, all banks seem to have a significant spike in embedding at level three in the year 2013. Such behaviour is attributable to the prominence in adopting the Equator Principles. However, after 2013, there is a significant decline in the embedding, with embedding decreasing on all levels.

However, Nedbank has a considerable rebound in 2017, in terms of embedding at level four. However, FNB has a prominent embedding at level two; mainly on level two in the years 2010 and 2012, but level three in 2012 and 2016. ABSA has remote embedding at level four in the years 2010 and 2012. Standard Bank has a somewhat balanced embedding over the years for level three, and this might allude to its substantial project finance business in its corporate banking business.

An interesting observation is how FNB has prominent embedding at level three, which can be attributable to its detailed explanation of how it deals with environmental risk in its credit processes. Although Nedbank leads in issues related to carbon finance, which is a branch of environmental finance, they have no clear outline of how they embed environmental risk into their credit processes. ABSA lacks information on how it deals with environmental risk in its credit process. However, in the period during which ABSA was part of the Barclays group, from 2013 to 2017, information on environmental risk and its embedding in general banking operations was present.

Further, in analysing the methods of embedding the environmental risk into the bank credit processes, it becomes apparent that the methods used by FNB and Nedbank are merely qualitative and not quantitative. FNB uses a due diligence checklist called ESRA (Environmental Social Risk Analysis) derived from the United Nations Environmental Programme Finance Initiative. However, there is no clarity about the tool that Standard Bank uses, and what aspects it considers in embedding environmental risk into the credit process. Standard Bank only mentioned that there is a system that considers the impact of environmental risk on a client’s operations before granting a loan.

Overall, the banks seemed to use a due diligence list mainly based on the Equator Principles that seldom extended to non-project finance lending. However, only FNB has an outline of its qualitative tools that embeds results in the judgemental credit process.

Therefore, from the study of the level of embedding, it can be firmly confirmed that banks in South Africa have not fully implemented or embedded environmental risk into their bank credit processes. The embedding is clustering at level three, which confirms adherence to the voluntary requirements of the Equator Principles that environmental investors require.

As seen from the radar charts, there was a spike in the Equator Principles' adoption in 2013 across all four banks. The proximity matrix results displayed in Appendix B provide more insights into how much banks have disclosed the embedding of environmental risk into the credit process.

The proximity matrix method examined the level of disclosure by the four banks. Each bank has proximity matrix results of dissimilarity and similarity. As explained in the methodology chapter, the 11 variables were objectified, and the counts or frequencies treated as distances between the objects (variables). Therefore, this facilitated the analysis of interactions within the 11 variables. However, the 11 variables were grouped into three classes, or defined in three dimensions, as follows:

- levels of embedding (one to four),
- Equator Principles' reports in class A, B and C, and
- the count of words (environmental in general and environmental risk close to credit process).

The results in Tables 5.2 and 5.3 show heat maps, representing the dissimilarity and similarity matrix results.

For the dissimilarity matrix, a result of zero is represented as green, meaning that there are low divergences between variables. A result of 1 is represented as red, which means that there are high dissimilarities between the variables.

The similarity matrix results are represented with 0, which is represented as red, and shows low similarities, and 1, which is represented as green, which means there are high similarities between the variables. In this case, variables that are far from each other refer to the dissimilarities matrix, and variables that are close to each other refer to the similarities matrix.

Scaling the Euclidian distance pronounces what the quality of embedding is, and by rule, anything below 0.5 is not considered significant for the similarity matrix, and anything below 0.5 is considered significant.

The analysis of the quality of embedding amongst the banks was done by comparing the count of words (environmental and environmental credit) with levels of embedding and equator principles (EP) number of deals reported.

Table 5.2 represents the environmental words compared with the levels of embedding and Equator Principles' deals reported. This comparison gives a clear understanding of the depth of embedding, which is deemed as the quality of embedding. The environmental words is a proxy for a general level of embedding, while environmental credit words is a proxy for the bank credit process-specific level of embedding.

Table 5.2: Environmental words against the embedding levels & EP number of deals

		L1 - EP (w)	L2 - EP ProjFin (w)	L3 - EP - ERA (w)	L4-ERA-CreEnv (w)		EP-A	EP - B	EP- C	EP -Total	Non-ProjFin
		Dissimilarity Matrix					**Dissimilarity Matrix**				
Enviro words	**ABSA**	0.306	0.856	0.265	0.306		0.678	0.658	0.306	0.498	0.602
	FNB	0.289	0.432	0.471	0.780		0.926	0.791	0.668	0.765	0.713
	Nedbank	0.383	0.624	0.601	0.735		0.551	0.611	0.918	0.617	0.383
	SBSA	0.047	0.466	0.038	0.751		0.656	0.599	0.705	0.172	0.788
		Similarity Matrix					**Similarity Matrix**				
	ABSA	0.436	0.331	0.870	0.436		0.781	0.895	0.436	0.742	0.413
	FNB	0.329	0.787	0.489	0.432		0.000	0.171	0.314	0.188	0.541
	Nedbank	0.453	0.611	0.284	0.202		0.644	0.434	0.183	0.479	0.453
	SBSA	0.516	0.946	0.566	0.687		0.409	0.309	0.196	0.518	0.390

Therefore, from observing the funnelled results in Table 5.2, it can be declared that at level four of embedding, Standard Bank has a more generalised way of embedding, which is evidenced by the highest similarity matrix score of 0.687, while Nedbank has the lowest score of 0.202, which shows that they are not general but specific.

The quality of embedding at the dimension of environmental words is above 0.500 for Standard Bank at level four. ABSA has a high similarity matrix score at level three and the other banks at level two. Therefore, it can be concluded that the banks have perfected or matured at incorporating the Equator Principles as a form of analysing environmental risk in project finance deals only. However, in terms of embedding beyond the Equator Principles, that is level three, FNB, Standard Bank and Nedbank are still struggling. The EP deals reported show that EP-A, which refers to deals that have no environmental impact, are quite low in terms of general environmental issues for FNB and Standard Bank.

These results confirm that the generalised level of disclosure also influences a low similarity matrix score. ABSA has high generalised disclosure of information for environmental issues, meaning that the quality of embedding in the bank credit process is low. However, a low similarity matrix score for the other banks, compared to ABSA, at a general level might indicate that a more specific approach to embedding is followed by the other banks (in our case in bank credit processes).

Table 5.3 presents the environmental credit words compared with the levels of embedding and Equator Principles' deals reported.

Table 5.3: Environmental credit words against the embedding levels & EP No. of deals

Enviro credit words	L1 - EP (w)	L2 - EP ProjFin (w)	L3 - EP - ERA (w)	L4-ERA-CreEnv (w)	EP-A	EP - B	EP- C	EP -Total	Non-ProjFin
	Dissimilarity Matrix				**Dissimilarity Matrix**				
ABSA	0.512	0.769	0.405	0.512	0.406	0.337	0.512	0.506	0.766
FNB	0.270	0.691	0.429	1.000	0.874	0.771	0.508	0.575	0.909
Nedbank	0.385	0.953	0.455	0.721	0.799	0.759	0.830	0.750	0.385
SBSA	0.000	0.582	0.027	0.750	0.603	0.508	0.511	0.010	0.645
	Similarity Matrix				**Similarity Matrix**				
ABSA	0.436	0.306	0.891	0.436	0.877	0.956	0.436	0.772	0.354
FNB	0.329	0.601	0.653	0.233	0.287	0.397	0.713	0.578	0.408
Nedbank	0.453	0.084	0.615	0.351	0.362	0.291	0.453	0.291	0.453
SBSA	0.516	0.261	0.895	0.190	0.298	0.412	0.560	0.840	0.488

Table 5.3 shows that ABSA has a similarity score of 0.436, which is the highest in terms of embedding at level four, in terms of environmental credit words, followed by Nedbank with 0.351. However, all the banks show a low quality of embedding at level four, which is below the 0.500 points mark.

As mentioned earlier, ABSA displayed improved reporting in terms of environmental issues in the credit process for the period 2013 to 2017 when it fell under the Barclays Group. However, on scrutinising the heat map, banks have perfected the embedding at level three, which refers to the use of the Equator Principles and the mentioning of the existence of an Environmental Risk Analysis tool but without providing any detail. Level four, which shows a full disclosure of environmental risk is embedded in the bank credit process, is on the low side for all banks. Therefore, it can be concluded that the banks have not matured in the proposed model of embedding environmental risk in bank credit processes.

Nedbank and FNB show the best results in terms of low impact EP-C credit deals. This result is an indication that they had perfected the underwriting of project finance deals that consider a low environmental impact. Nedbank, overall, shows no wide swings in all categories, and they show progress in terms of embedding environmental risk in their bank credit processes. However, Standard Bank's exceptional results show a mature embedding of environmental risk in their bank credit processes. Standard Bank has the highest similarity score between EP total and Environmental Credit words at level three.

With regards to the embedding of environmental risk into non-project finance credit deals, Standard Bank has the best result, with a similarity matrix score of 0.488, followed by Nedbank at 0.453. However, Nedbank's result was because there were no deals reported, as shown in Table 5.1.

FNB has the highest reported Non-Project finance deals, but is ranked third on the similarity matrix index. Therefore, overall the embedding is insignificant because of scant disclosure in terms of embedding. All the banks show a below 0.500 in the similarity proximity score when it comes to the environmental credit words against non-project finance credit deals.

This results confirm that South African banks are still not fully embedding environmental risk issues into mainstream credit deals, and they mainly consider project finance. Since banks have low proximity matrix scores for level four, it implies that banks are not embedding environmental risk into the whole credit value chain.

The next section of the study presents the results of the simulated incorporation of environmental risk into a credit-risk model and the implications on the credit process of South African banks.

5.3 QUANTITATIVE METHODS: CARBON RISK ANALYSIS AND PROBABILITY OF DEFAULT RESULTS

This section firstly presents the sampling results, followed by the carbon risk analysis results, then the carbon tax simulated results, and lastly the probability of default results.

The study commenced by calculating the carbon risk of the companies in the sample and determined the carbon exposure, carbon intensity, carbon dependency and carbon risk using the Hoffmann and Busch (2008) model. This analysis assisted in putting the carbon tax regime into perspective by comparing the results with the carbon tax to be paid by companies in the sample. The study went on to simulate all the carbon tax incentives that a company would receive. The study utilised all the publicly available information in constructing this tax framework, and hence, the results are based on publicly available information. To stress-test and see if the proxy for environmental risk, which is a carbon tax, would change the probability of default for South African companies, the study used a non-incentive carbon tax regime.

The sampling process consisted of two parts, the first, being the qualitative section of the study, and the second, the quantitative section. The first part (qualitative) consisted of a straightforward investigation into the four major banks: ABSA, FNB, Nedbank and Standard Bank. The banks were chosen on the basis that they make up 80% of the market through asset, deposits and loan size.

In the second part (quantitative), the sampling was done on the 100 JSE companies that are participants in the CDP programme, and that sent in questionnaires for a voluntary response from 2010 to 2017. The sampling criterion checked for companies that responded consistently to the CDP questionnaire in the period under review, namely, 2010 to 2017. The sampling results show that out of the 102 companies, 21 do not report to the CDP programme, and these were excluded from the sample.

Furthermore, of the remaining 81 companies, only 33 companies consistently reported their carbon emissions from 2010 to 2017, and these made up the sample.

Table 5.4 shows the sampling results, which indicate that most companies, mainly in the energy and materials sector, are the most carbon-intensive ones.

Table 5.4: Average carbon emissions per each JSE sector – (Ton CO_2e) 000s

JSE Sector	Consumer Discretionary	Consumer Staples	Energy	Financials	Health Care	Industrials	Materials	Telecommunication Services	Average CO2e emissions/Total No. of Companies in
No. of companies per sector	3	2	1	11	1	1	13	1	33
Year									
2017	1 817	881	92 339	5 812	231	386	83 169	1 609	37 785
2016	329	862	97 419	370	219	394	62 951	1 590	28 023
2015	263	845	97 111	3 588	210	375	79 291	1 532	35 514
2014	240	815	76 380	3 783	215	361	77 094	1 521	34 081
2013	186	800	121 304	379	195	294	71 402	1 041	32 042
2012	511	711	75 899	795	189	280	52 729	951	23 469
2011	179	715	74 981	258	170	202	7 679	1 123	5 488
2010	176	694	71 321	248	166	206	7 825	561	5 413
Ave. carbon emission per sector (2010–2017)	463	790	88 344	1 904	199	312	55 268	1 241	25 227

Table 5.5 shows the results for the average carbon tax calculated from the simulated carbon tax regime per sector. The simulation of the carbon tax regime projects that the energy and materials sector will pay higher carbon tax, given their higher carbon emissions, while the Health Care sector will pay the lowest carbon tax. The financial sector's average carbon tax ranks third, partly due to the number of companies in the

sample, and one of the companies has an abnormal carbon emission recorded in 2014.

By averaging the results per sector, an indicative comparison amongst the sectors is safely inferrable. As can be seen, on average, the energy and materials sectors have higher carbon emissions in the period under review than the average for the whole sample. Both these sectors have average carbon emissions of twice that of the average of the sample.

To obtain more detail and gain a deeper understanding of the implications of the results, the study did a carbon risk analysis, as seen in Table 5.5.

Table 5.5: Average carbon tax amounts – R millions

Sector (R millions) / Year	Consumer Discretionary	Consumer Staples	Energy	Financials	Health Care	Industrials	Materials	Telecommunication Services	Sample Average per annum
2017	R231.46	R110.88	R15 200.61	R688.69	R29.57	R45.17	R11 468.94	R209.91	**R5 244.64**
2016	R38.08	R100.96	R15 001.13	R36.84	R26.22	R43.82	R8 268.76	R190.98	**R3 741.74**
2015	R29.19	R95.41	R14 424.15	R378.56	R24.27	R39.59	R9 476.77	R177.09	**R4 312.29**
2014	R24.06	R94.70	R10 670.88	R375.18	R23.37	R37.08	R8 755.71	R165.72	**R3 912.42**
2013	R17.57	R87.25	R15 700.05	R18.81	R19.61	R27.85	R7 699.08	R102.44	**R3 526.43**
2012	R41.16	R71.58	R9 026.98	R54.10	R17.96	R24.07	R5 271.69	R89.18	**R2 380.36**
2011	R13.39	R67.55	R8 317.10	R14.28	R14.29	R15.74	R723.07	R90.05	**R550.59**
2010	R13.29	R63.14	R7 707.60	R18.13	R12.08	R17.34	R709.15	R47.16	**R526.32**
Ave. carbon tax per sector 2010 -2017	R51.03	R86.43	R12 006.06	R198.07	R20.92	R31.33	R6 546.65	R134.07	**R3 024.35**

The carbon risk analysis used the following main financial statement items: Non-current assets, Current assets, Non-current liabilities, Current liabilities, Long-term loans, Sales, Short-term loans and Total costs. These are adequate to show that beyond the carbon tax to be used in the simulation, companies have considerable carbon risk exposure that banks need to consider for credit risk and related risk. The individual company results are presented in Appendix E.

The results presented in Table 5.6 to Table 5.9 show the carbon intensity (Ci), carbon dependency (Cd), carbon exposure (Ce), and carbon risk (Cr) using the Hoffmann and Busch Model (2008), per each sector for the period under study.

Table 5.6 shows the average carbon intensity sector comparison between (1) short-term loans and long-term loans, (2) operating expenses and sales, (3) current liabilities and current assets, and (4) non-current assets and non-current liabilities.

In terms of carbon intensity, as presented in Table 5.6, the results show that financials have a high average carbon intensity in terms of long-term loans. However, the energy and material sectors (which are high carbon-emitting sectors) have a high average carbon-intensive in terms of short-term loans. The implication of this result means that for the financial sector, the long term loans contribute to the carbon emissions produced by the companies in this sector. For every one rand of long-term loans spent by a company in the financial sector, it produces 20 tCO_2e on average.

Industrials have a low carbon intensity because the company that is representative of the sector, is a light manufacturer. The carbon intensity across all the eight (8) financial statements used to calculate carbon intensity of the JSE sector, confirms that Energy and Materials are high carbon emitters, and the rest of the sectors are medium to low carbon emitters.

However, in terms of the short- and long-term loans, it can be confirmed that these are the significant drivers of carbon emissions, as observed by the carbon intensities compared to the financial statement's items used. On the eight financial items used for carbon risk analysis, short-term loan, current liabilities, and current assets have a higher carbon intensity than the long-term loan, non-current assets and non-current liabilities.

Table 5.6: Combined analysis of carbon intensity: JSE CDP sample by sector

Sector	Average Ci-LTL	Min Value Ci-LTL	Max Value Ci-LTL	Average Ci -STL	Min Value Ci -STL	Max Value Ci -STL
Consumer Discretionary	2.365	0.000	0.462	6.684	0.050	60.024
Consumer Staples	0.278	0.127	0.273	0.774	0.206	3.733
Energy	5.402	1.414	3.358	26.455	8.727	45.810
Financials	20.997	0.000	1.965	1.194	0.000	69.428
Health Care	0.007	0.007	0.058	0.199	0.035	0.678
Industrials	0.042	0.030	0.028	0.111	0.077	0.188
Materials	3.124	0.000	27.387	195.461	0.000	14701.228
Telecommunication Services	0.032	0.023	0.025	0.096	0.042	0.176
Sector	**Average Ci-OPEX**	**Min Value Ci-OPEX**	**Max Value Ci-OPEX**	**Average Ci-SALES**	**Min Value Ci-SALES**	**Max Value Ci-SALES**
Consumer Discretionary	0.007	0.011	0.026	0.014	0.004	0.073
Consumer Staples	0.044	0.007	0.235	0.044	0.005	0.116
Energy	0.523	1.096	0.786	0.528	0.377	0.669
Financials	0.009	0.001	0.314	0.038	0.000	0.703
Health Care	0.006	0.012	0.009	0.007	0.005	0.010
Industrials	0.005	0.008	0.007	0.005	0.004	0.006
Materials	0.128	0.045	4.083	0.733	0.017	9.226
Telecommunication Services	0.007	0.022	0.016	0.009	0.005	0.012

Sector	Average Ci-CL	Min Value Ci-CL Min	Max Value Ci-CL Max	Average Ci - NCL	Min Value Ci - NCL	Max Value Ci - NCL
Consumer Discretionary	0.078	0.004	0.462	0.351	0.008	0.032
Consumer Staples	0.124	0.019	0.273	0.311	0.193	0.137
Energy	2.513	1.770	3.358	2.425	1.668	0.781
Financials	0.072	0.000	1.965	0.079	0.000	0.130
Health Care	0.031	0.014	0.058	0.006	0.006	0.005
Industrials	0.023	0.018	0.028	0.036	0.032	0.028
Materials	3.126	0.072	27.387	0.487	0.107	0.894
Telecommunication Services	0.019	0.012	0.025	0.017	0.023	0.017
Sector	**Average Ci - NCA**	**Min Value Ci - NCA**	**Max Value Ci - NCA**	**Average Ci-CA**	**Min Value Ci-CA**	**Max Value Ci-CA**
Consumer Discretionary	0.052	0.002	0.265	0.057	0.009	0.476
Consumer Staples	0.063	0.034	0.110	0.115	0.022	0.327
Energy	0.518	0.297	0.759	1.093	0.784	1.354
Financials	0.028	0.000	0.450	0.071	0.000	1.628
Health Care	0.004	0.002	0.005	0.021	0.012	0.034
Industrials	0.019	0.016	0.021	0.014	0.011	0.016
Materials	4.572	0.023	240.974	1.806	0.053	16.494
Telecommunication Services	0.008	0.006	0.010	0.017	0.010	0.027

With regards to carbon dependency, the consumer discretionary sector shows the highest carbon dependency results in terms of both short-term and long-term loans. Thus, on an average, a company in the consumer discretionary sector will need an energy source that emits 8 tCO_2e so that they can pay every 1 (one) rand of a short-term loan and an energy source that emits 6.3 tCO_2e to pay their long-term loans. The lower the carbon dependency with respect to any of the eight items of the balance sheet (statement of financial position), the better a company in terms of its dependency to generate cash flows from energy sources that are high carbon-emitting.

Table 5.7 presents the average carbon dependency sector comparison between (1) short-term loans and long-term loans, (2) operating expenses and sales, (3) current liabilities and current assets, and (4) non-current assets and non-current liabilities.

Table 5.7: Combined analysis of carbon dependency: JSE CDP sample by sector

Sector	Average Cd -STL	Min Value Cd -STL	Max Value Cd -STL	Average Cd-LTL	Min Value Cd-LTL	Max Value Cd-LTL
Consumer Discretionary	8.110	0.027	117.641	6.309	-	103.640
Consumer Staples	1.783	0.507	12.439	1.164	0.755	2.349
Energy	1.346	0.344	3.732	1.385	0.235	2.529
Financials	2.767	-	84.578	3.092	-	59.290
Health Care	1.966	0.177	7.026	1.007	0.853	1.076
Industrials	0.798	0.583	1.271	0.987	0.774	1.348
Materials	4.602	-	113.179	1.545	-	16.571
Telecommunication Services	0.796	0.378	1.622	1.056	0.474	1.456
Sector	**Average Cd-OPEX**	**Min Value Cd-OPEX**	**Max Value Cd-OPEX**	**Average Cd-SALES**	**Min Value Cd-SALES**	**Max Value Cd-SALES**
Consumer Discretionary	1.194	0.132	4.498	1.197	0.130	4.526
Consumer Staples	1.616	0.124	10.367	1.038	0.766	1.359
Energy	1.105	0.624	2.096	1.061	0.669	1.776
Financials	1.790	0.001	27.384	1.801	0.001	26.140
Health Care	1.114	1.008	1.245	1.103	1.062	1.181
Industrials	0.980	0.763	1.271	0.983	0.812	1.212
Materials	1.589	0.020	44.935	1.127	0.025	9.418
Telecommunication Services	0.900	0.418	1.218	0.907	0.531	1.310

Sector	Average Cd-CL	Min Value Cd-CL	Max Value Cd-CL	Average Cd-NCL	Min Value Cd-NCL	Max Value Cd-NCL
Consumer Discretionary	1.285	0.121	3.744	2.903	0.104	28.027
Consumer Staples	1.053	0.737	1.434	1.155	0.766	2.121
Energy	1.123	0.732	1.714	1.216	0.890	1.786
Financials	2.442	0.001	75.263	2.775	0.001	58.275
Health Care	1.215	0.611	1.901	1.025	0.958	1.104
Industrials	0.978	0.823	1.231	1.025	0.805	1.301
Materials	1.219	0.023	11.377	1.246	0.034	16.571
Telecommunication Services	0.930	0.592	1.314	1.030	0.491	1.369
Sector	**Average Cd-CA**	**Min Value Cd-CA**	**Max Value Cd-CA**	**Average Cd-NCA**	**Min Value Cd-NCA**	**Max Value Cd-NCA**
Consumer Discretionary	1.191	0.125	3.904	1.476	0.112	5.017
Consumer Staples	1.107	0.789	1.372	1.061	0.737	1.514
Energy	1.065	0.856	1.726	1.169	0.723	1.817
Financials	2.359	0.001	63.634	2.678	0.001	80.370
Health Care	1.162	0.936	1.337	1.149	0.948	1.637
Industrials	1.000	0.849	1.333	1.011	0.764	1.160
Materials	1.161	0.025	7.997	1.265	0.031	16.138
Telecommunication Services	0.893	0.616	1.157	0.972	0.570	1.298

Therefore, with regards to carbon intensity and carbon dependency, the bank can use this as a criterion for selecting borrowing companies that have low figures. In respect of carbon intensity, in this case, the materials sector has one rand of the non-current assets on an average emitting 4.572 tCO_2e of carbon emissions. Thus, on average, a company in the materials sector, for each one rand they invested in fixed assets (non-current assets), that one-rand value of an asset (when sweated in profit-making) could emit an average of 4.572 tCO_2e over 2010 to 2017. Which means when carbon intensity and carbon dependency are compared, the materials sector sweated the assets way above the possible carbon dependency of 1.265 tCO_2e by 3.6 times (4.572 tCO_2e (Ci) divided by 1.265 tCO_2e (Cd).

The asset sweating factor of any business model will show how efficient a company is in using its assets to generate profits. In the same vein, carbon emissions become a factor here that indicates how the value of the asset links to the carbon emissions produced by the companies. In comparing current assets and non-current assets, on average across the sectors, companies have current assets contributing more to the emitting of carbon than non-current assets. However, with regards to carbon dependency, the sectors of consumer discretionary, energy, industrials, materials and telecommunications have a carbon dependency in terms of non-current assets that is higher than current assets.

The operating expenses of the materials, consumer staples and energy sectors have a higher carbon dependency than the sales carbon dependency factor. Which means that the operating expenditures in these sectors drive their carbon emissions more than their sales, compared to their sectors. Operating expenditure represents the input/processing side of the business and sales the output side of the business. Therefore, these sectors have their input/processing part of the business driving the emission of carbon more than the outputs.

In terms of the consumer discretionary sector, the non-current liabilities' carbon dependency is almost twice the current liabilities' carbon dependency factor, which also corresponds with its carbon intensity factors for non-current liabilities and current liabilities. This means that the non-current liabilities of this sector in the short term had higher propensities for causing more emissions than the current liabilities did.

The above results show the sensitivity of a business to the propensity for emitting carbon. The input (Assets, Liabilities and Operating expenses) and the output (Sales) represent the business model of these companies. Therefore, it is easy to translate this into a single figure to capture the average sensitivity of each sector in terms of the use of energy sources with high carbon. Carbon exposure and Carbon risk are good indicators of this and are presented in Tables 5.8 and 5.9.

Table 5.8 displays the average carbon exposure per sector, based on the carbon tax used as a proxy for the carbon price.

Table 5.8: Combined analysis of carbon exposure of the JSE CDP sample by sector

Sector (Million)	Average 2017 Ce	Average 2016 Ce	Average 2015 Ce	Average 2014 Ce	Average 2013 Ce	Average 2012 Ce	Average 2011 Ce	Average 2010 Ce
Consumer Discretionary	R335.73	R57.83	R43.35	R37.94	R27.69	R70.76	R23.00	R21.15
Consumer Staples	R162.78	R151.49	R139.26	R128.98	R119.22	R98.39	R91.76	R83.30
Energy	R17 064.52	R17 115.04	R16 006.13	R12 087.54	R18 086.51	R10 499.68	R9 628.46	R8 558.52
Financials	R1 074.00	R65.08	R591.33	R598.75	R56.57	R109.95	R33.13	R29.73
Health Care	R42.68	R38.55	R34.68	R34.03	R29.01	R26.12	R21.82	R19.92
Industrials	R71.27	R69.24	R61.83	R57.11	R43.82	R38.80	R25.90	R24.77
Materials	R15 369.87	R11 059.49	R13 069.03	R12 200.53	R10 646.05	R7 294.39	R986.03	R938.98
Telecommunication Services	R297.38	R279.32	R252.43	R240.69	R155.17	R131.50	R144.20	R67.37
Sample average	**R6 982.76**	**R4 923.27**	**R5 853.50**	**R5 393.46**	**R4 777.48**	**R3 246.72**	**R704.72**	**R649.53**

The highly carbon-intensive sectors, energy and materials, have the highest carbon exposures over time (2010 to 2017). Thus, energy companies, as an example, have exposed their financial profits to the indicative amount in each year. For illustration purposes, they need to produce enough cash flows to cover the carbon emissions costs incurred in that year. Therefore, on average, an energy company requires cash flow that is way above R17 billion to cover the carbon emission costs in 2017.

From a credit process point of view, if an energy company's operations do not show a reduction in carbon emission costs, or enough cash being generated to cover them, it is expected that its credit rating will be affected.

Therefore, the next step of the research was to investigate this proposition. Table 5.9, however, presents the change in carbon exposure expressed as carbon risk from year to year.

Table 5.9 presents the average carbon risk per sector which, as well, is derived from a proxy carbon price of the carbon tax.

Table 5.9: Combined analysis of carbon risk of the JSE CDP sample by sector

Sector	Average 2016 Cr	Average 2015 Cr	Average 2014 Cr	Average 2013 Cr	Average 2012 Cr	Average 2011 Cr	Average 2010 Cr
Consumer Discretionary	272%	57%	-1%	64%	-22%	116%	7%
Consumer Staples	9%	8%	12%	23%	13%	18%	11%
Energy	0%	7%	32%	-33%	72%	9%	13%
Financials	884%	-4%	2%	544%	11%	9152%	4%
Health Care	11%	11%	2%	17%	11%	20%	10%
Industrials	3%	12%	8%	30%	13%	50%	5%
Materials	10%	0%	2%	155%	51%	619%	12%
Telecommunication Services	6%	11%	5%	55%	18%	-9%	114%
Grand total	**325%**	**6%**	**4%**	**252%**	**26%**	**3308%**	**12%**

The following sectors show an overall decrease in carbon risk: consumer staples, energy, health care, industrials, materials and telecommunication services. However, the financials and consumer discretionary sectors show increases in carbon risk to changes in carbon emission measuring protocols. These changes in carbon risk need investigation and comparison to the probability of default.

The study, therefore, examined the results for the probability of default using a heat map. The probability of default is calculated on three data sets, firstly, on the standard financial statements, and secondly, with carbon tax incentive adjusted financials, and then thirdly, without carbon tax incentives adjusted financials.

Table 5.10 presents the results of the probability of default values per sector.

Table 5.10: Probability of default values per sector (2010 to 2017)

Sector	PD Average of 2017	PD Average of 2016	PD Average of 2015	PD Average of 2014	PD Average of 2013	PD Average of 2012	PD Average of 2011	PD Average of 2010
Consumer Discretionary	0.00000000000	0.00000003921	0.00000000028	0.00000000000	0.00000000000	0.00000000000	0.00000000000	0.00000000000
Carbon Adj.	0.00000000000	0.00000003938	0.00000000028	0.00000000000	0.00000000000	0.00000000000	0.00000000000	0.00000000000
No incentives	0.00000000000	0.00000003972	0.00000000029	0.00000000000	0.00000000000	0.00000000000	0.00000000000	0.00000000000
Normal	0.00000000000	0.00000003854	0.00000000027	0.00000000000	0.00000000000	0.00000000000	0.00000000000	0.00000000000
Consumer Staples	0.00001647497	0.00024034747	0.00001756948	0.00000009488	0.00000000000	0.00000000000	0.00000000000	0.00000000000
Carbon Adj.	0.00001650012	0.00024047320	0.00001762736	0.00000009512	0.00000000000	0.00000000000	0.00000000000	0.00000000000
No incentives	0.00001672939	0.00024265723	0.00001813299	0.00000009655	0.00000000000	0.00000000000	0.00000000000	0.00000000000
Normal	0.00001619542	0.00023791197	0.00001694809	0.00000009298	0.00000000000	0.00000000000	0.00000000000	0.00000000000
Energy	0.00000000001	0.00001314293	0.00000804009	0.00000000002	0.00000000000	0.00000000000	0.00000000001	0.00000000000
Carbon Adj.	0.00000000002	0.00001532782	0.00000972882	0.00000000003	0.00000000000	0.00000000000	0.00000000001	0.00000000000
No incentives	0.00000000002	0.00001650917	0.00001070329	0.00000000003	0.00000000000	0.00000000000	0.00000000002	0.00000000000
Normal	0.00000000000	0.00000759178	0.00000368816	0.00000000000	0.00000000000	0.00000000000	0.00000000000	0.00000000000
Financials	0.00001315475	0.00035643063	0.00026444596	0.00000039721	0.00000282921	0.00000016407	0.00000399434	0.00088251890
Carbon Adj.	0.00001315496	0.00035643044	0.00026477156	0.00000039721	0.00000339465	0.00000016404	0.00000399424	0.00001373650
No incentives	0.00001315683	0.00035646818	0.00026479077	0.00000039727	0.00000169766	0.00000016420	0.00000399552	0.00262008632
Normal	0.00001315246	0.00035639326	0.00026377556	0.00000039713	0.00000339533	0.00000016395	0.00000399327	0.00001373389

Health Care	0.00000059125	0.00083626379	0.00000000568	0.00000000001	0.00000000049	0.00000000001	0.00000000000	0.00000007057
Carbon Adj.	0.00000059188	0.00083657816	0.00000000569	0.00000000001	0.00000000049	0.00000000001	0.00000000000	0.00000007061
No incentives	0.00000059331	0.00083730229	0.00000000570	0.00000000001	0.00000000049	0.00000000001	0.00000000000	0.00000007085
Normal	0.00000058856	0.00083491092	0.00000000565	0.00000000001	0.00000000049	0.00000000001	0.00000000000	0.00000007024
Industrials	0.00000141029	0.00212386376	0.00005389373	0.00000000154	0.00000302962	0.00000091559	0.00000002105	0.00000042078
Carbon Adj.	0.00000141728	0.00212763225	0.00005404678	0.00000000155	0.00000303401	0.00000091810	0.00000002111	0.00000042223
No incentives	0.00000142111	0.00213019146	0.00005414663	0.00000000156	0.00000305306	0.00000092092	0.00000002118	0.00000042340
Normal	0.00000139249	0.00211376757	0.00005348777	0.00000000151	0.00000300180	0.00000090775	0.00000002086	0.00000041671
Materials	0.00051395808	0.02021434872	0.01304634152	0.00025625186	0.00054398800	0.00000001569	0.00000000876	0.00000000162
Carbon Adj.	0.00052394078	0.02146638896	0.01333832201	0.00025300407	0.00055611682	0.00000001588	0.00000000901	0.00000000165
No incentives	0.00058077830	0.02255572817	0.01706835195	0.00026364878	0.00055906402	0.00000002290	0.00000000959	0.00000000173
Normal	0.00043715517	0.01662092905	0.00873235059	0.00025210274	0.00051678315	0.00000000828	0.00000000768	0.00000000148
Telecomm. Services	0.00000000009	0.00089194149	0.00004143983	0.00000000000	0.00000000000	0.00000000000	0.00000000001	0.00000000000
Carbon Adj.	0.00000000009	0.00088972896	0.00004129152	0.00000000000	0.00000000000	0.00000000000	0.00000000001	0.00000000000
No incentives	0.00000000009	0.00089640557	0.00004173917	0.00000000000	0.00000000000	0.00000000000	0.00000000001	0.00000000000
Normal	0.00000000009	0.00088968995	0.00004128880	0.00000000000	0.00000000000	0.00000000000	0.00000000001	0.00000000000

In Table 5.10, the heat map analysis shows a shift from green, orange up to red in terms of change of default over the time of the study. The most significant PD figures are for the materials sector, with a red highlight in the years 2015 and 2016. There is little to no effect of the carbon tax on the PD values across sectors primarily through the years 2010 to 2014. Having PDs below 0.000 shows that companies have a zero chance of defaulting. Referencing the PDs to the leading credit rating agency maps, they are classified as mainly AAA credit ratings. These results would need more refining by adding more financial behavioural information which is difficult to get since this is privy to a bank account operated by these companies. However, these PDs are indicative of the granular changes that happen if the carbon tax is embedded in the financial statements.

Therefore, the granular movement observed is not earth-shattering, except for the materials sector where the companies are high carbon sensitive. However, between 2015 and 2017, the companies tapered into the orange zone showing that as the carbon tax amount is increased per tCO_2e, there seem to be a shift in the PD downwards, compared to the periods between 2010 and 2014.

These results imply that the carbon tax regime is not sufficient to affect behavioural change in companies relying on energy sources with high carbon emissions. Even if the carbon tax incentives are removed, the companies in the sector will not experience a significant change in their credit ratings. This possibly explains why South African banks have only qualitative methods of assessing the impact of carbon emissions on credit risk

5.4 TRIANGULATION OF RESULTS

Two significant outcomes can be observed from the results of the content analysis and the simulated carbon tax results on PD calculations. Firstly, these results explain why banks in South Africa have not bothered to embed carbon emission costs into the credit risk quantitative models. The content analysis results indicate that banks over the period under analysis, are at level three of the embedding proposed model, which indicates mainly adhering to the Equator Principles, and never being bothered by financed emissions.

Financed emissions, in this case, can be equated to a carbon tax or carbon exposure calculated under our carbon risk analysis step of the study. If a comparison is made, of the carbon exposure to the carbon tax, as shown in Figure 5.2 (on the next page), one realises how the profit margins comfortably cushion the companies from the added cost of the carbon tax. Therefore, the carbon tax incentives are not radical enough to cause a shift in moving from high carbon energy sources to low carbon energy sources.

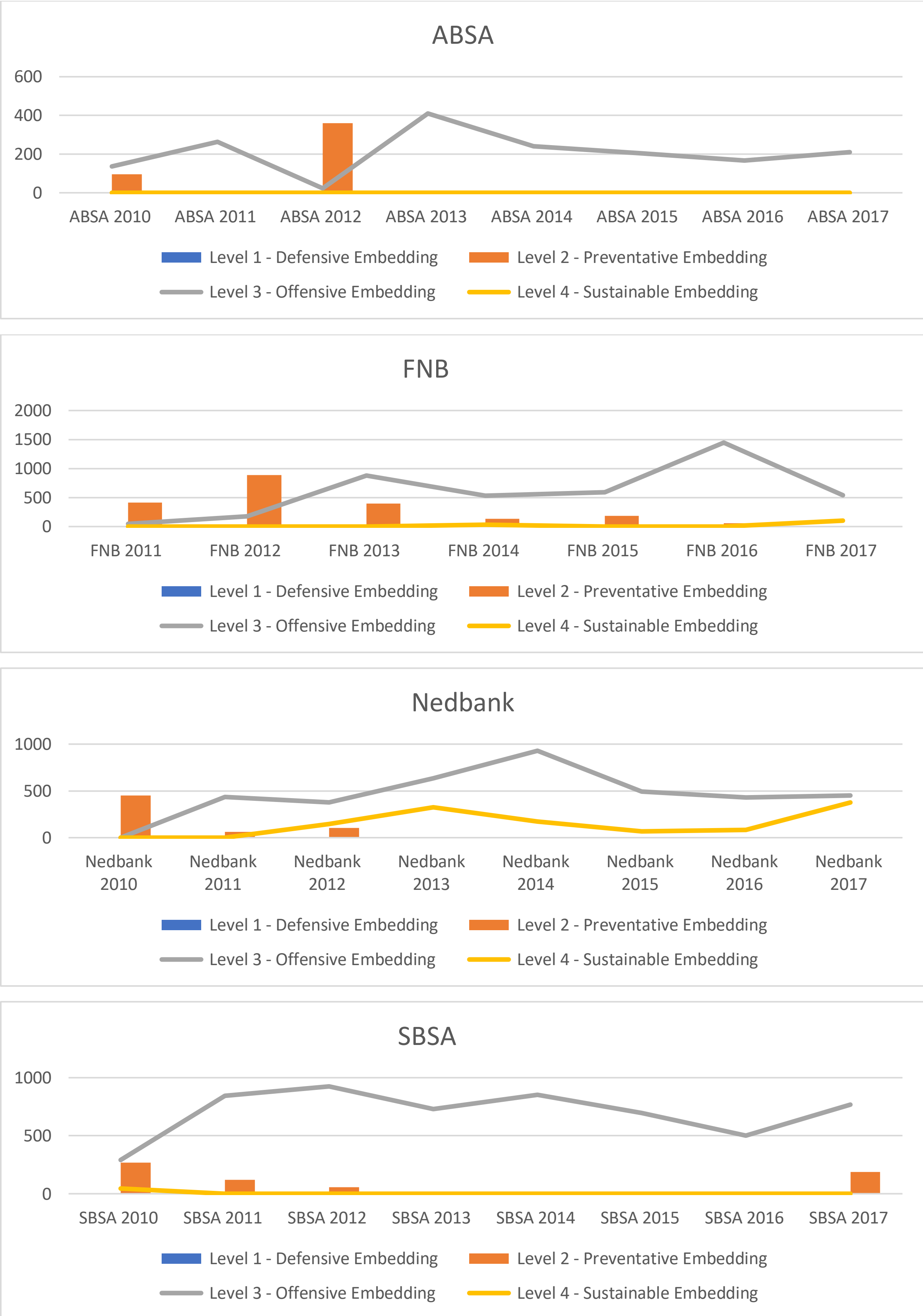


Figure 5.2: Comparison of levels of embedding between ABSA, FNB, Nedbank and SBSA

Secondly, the PDs by themselves cannot give a proper prediction of carbon risk impact on the financial health of a company. By employing the carbon risk analysis tool, the financial drivers link to carbon emissions output, providing a clearer picture of the propensity of carbon risk. This can be aligned to the overall credit rating, and possibly utilise realistic carbon price. According to Arndt *et al.* (2014), a phased-in carbon tax of USD30 or ZAR210 (at a rate of 1USD: ZAR7) per tCO_2e for the period 2010 to 2025, would bring about a required national emissions' reduction target. Comparing this to the phased-in R120 per tCO_2e shows a watered-down carbon tax regime.

Further to the two significant outcomes highlighted above, corroborating and relating the results of each bank to the PD and carbon risk analysis results of the companies, bring out unusual deductions. Though there is a need for more direct co-relating data and tools between the three tools used in this research, the answers to a couple of research questions are apparent. Firstly, the radical shift of banks from level one of embedding to level three between 2013 and 2017, aptly coincides with the change in carbon emission costs observed across the sectors from 2013 to 2017, mainly in the materials and energy sectors.

Across all the sectors, the rapid gradual change, seen mainly from 2013 to 2014 in the PDs compared to (1) change in carbon risk between 2013 and 2014, namely, a decline for all sectors, and (2) a rapid increase in adopting level three offensive embedding started in 2013, as shown in Figure 5.2.

The PDs granular movement in the energy and materials sector is also significant, compared to the 2010 and 2012 period. For instance, for the materials sector, the average PD moved from 0.0000000159 in 2012 to 0.0005439800 in 2013. Thus, the similarity index over time between environmental risk embedding at level 3 and the credit process is high for all banks above 0.5, showing the need to increase scrutiny of environmental risk in credit deals during this period.

Moreover, PD levels confirm the low similarity between environmental risk and credit process for most of these banks. As seen in Table 5.3, all banks have a low similarity score below 0.5 between environmental risk embedding at level 4 and credit processes. This is a good indication that banks are not willing to disclose, or they do not have frameworks for embedding environmental risk in the credit value chain.

5.5 SUMMARY

Three significant outcomes are identifiable in the research analysis undertaken. Firstly, the South African banks are at level three in terms of the offensive embedding of environmental risk into bank credit processes. Secondly, the Carbon tax incentivised regime is of no consequence to the credit standing of any company in the major economic sectors in South Africa. Thirdly, banks are only qualitatively embedding environmental risk into their bank credit processes. However, it is ideal for drilling down on each significant outcome.

With regards to the first outcome, the content analysis results confirmed that the embedding is at level three through the use of a similarity index between the proxies of environmental risk and bank credit processes which show that it is higher at level three than the other levels.

With regards to the second outcome, the PD analysis that was done on the sample JSE CDP reporting companies shows that companies do not experience a material shift in their PDs. Only the materials and energy sectors seem to have undergone radical shifts in their PDs in the years 2015 and 2016. However, although to an extent, all the sectors experience that radical PD shift after 2014, the credit rating does not shift from one credit rating band to another if mapped with credit rating agencies.

With regards to the third outcome, by triangulation of the results, it can be concluded that the banks are qualitatively embedding environmental risk given the: (1) results from the similarity matrix, (2) PD values (increase) shift between 2013 and 2014, and (3) carbon risk (decrease) shift from 2013 to 2014.

The research aptly fulfils the significant objectives of the research questions of (1) finding the environmental risk embedding levels of South African banks, and (2) recommendation of a bank credit model of embedding environment risk into bank credit processes.

As enunciated in the findings presented in Section 5.2, the banks are qualitatively embedding, and the results have shown that they have not reached level 4, namely, embedding environmental risk, which includes the disclosure of quantitative credit-risk models used. The credit-risk model recommended also shows how the carbon tax incentive regime, which is a proxy for carbon pricing, through carbon risk analysis and the probability of default calculations, affects the credit standing of a company.

However, the research also confirms that carbon pricing (Carbon tax) is inadequate to meet national carbon emissions targets. Conclusively, South African banks are situated between the reactive and proactive modes, which is an indication of the fear of incurring deteriorating credit portfolios due to borrowers with carbon risk/carbon exposure. Also, this is an indication of the South African banks not over-committing to an uncertain carbon pricing regime in South Africa. The study moves on to Chapter 6 to discuss the implication of the results.

CHAPTER 6:
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The purpose of this chapter is to reach a synthesis by corroborating the literature, the research problem, methodology, research findings, implications, and contribution of the research. Further, this chapter documents the achievement of the research objectives. Included in the discussion, are the obstacles and challenges encountered in the research and how they were resolved.

To an extent, the study managed to establish and prove some theories with acceptable and reasonable certainty. The results can be generalised to a similar context, and it is envisaged over time with the given suggestions of how to improve the research framework, more unique findings will be obtainable for the area of research undertaken.

Overall, financial institutions will still use their intermediary role of ameliorating risk in the business decision-making process. Being the main drivers of moving funds between surplus and deficits units, banks will influence these two units to change course in resource allocation, especially when it comes to deciding inputs into a business process that does not cause damage to the environment.

This chapter has seven sections, (1) summary of research methodology (2) summary of research findings, (3) implications and contributions of the research findings, (4) theoretical and practical contributions of the research (5) proposed environmental-credit risk process framework (6) limitations of this study and (7) future research.

6.2 SYNTHESIS OF LITERATURE REVIEW

There are four themes of literature that were pursued for this study: (1) the concept of environmental risk, (2) effect of climate change impact on financial intermediation theories, (3) bank credit processes and incorporation of environmental risk, and (4) the embedding methods and models of environmental risk in bank credit processes. These four themes assisted in shaping the research gap for this study, especially for the South African context.

With regards to the first theme, the concept of environmental risk differs from one area of expertise to another. However, this study established from the literature on how environmental risk is defined in the banking sector. In the general context, environmental risk is the risk to human health and ecosystems. Broadly speaking, this risk can be measured as the environmental quality of the economy, human health and ecosystems. In terms of ecosystems, this refers to natural plant-life and animal life (Jones, 2001; Cardenas, 1999).

Thompson (1998), Case (1996) and Wanless (1995) all agree on the categories of environmental risk that are faced by bank lenders in three aspects, namely, direct risk, indirect risk and reputational risk. Thompson argues that environmental risk is faced by lenders through the financial risk management concepts used in bank lending principles. One of the financial risk management concepts is credit risk management. Therefore, this first theme had a bank view of environmental risk and presented a framework of what to look for when designing the research methodology. This framework was used as a benchmark for how South African banks define environmental risk.

The second view of the first theme was related to how environmental risk is defined by business, and this was narrowed down to the South African context. For a business, environmental risk is multi-faceted. Aspects of environmental risk are explainable from a global view, and these range from local pollution problems to global warming. Sinclair-Desgagne and Gozlan (2003) define environmental risk as industrial risks that affect human health and the environment. They mainly focus on how the industrial activities, in a way, endanger human health standards and disrupt the balance of nature. From a business perspective, environmental risk varies widely depending on a company's industry, location, customer base, regulatory regime and even its shareholders' expectations.

Latham (2009) indicates that climate risk and carbon risk are sub-components of environmental risk. Latham further divides climate risk (termed climate change-related risks) into physical risk, regulatory risk and litigation (reputation or legal) risk. Climate risk is derived from the impacts of climate change caused by adverse weather (Onischka, 2008), and environmental risk is derived from how business, through its operations, faces litigation by contaminating the natural environment (Romilly, 2007). This definition can similarly be applied to the South African context.

With regards to the second theme, the study explored the nexus between financial intermediaries and climate change. Merton (1993) illustrates the financial intermediation concept by providing two frames of references. The first one is the institutional perspective and the second the functional perspective, which concurs with Hasman *et al.*'s (2014) categorisation of the functions of financial intermediaries.

Merton posits that the institutional perspective on financial intermediation stems from the existing financial institutions, or the prevailing public policy, that shapes the structure, survival and success of intermediaries. The functional perspective on financial intermediation guides the economic functions performed by the financial intermediaries. It solicits the best institutional structure for a financial intermediary to perform these functions.

The same frame of reference infers in this study how the function of credit risk management within the banking sector shapes the handling of environmental risk. Most of the public policies at the global and national level with regards to environmental risk and climate change, threaten bank operational processes and bank regulatory systems (Ryan-Collins, 2019). According to Scholten and Van Wensveen (2003), banks do not exist for the mere reasons of ameliorating information asymmetries presented in the form of adverse selection and moral hazard but to transform risk. The discussion in this theme concluded that environmental risk can be transformed from threat to opportunity through the various existing financial intermediation functions.

In a further discussion related to the third theme, Boyer and Laffont (1996) use the banking theories of agency problems, mainly moral hazard and adverse selection, in attempting to explain how a bank can handle environmental risk in bank lending. Their point of departure in doing so is the CERCLA act in the US which holds banks liable to pay for environmental damage caused by a borrowing company. They theoretically analyse the impact of lender liability under CERCLA on a bank being fully liable and partially liable for environmental damage. They assert that if the bank has complete information about the borrowing company, under full liability on the bank's side, rationally the borrowing company will have an excessive investment in high-risk environmental projects. Therefore, for the South African context, the research embarked on finding how far the banking institutions are embedding available environment risk information into bank credit processes, and to determine whether it is partial or full embedding.

With regards to the third theme, namely, embedding environmental risk into bank credit processes, in the literature Weber, Fenchel and Scholz (2008) investigated where banks have embedded environmental risks into the whole credit risk management process: in credit rating, loan costing, loan pricing, loan monitoring and loan workouts. Their results show that banks have only embedded environmental risk at the credit-rating stage (loan appraisal or evaluation stage) and not in other phases. The sample was mostly European banks. Weber *et al.* also researched the ‘where’ but did not investigate the ‘how’ part. They also emphasised the need for banks not only to rate or evaluate the environmental risk exposure of the borrower but to include the estimated cost of the environmental risk into the loan price. This study thus pursued both the ‘where’ and ‘how’ for the South African context.

With regards to the fourth and last theme, there are three main methods of embedding: (1) financed emissions, (2) carbon risk analysis, and (3) environmental stress testing. Weber *et al.* (2015) describe financed emissions as the general portfolio level aggregation of GHG emissions associated with a portfolio’s underlying entities or projects, allocated proportionally based on the financial stake in the underlying entity or project, and this is usually cross-sector and cross-asset class approach.

Carbon risk analysis involves three areas: (i) risk to physical assets; (ii) risk to financial assets, equities and credit, and (iii) risk to financial institutions. The first and third areas will be challenging to implement in South Africa. The last national carbon emissions data that is economic sector-specific was done in 2010, and the only carbon emission data available is company-specific. Therefore, the carbon risk analysis will be focused on company-level embedding.

In terms of environmental stress testing, this can be done at the company, portfolio and a financial or economic system level. However, in South Africa, the same predicament of non-availability of data at an economic sectorial and broad national level is encountered. For the South African context, data is available at a firm level and voluntary basis. Therefore, the fourth theme gave a framework for the data required in designing the research method.

6.3 RESEARCH METHODOLOGY

The study utilises an exploratory research design which comprised of a mixed methodology. A content analysis tool was used in the qualitative methodology to investigate the level of embedding of environmental risk into the bank credit processes against an adapted and contextualised model of embedding that was developed by Jeucken (2001) and Kaeufer (2010) in terms of sustainability banking models.

The embedding model created for this study has four levels. The first level is called defensive embedding, and a bank in this category makes no mention of rules, policies or procedures being in place to consider climate change issues in bank credit processes. Level two is called preventative embedding in which a bank's annual reports begin mentioning the embedding of climate change issues into the bank credit processes; nevertheless, there is no detail on how that is done. The third level, offensive embedding, involves a bank's annual reports showing limited embedding of climate change issues into the bank credit processes and credit products. The last level, level four, sustainable embedding, involves the bank's annual reports fully disclosing the processes used to embed environmental and climate change issues into bank credit process and credit products.

The proximity matrix method was used as a tool of analysis to further infer the embedding. The primary outcome was to determine the extent to which South African banks disclose their methods of embedding environmental risk in their bank credit process.

In the quantitative part of the methodology, two techniques were used to create a link between environmental risk and credit process. The first technique was the carbon risk analysis model by Hoffmann and Busch (2008), and the second technique was the Merton Model for calculating the probability of default.

The study, however, simulated data that was used in these two techniques to find out the impact of environmental risk on a company's credit rating. The study recreated the carbon tax regime from the carbon tax act to create a carbon price that was used in the carbon risk analysis and also in the calculations of the probability of default. In addition, the carbon emissions data of the JSE CDP reporting companies were used in the calculations as a proxy of environmental risk.

The primary outcome of the quantitative methodology was to determine the impact of environmental risk on the credit rating of a company. The credit rating embodies the financial wellbeing of a company, and in the case of this study, the focus is on environmental risk, while other factors are held constant.

The research methodology concluded with a triangulation of the qualitative and quantitative results to find patterns and correlations and to see of this clarified the main research question, namely: does the embedding of environmental risk into the bank credit process affect a company's credit rating or financial?

6.4 RESEARCH FINDINGS

Table 6.1 presents the main research findings or outcomes and links the research objectives and research questions to the findings. The study, by and large, has achieved the set-out objectives. Since the study was exploratory, the only concern would be, how the findings fare to standards observed in literature and practice.

With regards to embedding, project finance deals are screened for environmental risk and banks in South Africa use the Equator Principles, which is an international standard across financial institutions.

Through the use of the content analysis method, the study explored more details related to the big four South African banks' embedding behaviour. Starting with trend analysis, and then with one view, within a Jeucken (2001) and Kaeufer (2010) framework of the four levels of embedding, one can see the rapid movement from level 1, reactive embedding, to Level 3, defensive embedding. The study found scattered and shallow evidence of level 4, sustainable embedding, in the results of the four banks. See Figure 5.1 in the research findings for a summary of the results.

Table 6.1: Summary of research objectives, research questions and research findings

Research objective	Research question	Research finding/Outcome
To establish the theoretical concepts related to environmental risk and climate risk in bank lending.	a. What are the issues that emanate from adverse conditions of climate change that are of concern to the banking sector's lending or credit processes?	Through a literature review, the prominent theory is that of financed emissions. The proposition surmised in the research was related to how a bank finances an activity that releases emissions that exacerbate climate change effects. The theory of financed emissions revolves around the theory of financial intermediation and the risk amelioration of banking institutions in the economy.
To investigate the state of environmental and climate risk incorporation by banks into their lending decisions.	b. Why is environmental and climate risk of significance to the banking sector's lending processes?	Reputational risk is the main issue at stake for banks. There is a close relationship between environmental risk and reputational risk. If banks finance activities that damage the environment and increase climate change impacts, investors and depositors will shun them.
To investigate the overall engagement of banks in South Africa with regards to mitigating climate change through lending.	c. What are the current trends in the South African banking sector related to climate change mitigation in their lending or credit processes?	The study used the Jeucken and Kauffer Sustainability banking Models to create four levels of the embedding of environmental risk in bank credit processes. Most South Africa banks are at level 3 of embedding. Which is mostly qualitative in aspect, that is, they mostly adhere to the Equator Principles, and two of the banks had more pronounced independent systems of embedding. Using the triangulation method a trend was discerned, which is possibly a reason why South Africa banks only embed qualitatively.
To formulate a credit appraisal model that incorporates environmental and climate risk for South African banks.	d. How should environmental and climate risk be incorporated into the credit appraisal models of banks, given the economic sectors, government policy on climate change, financial sector regulations and international standards on environmental	The Carbon tax regime was used to create a proxy for environmental risk in a South African context, and the research managed to revaluate financial statements and calculate the probability of default. The use of financials adjusted for a carbon tax would not suffice for the quantitative measuring of the environmental risk. Therefore, a Hoffmann and Busch Carbon Risk Model was combined with the standard creditrisk modelling to see the impact of environmental risk on a company's credit rating. The results imply that either the carbon tax regime is less stringent, or the companies have healthy cash flows that enable them to afford the

	and climate risk management?	carbon tax. However, the incentives also shield the companies from paying an increased carbon tax. Using the Hoffmann and Busch Model, it became clear that there is an underestimation of the exposure and risk as related to the environmental risk in the carbon tax regime, and hence, the exposure is more extensive than that which the carbon tax envisages solving.

6.5 IMPLICATIONS AND CONTRIBUTIONS OF THE RESEARCH

The research invokes a couple of issues that the banking sector should be aware of considering environmental issues in the credit processes. Firstly, the study explains how the banks could consider embedding environmental risk in the credit value chain. Secondly, the empirical results obtained from the simulated carbon tax regime are indicative of the extent of carbon risk exposure, and banks need to take cognisance of this information in the credit portfolios. Thirdly, the link between the embedding level and investor confidence should be a priority for banking institutions. Fourthly, companies in both the high and low carbon-intensive groups should start recognising the extent of their activities, and how the carbon risk analysis results infer. The paragraphs below explain each of these implications.

In terms of the first implication, the study provides South African banks with the context within which environmental risk should be embedded into its bank credit process. The issue of where it fits in the value chain is of paramount importance to this study. The literature and practice reiterate that it is not just enough to embed it qualitatively, as the impact cannot then be measured. The proposed quantitative embedding aids the banks so that they have a clear view of a company's carbon risk. In addition, the study proves that the South African carbon tax regime will not be effective in changing company behaviour. A closer look at the carbon tax amounts shows that they do not impact the profits of most companies in the sample. Therefore, the carbon intensity and carbon dependency benchmarks obtained from the carbon risk analysis give a better view of how a company's business model is exposed to carbon risk (as a proxy for environmental risk in this study). Therefore, this study establishes a South African contextualised carbon risk analysis that can be used alongside regular credit-risk models.

The second implication refers to the banks considering all the aspects of the carbon tax regime, which include: trade intensity, carbon offsets, carbon reduction performance and the type of sector. The banks will need to be aware of the activities of companies in the energy and materials sector that will be paying carbon taxes that are close to 10% of their net income. It is of paramount importance that they should monitor the carbon tax issue. Banks will require carbon tax specialists and renewable energy specialists to analyse some of the companies in their portfolios to ensure that they prevent concentration risk caused by high carbon-intensive companies. Certain aspects of the carbon tax regime will require the expert knowledge of climate policy specialists, given that many changes have already, and will in future, take place with regards to the South African carbon tax act. The carbon tax draft act was almost ten years in the making, specifically due to the requisite refinements, and there are already indications that changes soon be made to the act to align it with the international standards in climate change policy.

The third implication of the research has to do with the bank's reputation as regards to all its stakeholders (depositors, investors, suppliers, shareholders, environmental lobbyist). There is an emergence of organisational and lobby groups that are advocating for banking institutions to desist from giving loans to companies whose activities involve high carbon-intensive activities. Banks should be able to show the reduction trend, or a divesting trend, in their credit portfolios with regards to the financing of companies with activities that are highly carbon-intensive. This should be done through the use of the carbon risk analysis tool indicators' average carbon intensities and carbon dependency benchmarks per sector.

The fourth implication comes from the benchmarking of carbon risk per sector level or company level. A company should benchmark itself against its peers in terms of carbon risk performance, and this means that the company managing its carbon risk in their business model will be able to get rid of assets and loans connected to high carbon energy sources. The study established the extent to which a carbon-risk activity can affect a company's ability to obtain a credit facility from environmentally conscious banks. Therefore, the study provides the banks with not only a benchmark but also a management tool that companies can use to produce climate-friendly products.

The fifth and last implication is related to the government, especially the Department of Environmental Affairs that should consider revising the carbon tax regime to ensure that it is able to effect change in company behaviour and ensure that companies adopt more climate change mitigation methods in their business models. In terms of carbon pricing that could lead to a reduction in climate change (as per the Paris agreement of a 2 ºC reduction), the impacts should be a lower bound of USD40–50/tCO_2e and a higher bound of USD80–100/tCO_2e for the period 2020–2030 (Carbon Market Watch, 2017). The price set for a carbon tax is USD8/tCO_2e (ZAR120 at USD/ZAR15).

Therefore, the government should introduce other mechanisms that would ensure a reduction in the impact of climate change caused by companies. The results obtained from banks and companies can assist the government to use the banks' intermediary role to implement changes in the climate change reduction behaviour of companies.

6.6 THEORETICAL AND PRACTICAL CONTRIBUTIONS OF THE RESEARCH

The quest to embed environmental risk aspects into the banks' processes is the most significant contribution of this study to the body of banking practice and theory literature. This study contributes to the body of knowledge and provides a South African contextualised solution to the plethora of quantitative embedding methods shown in the literature review. Practically, the embedding of carbon risk using a carbon tax regime will not work as a pricing mechanism. The market-determined carbon pricing, in the form of the EU-ETS, would assist in obtaining the accurate carbon exposure and risk profile of companies under their loan portfolios. The study contributes to the theoretical concept of financed emissions by tracing the amount of carbon emission that is embedded in both the short- and long-term loans that companies have.

The research done by UNEP FI and NAFTA[1] can be compared to this study. The research by UNEP FI and NAFTA evaluated the impact of climate change-related risks on bank borrowers. The study used the aggregated loan and lease data obtained from the Bank of America, CIBC, Citigroup, Scotiabank and TD Bank Financial Group, to analyse the impact of climate change-related risks on bank loans and leases. The primary outcome analysed four areas of climate change-related risk for each of the loan sectors, namely, policy risk, input price increases, output price decreases, and environmental exposure. The bank data included the total loan and lease portfolio values, and average weighted maturities for eleven sectors that were identified as potential at-risk sectors. However, the study found no correlation between the climate change-related proxy events and bonds issued by the companies in the at-risk sectors.

[1] United Nations Environment Program Finance Initiative (UNEP FI), North American Task Force (NAFTA)

The current study that this thesis is reporting on, also showed that there is no climate risk impact on the bank’s loans, either in the short- or long term. However, using the carbon risk analysis model and the content analysis model, the current study showed that there is a direct correlation between a company’s business model and the climate risk proxy used. The results for this study are the same as that obtained by the UNEP FI and the NAFTA study, which indicate that companies in high carbon-intensive sectors are susceptible to high policy exposure. For example, this current study found that high carbon-intensive sectors undergo huge swings when the carbon tax incentives are removed.

However, this study concurs with the UNEP FI and NAFTA study in that the banks in South Africa are not currently materially exposed to climate change risk in their loan and lease portfolios. The results showed that the probability of default values do not significantly change between the typical scenario and the carbon-adjusted scenarios. Moreover, the content analysis revealed that banks are still not embedding the physical aspects of climate change into their bank credit-risk models.

6.7 PROPOSED ENVIRONMENTAL CREDIT-RISK PROCESS FRAMEWORK

The solution proposed here mainly focuses on stress testing the loan portfolio for two of the three aspects of environmental risk, namely, climate change policy risk and transition risk.

In the South African context, a climate change policy risk is related to carbon budgets and the carbon tax implications on a company’s financial risk or credit risk. Transition risk, in South African terms, is related to a company transitioning from using inputs and operational processes that are carbon-intensive to those that are low or zero carbon dependent.

Therefore, being in possession of these factors allows for the development of a framework for the stress testing of companies to determine the carbon risk impact on credit risk.

The framework proposed by this study fits the company-level data that is readily available in South Africa. The model stress tests change in Revenue, Cost of Goods Sold, and Profit of companies, in sectors that are highly sensitive to climate change.

In this study, the companies are mainly in the cement and thermal power sectors. Therefore, the changes to the carbon tax policy will have an effect on the balance sheet and income statements of these companies. The parameters and scenarios of change are then simulated on the balance sheet and income statement. The financial indicators, coupled with qualitative indicators, will stress test the change in the credit rating of these companies. Figure 6.1 summarises the components of the environment risk stress-testing framework.

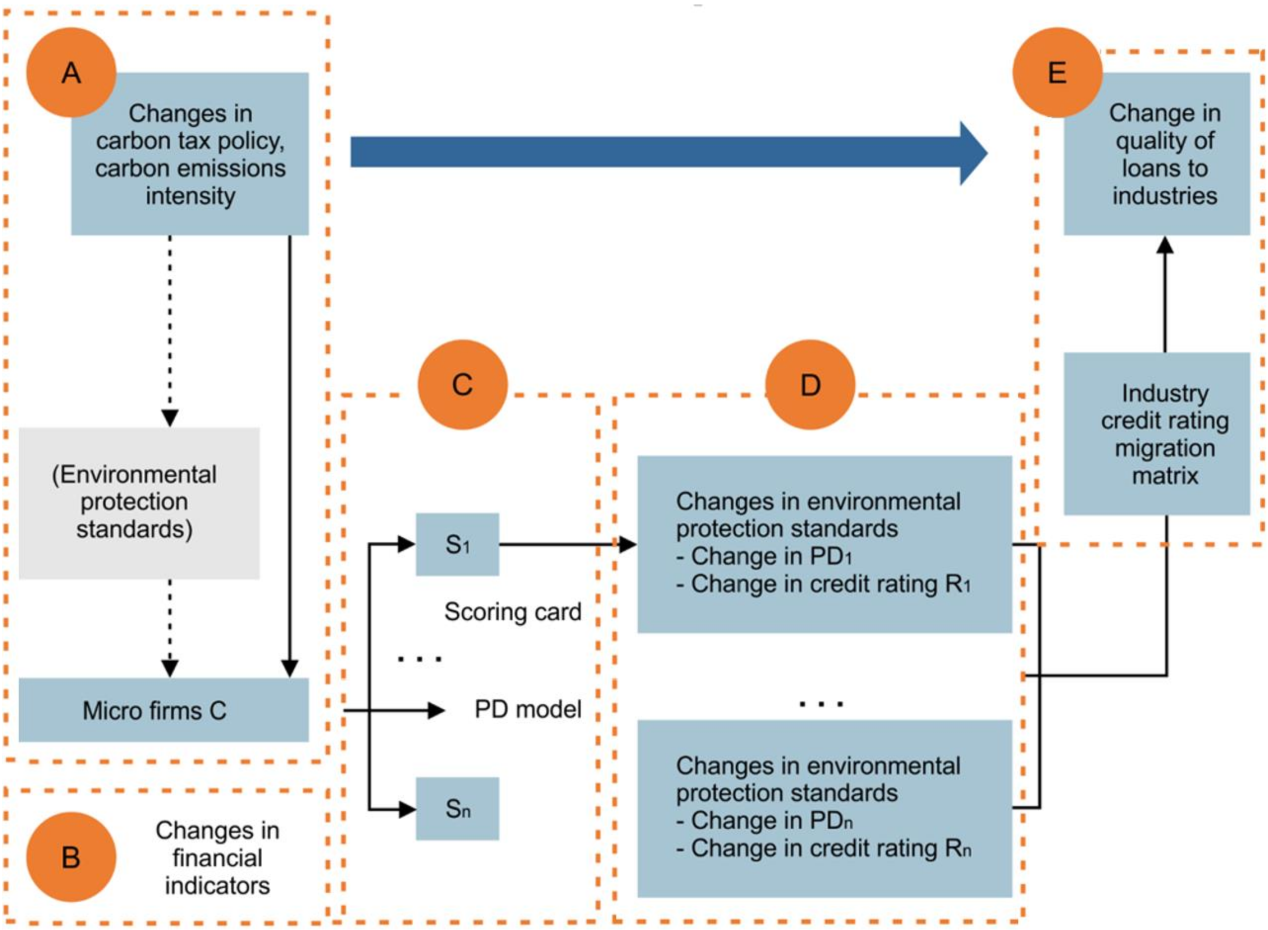


Figure 6.1: Environmental risk stress-testing model

As seen in Figure 6.1, there are five components that make up the proposed framework.

- Component A is the identified changes in the carbon tax and carbon intensity that have been demonstrated in this study. The South African carbon tax regime started in June 2019 and should generate enough data for stress testing. The companies are reporting their carbon emissions as a requirement of the carbon tax legislation, and thus there will be enough data to calculate carbon intensity.

- Component B is affected by component A, in that carbon tax policy affects the ability of the company to generate sustainable revenues as tax liability is increased.
- Component C involves the normal scoring card, or PD model that is applicable to the bank that has the companies in its portfolios credit rated.
- Component D of the framework shows the PD or credit rating in light of carbon tax policy regimes.
- Component E is the amalgamated industry migration credit-rating matrix, and this would help to see the changes in loan quality per industry. However, this solution needs to be further refined during its practical implementation.

The next section notes some issues that might be encountered in practicalising the results of this research, and if these are solved, the framework will be value-adding to a bank's credit process.

6.8 LIMITATIONS OF THIS STUDY

The study laid plans that would produce effective results; however, the study encountered a couple of obstacles. First of all, the CDP data that could be obtained was from the period 2010 to 2013, while the rest of the data (2014 to 2017) had to be corroborated from the companies' annual and integrated reports. The problem related to this was that the data from these two separate periods could not be standardised, and it might, therefore, skew the results. The study, if replicated with complete standardised CDP data from 2010 to 2017, may yield slightly different results.

The second issue, in simulating the carbon tax regime, many variables had to be inferred. For example, the carbon offsets regime has not yet been set up since the carbon tax was implemented on 1 June 2019. Therefore, the study used the declared carbon offsets in the CDP reports and the annual reports. Thus, future research might be required to compare these simulated results to the actual implemented carbon tax data.

The content analysis could have achieved enriched results if it had been possible to interview the bank professionals who actually manage sustainability issues. However, most banks regard their sustainability data, especially the environmental data, as proprietary data that, if shared, would divulge information to their competitors. Therefore, they were not willing to share much of what they are doing in the area of embedding environmental risk into bank processes, even if done anonymously, given that there were only four banks under consideration. Thus, the study ended up inferring from the annual reports and the integrated reports. However, by using the similarity matrix method in the content analysis, the study managed to find content that correlates to the Jeucken and Kauefer Sustainability Embedding Model on the embedding of environmental risk by the banks. The technique used is deemed sufficient in predicting how the banks are embedding environmental risk into their bank credit processes.

The calculation of the probability of default also presented challenges. The results needed more information to enable an enhanced credit rating of the companies in the sample. This information would involve insight into the individual's financial behaviour, which is a banking activity that is regarded as private, and which banks are not willing to share due to banker-client confidentiality. The results might have shown a significant magnitude of change after the financials were adjusted for the carbon tax. It will be imperative to replicate the study in the future, with the availing of more data, to correctly see the extent of the carbon risk impact on a company's credit rating. However, the given framework of calculating the probability of default guarantees the magnitude of change presented in the credit rating of a company as negligible. Hence, correlating these results with the results of the content analysis, it can be concluded that the South African banks might be justified in just embedding qualitatively in the credit value chain. The downside of the qualitative embedding is the non-quantification of the impact of environmental risk, and that it only becomes a checklist that does not transform the desired behaviour. Therefore, the study adequately proves that the carbon tax regime will not affect the necessary change in behaviour climate change mitigation.

Lastly, the sampling process ended up yielding an unbalanced number of companies in each sector, which threatened to lead to biased results. However, the methods of analysis used ensured comparability across companies and sectors. The sample ended up having more high carbon-intensive companies, while some other industries were represented by one company each. The averaging technique was used in comparing companies across different industries. The CDP data that was collected showed that some companies opted not to have their information displayed in the reports, and hence, could not be included in the sample.

In terms of the period of study, from 2010 to 2017, that was the only period where complete data could be used to simulate the carbon tax regime. The availability of data from more years could have yielded more robust results; however, a period of eight years is deemed sufficient to predict that which the research aimed to achieve.

6.9 FUTURE RESEARCH

First of all, the evolvement of sustainability issues will ensure that governance and social issues are added as variables, and it will allow a holistic view of how the three sustainability issues (Environment, Social and Governance) affect a company's credit rating. In addition, by broadening the environmental risk aspects to include aspects, such as environmental penalties, water use, waste recycling, paper use, and natural capital, would also broaden the embedding of environmental risk into the bank credit process. As companies disclose the data, this would be possible.

Another issue concerning this research that needs more exploration is to obtain direct loan data from a bank, which in combination with the banking behaviour will test the suppositions in this study. The results should be compared to see if the magnitude of carbon risk changes the credit rating of the company. It would also be interesting to extend the study to State-Owned Enterprises, such as ESKOM, and private companies as data become available, to see if there is a recognisable difference between a private company and a publicly-listed company in terms of carbon risk. As companies start releasing carbon tax data, it will be easy to do more elaborate calculations of the companies' carbon risk using the carbon risk analysis method. Therefore, this research provides the direction in terms of the analysis of the carbon tax on a borrower's payment ability. More so, this study just investigated the counterparty credit risk and not the credit transaction risk. It will be ideal to pursue the carbon risk constitution of transactional credit risk.

Creating a carbon risk index out of carbon tax data will broaden the issues that can be researched. Another exciting factor is that the data will be reported centrally to the Department of Environmental Affairs and South African Revenue Services. It will make it easy to create an index of both private and public companies using the Hoffmann and Busch (2008) carbon risk analysis model that was adapted for this study. Therefore, the study will be broadened beyond the JSE CDP reporting companies. This data can also be used to create an environmental credit-risk model that can predict credit risk that is adjusted for environmental risk using the default prediction model and theories.

Another connected line of research that can be pursued is the use of climate data to add dynamism to predicting the environmental risk of a company. The climate data can be in the form of predicted weather patterns, such as temperature, rainfall and temperature. The climate hazards can be used to predict how they can disrupt a client's business output, and hence, affect their ability to repay a loan. This can be pursued by using past data and aligning it with the historical financial results. In addition, the climate insurance that was in place would add to the prediction of the environmental risk connected to credit processes.

The current research study with the available data, but as more environmental data is availed, it will be easy to pursue more robust credit risk prediction models that embed environmental risk.

6.10 SUMMARY

This chapter presented the achievement of the research outcomes. Albeit, there were obstacles to the sampling, model building, carbon tax regime simulation and data challenges, and this chapter detailed the solutions to these challenges. The main objective of the research, namely, to formulate a credit appraisal that incorporates environmental risk, has been successfully achieved.

The study shows that the carbon tax regime is not effective in reducing carbon emissions to meet the national climate change mitigation targets. Further, this chapter details the recommendations and implications of the research based on the outcomes of the investigation. Ultimately, the study asserts that carbon risk is of little significance to a company's operations in the South African context.

Triangulation of the quantitative and qualitative parts of the study concluded that banks are tottering on reactive embedding and proactive embedding. Banks are not willing to bear unnecessary unlegalised costs or costs that have no legal implication, and thus the results reveal why they will not move to proactively managing carbon risk (a proxy for environmental risk).

Last of all, the carbon risk analysis that the study contextualised for South Africa can scrutinise beyond the carbon risk presented by the carbon tax and show the impact in business models indicators, and hence, create a true reflection of the carbon risk exposure in bank loan portfolios. Therefore, the big question is: how long will South African banks' reactive and non-proactive position last in the long run? South African banks are pursuing the proactive behaviour of the South African companies in terms of environmental risk that will prove detrimental to the attraction of investors of long-term capital.

Voluntary climate-related risk disclosure is increasing, and for banks, this particularly applies to the climate risk that is embedded in loan portfolios. The GRI (Global Report Institute), SASB (Sustainability Accounting Standards Board) and TCFD (Task Force on Climate Disclosure) are recognised as the leaders in integrated reporting, and they require the voluntary disclosure of environmental impacts on company operations and financial performance. This will definitely put pressure on the South African banking sector. Michael Bloomberg said, "Without effective disclosure of these (climate change) risks, the financial impacts of climate change may not be correctly priced, and as the costs eventually become clearer, the potential for rapid adjustments could have destabilising effects on markets."

LIST OF REFERENCES

2ºii (2 Degrees Investing Initiative). 2013. *Landscaping Carbon Risk for Financial Intermediaries*. Available at https://2degrees-investing.org/wp-content/uploads/2013/11/Landscaping-carbon-risk-for-financial-intermediaires-November-2013.pdf

Adeleke, F., Kiragu, E. & Murombo, T. 2014. *Background Paper on Climate Change in South Africa and the Proposed Measures to Promote Environmental Sustainability*, Mandela Institute.

Allen, F. & Santomero, A.M. 1997. The theory of financial intermediation. *Journal of Banking & Finance,* 21(11-12): 1461-1485.

Allen, F. & Santomero, A.M. 2001. What do financial intermediaries do? *Journal of Banking & Finance,* 25(2): 271-294.

Altman, E., Gande, A. & Saunders, A. 2006. The informational role of bank loan rating. *Journal of Financial Research,* 29(4): 481-501.

Al-Tawil, T.N. 2017. Is a lender environmentally liable for the simple act of lending money? *International Journal of Law and Management*, 59 (3): 341-364.

Arrow, K.J. & Debreu, G. 1954. Existence of an equilibrium for a competitive economy. *Econometrica: Journal of the Econometric Society*, 22(3): 265-290.

ADFIAP (Association of Development Financing Institutions in Asia and the Pacific). 2005. *Background Research on Environmental Aspects in Bank Lending Decisions*. Sustainability Research Institute, University of Leeds & Wuppertal Institute of Climate, Environment, Energy.

Avellaneda, M. & Zhu, J. 2001. Distance to default. *Risk*, 14(12): 125-129.

Ayaz, H. 2017. Analysis of carbon emission accounting practices of leading carbon emitting European Union companies. *Athens Journal of Business & Economics,* 3(4): 463-486.

Babbie, E. 2015. *The practice of social research.* Boston: Cengage Learning.

Bae, B. & Sami, H. 2004. Firm Characteristics and Accounting Policy Choices for Environmental Liabilities. *Advances in Quantitative Analysis of Finance and Accounting,* 1: 235-265.

Ballestoros, A., Nakhooda, S., Werksman, J. & Hurlburt, K. 2010. Power, responsibility, and accountability: rethinking the legitimacy of institutions for climate finance. *Climate law,* 1(2): 261-312.

BankTrack & Rainforest Action Network. 2012. *Bankrolling Climate Disruption: The Impacts of the Banking Sector's Financed Emissions*. (p. 13).

Basak, R. 2017. Agency theory and international climate change financing accountability regimes. *World Bank Research Observer*, 19(1): 41-60.

Battiston, S., Mandel, A., Monasterolo, I., Schütze, F. & Visentin, G. 2017. A climate stress-test of the financial system. *Nature Climate Change,* 7(4): 283.

Bauer, R. & Hann, D. 2010. Corporate environmental management and credit risk. Available at SSRN 1660470.

Bharath, S.T. & Shumway, T. 2008. Forecasting default with the Merton distance to default model. *The Review of Financial Studies*, 21(3): 1339-1369.

BIG (Business Innovations Group). 2011. *Report on high-level stakeholder engagements.* Research report commission by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Climate Support Programme to support the development of the National Climate Change Response White Paper.

Billiot, M.J. & Daughtrey, Z.W. 2001. Evaluating environmental liability through risk premiums charged on loans to agribusiness borrowers. *Agribusiness,* 17(2): 273-297.

Black, F. & Scholes, M. 1973. The pricing of options and corporate liabilities. *Journal of political economy,* 81(3): 637-654.

Bouwer, L.M. & Aerts, J.C. 2006. Financing climate change adaptation. *Disasters,* 30(1): 49-63.

Bowman, M. 2010. The role of the banking industry in facilitating climate change mitigation and the transition to a low-carbon global economy. *Environment and Planning Law Journal,* 27: 448.

Boyer, M. & Laffont, J. 1996. Environmental protection, producer insolvency and lender liability. *Economic Policy for the Environment and Natural Resources, Edward Elgar.* Citeseer.

Bray, C., Colley, M. & Connell, R. 2007. Credit risk impacts of a changing climate: 60. *London: Barclays Environmental Risk Management, Acclimatise*.

Brierley, J.A., 2017. The role of a pragmatist paradigm when adopting mixed methods in behavioural accounting research. *International Journal of Behavioural Accounting and Finance*, 6(2):140-154.

Brimble, M., Stewart, J. & de Zwaan, L. 2010. Climate Change and Financial Regulation: Challenges for the Financial Sector Following the Global Financial Crisis. *Griffith L. Review,* 19: 71.

Brooks, N. 2003. Vulnerability, risk and adaptation: A conceptual framework. *Tyndall Centre for Climate Change Research Working Paper*, 38(38): 1-16.

Brunner, S. & Enting, K. 2014. Climate finance: A transaction cost perspective on the structure of state-to-state transfers. *Global environmental change*, 27: 138-143.

Buchner, B., Falconer, A., Hervé-Mignucci, M., Trabacchi, C. & Brinkman, M. 2011. The Landscape of Climate Finance. *Climate Policy Initiative: Venice,* 27.

Camco & TIPS. 2010. *Climate Change Risks and Opportunities for the South African Economy - An Assessment of Mitigation Response Measures* [online]. Available at https://www.tips.org.za/files/u72/climate_change_risks_and_opportunities_for_the_south_african_economy.pdf

Campbell, D. & Slack, R. 2011. Environmental disclosure and environmental risk: Sceptical attitudes of UK sell-side bank analysts. *The British Accounting Review,* 43(1): 54-64.

Cardenas, M.L. 1999. "Chapter 1: Environmental Risk Assessment (EnRA)" in *Technical Workbook on Environmental Management Tools for Decision Analysis.* United Nations Environment Programme.

Carbon Market Watch. 2017. Pricing carbon to achieve the Paris goals. Policy Briefing.

Case, P. 1996. Land, lending and liability. *Chartered Banker*, 2(4): 44-49.

Chava, S. 2010. *Do environmental concerns affect the cost of bank loans*.

Chava, S., 2010. Do Environmental Concerns Affect the Cost of Bank Loans?. Working paper: George Institute of Technology-College of Management.

Chenet, H. 2019. Climate change and financial risk. Working paper. *Social Science Research Network (SSRN) Electronic Journal*. https://doi.org/10.2139/ssrn.3407940.

Clayton, A.F., Rogerson, J.M. & Rampedi, I. 2015. Integrated reporting vs. sustainability reporting for corporate responsibility in South Africa. *Bulletin of Geography. Socio-economic series*, 29(29): 7-17.

Cogan, D.G. 2008. *Corporate Governance and Climate Change: The Banking Sector: a Ceres Report.* Boston: Ceres Inc. Available at www.ceres.org

Coulson, A. 2002. A Benchmarking Study: Environmental Credit Risk Factors in the Pan-European Banking Sector. *London: ISIS Asset Management*.

Coulson, A.B. 2009. How should banks govern the environment? Challenging the construction of action versus veto. *Business Strategy and the Environment,* 18(3): 149-161.

Coulson, A.B. & Monks, V. 1999. Corporate environmental performance considerations within bank lending decisions. *Corporate Social-Responsibility and Environmental Management,* 6(1): 1.

Cowton, C.J. & Thompson, P. 2000. Do codes make a difference? The case of bank lending and the environment. *Journal of Business Ethics,* 24(2): 165-178.

Cox, P.M., Betts, R.A., Jones, C.D., Spall, S.A. & Totterdell, I.J. 2000. Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. *Nature,* 408, no. 6809: 184-187.

Davies, P. 2011. *The SAGE Dictionary of Social Research Methods.* London: SAGE Publications.

Department of Environmental Affairs. 2011. *National Climate Change Response Paper*, Department of Environmental Affairs - Republic of South Africa, Pretoria, South Africa.

Department of Energy. 2018. South African Energy Sector Report. Available on: http://www.energy.gov.za/files/media/explained/2018-South-African-Energy-Sector-Report.pdf

Department of Industry & Trade. 2007. National Industrial Policy Framework. Department of Trade & Industry. Republic of South Africa. ISBN 1-920106-10-3. Available on: http://www.thedtic.gov.za/wp-content/uploads/NIPF_r2.pdf

Diaz-Rainey, I., Robertson, B. & Wilson, C. 2017. Stranded research? Leading finance journals are silent on climate change. *Climatic Change*, 143(1-2): 243-260.

Dietz, T., Gardner, G.T., Gilligan, J., Stern, P.C. & Vandenbergh, M.P. 2009. Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions. *Proceedings of the National Academy of Sciences,* 106(44): 18452-18456.

Dionne, G. & Spaeter, S. 2003. Environmental risk and extended liability: The case of green technologies. *Journal of Public Economics,* 87(5): 1025-1060.

Doherty, N.A. 1997. Innovations in managing catastrophe risk. *The Journal of risk and insurance,* 64(4): 713-718.

Duan, J. & Wang, T. 2012. Measuring distance-to-default for financial and non-financial firms. *Global Credit Review,* 2(1): 95-108.

Dyllick, T. & Hockerts, K. 2002. Beyond the business case for corporate sustainability. *Business strategy and the environment,* 11(2): 130-141.

ElAlfy, A. & Weber, O. 2019. Corporate Sustainability Reporting: The Case of the Banking Industry. CIGI Paper No. 211. *Centre for International Governance Innovation.* Waterloo, Canada: CIGI.

Elsakit, O.M. & Worthington, A.C. 2012. The Attitudes of Managers and Stakeholders towards Corporate Social and Environmental Disclosure. *International Journal of Economics and Finance,* 4(12): 240.

Energy Research Centre, University of Cape Town. 2013. *Comments on the Carbon Tax Policy Paper issued by National Treasury in May 2013.* [Online]. Available at http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2013/13ERC_Comments_Treasury_Carbon_Tax_Paper.pdf

Epstein, M.J. & IMA Foundation for Applied Research. 1996. *Measuring corporate environmental performance: best practices for costing and managing an effective environmental strategy.* New York: McGraw-Hill.

Erina, J. & Lace, N. 2012. Environmental Question Impact for Lenders and the Risk Management Process. *Economics and Management,* 17(2): 733-739.

Fankhauser, S. 2010. The costs of adaptation. *Wiley Interdisciplinary Reviews: Climate Change,* 1(1): 23-30.

Figge, F. 1998. *Systematisation of Economic Risks through Global Environmental Problems: A Threat to Financial Markets?* Center of Economics and Business Administration (WWZ) at the University of Basel.

Financial Stability Board, UK. 2017. Task Force on Climate Related Financial Disclosures – Final report: recommendations of the task force on climate-related financial disclosures. Available at: www. fsb-tcfd. org/wp-content/uploads/2017/06/FINAL-TCFD-Report-062817.pdf

Fischer, H., Kumke, T., Lohmann, G., Miller, H. and Negendank, J. eds., 2013. The climate in historical times: towards a synthesis of holocene proxy data and climate models. Springer Science & Business Media.

FORGE. 2002. *Guidelines on Environmental Management and Reporting for the Financial Services Sector*, London: FORGE Group.

Foxon, T.J. 2011. A coevolutionary framework for analysing a transition to a sustainable low carbon economy. *Ecological Economics,* 70(1)12: 2258-2267.

Fuller, M.C., Portis, S.C. & Kammen, D.M. 2009. Toward a low-carbon economy: Municipal financing for energy efficiency and solar power. *Environment: Science and Policy for Sustainable Development,* 51(1): 22-33.

Fulton, M. & Weber, C. 2014. *Carbon Asset Risk: Discussion Framework. WRI and UNEP-FI Portfolio Carbon Initiative.* World Resources International and United Nations Environmental Program - Financial Institutions.

Furrer, B., Hamprecht, J. & Hoffmann, V.H. 2012. Much Ado about Nothing? How Banks Respond to Climate Change. *Business & Society,* 51(1) : 62-88

Füssel, H.M. 2007. Vulnerability: A generally applicable conceptual framework for climate change research. *Global environmental change*, 17(2): 155-167.

G20 Green Finance Study Group. 2017. G20 green finance synthesis report 2017. G20 Green Finance Study Group: Sanya, China.

Gamble, G.O., Hsu, K., Kite, D. & Radtke, R.R. 1995. Environmental disclosures in annual reports and 10Ks: An examination. *Accounting Horizons,* 9(3): 34.

Gao, L.S. 2011. Do investors value environmental capital spending? Evidence from the electric utility sector. *Journal of Finance and Accountancy,* 7: 1.

Garcia, A.S., Mendes-Da-Silva, W. & Orsato, R.J. 2019. “Corporate Sustainability, Capital Markets, and ESG Performance”. In W. Medes-Da-Silva (ed.), *Individual Behaviors and Technologies for Financial Innovations* (pp. 287-309). New York: Springer.

David Gardiner & Associates, Coalition for Environmentally Responsible Economies, Pew Charitable Trusts, & Surdna Foundation. 2006) Best practices in climate change risk analysis for the electric power sector: the results of the Ceres electric power/investor dialogue. Boston, MA: Ceres.

Ge, W. & Liu, M. 2015. Corporate social responsibility and the cost of corporate bonds. *Journal of Accounting and Public Policy,* 34(6): 597-624.

Glaser, B.G. & Strauss, A.L. 2017. *Discovery of grounded theory: Strategies for qualitative research.* New York: Routledge.

Goldstein, A., Turner, W.R., Gladstone, J. & Hole, D.G. 2019. The private sector’s climate change risk and adaptation blind spots. *Nature Climate Change,* 9: 18–25.

Gore, A., Guggenheim, D., David, L., Bender, L., Burns, S.Z., Skoll, J., Chilcott. L., Richman, B. *et al.* 2006. *An inconvenient truth.* [Documentary video]. Hollywood, CA: Paramount Home Entertainment.

Goss, A. & Roberts, G.S. 2011. The impact of corporate social responsibility on the cost of bank loans. *Journal of Banking & Finance,* 35(7): 1794-1810.

Graham, A. & Maher, J.J. 2006. Environmental liabilities, bond ratings, and bond yields. *Advances in Environmental Accounting & Management,* 3: 111-142.

Graham, A., Maher, J.J. & Northcut, W.D. 2001. Environmental liability information and bond ratings. *Journal of Accounting, Auditing & Finance,* 16(2): 93-116.

Gray, R. & Bebbington, J. 2001. *Accounting for the Environment,* 2nd ed. Thousand Oaks, CA: Sage.

Gray, R., Kouhy, R. & Lavers, S. 1995. Constructing a research database of social and environmental reporting by UK companies. *Accounting, Auditing & Accountability Journal,* 8(2): 78-101.

GRI (Global Reporting Initiative). 2008. *Sustainability reporting guidelines & financial services sector supplement*, UNEP-FI, Amsterdam.

Groth, J.C. 1994. Environmental risk: implications of rational lender behaviour. *Journal of Property Finance,* 5(3): 19-32.

Guthrie, J. & Abeysekera, I. 2006. Content analysis of social, environmental reporting: what is new? *Journal of Human Resource Costing & Accounting,* 10(2): 114-126.

Hamilton, K., Sjardin, M., Shapiro, A. & Marcello, T. 2009. Fortifying the Foundation: State of the Voluntary Carbon Markets 2009 A report by Ecosystem Marketplace and New Carbon Finance.

Hart, C. 2007. "Financial Risks and Climate Change." in N. Choucri, D. Mistree, F. Haghseta, T. Mezher, W.R. Baker, & C.I. Ortiz (eds.). *Mapping Sustainability*, pp. 367-377. Berlin/Heidelberg, Germany: Springer.

Hasman, A., Samartín, M. & van Bommel, J. 2014. Financial intermediation in an overlapping generations' model with transaction costs. *Journal of Economic Dynamics and Control,* 45: 111-125.

Herbohn, K., Gao, R. & Clarkson, P. 2019. Evidence on whether banks consider carbon risk in their lending decisions. *Journal of Business Ethics*, 158(1):155-175.

Heyes, A.G. 1996. Lender penalty for environmental damage and the equilibrium cost of capital. *Economica,* 63: 311-323.

Hillerbrand, R. 2012. "Climate Change as Risk?" in S. Roeser, R. Hillerbrand, P. Sandin & M. Peterson (eds.). *Handbook of Risk Theory, Epistemology, Decision Theory, Ethics, and Social Implications of Risk,* pp. 319-339. Berlin/Heidelberg, Germany: Springer.

Hoffmann, V.H. & Busch, T. 2008. Corporate carbon performance indicators. *Journal of Industrial Ecology,* 12(4): 505-520.

Hollenstein, K. 2005. Reconsidering the risk assessment concept: Standardizing the impact description as a building block for vulnerability assessment. *Natural Hazards and Earth System Science,* 5(3): 301-307.

Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, Paul, J., Dai, X., Maskell, K. & Johnson, C. 2001. *Climate change 2001: the scientific basis.* Cambridge: Cambridge University Press.

Huang, B., Punzi, M.T. & Wu, Y. 2019. Do banks price environmental risk? Evidence from a quasi natural experiment in the People's Republic of China. ADBI Working Paper 974, Available at SSRN: https://ssrn.com/abstract=3541472 or http://dx.doi.org/ 10.2139/ssrn.3541472

International Energy Agency. 2019. Africa Energy Outlook 2019. Overview: South Africa. Available at: www.iea.org/reports/africa-energy-outlook-2019

ICBC (Industrial and Commercial Bank of China). 2018. Impact of Environmental Factors on Credit Risk of Commercial Banks. Available at: http://www.gflp.org.cn/public/ueditor/php/ upload/file/20181101/1541043409628572.pdf

Innovest Strategic Value Advisors. 2007. *Carbon Beta™ and Equity Performance: An Empirical Analysis - Moving from Disclosure to Performance*, Innovest Strategic Value Advisors.

IPCC (International Panel on Climate Change). 2007. *Climate Change 2007: Synthesis Report*. Contribution of Working Groups I. II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: IPCC.

Jaffe, A.B., Newell, R.G. & Stavins, R.N. 2005. A tale of two market failures: Technology and environmental policy. *Ecological Economics,* 54(2): 164-174.

Jeucken, M. 2004. *Sustainability in finance: Banking on the planet.* Utrecht, Netherlands: Eburon Academic Publishers.

Jeucken, M. 2010. *Sustainable finance and banking: The financial sector and the future of the planet.* New York: Routledge.

Jeucken, M. & Bouma, J.J. 2001. The changing environment of banks, *Sustainable banking: The greening of finance,* 24(38): 15.

Johnston, D. 2005. An investigation of regulatory and voluntary environmental capital expenditures. *Journal of Accounting and Public Policy,* 24(3): 175-206.

Jones, R. 2003. "Managing Climate Change Risks". *OECD Workshop on the Benefits of Climate Policy: Improving Information for Policy Makers*. Organisation for Economic

Cooperation and Development, Paris, France. [Online]. Available at https://www.oecd.org/ env/ cc/19519189.pdf

Jones, R.N. 2001. An environmental risk assessment/management framework for climate change impact assessments. *Natural Hazards,* 23(2)-3: 197-230.

Jones, R., Boer, R., Magezi, S. & Mearns, L. 2004. "Technical Paper 4: Assessing current climate risks". In B. Lim & E. Spanger-Siegfrie (eds.) Adaptation policy frameworks for climate change: developing strategies, policies and measures, p. 93. Cambridge, UK: Press Syndicate of the University of Cambridge.

Kaeufer, K. 2010. *Banking as a vehicle for socio-economic development and change: Case studies of socially responsible and green banks*. Cambridge, MA: Presencing Institute.

Kim, Y., An, H.T. & Kim, J.D. 2015. The effect of carbon risk on the cost of equity capital. *Journal of Cleaner Production,* 93: 279-287.

Klotz, G.L. & Siakotos, E.C. 1987. Lender Liability under Federal and State Environmental Law. *Commercial Law Journal*, 92(3): 275.

Kossoy, A. & Ambrosi, P. 2010. *State and trends of the carbon market 2010* (No. 55419, pp. 1-126). The World Bank.

Kousky, C. & Cooke, R.M. 2009. *Climate Change and Risk Management: Challenges for Insurance, Adaptation, and Loss Estimation.* Working Paper. Available at https://www.researchgate.net/publication/24047557_Climate_Change_and_Risk_Management_Challenges_for_Insurance_Adaptation_and_Loss_Estimation

Kovacova, M. & Kollar, B. 2018. "Modeling Default Probability via Structural Models of Credit Risk in Context of Emerging Markets". In S. Gokten (ed.) *Financial Management from an Emerging Market Perspective.* DOI: 10.5772/intechopen.71021

Kunreuther, H., Heal, G., Allen, M., Edenhofer, O., Field, C.B. & Yohe, G. 2013. Risk management and climate change. *Nature Climate Change,* 3: 447–450. https://doi.org/10.1038/nclimate1740

Labatt, S. & White, R.R. 2007. *Carbon finance: the financial implications of climate change.* Hoboken, NJ: John Wiley & Sons Inc.

Lamperti, F., Bosetti, V., Roventini, A. & Tavoni, M. 2019. The public costs of climate-induced financial instability. *Nature Climate Change*, 9(11): 829-833.

Latham, M. 2009, Environmental liabilities and the federal securities laws: A proposal for improved disclosure of climate change-related risks. *Environmental Law,* 39: 647.

Löeffler, G. & Posch, P.N. 2011. *Credit risk modeling using Excel and VBA.* Hoboken, NJ: John Wiley & Sons Inc.

Lorenz, D. 2008. “Prudence, profit and the perfect storm: climate change risk and fiduciary duty of directors". In B. Hansjürgens & R. Antes (eds.) *Economics and Management of Climate Change,* pp. 271-292 Berlin/ Heidelberg, Germany: Springer.

Lovell, H., Sales de Aguiar, T., Bebbington, J. & Larrinaga-Gonzalez, C. 2010. *Accounting for carbon*. Research Report 122, ACCA and IETA Certified Accountant Educational Trust, London.

Lundgren, M. & Catasus, B. 2000. The banks' impact on the natural environment-on the space between 'what is' and 'what if'. *Business Strategy and the Environment,* 9(3): 186.

Mabey, N., Gulledge, J., Finel, B. & Silverthorne, K. 2011. *Degrees of Risk: Defining a Risk Management Framework for Climate Security.* London: Third Generation Environmentalism Ltd.

Maubane, P., Prinsloo, A. & Van Rooyen, N. 2014. Sustainability reporting patterns of companies listed on the Johannesburg securities exchange. *Public Relations Review*, 40(2): 153-160.

MacKenzie, D. 2009. Making things the same: Gases, emission rights and the politics of carbon markets. *Accounting, Organizations and Society,* 34(3-4): 440-455.

Makower, J. & Pike, C. 2009. *Strategies for the green economy: Opportunities and challenges in the new world of business.* Columbus, OH: McGraw-Hill.

McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. & White, K.S. 2001. *Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

Mengze, H. & Wei, L. 2015. A Comparative Study on Environment Credit Risk Management of Commercial Banks in the Asia-Pacific Region. *Business Strategy and the Environment,* 24(3): 159-174.

Merton, R.C. 1974. On the pricing of corporate debt: The risk structure of interest rates. *The Journal of Finance,* 29(2): 449-470.

Merton, R.C. 1995. A functional perspective of financial intermediation. *Financial Management*: 23-41.

Mitchell, W.R. 2018. CERLA: The Problem of Lender Liability. *Florida State University Journal of Land Use and Environmental Law*, *7*(1): 4.

Mishkin, F.S. 2004. *The Economics of Money, Banking, and Financial Markets,* 7th ed. Boston, MA: Pearson-Addison Wesley.

Montmasson-Clair, G. 2012. Green Economy Policy Framework and Employment Opportunity: A South African Case Study. *Trade and Industrial Policy Strategies (TIPS): Working Paper Series,* no. 2012-02.

Mulder, I. 2007. *Biodiversity, the next challenge for financial institutions? A scoping study to assess exposure of financial institutions to biodiversity business risks and identifying options for business opportunities*, The World Conservation Union IUCN, Gland, Switzerland.

Naidoo, C. 2011. *Financing Climate Change.* Department of Environmental Affairs, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Pretoria. [Online]. Available at https://www.environment.gov.za/sites/default/files/docs/financing_climate_change.pdf

NBI (National Business Initiative). 2008. Carbon Disclosure Project 2008. *Carbon Disclosure Project Report 2008 - JSE Top 100*. [online]. Available at http://www.nbi.org.za/wp-content/uploads/2016/06/67_329_169_CDP-South-Africa-Report-2008.pdf

NBI. 2013. Carbon Disclosure Project 2013. *CDP South Africa 100 Climate Change Report 2013 - The South African business response to climate change: Is it delivering the required performance?* [online]. Available at http://www.nbi.org.za/wp-content/uploads/2016/06/CDP-South-Africa-Climate-Change-Report-2013.pdf

NBI. 2017. *CDP South Africa Climate Change 2017.* Carbon Disclosure Project (CDP) & ADEC Innovations, NBI, Johannesburg. Available at http://piv.nbi.org.za/2017/CDP_Climate_change_2017.pdf

National Planning Commission. 2011. *National Development Plan: Vision for 2030*. Pretoria: National Planning Commission.

National Treasury, Republic of South Africa. 2010. *Reducing Greenhouse Gas Emissions: the Carbon Tax Option, Discussion Paper for Public Comment*, National Treasury Tax Policy Unit, Pretoria.

National Treasury, Republic of South Africa. 2013. *Carbon Tax Policy paper - Reducing greenhouse gas emissions and facilitating the transition to a green economy*, Pretoria, South Africa.

National Treasury, Republic of South Africa. 2018. *Explanatory Memorandum on the Carbon Tax Bill, 2018*. Pretoria

Nielsen, J., Luttmer, M. & van der Hoek, B. 2009. *Carbon footprinting of financed emissions: Existing methodologies-A review and recommendation.* (Online) url:

https://www.banktrack.org/download/carbon_footprinting_of_financed_emissions/110216_carbon_footprinting_financed_emissions.pdf. [Accessed on 21 May 2017].

Nieto, M. 2019. Banks, climate risk and financial stability. *Journal of Financial Regulation and Compliance*, 27(2): 243-262.

Nizam, E., Ng, A., Dewandaru, G., Nagayev, R. & Nkoba, M.A. 2019. The impact of social and environmental sustainability on financial performance: A global analysis of the banking sector. *Journal of Multinational Financial Management*, 49:35-53.

Öker, F. & Adıgüzel, H. 2017. Reporting for Carbon Trading and International Accounting Standards. *Accounting and Corporate Reporting:* 111.

Onischka, M. 2008. Environmental and Climate Risks in Financial Analysis. *WIT Transactions on Ecology and the Environment:* 108.

Parker, L.D. 2005. Social and environmental accountability research: A view from the commentary box. *Accounting, Auditing & Accountability Journal,* 18, no. 6: 842-860.

Patton, M.G. & Gable, A.G. 2018. Lender and Bank Liability in Oil and Gas Transactions and the Changing Legal Environment: Implications of Gloria's Ranch LLC v. Tauren Exploration, Inc. *Annual. Institute. on Mineral. Law.*, 65: 250.

Pearce, D.W., Cline, W.R., Achanta, A.N., Fankhauser, S., Pachauri, R.K., Tol, R.S. & Vellinga, P. 1996. The social costs of climate change: greenhouse damage and the benefits of control. *Climate change 1995: Economic and social dimensions of climate change*: 179-224.

Pearce, D.W., Markandya, A. & Barbier, E.B. 1989. *Blueprint for a green economy: a report,* Earthscan.

Pitchford, R. 1995. How liable should a lender be? The case of judgment-proof firms and environmental risk. *The American Economic Review*: 1171-1186.

Platform Carbon Accounting Financials. 2018. *Harmonising and implementing a carbon accounting approach for the financial sector: Platform Carbon Accounting Financials (PCAF) report 2018*, Platform Carbon Accounting Financials, Netherlands.

Plassmann, K., Norton, A., Attarzadeh, N., Jensen, M., Brenton, P. & Edwards-Jones, G. 2010. Methodological complexities of product carbon footprinting: a sensitivity analysis of key variables in a developing country context. *Environmental Science & Policy,* 13(5): 393-404.

Porter, M.E. & Kramer, M.R. 2006. Strategy and society: the link between competitive advantage and corporate social responsibility. *Harvard Business Review December*: 78-93.

Porter, M.E. & van der Linde, C. 2002. Toward a new conception of the environment-competitiveness relationship. *International Business: Critical Perspectives on Business and Management,* 4(4): 261.

Rees, W. & Wackernagel, M. 1996. Urban ecological footprints: why cities cannot be sustainable and why they are a key to sustainability. *Environmental Impact Assessment Review,* 16(4-6): 223-248.

Reinhardt, F.L. 1999. Bringing the environment down to earth. *Harvard business review,* 77(4): 149-157, 186.

Republic of South Africa. 2010. National Climate Change Response White Paper [online] Available at: https://www.environment.gov.za/sites/default/files/legislations/national_climatechange_response_whitepaper.pdf

Riley, S. 2007. Emission Rights Accounting: Accounting for Hot Air. *Student Accountant ACCA,* 3: 48-51.

Ritchie, H. & Roser, M. 2017. "CO_2 and Greenhouse Gas Emissions". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions' [Online Resource]

Romilly, P. 2007. Business and climate change risk: A regional time series analysis. *Journal of International Business Studies,* 38(3): 474-480.

Rubino, M.C. 2000. Biodiversity finance. *International Affairs,* 76(2): 223-240.

Russell, S., Haigh, N. & Griffiths, A. 2007. Understanding corporate sustainability. *Corporate governance and sustainability:* 36-56.

Ryan-Collins, J. 2019. Beyond voluntary disclosure: why a “market-shaping” approach to financial regulation is needed to deal with the uncertainty of the transition to a more sustainable economy. SUERF Policy Note, Issue No. 61.

Sauer, A. & Wellington, F. 2005. Framing Climate Risk in Portfolio Management. *World Resources Institute–CERES: Boston, MA.*

Schmitt, A. & Spaeter, S. 2005. Improving the prevention of environmental risks with convertible bonds. *Journal of Environmental Economics and Management,* 50(3): 637-657.

Schneider, T.E. 2011. Is environmental performance a determinant of bond pricing? Evidence from the US pulp and paper and chemical industries. *Contemporary Accounting Research,* 28(5): 1537-1561.

Scholtens, B. 2017. Why finance should care about ecology. *Trends in Ecology & Evolution*, 32(7): 500-505.

Scholtens, B. & Dam, L. 2007. Banking on the Equator. Are banks that adopted the Equator Principles different from non-adopters? *World Development,* 35(8): 1307-1328.

Schwarcz, S.L. 2017. Too big to fool: Moral hazard, bailouts, and corporate responsibility. *Minnesota. Law. Review.*, 102: 761.

Sharfman, M.P. & Fernando, C.S. 2008. Environmental risk management and the cost of capital. *Strategic Management Journal,* 29(6): 569-592.

Sims, R.E., Rogner, H. & Gregory, K. 2003. Carbon emission and mitigation cost comparisons between fossil fuel, nuclear and renewable energy resources for electricity generation. *Energy Policy,* 31(13): 1315-1326.

Sinclair-Desgagne, B. & Gozlan, E. 2003. A theory of environmental risk disclosure. *Journal of Environmental Economics and Management,* 45(2): 377-393.

Solomon, J. & Maroun, W. 2012. Integrated reporting: the influence of King III on social, ethical and environmental reporting: ACCA Research Report, The Association of Chartered Certified Accountants, London.

StatsSA. 2018. Annual Financial Statistics Survey. Statistical release P0021,Pretoria, South Africa. Available online: http://www.statssa.gov.za/publications/P0021/P00212017.pdf

Stern, N.N.H. 2007. *The economics of climate change: the Stern Review.* Cambridge: Cambridge University Press.

Stiglitz, J.E. & Weiss, A. 1981. Credit rationing in markets with imperfect information. *The American Economic Review,* 71(3): 393-410.

Suto, M. & Takehara, H. 2018. “Effects of Corporate Social Performance on Default Risk: Structural Model-Based Analysis on Japanese Firms" In Sato, R & Mino, K (eds.). *Corporate Social Responsibility and Corporate Finance in Japan.* (pp. 179-199). Springer, Available at https://doi.org/10.1007/978-981-10-8986-2

Thompson, P. 1998. Bank lending and the environment: policies and opportunities. *International Journal of Bank Marketing,* 16(6): 243-252.

Travis, W.R. & Bates, B. 2014. What is climate risk management? *Climate Risk Management,* 1: 1-4.

Trouw, M., Weiler, S. & Silverstein, J. 2020. Brownfield Development: Uncertainty, Asymmetric Information, and Risk Premia. *Sustainability*, 12(5): 2046.

Trucost. 2011. Principles for Responsible Investment, United Nations Environment Program Finance Initiative. *Universal Ownership - Why Environmental Externalities matter to Institutional Investors*.

Turner, K., O'Riordan, T. & Kemp, R. 1991. “Climate change and risk management" in *Climate Change: Science, Impacts and Policy: Proceedings of the Second World Climate Conference* Cambridge University Press: Cambridge. pp. 397-408.

Ulph, A. & Valentini, L. 2004. Environmental liability and the capital structure of firms. *Resource and Energy Economics,* 26(4): 393-410.

UNEP FI & SBI (United Nations Environment Programme Finance Initiative & Sustainable Business Institute). 2011. *Advancing adaptation through climate information services - Results of a global survey on the information requirements of the financial sector*, UNEP FI & SBI.

Verweij, M., Douglas, M., Ellis, R., Engel, C., Hendriks, F., Lohmann, S., Ney, S., Rayner, S. & Thompson, M. 2006. Clumsy solutions for a complex world: the case of climate change. *Public Administration,* 84(4): 817-843.

Wanless D. 1995. *The Gilbert Lecture 1995: Banking and the Environment*. Chartered Institute of Bankers: London.

Warwick, P. & Ng, C. 2012. The ‘cost’ of climate change: how carbon emissions allowances are accounted for amongst European Union companies. *Australian Accounting Review,* 22(1): 54-67.

Weber, C., Thoma, J., Dupre, S., Fischer, R., Cummis, C. & Patel, S. 2015. *Exploring Metrics to Measure the Climate Progress of Banks*, 2 Degrees Investing Initiative, United Nations Environment Programme Finance Initiative, World Resources Institute.

Weber, O. 2005. Sustainability benchmarking of European banks and financial service organizations. *Corporate Social Responsibility and Environmental Management,* 12(2): 73-87.

Weber, O. 2012. Environmental credit risk management in banks and financial service institutions. *Business Strategy and the Environment,* 21(4): 248-263.

Weber, O. 2014. The financial sector's impact on sustainable development. *Journal of Sustainable Finance & Investment*, 4(1): 1-8. DOI: 10.1080/20430795.2014.887345

Weber, O. & Acheta, E. 2014. The Equator Principles: Ten Teenage Years of Implementation and a Search for Outcome. *CIGI Papers,* no. 24: 1-20.

Weber, O., Fenchel, M. & Scholz, R.W. 2008. Empirical analysis of the integration of environmental risks into the credit risk management process of European banks. *Business Strategy and the Environment*, 17(3): 149-159.

Weber, O., Scholz, R.W. & Michalik, G. 2010. Incorporating sustainability criteria into credit risk management. *Business strategy and the environment,* 19(1): 39-50.

Whyte, V.A., Burton, I. & International Council of Scientific Unions (eds). 1980. *Scientific Committee on Problems of the Environment (SCOPE 15) Environmental Risk Assessment*, SCOPE 15th ed. Chichester, New York, Brisbane, Toronto: John Wiley & Sons Inc.

Wiedmann, T. 2009. Carbon Footprint and Input-Output Analysis: An Introduction. *Economic Systems Research*, 21(3): 175-186.

Wilson, F. & Post, J.E. 2013. Business models for people, planet (& profits): exploring the phenomena of social business, a market-based approach to social value creation. *Small Business Economics,* 40(3): 715-737.

Winkler, H., Jooste, M. & Marquard, A. 2010. Structuring approaches to pricing carbon in energy-and trade-intensive sectors in South Africa. *Climate Policy*, 10(5): 527-542.

Winkler, H. & Marquard, A. 2009. Changing development paths: From an energy-intensive to low-carbon economy in South Africa. *Climate and Development,* 1(1): 47-65.

World Economic Forum. 2016. *Global Risks 2014.* World Economic Forum, Geneva, Switzerland.

Wright, C. & Rwabizambuga, A. 2006. Institutional pressures, corporate reputation, and voluntary codes of conduct: An examination of the equator principles. *Business and Society Review,* 111(1): 89-117.

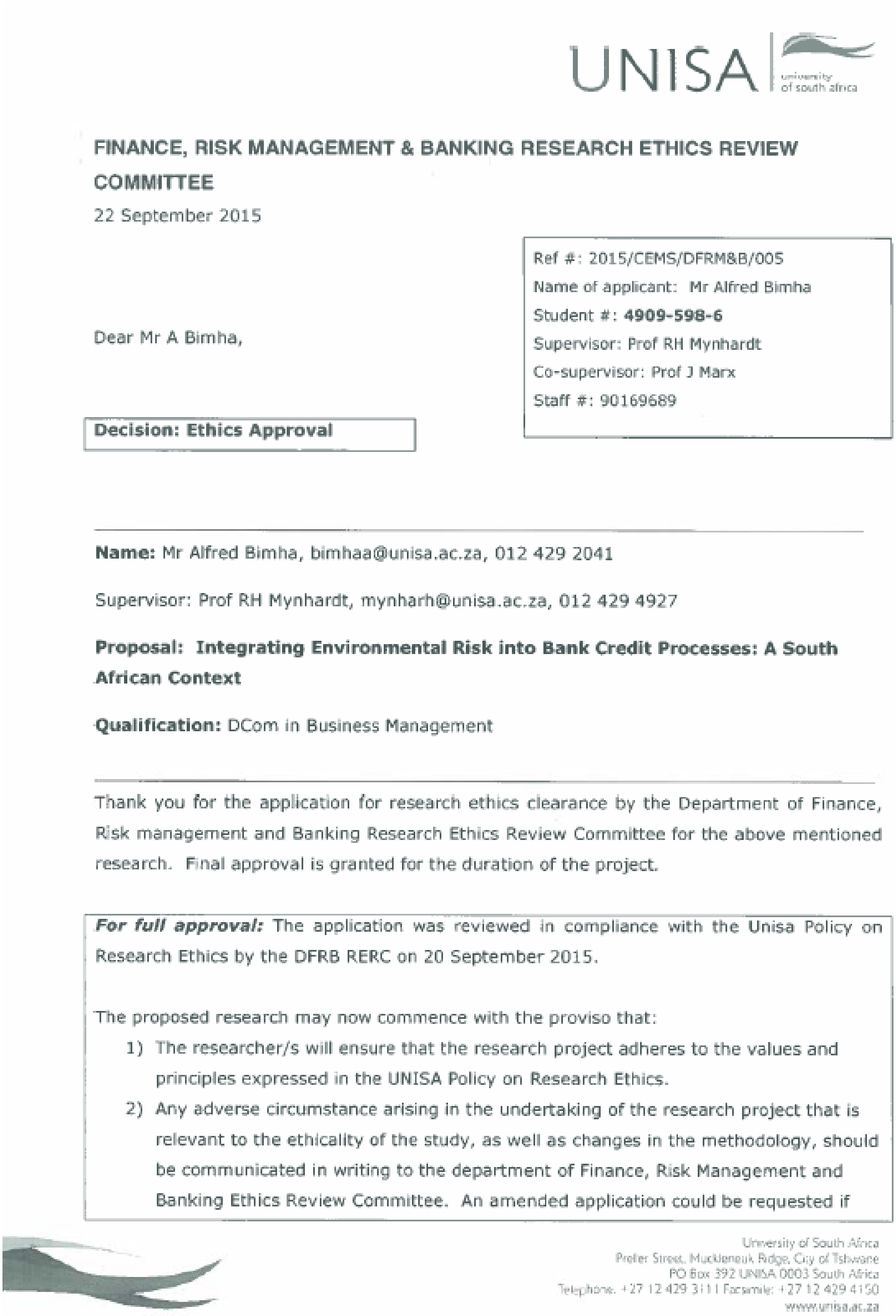
Yamin, F. 2005. *Climate change and carbon markets: a handbook of emission reduction mechanisms,* Earthscan.

Yamin, F. 2005. *The international rules on the Kyoto mechanisms. Climate change and carbon markets: A handbook of emissions reductions mechanisms*, pp.1-74. London: Earthscan.

Yohe, G.W. 2010. “Addressing Climate Change through a Risk Management Lens”, in J. Gulledge, L.J. Richardson, L. Adkins & S. Seidel (eds.). *Assessing the Benefits of Avoided Climate Change: Cost-Benefit Analysis and Beyond,* (pp. 201 – 231). Arlington, VA: Pew Center on Global Climate Change.

APPENDIX A:

ETHICAL CLEARANCE CERTIFICATE



UNISA university of south africa

FINANCE, RISK MANAGEMENT & BANKING RESEARCH ETHICS REVIEW COMMITTEE

22 September 2015

Ref #: 2015/CEMS/DFRM&B/005
Name of applicant: Mr Alfred Bimha
Student #: **4909-598-6**
Supervisor: Prof RH Mynhardt
Co-supervisor: Prof J Marx
Staff #: 90169689

Dear Mr A Bimha,

Decision: Ethics Approval

Name: Mr Alfred Bimha, bimhaa@unisa.ac.za, 012 429 2041

Supervisor: Prof RH Mynhardt, mynharh@unisa.ac.za, 012 429 4927

Proposal: Integrating Environmental Risk into Bank Credit Processes: A South African Context

Qualification: DCom in Business Management

Thank you for the application for research ethics clearance by the Department of Finance, Risk management and Banking Research Ethics Review Committee for the above mentioned research. Final approval is granted for the duration of the project.

For full approval: The application was reviewed in compliance with the Unisa Policy on Research Ethics by the DFRB RERC on 20 September 2015.

The proposed research may now commence with the proviso that:

1) The researcher/s will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2) Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study, as well as changes in the methodology, should be communicated in writing to the department of Finance, Risk Management and Banking Ethics Review Committee. An amended application could be requested if

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

there are substantial changes from the existing proposal, especially if those changes affect any of the study-related risks for the research participants.

3) The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study.

Note:

The reference number 2015/CEMS/FRM&B/005 should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants, as well as with the [add unit/sub unit name] RERC.

Kind regards,

Mutezo
....

Ashley Mutezo
Chairperson: DFRB Research Ethics Review Committee
0124294595/muteza@unisa.ac.za

....

Prof Raphael Mpofu
Acting Executive Dean: CEMS

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

APPENDIX B:
PROXIMITY MATRICE RESULTS

ABSA Proximity Matrix- Dissimilarity Matrix

Rescaled Euclidean Distance

	L1 - EP (w)	L2 - EP ProjFin (w)	L3 - EP - ERA (w)	L4-ERA-CreEnv (w)	EP - A	EP - B	EP- C	EP - Total	Non-ProjFin	# of Enviro Words	Enviro - Words Cr
L1 - EP (w)	0.000	0.736	0.391	0.000	0.725	0.735	0.000	0.569	0.508	0.306	0.512
L2 - EP ProjFin (w)	0.736	0.000	**1.000**	0.736	0.792	0.774	0.736	0.759	**0.976**	**0.856**	0.769
L3 - EP - ERA (w)	0.391	**1.000**	0.000	0.391	0.671	0.659	0.391	0.619	0.653	0.265	0.405
L4-ERA-CreEnv (w)	0.000	0.736	0.391	0.000	0.725	0.735	0.000	0.569	0.508	0.306	0.512
EP - A	0.725	0.792	0.671	0.725	0.000	0.163	0.725	0.732	**0.995**	0.678	0.406
EP - B	0.735	0.774	0.659	0.735	0.163	0.000	0.735	0.721	**0.966**	0.658	0.337
EP- C	0.000	0.736	0.391	0.000	0.725	0.735	0.000	0.569	0.508	0.306	0.512
EP -Total	0.569	0.759	0.619	0.569	0.732	0.721	0.569	0.000	**0.984**	0.498	0.506
Non-ProjFin	0.508	**0.976**	0.653	0.508	**0.995**	**0.966**	0.508	**0.984**	0.000	0.602	0.766
# of Enviro Words	0.306	**0.856**	0.265	0.306	0.678	0.658	0.306	0.498	0.602	0.000	0.371
Enviro -Words Cr	0.512	0.769	0.405	0.512	0.406	0.337	0.512	0.506	0.766	0.371	0.000

ABSA Proximity Matrix- Similarity Matrix

Rescaled Correlation between Vectors of Values

	L1 - EP (w)	L2 - EP ProjFin (w)	L3 - EP - ERA (w)	L4-ERA-CreEnv (w)	EP - A	EP - B	EP- C	EP - Total	Non-ProjFin	# of Enviro Words	Enviro - Words Cr
L1 - EP (w)	1.000	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436
L2 - EP ProjFin (w)	0.436	1.000	0.000	0.436	0.375	0.349	0.436	0.621	0.276	0.331	0.306
L3 - EP - ERA (w)	0.436	0.000	1.000	0.436	0.758	0.829	0.436	0.564	0.412	0.870	0.891
L4-ERA-CreEnv (w)	0.436	0.436	0.436	1.000	0.436	0.436	0.436	0.436	0.436	0.436	0.436
EP - A	0.436	0.375	0.758	0.436	1.000	1.000	0.436	0.643	0.231	0.781	0.877
EP - B	0.436	0.349	0.829	0.436	1.000	1.000	0.436	0.679	0.296	0.895	0.956
EP- C	0.436	0.436	0.436	0.436	0.436	0.436	1.000	0.436	0.436	0.436	0.436
EP -Total	0.436	0.621	0.564	0.436	0.643	0.679	0.436	1.000	0.039	0.742	0.772
Non-ProjFin	0.436	0.276	0.412	0.436	0.231	0.296	0.436	0.039	1.000	0.413	0.354
# of Enviro Words	0.436	0.331	0.870	0.436	0.781	0.895	0.436	0.742	0.413	1.000	0.989
Enviro -Words Cr	0.436	0.306	0.891	0.436	0.877	0.956	0.436	0.772	0.354	0.989	1.000

FNB Proximity Matrix- Dissimilarity Matrix

	Rescaled Euclidean Distance										
	L1 - EP (w)	L2 - EP ProjFin (w)	L3 - EP - ERA (w)	L4-ERA-CreEnv (w)	EP - A	EP - B	EP- C	EP-Total	Non-ProjFin	# of Enviro Words	Enviro - Words Cr
L1 - EP (w)	0.000	0.598	0.384	0.744	0.640	0.583	0.512	0.525	0.743	0.289	0.270
L2 - EP ProjFin (w)	0.598	0.000	0.854	0.879	0.786	0.675	0.822	0.861	0.968	0.432	0.691
L3 - EP - ERA (w)	0.384	0.854	0.000	0.802	0.887	0.751	0.539	0.691	0.570	0.471	0.429
L4-ERA-CreEnv (w)	0.744	0.879	0.802	0.000	0.840	0.866	0.750	0.904	0.295	0.780	1.000
EP - A	0.640	0.786	0.887	0.840	0.000	0.588	0.479	0.434	0.931	0.926	0.874
EP - B	0.583	0.675	0.751	0.866	0.588	0.000	0.341	0.253	0.872	0.791	0.771
EP- C	0.512	0.822	0.539	0.750	0.479	0.341	0.000	0.000	0.715	0.668	0.508
EP-Total	0.525	0.861	0.691	0.904	0.434	0.253	0.000	0.000	0.882	0.765	0.575
Non-ProjFin	0.743	0.968	0.570	0.295	0.931	0.872	0.715	0.882	0.000	0.713	0.909
# of Enviro Words	0.289	0.432	0.471	0.780	0.926	0.791	0.668	0.765	0.713	0.000	0.180
Enviro -Words Cr	0.270	0.691	0.429	1.000	0.874	0.771	0.508	0.575	0.909	0.180	0.000

FNB Proximity Matrix- Similarity Matrix

	Rescaled Correlation between Vectors of Values										
	L1 - EP (w)	L2 - EP ProjFin (w)	L3 - EP - ERA (w)	L4-ERA-CreEnv (w)	EP - A	EP - B	EP- C	EP-Total	Non-ProjFin	# of Enviro Words	Enviro - Words Cr
L1 - EP (w)	1.000	0.329	0.329	0.329	0.329	0.329	0.329	0.329	0.329	0.329	0.329
L2 - EP ProjFin (w)	0.329	1.000	0.035	0.073	0.234	0.350	0.152	0.206	0.033	0.787	0.601
L3 - EP - ERA (w)	0.329	0.035	1.000	0.307	0.070	0.230	0.511	0.346	0.661	0.489	0.653
L4-ERA-CreEnv (w)	0.329	0.073	0.307	1.000	0.229	0.142	0.384	0.274	0.850	0.432	0.233
EP - A	0.329	0.234	0.070	0.229	1.000	0.526	0.670	0.772	0.176	0.000	0.287
EP - B	0.329	0.350	0.230	0.142	0.526	1.000	0.775	0.896	0.217	0.171	0.397
EP- C	0.329	0.152	0.511	0.384	0.670	0.775	1.000	1.000	0.468	0.314	0.713
EP-Total	0.329	0.206	0.346	0.274	0.772	0.896	1.000	1.000	0.339	0.188	0.578
Non-ProjFin	0.329	0.033	0.661	0.850	0.176	0.217	0.468	0.339	1.000	0.541	0.408
# of Enviro Words	0.329	0.787	0.489	0.432	0.000	0.171	0.314	0.188	0.541	1.000	0.849
Enviro -Words Cr	0.329	0.601	0.653	0.233	0.287	0.397	0.713	0.578	0.408	0.849	1.000

Nedbank Proximity Matrix- Dissimilarity Matrix

Rescaled Euclidean Distance

	L1 - EP (w)	L2 - EP ProjFin (w)	L3 - EP - ERA (w)	L4-ERA-CreEnv (w)	EP - A	EP - B	EP- C	EP-Total	Non-ProjFin	# of Enviro Words	Enviro - Words Cr
L1 - EP (w)	0.000	0.648	0.366	0.514	0.578	0.514	0.701	0.525	0.000	0.383	0.385
L2 - EP ProjFin (w)	0.648	0.000	0.907	0.868	0.659	0.734	1.000	0.835	0.648	0.624	0.953
L3 - EP - ERA (w)	0.366	0.907	0.000	0.496	0.696	0.576	0.533	0.571	0.366	0.601	0.455
L4-ERA-CreEnv (w)	0.514	0.868	0.496	0.000	0.742	0.511	0.735	0.587	0.514	0.735	0.721
EP - A	0.578	0.659	0.696	0.742	0.000	0.532	0.886	0.507	0.578	0.551	0.799
EP - B	0.514	0.734	0.576	0.511	0.532	0.000	0.650	0.212	0.514	0.611	0.759
EP- C	0.701	1.000	0.533	0.735	0.886	0.650	0.000	0.687	0.701	0.918	0.830
EP-Total	0.525	0.835	0.571	0.587	0.507	0.212	0.687	0.000	0.525	0.617	0.750
Non-ProjFin	0.000	0.648	0.366	0.514	0.578	0.514	0.701	0.525	0.000	0.383	0.385
# of Enviro Words	0.383	0.624	0.601	0.735	0.551	0.611	0.918	0.617	0.383	0.000	0.588
Enviro -Words Cr	0.385	0.953	0.455	0.721	0.799	0.759	0.830	0.750	0.385	0.588	0.000

Nedbank Proximity Matrix- Similarity Matrix

Rescaled Correlation between Vectors of Values

	L1 - EP (w)	L2 - EP ProjFin (w)	L3 - EP - ERA (w)	L4-ERA-CreEnv (w)	EP - A	EP - B	EP- C	EP-Total	Non-ProjFin	# of Enviro Words	Enviro - Words Cr
L1 - EP (w)	1.000	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453
L2 - EP ProjFin (w)	0.453	1.000	0.000	0.174	0.407	0.313	0.219	0.303	0.453	0.611	0.084
L3 - EP - ERA (w)	0.453	0.000	1.000	0.702	0.435	0.578	0.851	0.584	0.453	0.284	0.615
L4-ERA-CreEnv (w)	0.453	0.174	0.702	1.000	0.356	0.699	0.592	0.632	0.453	0.202	0.351
EP - A	0.453	0.407	0.435	0.356	1.000	0.626	0.363	0.783	0.453	0.644	0.362
EP - B	0.453	0.313	0.578	0.699	0.626	1.000	0.684	1.000	0.453	0.434	0.291
EP- C	0.453	0.219	0.851	0.592	0.363	0.684	1.000	0.661	0.453	0.183	0.453
EP-Total	0.453	0.303	0.584	0.632	0.783	1.000	0.661	1.000	0.453	0.479	0.291
Non-ProjFin	0.453	0.453	0.453	0.453	0.453	0.453	0.453	0.453	1.000	0.453	0.453
# of Enviro Words	0.453	0.611	0.284	0.202	0.644	0.434	0.183	0.479	0.453	1.000	0.400
Enviro -Words Cr	0.453	0.084	0.615	0.351	0.362	0.291	0.453	0.291	0.453	0.400	1.000

SBSA Proximity Matrix- Dissimilarity Matrix

	Rescaled Euclidean Distance										
	L1 - EP (w)	L2 - EP ProjFin (w)	L3 - EP - ERA (w)	L4-ERA-CreEnv (w)	EP - A	EP - B	EP- C	EP-Total	Non-ProjFin	# of Enviro Words	Enviro - Words Cr
L1 - EP (w)	0.000	0.311	0.171	0.457	0.342	0.306	0.342	0.042	0.437	0.047	0.000
L2 - EP ProjFin (w)	0.311	0.000	0.762	0.115	0.563	0.608	0.689	0.452	0.592	0.466	0.582
L3 - EP - ERA (w)	0.171	0.762	0.000	1.000	0.655	0.603	0.732	0.212	0.915	0.038	0.027
L4-ERA-CreEnv (w)	0.457	0.115	1.000	0.000	0.558	0.678	0.558	0.577	0.458	0.751	0.750
EP - A	0.342	0.563	0.655	0.558	0.000	0.091	0.205	0.634	0.556	0.656	0.603
EP - B	0.306	0.608	0.603	0.678	0.091	0.000	0.091	0.656	0.530	0.599	0.508
EP- C	0.342	0.689	0.732	0.558	0.205	0.091	0.000	0.634	0.341	0.705	0.511
EP-Total	0.042	0.452	0.212	0.577	0.634	0.656	0.634	0.000	0.728	0.172	0.010
Non-ProjFin	0.437	0.592	0.915	0.458	0.556	0.530	0.341	0.728	0.000	0.788	0.645
# of Enviro Words	0.047	0.466	0.038	0.751	0.656	0.599	0.705	0.172	0.788	0.000	0.076
Enviro -Words Cr	0.000	0.582	0.027	0.750	0.603	0.508	0.511	0.010	0.645	0.076	0.000

SBSA Proximity Matrix- Similarity Matrix

	Rescaled Correlation between Vectors of Values										
	L1 - EP (w)	L2 - EP ProjFin (w)	L3 - EP - ERA (w)	L4-ERA-CreEnv (w)	EP - A	EP - B	EP- C	EP-Total	Non-ProjFin	# of Enviro Words	Enviro - Words Cr
L1 - EP (w)	1.000	0.516	0.516	0.516	0.516	0.516	0.516	0.516	0.516	0.516	0.516
L2 - EP ProjFin (w)	0.516	1.000	0.222	1.000	0.364	0.362	0.140	0.570	0.311	0.946	0.261
L3 - EP - ERA (w)	0.516	0.222	1.000	0.000	0.731	0.582	0.484	0.653	0.280	0.566	0.895
L4-ERA-CreEnv (w)	0.516	1.000	0.000	1.000	0.342	0.291	0.342	0.646	0.413	0.687	0.190
EP - A	0.516	0.364	0.731	0.342	1.000	0.996	0.842	0.217	0.327	0.409	0.298
EP - B	0.516	0.362	0.582	0.291	0.996	1.000	0.996	0.094	0.529	0.309	0.412
EP- C	0.516	0.140	0.484	0.342	0.842	0.996	1.000	0.217	0.678	0.196	0.560
EP-Total	0.516	0.570	0.653	0.646	0.217	0.094	0.217	1.000	0.170	0.518	0.840
Non-ProjFin	0.516	0.311	0.280	0.413	0.327	0.529	0.678	0.170	1.000	0.390	0.488
# of Enviro Words	0.516	0.946	0.566	0.687	0.409	0.309	0.196	0.518	0.390	1.000	0.551
Enviro -Words Cr	0.516	0.261	0.895	0.190	0.298	0.412	0.560	0.840	0.488	0.551	1.000

This is a similarity matrix

APPENDIX C:

CARBON TAX AMOUNTS DERIVED FROM A SIMULATION OF THE CARBON TAX INCENTIVE REGIME

Company	2017 C-Tax Amt	2016 C-Tax Amt	2015 C-Tax Amt	2014 C-Tax Amt	2013 C-Tax Amt	2012 C-Tax Amt	2011 C-Tax Amt	2010 C-Tax Amt
Absa Group	27 963 178.95	25 222 650.26	31 566 291.10	34 026 446.96	-62 294 439.54	-61 357 247.22	27 717 143.57	28 333 568.54
AECI Ltd Ord	110 029 893.90	67 355 673.11	77 366 284.54	65 826 328.71	57 504 338.61	26 679 779.03	53 556 172.82	45 061 710.68
African Rainbow Minerals	572 478 183.47	591 321 092.89	5 664 037 327.14	12 177 757 706.14	540 199 115.17	211 329 982.30	302 259 587.09	241 048 503.08
Anglo American	33 359 501 192.41	30 837 101 073.38	38 484 891 223.87	32 206 991 285.37	33 986 778 767.32	18 564 617 805.17	1 781 027 397.68	1 604 568 000.00
Anglo American Platinum	995 244 409.65	1 011 253 475.99	881 228 518.23	893 536 052.57	839 946 640.97	644 397 869.11	562 386 907.89	536 663 636.44
AngloGold Ashanti	649 689 998.02	650 627 292.91	634 162 970.93	526 407 055.44	488 154 443.85	430 331 267.01	453 850 974.72	448 512 000.00
Barloworld	45 171 178.38	43 815 903.25	39 590 724.42	37 077 258.77	27 845 466.18	24 069 181.10	15 738 136.40	17 336 676.00
BHP Billiton	81 671 371 794.23	45 057 098 394.58	50 245 731 097.93	44 393 828 354.86	41 043 123 198.14	35 896 229 596.14	4 309 754 230.53	4 378 682 944.48
Discovery Holdings Ltd	6 007 670.07	5 406 862.95	6 045 334.59	5 338 923.55	4 759 482.80	4 610 764.82	2 851 475.45	7 268 869.87
Clicks Group Ltd	50 978 606.68	29 266 123.29	11 940 306.91	11 836 480.41	10 512 107.01	9 865 798.80	7 204 240.74	6 943 824.00
Exxaro Resources Ltd	12 022 916 539.81	11 544 335 594.44	9 949 933 695.26	8 913 149 904.50	8 500 736 799.19	8 009 654 052.60	243 565 010.14	249 550 966.08
FirstRand Limited	32 224 221.73	32 610 150.62	28 766 745.21	25 264 735.18	25 194 606.61	23 054 565.66	24 652 306.44	16 241 270.03
Gold Fields Ltd	201 172 365.95	198 349 211.48	195 197 061.90	182 183 013.57	866 190 392.50	704 688 529.17	600 204 121.55	653 032 050.00
Growthpoint Properties	111 523 759.65	79 665 687.29	71 010 521.61	73 966 625.15	78 279 404.58	72 806 471.36	1 164 755.64	88 132.21
Hosken Consolidated Investments	74 065 793.05	64 817 527.85	58 340 958.59	507 188 864.18	32 768 794.92	461 099 090.86	15 165 275.30	27 765 036.00
Impala Platinum Holdings	526 919 732.33	468 840 754.35	390 825 661.63	452 760 948.62	439 285 358.77	413 492 499.76	374 842 635.41	350 744 013.42
Investec Ltd	7 079 221.91	7 589 951.83	6 904 109.80	3 818 690.41	4 712 128.21	4 555 926.72	2 667 028.40	2 960 924.70
Kumba Iron Ore	18 192 444 687.11	16 185 059 495.31	15 891 705 126.03	13 222 849 516.90	12 587 951 321.43	2 902 983 696.96	84 028 496.95	67 297 248.00
Massmart Holdings Ltd	65 506 672.22	53 358 980.63	51 101 227.53	45 826 307.36	29 939 040.70	33 695 805.10	23 623 438.92	20 974 248.00
Mediclinic International	29 570 716.50	26 221 249.45	24 268 069.35	23 366 551.11	19 611 267.29	17 956 808.29	14 294 645.44	12 077 154.14
MTN Group	209 909 248.58	190 977 410.15	177 088 737.74	165 724 567.83	102 442 059.63	89 182 328.78	90 054 142.21	47 161 548.00
Nampak Ltd	80 378 882.48	145 311 348.43	102 199 028.01	105 927 003.55	97 717 871.98	84 739 608.23	51 582 157.49	56 788 986.29

Nedbank Ltd	22 824 346.02	22 134 673.73	21 069 897.02	20 618 972.31	- 8 634 824.37	7 247 559.31	3 905 224.80	12 166 429.64
Northam Platinum Ltd	107 402 333.35	110 463 940.88	94 978 475.31	78 882 718.89	68 150 009.86	64 540 513.85	65 464 686.85	63 783 769.13
Old Mutual Group	7 139 517 513.83	38 028 138.41	3 801 982 573.39	3 338 415 796.90	32 948 238.09	15 819 556.99	26 065 417.35	43 602 120.00
PPC Ltd	606 638 662.25	626 760 405.14	585 758 916.24	604 095 568.49	572 246 967.14	578 299 110.29	517 350 905.02	523 233 710.88
Remgro	110 175 899.60	90 538 749.00	101 450 643.69	77 306 220.68	63 618 908.09	62 943 503.47	47 489 071.00	47 159 954.57
Sanlam	12 664 461.97	5 559 214.20	5 240 436.73	5 016 727.65	750 360.38	4 034 557.27	3 323 844.82	3 049 736.21
Sasol Limited	15 200 606 224.62	15 001 129 621.90	14 424 146 368.98	10 670 878 540.59	15 700 053 310.58	9 026 975 808.99	8 317 104 824.23	7 707 604 319.93
Standard Bank Group	31 525 974.55	33 655 096.79	31 784 397.03	35 979 421.65	34 857 839.52	14 744 638.42	12 271 725.08	10 779 293.40
Tongaat Hulett Ltd	156 253 261.83	148 566 435.62	139 726 559.77	143 572 833.94	144 562 296.45	109 465 568.22	111 468 368.89	105 296 337.23
Truworths International	11 562 933.97	10 475 969.45	8 638 268.28	17 771 595.36	6 498 759.55	6 927 977.34	5 790 348.92	5 531 004.28
Woolworths Holdings Ltd	631 844 599.60	74 487 435.51	66 991 271.01	42 559 073.86	35 685 964.70	106 699 518.74	27 180 824.20	27 394 741.28

APPENDIX D:
CARBON TAX CALCULATION FRAMEWORK AS PER CARBON TAX ACT

Below are examples from the National Treasury (2018) that have been used to calculate carbon tax in this study. The amount of tax payable will be calculated using this formula:

$$T = \{[(E - S) \times (1 - C) - D \times (1 - M)] + [P \times (1 - J)] + [F \times (1 - K]\} \times R$$

Where:

T is carbon tax payable

E is Energy combustion emissions

S is emissions sequestered by the company as verified by DEA (Department of Environmental Affairs

C is the sum of the allowable tax-free thresholds related to combustion

D is diesel and petrol emissions

M is the sum of allowable tax-free thresholds related to diesel and petrol emissions

P is the process emissions

J is the sum of the allowable tax-free thresholds related to process emissions

F is fugitive emissions

K is the sum of the allowable tax-free thresholds related to fugitive emissions

R is the carbon tax rate

Table D1: Explanation of the Carbon Tax-Free Allowances

<table>
<tr><th>Tax-Free Allowance</th><th colspan="2">Description of how it will be applied as stated in the Carbon Tax Bill (2015)</th></tr>
<tr><td>Basic tax-free allowance for fossil fuel combustion emissions – Section 7</td><td colspan="2">All entities that generate emissions from energy combustion will be allocated a basic, percentage-based, tax-free threshold on actual energy combustion emissions of 60%, below which the tax will not be payable.</td></tr>
<tr><td>Basic tax-free allowance for industrial process emissions – Section 8</td><td colspan="2">Emissions from chemical processes that occur in fixed stoichiometric ratios have limited potential for mitigation over the short term. Examples are coal gasification, crude oil cracking, production of cement, iron, steel, glass, ceramic and certain chemicals, such as calcium carbide and titanium dioxide. A higher tax-free basic percentage-based threshold is therefore provided for these emissions compared to energy combustion emissions. A basic percentage-based threshold on actual industrial process and product use emissions of 70% are applied, below which the tax will not be payable.</td></tr>
<tr><td>Allowance in respect of fugitive emissions – Section 9</td><td colspan="2">An additional tax-free allowance of 10% will be provided to sectors with fugitive emissions. This allowance is provided due to the limited potential for mitigation of fugitive emissions over the short term.</td></tr>
<tr><td rowspan="3">Trade exposure allowance – Section 10</td><td rowspan="3">This section deals with the allocation of a tax-free allowance to entities that are exposed to trade and international competitiveness. Potential</td><td>Trade-exposed, tax-free threshold relief</td></tr>
<tr><td>Exports</td></tr>
<tr><td>0.4</td></tr>
</table>

<table>
<tr><td rowspan="10"></td><td rowspan="10">adverse impacts on industry competitiveness are addressed by providing an additional maximum of 10% tax-free trade exposure allowance for energy-intensive and trade intensive sectors (EITI). Trade-intensive industries can be defined as those industries in which exports are more than 40% of their domestic sales. This tax-free allowance will be structured as graduated relief. Firms will use their exports as a percentage of sales as an indication of their trade intensity. The additional percentage of relief (tax-free threshold) will be:
$Y2 = 0.4 \times (E)$
where E = the value of exports expressed as a percentage of sales (it must be greater than 5%), up to a maximum of 10%, as indicated in the adjacent columns.</td><td>% relief (Y2)</td><td>% of Sales</td></tr>
<tr><td>0</td><td>Below 5</td></tr>
<tr><td>2</td><td>5</td></tr>
<tr><td>4</td><td>10</td></tr>
<tr><td>6</td><td>15</td></tr>
<tr><td>7.2</td><td>18</td></tr>
<tr><td>8</td><td>20</td></tr>
<tr><td>10</td><td>25</td></tr>
<tr><td>10</td><td>30</td></tr>
<tr><td>10</td><td>35</td></tr>
<tr><td>Performance Allowance (Z-factor): Section 11</td><td colspan="3">This section deals with the allocation of a tax-free allowance to entities that have proactively implemented GHG mitigation measures.
An additional tax-free allowance of 5%, based on the Z-factor formula, is available to reward all companies that have taken voluntary actions to reduce their GHG emissions. This will be accommodated by adjusting the basic tax-free threshold of 60 or 70% by a factor (Z), calculated with reference to the agreed GHG emissions intensity benchmark (including both Scope 1 and Scope 2 emissions) for the sector or sub-sector. Necessarily, firms below the emissions intensity benchmark will be rewarded. Calculation of the Z-factor and application of GHG emissions intensity benchmarks for different industrial sectors or sub-sectors will be specified in the regulation. The development of this regulation will be done based on inputs received from different industry associations or companies.
The Z factor could be stated conceptually as the ratio of the emissions intensity of the firms relative to a ‘benchmark emissions intensity’ and a simple representation in the following formula might help those mathematically inclined:
$$z = \frac{EI_{firm}}{EI_{sector\ benchmark}}$$</td></tr>
<tr><td>Carbon budget system allowance: Section 12</td><td colspan="3">In recognition of the carbon budgets process being developed by DEA, an additional 5% allowance, to companies participating in phase 1 of the carbon budget system, will be provided.</td></tr>
<tr><td>Offset allowance: Section 13</td><td colspan="3">This section deals with tax-free allowances for entities that would like to purchase carbon offsets to reduce their tax liability. Carbon offsets are proposed to provide entities with additional flexibility to reduce their GHG emissions. Carbon offsets can be used by firms to reduce their carbon tax liability by 5 or 10% of their total emissions. Work is currently underway to finalise Regulations on the specifics of the proposed carbon offset mechanism.</td></tr>
</table>

Source: Adapted National Treasury (RSA), Draft Explanatory Memorandum for the Carbon Tax Bill (2015)

APPENDIX E:
CARBON RISK ANALYSIS RESULTS

Table E1: Long Term Loans Carbon Intensity (Ci) and Carbon Dependency (Cd) Results by Company and Sector – 2010 to 2017

Company	Sector	2017 Ci	2016 Ci	2015 Ci	2014 Ci	2013 Ci	2012 Ci	2011 Ci	2010 Ci	2017 Cd	2016 Cd	2015 Cd	2014 Cd	2013 Cd	2012 Cd	2011 Cd	2010 Cd
Clicks Group Ltd	Consumer Discretionary	0.057	0.053	0.136	0.302	0.277	0.300	0.236	0.000	93%	256%	221%	92%	109%	79%	0%	0%
Truworths International	Consumer Discretionary	0.025	0.022	0.000	0.000	0.000	0.000	0.000	0.000	89%	0%	0%	0%	0%	0%	0%	0%
Woolworths Holdings Ltd	Consumer Discretionary	0.403	0.039	0.039	0.646	0.513	53.154	0.286	0.280	10%	99%	1659%	79%	10364%	1%	98%	0%
Massmart Holdings Ltd	Consumer Staples	0.166	0.127	0.204	0.160	0.172	0.403	0.304	0.360	77%	161%	78%	107%	235%	75%	118%	0%
Tongaat Hulett Ltd	Consumer Staples	0.229	0.262	0.235	0.238	0.298	0.416	0.428	0.450	114%	90%	101%	125%	140%	103%	105%	0%
Sasol Limited	Energy	1.466	1.414	3.576	4.982	8.541	15.776	3.712	3.752	96%	253%	139%	171%	185%	24%	101%	0%
Absa Group	Financials	0.002	0.002	0.002	0.006	0.004	0.011	0.014	0.014	95%	138%	267%	65%	291%	122%	102%	0%
Discovery Holdings Ltd	Financials	0.000	0.000	0.000	0.000	0.000	0.000	1814.053	6.039	0%	0%	0%	0%	0%	0%	0%	0%
FirstRand Limited	Financials	0.001	0.001	0.001	0.002	0.002	0.003	0.004	0.002	107%	94%	195%	110%	108%	152%	61%	0%
Growthpoint Properties	Financials	0.022	0.019	0.022	0.032	0.015	0.017	0.000	0.000	86%	117%	146%	45%	117%	0%	178%	0%
Hosken Consolidated Investments	Financials	0.056	0.058	0.054	2.653	0.567	6.226	0.475	0.117	103%	93%	4930%	21%	1099%	8%	25%	0%
Investec Ltd	Financials	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	45%	93%	30%	270%	130%	64%	180%	0%
Nedbank Ltd	Financials	0.004	0.004	0.005	0.006	0.007	0.007	0.006	0.005	102%	115%	131%	110%	106%	79%	84%	0%
Old Mutual Group	Financials	3.114	0.007	0.315	0.333	0.006	0.007	0.001	0.001	0%	4504%	105%	2%	101%	16%	72%	0%

Remgro	Financials	0.061	0.049	0.289	1.904	0.125	7.426	1.594	1.839	81%	586%	658%	7%	5929%	21%	115%	0%
Sanlam	Financials	0.020	0.011	0.012	0.000	0.000	0.000	0.000	0.000	54%	112%	1%	183%	149%	101%	47%	0%
Standard Bank Group	Financials	0.012	0.013	0.012	0.003	0.003	0.000	0.000	0.000	107%	94%	23%	108%	16%	105%	97%	0%
Mediclinic International	Health Care	0.007	0.007	0.007	0.008	0.008	0.007	0.007	0.007	105%	103%	105%	103%	85%	108%	96%	0%
Barloworld	Industrials	0.051	0.047	0.041	0.052	0.040	0.034	0.030	0.040	93%	88%	126%	77%	83%	88%	135%	0%
AECI Ltd Ord	Materials	0.684	0.327	0.921	0.380	0.461	0.462	0.350	0.420	48%	282%	41%	121%	100%	76%	120%	0%
African Rainbow Minerals	Materials	1.842	0.972	16.107	38.138	1.401	0.894	1.230	1.002	53%	1657%	237%	4%	64%	138%	81%	0%
Anglo American	Materials	1.753	1.462	1.604	1.616	2.178	1.592	0.233	0.206	83%	110%	101%	135%	73%	15%	89%	0%
Anglo American Platinum	Materials	0.701	0.775	0.547	0.761	0.800	0.772	5.976	0.843	111%	71%	139%	105%	97%	774%	14%	0%
AngloGold Ashanti	Materials	0.165	0.165	0.158	0.119	0.131	0.205	0.229	0.259	100%	96%	75%	110%	157%	112%	113%	0%
BHP Billiton	Materials	1.572	0.758	1.224	1.245	1.324	1.751	0.509	0.493	48%	161%	102%	106%	132%	29%	97%	0%
Exxaro Resources Ltd	Materials	10.550	12.331	18.377	13.116	12.698	12.563	0.504	0.420	117%	149%	71%	97%	99%	4%	83%	0%
Gold Fields Ltd	Materials	0.083	0.079	0.075	0.090	0.350	0.424	0.591	0.835	96%	95%	120%	387%	121%	140%	141%	0%
Impala Platinum Holdings	Materials	0.476	0.408	0.340	0.495	0.526	0.523	1.281	1.153	86%	83%	145%	106%	99%	245%	90%	0%
Kumba Iron Ore	Materials	0.000	24.658	14.841	17.853	26.528	5.769	0.929	0.182	0%	60%	120%	149%	22%	16%	20%	0%
Nampak Ltd	Materials	0.091	0.171	0.188	0.182	0.239	0.508	0.285	0.211	187%	110%	97%	131%	212%	56%	74%	0%
Northam Platinum Ltd	Materials	1.251	1.158	18.031	0.384	0.408	4.384	3.992	4.923	93%	1557%	2%	106%	1075%	91%	123%	0%
PPC Ltd	Materials	1.208	0.990	0.667	0.859	1.453	2.026	2.171	2.395	82%	67%	129%	169%	139%	107%	110%	0%
MTN Group	Telecommunication Services	0.023	0.024	0.029	0.039	0.030	0.044	0.048	0.023	104%	123%	132%	78%	146%	109%	47%	0%

Table E2: Short Term Loans Carbon Intensity(Ci) and Carbon Dependency (Cd) Results by Company and Sector

Company	Sector	2017 Ci	2016 Ci	2015 Ci	2014 Ci	2013 Ci	2012 Ci	2011 Ci	2010 Ci	2017 Cd	2016 Cd	2015 Cd	2014 Cd	2013 Cd	2012 Cd	2011 Cd	2010 Cd
Clicks Group Ltd	Consumer Discretionary	1.2160	4.0583	1.7505	0.8276	0.5102	60.0240	47.1620	3.5719	334%	43%	47%	62%	11764%	79%	8%	0%
Truworths International	Consumer Discretionary	0.6272	0.2432	3.4952	9.0640	3.0914	3.2902	1.7972	1.7155	39%	1437%	259%	34%	106%	55%	95%	0%
Woolworths Holdings Ltd	Consumer Discretionary	4.1206	2.8580	1.8266	0.0500	2.3479	2.5263	3.9096	0.3343	69%	64%	3%	4696%	108%	155%	9%	0
Massmart Holdings Ltd	Consumer Staples	0.4322	0.4470	0.3309	0.3225	0.2525	0.4060	0.2057	0.9022	103%	74%	97%	78%	161%	51%	439%	0%
Tongaat Hulett Ltd	Consumer Staples	0.3723	0.3228	0.6906	0.8819	0.5460	0.3001	3.7328	2.2436	87%	214%	128%	62%	55%	1244%	60%	0%
Sasol Limited	Energy	8.7269	32.5706	25.2367	22.0623	45.8096	15.7662	28.5860	32.8820	373%	77%	87%	208%	34%	181%	115%	0%
Absa Group	Financials	0.0003	0.0003	0.0004	0.0005	0.0006	0.0006	0.0007	0.0007	100%	122%	118%	110%	104%	115%	105%	0%
Discovery Holdings Ltd	Financials	0.0000	0.0000	0.0000	0.0000	0.1347	0.2229	0.0910	0.7973	0%	0%	0%	0%	165%	41%	876%	0%
FirstRand Limited	Financials	0.0004	0.0005	0.0005	0.0004	0.0004	0.0005	0.0006	0.0003	119%	94%	89%	108%	112%	122%	57%	0%
Growthpoint Properties	Financials	0.1870	0.1435	0.1073	0.1541	0.4031	0.5423	0.0002	0.0005	77%	75%	144%	262%	135%	0%	204%	0%
Hosken Consolidated Investments	Financials	0.0851	0.0947	0.0930	2.1728	0.3020	3.9059	0.4355	0.1393	111%	98%	2337%	14%	1293%	11%	32%	0%
Investec Ltd	Financials	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	125%	101%	63%	158%	125%	55%	115%	0%
Nedbank Ltd	Financials	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004	0.0003	0.0003	105%	104%	115%	108%	108%	81%	107%	0%
Old Mutual Group	Financials	4.7263	0.0007	0.0614	0.0182	0.0005	0.0005	0.0006	0.0005	0%	8458%	30%	3%	114%	118%	78%	0%
Remgro	Financials	2.0915	0.5296	2.7811	0.1777	1.9814	2.7360	69.4282	10.3639	25%	525%	6%	1115%	138%	2538%	15%	0%
Sanlam	Financials	0.1336	0.0325	0.0033	0.0039	0.0003	0.0003	0.0003	0.0038	24%	10%	119%	7%	98%	110%	1288%	0%

Standard Bank Group	Financials	0.0002	0.0003	0.0003	0.0004	0.0005	0.0002	0.0002	0.0002	117%	101%	132%	135%	40%	86%	106%	0%
Mediclinic International	Health Care	0.1951	0.0346	0.1683	0.1319	0.1816	0.1042	0.0965	0.6777	18%	486%	78%	138%	57%	93%	703%	0%
Barloworld	Industrials	0.1877	0.1479	0.0862	0.0821	0.0990	0.0923	0.1172	0.0767	79%	58%	95%	121%	93%	127%	65%	0%
AECI Ltd Ord	Materials	1.1399	2.2045	0.2330	0.8775	0.2690	0.3323	0.3710	0.3480	193%	11%	377%	31%	124%	112%	94%	0%
African Rainbow Minerals	Materials	4.8721	2.9377	29.4993	85.2986	6.6018	1.9394	3.9283	3.1191	60%	1004%	289%	8%	29%	203%	79%	0%
Anglo American	Materials	13.7765	9.2013	15.8701	16.8923	16.2641	8.3621	2.3368	1.6153	67%	172%	106%	96%	51%	28%	69%	0%
Anglo American Platinum	Materials	3.9315	2.2432	3.0075	1.1311	2.3887	1.3493	1.0788	53.1436	57%	134%	38%	211%	56%	80%	4926%	0%
AngloGold Ashanti	Materials	9.7052	10.4108	4.1728	1.8711	1.7106	0.6506	18.3477	5.2731	107%	40%	45%	91%	38%	2820%	29%	0%
BHP Billiton	Materials	37.0256	5.1770	9.9362	8.8238	7.4569	12.2993	1.7917	3.0570	14%	192%	89%	85%	165%	15%	171%	0%
Exxaro Resources Ltd	Materials	181.1043	19.3405	86.7354	2164.9902	1369.3068	14701.2276	1.9599	2.0877	11%	448%	2496%	63%	1074%	0%	107%	0%
Gold Fields Ltd	Materials	0.6784	0.6340	2.2634	1.0995	5.3497	19.3628	1.4711	3.6249	93%	357%	49%	487%	362%	8%	246%	0%
Impala Platinum Holdings	Materials	3.4700	6.0553	4.1762	5.8994	3.5470	5.2184	25.6457	12.0381	175%	69%	141%	60%	147%	491%	47%	0%
Kumba Iron Ore	Materials	0.0000	0.0000	579.1717	19.0375	174.3966	9.9782	0.2613	23.3671	0%	0%	3%	916%	6%	3%	8943%	0%
Nampak Ltd	Materials	0.1973	0.7999	0.1922	0.3720	0.3379	0.5083	17.1057	1.4152	405%	24%	194%	91%	150%	3365%	8%	0%
Northam Platinum Ltd	Materials	62.4419	60.9545	0.5022	8.6137	2.2952	259.7634	0.0000	1.2321	98%	1%	1715%	27%	11318%	0%	0%	0%
PPC Ltd	Materials	1.9685	1.0019	2.8763	10.4496	8.6155	6.0200	6.2831	6.2100	51%	287%	363%	82%	70%	104%	99%	0%
MTN Group	Telecommunication Services	0.1758	0.0810	0.0680	0.1103	0.0890	0.0876	0.1117	0.0422	46%	84%	162%	81%	98%	128%	38%	0%

Table E3: Operating Expenditures Carbon Intensity (Ci) and Carbon Dependency (Cd) Results by Company and Sector

Company	Sector	2017 Ci	2016 Ci	2015 Ci	2014 Ci	2013 Ci	2012 Ci	2011 Ci	2010 Ci	2017 Cd	2016 Cd	2015 Cd	2014 Cd	2013 Cd	2012 Cd	2011 Cd	2010 Cd
Clicks Group Ltd	Consumer Discretionary	0.011	0.007	0.003	0.004	0.006	0.007	0.007	0.009	65%	48%	128%	125%	131%	90%	131%	0%
Truworths International	Consumer Discretionary	0.006	0.006	0.010	0.023	0.010	0.013	0.013	0.014	110%	151%	241%	45%	125%	100%	110%	0%
Woolworths Holdings Ltd	Consumer Discretionary	0.078	0.010	0.011	0.011	0.011	0.051	0.016	0.016	13%	110%	100%	101%	450%	31%	105%	0%
Massmart Holdings Ltd	Consumer Staples	0.007	0.006	0.007	0.006	0.005	0.006	0.006	0.006	93%	110%	91%	77%	130%	94%	106%	0%
Tongaat Hulett Ltd	Consumer Staples	0.082	0.086	0.088	0.099	0.112	1.157	0.144	0.114	105%	102%	112%	113%	1037%	12%	79%	0%
Sasol Limited	Energy	0.743	0.741	0.771	0.523	1.096	0.684	0.829	0.901	100%	104%	68%	210%	62%	121%	109%	0%
Absa Group	Financials	0.006	0.006	0.008	0.010	0.010	0.012	0.015	0.016	104%	134%	121%	103%	110%	133%	102%	0%
Discovery Holdings Ltd	Financials	0.002	0.002	0.002	0.003	0.003	0.003	0.002	0.008	105%	108%	108%	104%	118%	79%	308%	0%
FirstRand Limited	Financials	0.007	0.008	0.008	0.009	0.011	0.011	0.015	0.011	115%	99%	116%	121%	107%	134%	71%	0%
Growthpoint Properties	Financials	0.313	0.265	0.329	0.424	0.547	0.634	0.001	0.001	84%	124%	129%	129%	116%	0%	155%	0%
Hosken Consolidated Investments	Financials	0.038	0.039	0.034	0.693	0.077	0.875	0.065	0.074	101%	89%	2028%	11%	1143%	7%	114%	0%
Investec Ltd	Financials	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	104%	112%	75%	176%	144%	68%	125%	0%
Nedbank Ltd	Financials	0.007	0.008	0.008	0.009	0.010	0.011	0.009	0.010	109%	108%	111%	112%	105%	84%	115%	0%
Old Mutual Group	Financials	0.353	0.006	0.153	0.132	0.003	0.005	0.003	0.003	2%	2738%	87%	2%	203%	61%	91%	0%
Remgro	Financials	0.037	0.032	0.043	0.035	0.045	0.061	0.044	0.059	86%	132%	81%	130%	136%	72%	136%	0%
Sanlam	Financials	0.003	0.001	0.002	0.003	0.003	0.003	0.003	0.006	51%	178%	112%	109%	110%	102%	176%	0%
Standard Bank Group	Financials	0.004	0.004	0.005	0.006	0.007	0.003	0.004	0.003	117%	107%	133%	116%	47%	102%	91%	0%
Mediclinic International	Health Care	0.006	0.006	0.008	0.009	0.010	0.011	0.012	0.012	107%	124%	120%	111%	108%	108%	101%	0%
Barloworld	Industrials	0.008	0.008	0.008	0.007	0.006	0.006	0.005	0.006	94%	101%	97%	76%	106%	85%	127%	0%

AECI Ltd Ord	Materials	0.045	0.030	0.037	0.036	0.035	0.043	0.044	0.045	68%	122%	98%	96%	122%	103%	104%	0%
African Rainbow Minerals	Materials	0.424	0.469	4.918	11.076	0.323	0.161	0.303	0.280	111%	1050%	225%	3%	50%	188%	92%	0%
Anglo American	Materials	0.899	0.843	1.065	1.015	1.273	0.796	0.130	0.135	94%	126%	95%	125%	63%	16%	104%	0%
Anglo American Platinum	Materials	0.120	0.131	0.123	0.136	0.164	0.149	0.132	0.147	109%	93%	111%	121%	91%	88%	111%	0%
AngloGold Ashanti	Materials	1.146	1.443	0.114	0.089	0.059	0.110	0.094	0.117	126%	8%	78%	67%	185%	86%	125%	0%
BHP Billiton	Materials	1.668	0.679	0.925	1.034	1.074	0.879	0.156	0.201	41%	136%	112%	104%	82%	18%	129%	0%
Exxaro Resources Ltd	Materials	4.396	4.869	5.841	4.625	5.814	6.772	0.136	0.211	111%	120%	79%	126%	116%	2%	155%	0%
Gold Fields Ltd	Materials	0.061	0.058	0.064	0.068	3.073	0.375	0.458	0.269	95%	111%	106%	4494%	12%	122%	59%	0%
Impala Platinum Holdings	Materials	0.078	0.092	0.078	0.124	0.134	0.172	0.161	0.197	119%	84%	160%	108%	129%	93%	122%	0%
Kumba Iron Ore	Materials	4.683	4.460	3.545	3.749	4.113	1.223	0.050	0.052	95%	79%	106%	110%	30%	4%	102%	0%
Nampak Ltd	Materials	0.031	0.062	0.051	0.064	0.052	0.055	0.049	0.041	203%	81%	127%	81%	105%	90%	82%	0%
Northam Platinum Ltd	Materials	0.145	0.157	0.159	0.167	0.208	0.231	0.281	0.285	108%	101%	105%	124%	111%	122%	101%	0%
PPC Ltd	Materials	0.511	0.604	0.592	0.676	0.786	1.004	1.044	1.216	118%	98%	114%	116%	128%	104%	117%	0%
MTN Group	Telecommunication Services	0.022	0.016	0.019	0.021	0.014	0.014	0.017	0.007	75%	118%	106%	66%	101%	122%	42%	0%

Table E4: Sales Carbon Intensity (Ci) and Carbon Dependency (Cd) Results by Company and Sector

Company	Sector	2017 Ci	2016 Ci	2015 Ci	2014 Ci	2013 Ci	2012 Ci	2011 Ci	2010 Ci	2017 Cd	2016 Cd	2015 Cd	2014 Cd	2013 Cd	2012 Cd	2011 Cd	2010 Cd
Clicks Group Ltd	Consumer Discretionary	0.0139	0.0086	0.0044	0.0055	0.0066	0.0082	0.0076	0.0123	62%	51%	126%	121%	124%	92%	162%	0%
Truworths International	Consumer Discretionary	0.0050	0.0053	0.0077	0.0182	0.0079	0.0097	0.0096	0.0109	107%	145%	235%	43%	122%	99%	113%	0%
Woolworths Holdings Ltd	Consumer Discretionary	0.0726	0.0095	0.0103	0.0101	0.0103	0.0465	0.0144	0.0152	13%	109%	99%	101%	453%	31%	106%	0%
Massmart Holdings Ltd	Consumer Staples	0.0067	0.0063	0.0069	0.0063	0.0048	0.0060	0.0054	0.0061	94%	109%	91%	77%	125%	90%	113%	0%
Tongaat Hulett Ltd	Consumer Staples	0.0635	0.0690	0.0686	0.0726	0.0871	0.0851	0.1157	0.0985	109%	99%	106%	120%	98%	136%	85%	0%
Sasol Limited	Energy	0.5356	0.5633	0.5242	0.3768	0.6692	0.4479	0.5264	0.5834	105%	93%	72%	178%	67%	118%	111%	0%
Absa Group	Financials	0.0036	0.0035	0.0048	0.0058	0.0059	0.0078	0.0100	0.0106	97%	136%	122%	102%	132%	128%	106%	0%
Discovery Holdings Ltd	Financials	0.0021	0.0022	0.0024	0.0026	0.0026	0.0031	0.0024	0.0075	105%	108%	108%	103%	118%	78%	309%	0%
FirstRand Limited	Financials	0.0038	0.0044	0.0053	0.0055	0.0069	0.0008	0.0094	0.0080	117%	120%	105%	125%	11%	1251%	85%	0%
Growthpoint Properties	Financials	0.0776	0.0631	0.0809	0.1060	0.1394	0.1533	0.0002	0.0003	81%	128%	131%	132%	110%	0%	153%	0%
Hosken Consolidated Investments	Financials	0.0275	0.0400	0.0473	0.5718	0.0629	0.7025	0.0390	0.0394	145%	118%	1209%	11%	1118%	6%	101%	0%
Investec Ltd	Financials	0.0003	0.0004	0.0004	0.0003	0.0005	0.0007	0.0005	0.0006	101%	113%	79%	169%	139%	64%	119%	0%
Nedbank Ltd	Financials	0.0043	0.0047	0.0052	0.0057	0.0065	0.0069	0.0059	0.0071	110%	110%	109%	113%	106%	87%	120%	0%
Old Mutual Group	Financials	0.3386	0.0053	0.1394	0.1210	0.0023	0.0023	0.0060	0.0027	2%	2614%	87%	2%	99%	259%	45%	0%
Remgro	Financials	0.0364	0.0317	0.0401	0.0337	0.0440	0.0576	0.0418	0.0551	87%	126%	84%	130%	131%	73%	132%	0%
Sanlam	Financials	0.0006	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004	0.0003	47%	129%	119%	105%	101%	90%	86%	0%
Standard Bank Group	Financials	0.0022	0.0027	0.0052	0.0068	0.0080	0.0038	0.0040	0.0023	120%	194%	129%	118%	48%	105%	57%	0%
Mediclinic International	Health Care	0.0049	0.0052	0.0060	0.0071	0.0079	0.0086	0.0091	0.0097	106%	115%	118%	112%	108%	106%	106%	0%
Barloworld	Industrials	0.0058	0.0059	0.0060	0.0056	0.0045	0.0048	0.0040	0.0049	101%	101%	93%	81%	106%	85%	121%	0%
AECI Ltd Ord	Materials	0.0407	0.0281	0.0335	0.0328	0.0318	0.0387	0.0394	0.0412	69%	119%	98%	97%	122%	102%	105%	0%

African Rainbow Minerals	Materials	0.4521	0.4636	4.3661	9.2256	0.2325	0.1130	0.1931	0.2162	103%	942%	211%	3%	49%	171%	112%	0%
Anglo American	Materials	0.7092	0.7773	1.2794	1.0096	1.1685	0.8385	0.0902	0.0933	110%	165%	79%	116%	72%	11%	103%	0%
Anglo American Platinum	Materials	0.1035	0.1188	0.1117	0.1293	0.1436	0.1450	0.1090	0.1204	115%	94%	116%	111%	101%	75%	110%	0%
AngloGold Ashanti	Materials	0.0850	0.0838	0.0968	0.0780	0.0842	0.0852	0.0939	0.1173	99%	115%	81%	108%	101%	110%	125%	0%
BHP Billiton	Materials	1.2002	0.7793	0.6547	0.5617	0.5994	0.6013	0.0879	0.1269	65%	84%	86%	107%	100%	15%	144%	0%
Exxaro Resources Ltd	Materials	3.3898	3.8242	4.2729	4.4881	5.4498	4.5594	0.1225	0.1621	113%	112%	105%	121%	84%	3%	132%	0%
Gold Fields Ltd	Materials	0.0467	0.0434	0.0522	0.0557	0.2285	0.1460	0.1562	0.1284	93%	120%	107%	411%	64%	107%	82%	0%
Impala Platinum Holdings	Materials	0.1025	0.0950	0.0913	0.1256	0.1255	0.1375	0.1115	0.1424	93%	96%	138%	100%	110%	81%	128%	0%
Kumba Iron Ore	Materials	2.5230	2.7634	3.2855	2.2371	1.9694	0.5865	0.0172	0.0181	110%	119%	68%	88%	30%	3%	105%	0%
Nampak Ltd	Materials	0.0291	0.0553	0.0383	0.0414	0.0437	0.0459	0.0418	0.0319	190%	69%	108%	105%	105%	91%	76%	0%
Northam Platinum Ltd	Materials	0.1222	0.1320	0.1194	0.1190	0.1404	0.1713	0.1816	0.1676	108%	90%	100%	118%	122%	106%	92%	0%
PPC Ltd	Materials	0.4453	1.0143	0.4854	0.5457	0.6050	0.7490	0.7824	0.8384	228%	48%	112%	111%	124%	104%	107%	0%
MTN Group	Telecommunication Services	0.0121	0.0107	0.0104	0.0104	0.0076	0.0070	0.0092	0.0049	89%	97%	99%	74%	92%	131%	53%	0%

Table E5: Current Liabilities Carbon Intensity (Ci) and Carbon Dependency (Cd) Results by Company and Sector

Company	Sector	2017 Ci	2016 Ci	2015 Ci	2014 Ci	2013 Ci	2012 Ci	2011 Ci	2010 Ci	2017 Cd	2016 Cd	2015 Cd	2014 Cd	2013 Cd	2012 Cd	2011 Cd	2010 Cd
Clicks Group Ltd	Consumer Discretionary	0.0071	0.0046	0.0056	0.0041	0.0043	0.0102	0.0181	0.0204	64%	122%	74%	103%	239%	177%	113%	0%
Truworths International	Consumer Discretionary	0.0456	0.0301	0.0598	0.1414	0.0809	0.1020	0.0690	0.0802	66%	199%	236%	57%	126%	68%	116%	0%
Woolworths Holdings Ltd	Consumer Discretionary	0.4622	0.0560	0.0639	0.0300	0.0826	0.3093	0.1046	0.0850	12%	114%	47%	275%	374%	34%	81%	0%
Massmart Holdings Ltd	Consumer Staples	0.0284	0.0274	0.0266	0.0243	0.0187	0.0233	0.0260	0.0297	96%	97%	91%	77%	125%	112%	114%	0%
Tongaat Hulett Ltd	Consumer Staples	0.1643	0.1602	0.2297	0.2732	0.2642	0.1947	0.2299	0.2602	97%	143%	119%	97%	74%	118%	113%	0%
Sasol Limited	Energy	1.7699	2.3417	2.3490	1.9588	3.3579	2.4571	2.7492	3.1187	132%	100%	83%	171%	73%	112%	113%	0%
Absa Group	Financials	0.0003	0.0003	0.0004	0.0005	0.0005	0.0005	0.0006	0.0006	102%	116%	132%	103%	104%	115%	106%	0%
Discovery Holdings Ltd	Financials	0.0093	0.0096	0.0100	0.0113	0.0121	0.0153	0.0114	0.0375	103%	104%	113%	107%	126%	74%	329%	0%
FirstRand Limited	Financials	0.0004	0.0004	0.0005	0.0004	0.0004	0.0005	0.0005	0.0004	117%	104%	83%	116%	112%	107%	74%	0%
Growthpoint Properties	Financials	0.1179	0.0948	0.0800	0.1138	0.1692	0.1878	0.0001	0.0003	80%	84%	142%	149%	111%	0%	184%	0%
Hosken Consolidated Investments	Financials	0.0564	0.0592	0.0593	1.2133	0.1491	1.9650	0.1584	0.0778	105%	100%	2046%	12%	1318%	8%	49%	0%
Investec Ltd	Financials	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	121%	103%	63%	132%	137%	68%	133%	0%
Nedbank Ltd	Financials	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004	0.0003	0.0003	104%	104%	118%	108%	108%	81%	106%	0%
Old Mutual Group	Financials	0.1152	0.0002	0.0181	0.0175	0.0014	0.0012	0.0012	0.0009	0%	7526%	96%	8%	85%	108%	70%	0%
Remgro	Financials	0.1909	0.1328	0.0768	0.0978	0.1811	0.2792	0.2872	0.2656	70%	58%	127%	185%	154%	103%	93%	0%
Sanlam	Financials	0.0022	0.0013	0.0002	0.0010	0.0008	0.0010	0.0010	0.0009	58%	14%	601%	73%	137%	98%	90%	0%
Standard Bank Group	Financials	0.0002	0.0002	0.0002	0.0004	0.0004	0.0002	0.0002	0.0002	116%	97%	172%	111%	43%	84%	103%	0%

Mediclinic International	Health Care	0.0228	0.0139	0.0265	0.0261	0.0321	0.0324	0.0336	0.0583	61%	190%	98%	123%	101%	104%	173%	0%
Barloworld	Industrials	0.0279	0.0285	0.0235	0.0215	0.0195	0.0205	0.0183	0.0226	102%	82%	91%	91%	105%	89%	123%	0%
AECI Ltd Ord	Materials	0.1504	0.1174	0.0899	0.1292	0.0955	0.1201	0.1161	0.1306	78%	77%	144%	74%	126%	97%	112%	0%
African Rainbow Minerals	Materials	1.4356	1.0969	12.4787	27.3867	1.0358	0.4918	0.7695	0.6509	76%	1138%	219%	4%	47%	156%	85%	0%
Anglo American	Materials	2.5319	2.5467	4.4819	4.0630	4.1055	2.7396	0.3372	0.3310	101%	176%	91%	101%	67%	12%	98%	0%
Anglo American Platinum	Materials	0.3338	0.3931	0.5990	0.4140	0.4448	0.4121	0.3715	0.6194	118%	152%	69%	107%	93%	90%	167%	0%
AngloGold Ashanti	Materials	0.5059	0.4657	0.5902	0.4241	0.4033	0.2859	0.6234	0.7302	92%	127%	72%	95%	71%	218%	117%	0%
BHP Billiton	Materials	4.0427	1.9521	2.6624	2.0897	1.9411	1.9710	0.3195	0.5136	48%	136%	78%	93%	102%	16%	161%	0%
Exxaro Resources Ltd	Materials	18.7380	10.7110	16.8254	20.5041	19.1959	14.1521	0.5932	0.7035	57%	157%	122%	94%	74%	4%	119%	0%
Gold Fields Ltd	Materials	0.1538	0.1387	0.2355	0.2239	1.0859	0.3520	0.5423	0.8791	90%	170%	95%	485%	32%	154%	162%	0%
Impala Platinum Holdings	Materials	0.4291	0.4409	0.3948	0.5850	0.5848	0.6244	0.5669	0.6284	103%	90%	148%	100%	107%	91%	111%	0%
Kumba Iron Ore	Materials	22.7168	19.0953	24.0004	10.9398	19.7776	4.5096	0.1050	0.2080	84%	126%	46%	181%	23%	2%	198%	0%
Nampak Ltd	Materials	0.0718	0.1671	0.0918	0.1317	0.1363	0.1571	0.1772	0.1429	233%	55%	143%	103%	115%	113%	81%	0%
Northam Platinum Ltd	Materials	0.5196	0.6832	0.2746	0.5330	0.4020	0.5340	0.5520	0.9798	131%	40%	194%	75%	133%	103%	177%	0%
PPC Ltd	Materials	1.0669	0.7488	1.3654	2.5024	2.7434	3.1934	3.2825	3.4318	70%	182%	183%	110%	116%	103%	105%	0%
MTN Group	Telecommunication Services	0.0247	0.0205	0.0171	0.0225	0.0179	0.0172	0.0203	0.0120	83%	84%	131%	80%	96%	118%	59%	0%

Table E6: Non-Current Liabilities Carbon Intensity (Ci) and Carbon Dependency (Cd) Results by Company and Sector

Company	Sector	2017 Ci	2016 Ci	2015 Ci	2014 Ci	2013 Ci	2012 Ci	2011 Ci	2010 Ci	2017 Cd	2016 Cd	2015 Cd	2014 Cd	2013 Cd	2012 Cd	2011 Cd	2010 Cd
Clicks Group Ltd	Consumer Discretionary	0.0140	0.0110	0.0030	0.0052	0.0087	0.0070	0.0056	0.0122	79%	27%	175%	167%	80%	81%	217%	0%
Truworths International	Consumer Discretionary	0.0192	0.0162	0.4551	2.1630	0.7968	0.8819	0.8986	0.7782	85%	2803%	475%	37%	111%	102%	87%	0%
Woolworths Holdings Ltd	Consumer Discretionary	0.3192	0.0331	0.0321	0.2097	0.1895	1.1290	0.2517	0.2619	10%	97%	653%	90%	596%	22%	104%	0%
Massmart Holdings Ltd	Consumer Staples	0.1587	0.1216	0.1906	0.1513	0.1571	0.3333	0.2566	0.3254	77%	157%	79%	104%	212%	77%	127%	0%
Tongaat Hulett Ltd	Consumer Staples	0.1371	0.1417	0.1395	0.1498	0.1840	0.2185	0.2813	0.2959	103%	98%	107%	123%	119%	129%	105%	0%
Sasol Limited	Energy	0.7859	0.7811	1.3183	1.3080	2.3364	2.0797	2.3090	2.4248	99%	169%	99%	179%	89%	111%	105%	0%
Absa Group	Financials	0.0017	0.0016	0.0023	0.0060	0.0039	0.0114	0.0139	0.0141	95%	138%	267%	65%	291%	122%	102%	0%
Discovery Holdings Ltd	Financials	0.1391	0.1305	0.1699	0.1711	0.1838	0.1680	0.1301	0.3374	94%	130%	101%	107%	91%	77%	259%	0%
FirstRand Limited	Financials	0.0010	0.0010	0.0009	0.0020	0.0022	0.0023	0.0184	0.0011	108%	90%	222%	107%	104%	807%	6%	0%
Growthpoint Properties	Financials	0.0203	0.0172	0.0210	0.0304	0.0142	0.0168	0.0000	0.0000	84%	122%	145%	47%	118%	0%	178%	0%
Hosken Consolidated Investments	Financials	0.0307	0.0304	0.0407	2.0297	0.3890	4.5242	0.3371	0.0804	99%	134%	4990%	19%	1163%	7%	24%	0%
Investec Ltd	Financials	0.0004	0.0003	0.0003	0.0002	0.0003	0.0003	0.0002	0.0002	98%	93%	53%	169%	119%	60%	118%	0%
Nedbank Ltd	Financials	0.0023	0.0026	0.0025	0.0033	0.0046	0.0038	0.0030	0.0036	111%	98%	129%	142%	82%	79%	119%	0%
Old Mutual Group	Financials	0.0250	0.0014	0.0797	0.0726	0.0005	0.0005	0.0006	0.0004	5%	5828%	91%	1%	105%	113%	79%	0%
Remgro	Financials	0.0543	0.0422	0.1899	0.3480	0.0939	0.7949	0.4219	0.4304	78%	450%	183%	27%	846%	53%	102%	0%
Sanlam	Financials	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	51%	183%	61%	110%	123%	103%	92%	0%
Standard Bank Group	Financials	0.0006	0.0008	0.0008	0.0005	0.0007	0.0004	0.0004	0.0005	125%	98%	65%	136%	57%	111%	106%	0%
Mediclinic International	Health Care	0.0050	0.0050	0.0055	0.0058	0.0060	0.0057	0.0061	0.0060	99%	110%	105%	103%	96%	106%	98%	0%

Barloworld	Industrials	0.0331	0.0315	0.0309	0.0372	0.0299	0.0313	0.0277	0.0360	95%	98%	120%	80%	104%	89%	130%	0%
AECI Ltd Ord	Materials	0.6840	0.3265	0.9208	0.3801	0.4606	0.4616	0.3498	0.4202	48%	282%	41%	121%	100%	76%	120%	0%
African Rainbow Minerals	Materials	1.8422	0.9720	16.1065	38.1376	1.4014	0.8936	1.2304	0.9229	53%	1657%	237%	4%	64%	138%	75%	0%
Anglo American	Materials	1.7526	1.4624	1.6037	1.6156	2.1782	1.5918	0.2326	0.2061	83%	110%	101%	135%	73%	15%	89%	0%
Anglo American Platinum	Materials	0.3499	0.3837	0.2935	0.3257	0.3452	0.3026	0.3637	0.2822	110%	76%	111%	106%	88%	120%	78%	0%
AngloGold Ashanti	Materials	0.0974	0.0973	0.1015	0.0790	0.0883	0.1060	0.1243	0.1600	100%	104%	78%	112%	120%	117%	129%	0%
BHP Billiton	Materials	1.0707	0.5176	0.8309	0.7870	0.8653	1.0816	0.2482	0.2529	48%	161%	95%	110%	125%	23%	102%	0%
Exxaro Resources Ltd	Materials	4.0573	4.5973	5.6982	7.8192	7.8813	8.7331	0.2930	0.3840	113%	124%	137%	101%	111%	3%	131%	0%
Gold Fields Ltd	Materials	0.0556	0.0521	0.0522	0.0643	0.2577	0.2882	0.2708	0.3575	94%	100%	123%	400%	112%	94%	132%	0%
Impala Platinum Holdings	Materials	0.2443	0.1815	0.1710	0.1948	0.1918	0.2695	0.3217	0.3273	74%	94%	114%	98%	141%	119%	102%	0%
Kumba Iron Ore	Materials	9.9426	7.4647	6.4538	7.5169	8.9895	2.3550	0.1433	0.1144	75%	86%	116%	120%	26%	6%	80%	0%
Nampak Ltd	Materials	0.0691	0.1271	0.1197	0.1166	0.1293	0.2090	0.2201	0.1731	184%	94%	97%	111%	162%	105%	79%	0%
Northam Platinum Ltd	Materials	0.5084	0.4899	0.8808	0.2944	0.3107	0.9732	1.0138	1.1368	96%	180%	33%	106%	313%	104%	112%	0%
PPC Ltd	Materials	0.7631	0.6785	0.5082	0.6864	1.0268	1.3728	1.3919	1.5893	89%	75%	135%	150%	134%	101%	114%	0%
MTN Group	Telecommunication Services	0.0194	0.0185	0.0211	0.0289	0.0212	0.0285	0.0336	0.0165	96%	114%	137%	73%	135%	118%	49%	0%

Table E7: Current Assets Carbon Intensity (Ci) and Carbon Dependency (Cd) Results by Company and Sector

Company	Sector	2017 Ci	2016 Ci	2015 Ci	2014 Ci	2013 Ci	2012 Ci	2011 Ci	2010 Ci	2017 Cd	2016 Cd	2015 Cd	2014 Cd	2013 Cd	2012 Cd	2011 Cd	2010 Cd
Clicks Group Ltd	Consumer Discretionary	0.028	0.018	0.010	0.020	0.015	0.027	0.011	0.014	65%	53%	208%	75%	174%	40%	129%	0%
Truworths International	Consumer Discretionary	0.009	0.009	0.012	0.028	0.013	0.015	0.015	0.017	98%	130%	236%	46%	116%	98%	116%	0%
Woolworths Holdings Ltd	Consumer Discretionary	0.476	0.059	0.070	0.029	0.068	0.264	0.074	0.066	12%	118%	41%	237%	390%	28%	89%	0%
Massmart Holdings Ltd	Consumer Staples	0.033	0.030	0.031	0.027	0.022	0.026	0.027	0.031	90%	105%	88%	79%	118%	106%	116%	0%
Tongaat Hulett Ltd	Consumer Staples	0.088	0.114	0.138	0.168	0.224	0.232	0.318	0.327	129%	121%	122%	133%	103%	137%	103%	0%
Sasol Limited	Energy	1.050	0.901	0.910	0.784	1.354	1.159	1.254	1.328	86%	101%	86%	173%	86%	108%	106%	0%
Absa Group	Financials	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	105%	101%	153%	72%	219%	106%	128%	0%
Discovery Holdings Ltd	Financials	0.008	0.009	0.009	0.011	0.012	0.015	0.012	0.037	111%	105%	117%	108%	122%	83%	303%	0%
FirstRand Limited	Financials	0.002	0.002	0.003	0.001	0.001	0.001	0.001	0.000	107%	102%	32%	113%	115%	56%	75%	0%
Growthpoint Properties	Financials	0.218	0.120	0.198	0.419	0.266	0.541	0.001	0.001	55%	164%	212%	63%	204%	0%	138%	0%
Hosken Consolidated Investments	Financials	0.076	0.068	0.066	1.066	0.106	1.628	0.122	0.094	90%	97%	1620%	10%	1538%	7%	77%	0%
Investec Ltd	Financials	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	108%	107%	57%	137%	94%	44%	125%	0%
Nedbank Ltd	Financials	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	104%	183%	74%	100%	108%	85%	831%	0%
Old Mutual Group	Financials	0.480	0.000	0.027	0.084	0.002	0.006	0.006	0.004	0%	6363%	307%	3%	246%	114%	58%	0%
Remgro	Financials	0.045	0.062	0.049	0.075	0.057	0.057	0.058	0.069	138%	78%	154%	77%	99%	101%	120%	0%
Sanlam	Financials	0.001	0.001	0.000	0.000	0.001	0.001	0.001	0.000	119%	16%	260%	160%	91%	79%	82%	0%

Standard Bank Group	Financials	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	117%	77%	127%	95%	39%	84%	94%	0%
Mediclinic International	Health Care	0.013	0.012	0.016	0.019	0.022	0.023	0.026	0.034	94%	134%	122%	114%	106%	111%	134%	0%
Barloworld	Industrials	0.016	0.016	0.013	0.014	0.012	0.013	0.011	0.015	100%	85%	101%	89%	104%	88%	133%	0%
AECI Ltd Ord	Materials	0.087	0.063	0.066	0.073	0.064	0.086	0.082	0.102	72%	104%	111%	88%	134%	96%	125%	0%
African Rainbow Minerals	Materials	0.867	0.894	7.152	14.464	0.367	0.205	0.319	0.300	103%	800%	202%	3%	56%	155%	94%	0%
Anglo American	Materials	1.274	1.335	1.900	1.910	2.122	1.336	0.143	0.182	105%	142%	101%	111%	63%	11%	127%	0%
Anglo American Platinum	Materials	0.217	0.283	0.307	0.309	0.305	0.294	0.307	0.303	130%	109%	100%	99%	96%	104%	99%	0%
AngloGold Ashanti	Materials	0.322	0.304	0.309	0.253	0.225	0.208	0.228	0.412	94%	102%	82%	89%	93%	110%	181%	0%
BHP Billiton	Materials	2.182	1.360	2.091	1.693	1.999	2.124	0.249	0.266	62%	154%	81%	118%	106%	12%	107%	0%
Exxaro Resources Ltd	Materials	7.071	8.120	13.019	12.930	16.494	14.784	0.577	0.305	115%	160%	99%	128%	90%	4%	53%	0%
Gold Fields Ltd	Materials	0.118	0.113	0.146	0.146	0.638	0.200	0.465	0.575	96%	129%	100%	437%	31%	233%	124%	0%
Impala Platinum Holdings	Materials	0.178	0.173	0.194	0.240	0.210	0.277	0.250	0.282	97%	112%	124%	87%	132%	90%	113%	0%
Kumba Iron Ore	Materials	5.668	4.740	8.229	7.884	8.686	2.646	0.069	0.063	84%	174%	96%	110%	30%	3%	92%	0%
Nampak Ltd	Materials	0.053	0.113	0.089	0.106	0.079	0.106	0.106	0.103	213%	78%	119%	75%	133%	101%	96%	0%
Northam Platinum Ltd	Materials	0.204	0.165	0.125	0.318	0.358	0.512	0.238	0.312	81%	75%	256%	112%	143%	46%	131%	0%
PPC Ltd	Materials	1.128	1.649	1.503	1.870	2.041	2.882	2.912	3.432	146%	91%	124%	109%	141%	101%	118%	0%
MTN Group	Telecommunication Services	0.027	0.020	0.016	0.018	0.014	0.016	0.017	0.010	74%	80%	109%	79%	116%	104%	62%	0%

Table E8: Non-Current Assets Carbon Intensity (Ci) and Carbon Dependency (Cd) Results by Company and Sector

Company	Sector	2017 Ci	2016 Ci	2015 Ci	2014 Ci	2013 Ci	2012 Ci	2011 Ci	2010 Ci	2017 Cd	2016 Cd	2015 Cd	2014 Cd	2013 Cd	2012 Cd	2011 Cd	2010 Cd
Clicks Group Ltd	Consumer Discretionary	0.0041	0.0028	0.0016	0.0019	0.0025	0.0033	0.0043	0.0069	68%	57%	123%	131%	132%	129%	161%	0%
Truworths International	Consumer Discretionary	0.0138	0.0120	0.0466	0.1400	0.0604	0.0715	0.0691	0.0757	87%	388%	300%	43%	118%	97%	110%	0%
Woolworths Holdings Ltd	Consumer Discretionary	0.1410	0.0157	0.0175	0.0491	0.0529	0.2652	0.0893	0.0982	11%	111%	281%	108%	502%	34%	110%	0%
Massmart Holdings Ltd	Consumer Staples	0.0465	0.0458	0.0483	0.0444	0.0343	0.0519	0.0529	0.0586	98%	105%	92%	77%	151%	102%	111%	0%
Tongaat Hulett Ltd	Consumer Staples	0.0754	0.0556	0.0598	0.0663	0.0797	0.0770	0.1021	0.1096	74%	108%	111%	120%	97%	133%	107%	0%
Sasol Limited	Energy	0.2969	0.3447	0.4477	0.4176	0.7587	0.5489	0.6344	0.6940	116%	130%	93%	182%	72%	116%	109%	0%
Absa Group	Financials	0.0758	0.0809	0.0900	0.0038	0.0066	0.0729	0.4505	0.4025	107%	111%	4%	174%	1097%	618%	89%	0%
Discovery Holdings Ltd	Financials	0.0196	0.0211	0.0261	0.0277	0.0293	0.0323	0.0244	0.0724	108%	124%	106%	106%	110%	75%	297%	0%
FirstRand Limited	Financials	0.0003	0.0003	0.0003	0.0004	0.0005	0.0006	0.0021	0.0007	115%	99%	145%	115%	109%	381%	31%	0%
Growthpoint Properties	Financials	0.0068	0.0057	0.0062	0.0086	0.0132	0.0149	0.0000	0.0000	84%	108%	139%	154%	113%	0%	181%	0%
Hosken Consolidated Investments	Financials	0.0105	0.0108	0.0149	0.2946	0.0337	0.3855	0.0278	0.0236	103%	137%	1983%	11%	1144%	7%	85%	0%
Investec Ltd	Financials	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	119%	96%	62%	146%	162%	104%	137%	0%
Nedbank Ltd	Financials	0.0018	0.0020	0.0005	0.0014	0.0028	0.0026	0.0015	0.0003	113%	23%	305%	197%	92%	60%	20%	0%
Old Mutual Group	Financials	0.0201	0.0003	0.0277	0.0156	0.0004	0.0003	0.0004	0.0003	2%	8037%	56%	2%	89%	111%	78%	0%
Remgro	Financials	0.0104	0.0092	0.0139	0.0121	0.0120	0.0176	0.0138	0.0169	89%	151%	87%	99%	146%	79%	122%	0%

Sanlam	Financials	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	46%	167%	76%	97%	131%	109%	95%	0%
Standard Bank Group	Financials	0.0002	0.0002	0.0002	0.0003	0.0004	0.0002	0.0002	0.0002	119%	104%	125%	132%	53%	98%	113%	0%
Mediclinic International	Health Care	0.0021	0.0020	0.0032	0.0036	0.0041	0.0045	0.0046	0.0050	95%	164%	113%	112%	111%	102%	108%	0%
Barloworld	Industrials	0.0176	0.0188	0.0187	0.0209	0.0180	0.0208	0.0159	0.0177	107%	99%	112%	86%	116%	76%	111%	0%
AECI Ltd Ord	Materials	0.8530	0.4707	0.4114	0.7556	0.7243	0.8238	0.7916	0.8124	55%	87%	184%	96%	114%	96%	103%	0%
African Rainbow Minerals	Materials	1.6312	26.3249	69.9715	240.9741	7.4913	13.7510	13.2514	12.4115	1614%	266%	344%	3%	184%	96%	94%	0%
Anglo American	Materials	5.3575	5.6235	10.2026	7.4413	10.2038	3.8153	1.2927	1.2652	105%	181%	73%	137%	37%	34%	98%	0%
Anglo American Platinum	Materials	0.1374	0.1425	0.1281	0.1079	0.1183	0.0968	0.0814	0.0853	104%	90%	84%	110%	82%	84%	105%	0%
AngloGold Ashanti	Materials	0.0607	0.0591	0.0703	0.0557	0.0629	0.0558	0.0709	0.0911	97%	119%	79%	113%	89%	127%	128%	0%
BHP Billiton	Materials	0.4789	0.2379	0.3162	0.2924	0.3342	0.3991	0.0812	0.1051	50%	133%	92%	114%	119%	20%	129%	0%
Exxaro Resources Ltd	Materials	1.4982	1.5955	1.6804	1.7637	1.6423	1.9630	0.0806	0.1427	106%	105%	105%	93%	120%	4%	177%	0%
Gold Fields Ltd	Materials	0.0239	0.0226	0.0267	0.0277	0.1086	0.1073	0.0932	0.1055	95%	118%	104%	392%	99%	87%	113%	0%
Impala Platinum Holdings	Materials	0.0722	0.0523	0.0479	0.0564	0.0601	0.0644	0.0699	0.0728	72%	91%	118%	107%	107%	109%	104%	0%
Kumba Iron Ore	Materials	2.7979	3.2828	3.4837	2.8475	3.3319	1.0071	0.0377	0.0417	117%	106%	82%	117%	30%	4%	111%	0%
Nampak Ltd	Materials	0.0366	0.0716	0.0510	0.0632	0.0932	0.1070	0.1132	0.0826	196%	71%	124%	147%	115%	106%	73%	0%
Northam Platinum Ltd	Materials	0.0540	0.0570	0.0539	0.0498	0.0492	0.0573	0.0705	0.0829	106%	95%	92%	99%	117%	123%	118%	0%
PPC Ltd	Materials	0.3017	0.3352	0.3648	0.5518	0.7848	1.1009	1.1648	1.2828	111%	109%	151%	142%	140%	106%	110%	0%

MTN Group	Telecommunication Services	0.0088	0.0084	0.0070	0.0091	0.0068	0.0078	0.0098	0.0056		95%	83%	130%	75%	114%	126%	57%	0%

APPENDIX F:

PROBABILITY OF DEFAULT VALUES PER COMPANY & PER SECTOR (2010 TO 2017)

Company	Sector	Scenario	2017	2016	2015	2014	2013	2012	2011	2010
Absa Group	Financials	No incentives	0.000120887762	0.001384141320	0.000553661166	0.000000087654	0.000014990465	0.000000378876	0.000010450386	0.000002897535
		Carbon Adj.	0.000120869921	0.001383926239	0.000553598015	0.000000087580	0.000014973499	0.000000378537	0.000010447855	0.000002896501
		Normal	0.000120847289	0.001383790168	0.000553512648	0.000000087534	0.000014982849	0.000000378592	0.000010444060	0.000002895090
AECI Ltd Ord	Materials	No incentives	0.000000000000	0.000000000175	0.000002464720	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Carbon Adj.	0.000000000000	0.000000000117	0.000002170166	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Normal	0.000000000000	0.000000000102	0.000002106959	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
African Rainbow Minerals	Materials	No incentives	0.000004073332	0.005267593004	0.020517743640	0.000015667348	0.000000000601	0.000000000001	0.000000007948	0.000000000488
		Carbon Adj.	0.000002553410	0.004665604591	0.017638090815	0.000002988503	0.000000000342	0.000000000001	0.000000005667	0.000000000351
		Normal	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
Anglo American	Materials	No incentives	0.000012532358	0.042531381864	0.020375563859	0.000005562043	0.000008601154	0.000000203861	0.000000103412	0.000000021996
		Carbon Adj.	0.000009578722	0.040828324979	0.018824265413	0.000004027271	0.000098799094	0.000000148420	0.000000099188	0.000000021107
		Normal	0.000004164397	0.036029580604	0.015262872330	0.000001748451	0.000002363884	0.000000069765	0.000000089924	0.000000019153
Anglo American Platinum	Materials	No incentives	0.000003902222	0.005106843029	0.042963871069	0.000000082672	0.000000680671	0.000000000006	0.000000000001	0.000000000031
		Carbon Adj.	0.000003010521	0.003991499298	0.002676059386	0.000000041693	0.000000395644	0.000000000003	0.000000000000	0.000000000019
		Normal	0.000002423650	0.003659460318	0.002436295477	0.000000031744	0.000000318641	0.000000000002	0.000000000000	0.000000000014
AngloGold Ashanti	Materials	No incentives	0.000460769287	0.009144589268	0.015650619210	0.003252110363	0.002658580860	0.000000033326	0.000000000010	0.000000000000
		Carbon Adj.	0.000435034897	0.008893980697	0.015291140553	0.003132550547	0.002600829133	0.000000030668	0.000000000009	0.000000000000
		Normal	0.000425980819	0.008806884764	0.015145976094	0.003132550401	0.002554853535	0.000000029159	0.000000000008	0.000000000000
Barloworld	Industrials	No incentives	0.000001421113	0.002130191463	0.000054146630	0.000000001561	0.000003053065	0.000000920924	0.000000021184	0.000000423399
		Carbon Adj.	0.000001417276	0.002127632250	0.000054046783	0.000000001549	0.000003034008	0.000000918102	0.000000021111	0.000000422234
		Normal	0.000001392492	0.002113767569	0.000053487774	0.000000001514	0.000003001799	0.000000907753	0.000000020857	0.000000416708
BHP Billiton	Materials	No incentives	0.000000000004	0.000023138780	0.000001724029	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000

		Carbon Adj.	0.000000000000	0.000008547084	0.000000280035	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Normal	0.000000000000	0.000000068514	0.000000000093	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
Clicks Group Ltd	Consumer Discretionary	No incentives	0.000000000000	0.000000000000	0.000000000497	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Carbon Adj.	0.000000000000	0.000000000000	0.000000000487	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Normal	0.000000000000	0.000000000000	0.000000000472	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
Discovery Holdings Ltd	Financials	No incentives	0.000000000002	0.000009370386	0.000021245365	0.000000000045	0.000000690064	0.000000000000	0.000000000000	0.028669830399
		Carbon Adj.	0.000000000002	0.000009366921	0.000021238493	0.000000000045	0.000000689707	0.000000000000	0.000000000000	0.000000000000
		Normal	0.000000000002	0.000009361909	0.000021222838	0.000000000044	0.000000688853	0.000000000000	0.000000000000	0.000000000000
Exxaro Resources Ltd	Materials	No incentives	0.000216222553	0.019519339751	0.012474202040	0.000000033296	0.000000002129	0.000000048848	0.000000000314	0.000000000002
		Carbon Adj.	0.000153193562	0.017193621323	0.009615138905	0.000000007371	0.000000000438	0.000000016335	0.000000000285	0.000000000002
		Normal	0.000008629460	0.006369348396	0.002326264734	0.000000000001	0.000000000000	0.000000000020	0.000000000219	0.000000000001
FirstRand Limited	Financials	No incentives	0.000001182617	0.000611446187	0.000595088668	0.000000140705	0.000001921069	0.000000849533	0.000013632734	0.000114902946
		Carbon Adj.	0.000001182363	0.000611371091	0.000595030743	0.000000140668	0.000001920785	0.000000849703	0.000013627287	0.000114891997
		Normal	0.000001181967	0.000611269825	0.000584320709	0.000000140614	0.000001920063	0.000000848996	0.000013622557	0.000114875406
Gold Fields Ltd	Materials	No incentives	0.000266066086	0.026409581032	0.024432498317	0.000149263164	0.004598463331	0.000000011677	0.000000013045	0.000000000000
		Carbon Adj.	0.000261939725	0.026299348027	0.024332667734	0.000147029282	0.004528246895	0.000000010962	0.000000012027	0.000000000000
		Normal	0.000255051084	0.026086137547	0.024100589333	0.000142407660	0.004159400742	0.000000008734	0.000000009714	0.000000000000
Growthpoint Properties	Financials	No incentives	0.000000000000	0.000000000016	0.000000004728	0.000000000000	0.000000616014	0.000000000000	0.000000000000	0.000000000000
		Carbon Adj.	0.000000000000	0.000000000016	0.000000004545	0.000000000000	0.000000603095	0.000000000000	0.000000000000	0.000000000000
		Normal	0.000000000000	0.000000000016	0.000000004545	0.000000000000	0.000000603095	0.000000000000	0.000000000000	0.000000000000
Hosken Consolidated Investments	Financials	No incentives	0.000000018185	0.000000671302	0.000000146741	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Carbon Adj.	0.000000017810	0.000000661397	0.000000143776	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Normal	0.000000017209	0.000000645075	0.000000139427	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
Impala Platinum Holdings	Materials	No incentives	0.002653816723	0.027038283891	0.005637675803	0.000000726188	0.000001472069	0.000000000006	0.000000000003	0.000000000000
		Carbon Adj.	0.002385617499	0.025944008607	0.005298799777	0.000000577812	0.000001216874	0.000000000004	0.000000000002	0.000000000000
		Normal	0.002385611830	0.025943988609	0.005298801055	0.000000577810	0.000001216857	0.000000000004	0.000000000002	0.000000000000

Investec Ltd	Financials	No incentives	0.000000000000	0.000000014818	0.000000047275	0.000000000004	0.000000097202	0.000000000189	0.000001821248	0.000003434657
		Carbon Adj.	0.000000000000	0.000000014818	0.000000047275	0.000000000004	0.000000097203	0.000000000189	0.000001821245	0.000003434654
		Normal	0.000000000000	0.000000014782	0.000000047174	0.000000000004	0.000000097090	0.000000000189	0.000001820165	0.000003432355
Kumba Iron Ore	Materials	No incentives	0.000490102628	0.071439663497	0.077308923956	0.000003977071	0.000000000569	0.000000000000	0.000000000000	0.000000000000
		Carbon Adj.	0.000321079277	0.065362735824	0.077309894695	0.000001820836	0.000000000130	0.000000000000	0.000000000000	0.000000000000
		Normal	0.000003836303	0.026930371179	0.046929227975	0.000000015691	0.000000000000	0.000000000000	0.000000000000	0.000000000000
Massmart Holdings Ltd	Consumer Staples	No incentives	0.000033458771	0.000485157752	0.000020457006	0.000000193017	0.000000000000	0.000000000000	0.000000000000	0.000000000001
		Carbon Adj.	0.000033000233	0.000480799836	0.000020167712	0.000000190157	0.000000000000	0.000000000000	0.000000000000	0.000000000001
		Normal	0.000032390835	0.000475689679	0.000019841786	0.000000185886	0.000000000000	0.000000000000	0.000000000000	0.000000000001
Mediclinic International	Health Care	No incentives	0.000000593308	0.000837302287	0.000000005704	0.000000000009	0.000000000493	0.000000000005	0.000000000000	0.000000070853
		Carbon Adj.	0.000000591883	0.000836578157	0.000000005686	0.000000000009	0.000000000492	0.000000000005	0.000000000000	0.000000070610
		Normal	0.000000588560	0.000834910915	0.000000005645	0.000000000009	0.000000000488	0.000000000005	0.000000000000	0.000000070236
MTN Group	Telecommunication Services	No incentives	0.000000000088	0.000896405566	0.000041739168	0.000000000000	0.000000000001	0.000000000000	0.000000000015	0.000000000003
		Carbon Adj.	0.000000000085	0.000889728957	0.000041291520	0.000000000000	0.000000000001	0.000000000000	0.000000000015	0.000000000003
		Normal	0.000000000085	0.000889689952	0.000041288798	0.000000000000	0.000000000001	0.000000000000	0.000000000015	0.000000000003
Nampak Ltd	Materials	No incentives	0.000043294679	0.001275036518	0.000183461172	0.000000000080	0.000000030890	0.000000000000	0.000000000000	0.000000000018
		Carbon Adj.	0.000042886534	0.001261295705	0.000181461388	0.000000000078	0.000000030100	0.000000000000	0.000000000000	0.000000000018
		Normal	0.000041258785	0.001207344296	0.000174349772	0.000000000068	0.000000027332	0.000000000000	0.000000000000	0.000000000015
Nedbank Ltd	Financials	No incentives	0.000003976257	0.000317942656	0.000122686339	0.000001566557	0.000000164326	0.000000346783	0.000012596964	0.000015910855
		Carbon Adj.	0.000003976242	0.000317910963	0.000122671988	0.000001566232	0.000000164220	0.000000346576	0.000012592929	0.000015908814
		Normal	0.000003975189	0.000317862541	0.000122651085	0.000001565745	0.000000164220	0.000000346576	0.000012592929	0.000015905735
Northam Platinum Ltd	Materials	No incentives	0.000000001059	0.000000521153	0.000084486737	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Carbon Adj.	0.000000000759	0.000000420231	0.000077257538	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Normal	0.000000000594	0.000000343725	0.000069251376	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
Old Mutual Group	Financials	No incentives	0.000000000000	0.000000413394	0.000000007409	0.000000000000	0.000000000131	0.000000225825	0.000000294726	0.000001726556
		Carbon Adj.	0.000000000000	0.000000411226	0.000000005876	0.000000000000	0.000000000130	0.000000224491	0.000000293318	0.000001723634

		Normal	0.000000000000	0.000000410132	0.000000003808	0.000000000000	0.000000000129	0.000000224173	0.000000292716	0.000001719260
PPC Ltd	Materials	No incentives	0.003399336911	0.085468494205	0.002255340771	0.000000011924	0.000000000021	0.000000000000	0.000000000002	0.000000000000
		Carbon Adj.	0.003196335180	0.084613669971	0.002150959752	0.000000009483	0.000000000014	0.000000000000	0.000000000001	0.000000000000
		Normal	0.002556060328	0.081038549555	0.001774822433	0.000000003797	0.000000000003	0.000000000000	0.000000000000	0.000000000000
Remgro	Financials	No incentives	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Carbon Adj.	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Normal	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
Sanlam	Financials	No incentives	0.000010007860	0.000726121600	0.001101193886	0.000002251766	0.000000000000	0.000000000025	0.000001668479	0.000000093684
		Carbon Adj.	0.000010006694	0.000726098889	0.001101174345	0.000002251625	0.000018697637	0.000000000025	0.000001668354	0.000000093674
		Normal	0.000010004946	0.000726081547	0.001101124584	0.000002251411	0.000018697422	0.000000000025	0.000001668177	0.000000093662
Sasol Limited	Energy	No incentives	0.000000000021	0.000016509174	0.000010703289	0.000000000034	0.000000000000	0.000000000000	0.000000000015	0.000000000000
		Carbon Adj.	0.000000000018	0.000015327821	0.000009728817	0.000000000028	0.000000000000	0.000000000000	0.000000000011	0.000000000000
		Normal	0.000000000003	0.000007591781	0.000003688157	0.000000000004	0.000000000000	0.000000000000	0.000000000001	0.000000000000
Standard Bank Group	Financials	No incentives	0.000008652425	0.000871028284	0.000518616914	0.000000323249	0.000000194965	0.000000004952	0.000003486219	0.000012152866
		Carbon Adj.	0.000008651474	0.000870973304	0.000518572140	0.000000323192	0.000000194923	0.000000004952	0.000003485671	0.000012152217
		Normal	0.000008650452	0.000870889881	0.000518504337	0.000000323107	0.000000194864	0.000000004951	0.000003485339	0.000012151239
Tongaat Hulett Ltd	Consumer Staples	No incentives	0.000000000000	0.000000156715	0.000015808968	0.000000000084	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Carbon Adj.	0.000000000000	0.000000146573	0.000015087006	0.000000000080	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Normal	0.000000000000	0.000000134259	0.000014054399	0.000000000064	0.000000000000	0.000000000000	0.000000000000	0.000000000000
Truworths International	Consumer Discretionary	No incentives	0.000000000005	0.000000059470	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Carbon Adj.	0.000000000005	0.000000059176	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Normal	0.000000000005	0.000000058384	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
Woolworths Holdings Ltd	Consumer Discretionary	No incentives	0.000000000004	0.000000059695	0.000000000365	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Carbon Adj.	0.000000000003	0.000000058963	0.000000000359	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000
		Normal	0.000000000002	0.000000057234	0.000000000346	0.000000000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000

APPENDIX G:
DECLARATION OF PROFESSIONAL EDIT

Retha Burger
B.A.(H.E.D.)
tel : 012 807 3864
cell : 083 653 5255
fax : 012 807 3864
e-mail : retha@skillnet.co.za
Independent Skills Development Facilitator

Dear Mr Bimha

This letter is to record that I have completed a language edit of your PhD thesis entitled, "Integrating environmental risk into bank credit processes: a South African banking context".

The edit that I carried out included the following:

-Spelling	-Grammar
-Vocabulary	-Punctuation
-Pronoun matches	-Word usage
-Sentence structure	-Correct acronyms (matching your supplied list)

-Captions and labels for figures and tables
-Spot checking of 10 references

The edit that I carried out excluded the following:

-Content
-Correctness or truth of information (unless obvious)
-Correctness/spelling of specific technical terms and words (unless obvious)
-Correctness/spelling of unfamiliar names and proper nouns (unless obvious)
-Correctness of specific formulae or symbols, or illustrations.

Yours sincerely

Retha Burger

26 October 2020