

# Contents

<b>List of Figures</b>	<b>xv</b>
<b>List of Tables</b>	<b>xvii</b>
<b>Abbreviations</b>	<b>xix</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Motivation and key research questions . . . . .	1
1.2 Book outline by chapter . . . . .	4
<b>2 Credit rating: The research framework</b>	<b>7</b>
2.1 Development: The probability of default as a research topic . . . . .	7
2.1.1 Business development . . . . .	7
2.1.2 Institutional development . . . . .	10
2.2 Notions of rating: Basic terms and concepts . . . . .	13
2.3 The rating object: The input space of financial rating . . . . .	17
2.3.1 Financial statement analysis . . . . .	17
2.3.1.1 Types of ratios . . . . .	18
2.3.1.2 Analysis of the general financial situation . . . . .	20
2.3.1.3 Analysis of income statement . . . . .	27
2.3.2 Feature transformation . . . . .	31
2.3.3 Feature selection . . . . .	33
2.3.4 Case control studies . . . . .	36
2.4 Summary and discussion . . . . .	37
<b>3 Pattern classification in credit rating</b>	<b>39</b>
3.1 Forecasting and statistical learning . . . . .	39
3.1.1 Statistical inference . . . . .	39
3.1.2 Types of learning . . . . .	41
3.1.3 Types of forecasting . . . . .	42
3.1.4 Statistical learning theory . . . . .	44
3.2 Classifiers: An introduction . . . . .	47
3.2.1 Classifier based on Bayes decision theory . . . . .	48
3.2.2 Estimating unknown probability density functions . . . . .	49
3.2.3 Linear and nonlinear discriminant functions . . . . .	55
3.3 Developments and milestones in credit risk research . . . . .	59
3.3.1 Introductory analysis of literature . . . . .	59
3.3.2 The classic cross-sectional models . . . . .	62

3.3.3	Kernel methods . . . . .	68
3.3.3.1	Support Vector Machine . . . . .	70
3.3.3.2	Kernel Fisher Discriminant . . . . .	75
3.3.3.3	Gaussian Process Classification . . . . .	77
3.4	Measuring classification accuracy . . . . .	82
3.4.1	Testing group differences . . . . .	83
3.4.2	Contingency tables and derived measures . . . . .	87
3.4.3	The Area under the Receiver Operating Characteristic . . . . .	89
3.4.4	How to control generalization: Training and testing . . . . .	92
3.5	Summary and discussion . . . . .	95
<b>4</b>	<b>Calibration of rating models</b>	<b>99</b>
4.1	Introduction . . . . .	99
4.2	Notions of calibration . . . . .	99
4.2.1	The nature of calibration . . . . .	99
4.2.2	Calibration: The framework . . . . .	103
4.3	Calibration methods for credit rating . . . . .	106
4.3.1	Mapping . . . . .	107
4.3.1.1	Logistic regression . . . . .	107
4.3.1.2	Regression based on rating class ODFs . . . . .	107
4.3.1.3	Isotonic regression . . . . .	108
4.3.1.4	A calibration curve based on the AUROC . . . . .	109
4.3.2	Bayes calibration . . . . .	111
4.3.2.1	Symmetric distributions . . . . .	111
4.3.2.2	Asymmetric distributions . . . . .	114
4.3.2.3	Kernel estimation . . . . .	115
4.3.3	Recalibration . . . . .	115
4.3.3.1	Adjusting the logistic regression . . . . .	116
4.3.3.2	Adjusting the regression on rating class ODFs . . . . .	117
4.3.3.3	Adjustment using the Bayes rule . . . . .	117
4.4	Evaluating calibration . . . . .	118
4.4.1	Introduction . . . . .	118
4.4.2	The Brier score . . . . .	119
4.4.3	Resolution: The AUROC as computed from probabilities . . . . .	123
4.4.3.1	Computing the AUROC from probabilities . . . . .	123
4.4.3.2	The NCC: Refinement, resolution, discrimination . . . . .	128
4.5	Summary and discussion . . . . .	130
<b>5</b>	<b>Empirical investigation</b>	<b>135</b>
5.1	Introduction: Key research questions and goals . . . . .	135
5.2	Data description . . . . .	135
5.2.1	Preparation of available data . . . . .	135
5.2.2	Data description . . . . .	137
5.2.3	Financial ratios . . . . .	139
5.2.4	Training set and validation set . . . . .	145

5.3 Empirical results . . . . .	147
5.3.1 Transformation of variables . . . . .	147
5.3.2 Variable selection . . . . .	149
5.3.3 Classification accuracy . . . . .	156
5.3.3.1 Classifier configuration . . . . .	156
5.3.3.2 Out-of-universe results (bootsplit) . . . . .	157
5.3.3.3 Out-of-time-and-universe results . . . . .	159
5.3.3.4 Comparison of sets of variables . . . . .	161
5.3.3.5 Discussion . . . . .	167
5.3.4 Calibration accuracy . . . . .	170
5.3.4.1 Configuration of the calibration methods . . . . .	171
5.3.4.2 Deterioration of classification performance . . . . .	172
5.3.4.3 Calibration accuracy training . . . . .	173
5.3.4.4 Calibration accuracy testing . . . . .	176
5.3.4.5 Recalibration . . . . .	179
5.3.4.6 Summary . . . . .	181
5.3.4.7 Testing accuracy . . . . .	182
5.3.4.8 Discussion . . . . .	184
<b>6 Concluding discussion of results</b>	<b>187</b>
<b>A Appendix</b>	<b>193</b>
A.1 Chapter 3: Pattern classification in credit rating . . . . .	193
A.1.1 Alternative models in credit risk research . . . . .	193
A.1.2 AUROC . . . . .	197
A.2 Chapter 4: Calibration of rating models . . . . .	198
A.2.1 Denominator . . . . .	198
A.2.2 Numerator . . . . .	198
A.2.3 AUROC representations . . . . .	199
A.2.4 Further details and formulas from the theory of numbers . . . . .	200
A.3 Chapter 5: Empirical investigation . . . . .	201
A.3.1 Plausibility checking rules . . . . .	201
A.3.2 Industry affiliation . . . . .	202
<b>Bibliography</b>	<b>203</b>