

*Application of Classification
Techniques in Business,
Banking and Finance*



**CONTEMPORARY STUDIES IN
ECONOMIC AND FINANCIAL ANALYSIS, Volume 3**

*Editors: Professor Edward I. Altman and Ingo Walter, Associate Dean
Graduate School of Business Administration, New York University*

CONTENTS

<i>List of Figures</i>	xiii
<i>List of Tables</i>	xv
<i>Preface</i>	xix

I. Two-Group Classification Techniques:	
Conceptual Issues	1
Introduction	1
Linear Probability Model	3
<i>Introduction—Least Square</i>	3
<i>Heteroskedastic Adjustment</i>	5
<i>The Linear Probability Model</i>	7
<i>Constrained Estimation</i>	8
<i>Example—Director Interlocks I</i>	11
Probit and Logit Analysis	13
<i>Introduction</i>	13
<i>The Probit Model</i>	14
<i>The Logit Model</i>	16
<i>Probit/Logit Models and Probabilistic Choice</i>	18
<i>Parameter Estimation—Many Observations per Cell</i>	23
<i>Parameter Estimation—Individual Data</i>	27
<i>Example—Director Interlocks II</i>	31
Discriminant Analysis	33
<i>Introduction</i>	33
<i>Classification Probabilities</i>	34
<i>Classification—Group Assignment</i>	39
<i>Significance Tests and Examinations of Group Overlaps</i>	42
<i>Discriminant Functions</i>	47
<i>Example—Director Interlocks III</i>	52
Appendix	54
Maximum Likelihood Estimation	54

II. Multigroup Classification Techniques:	59
Conceptual Issues	59
Introduction	59
Regression, Probit, and Logit—Multiple Choice	60
<i>Introduction</i>	60
<i>Ordered Multiple Choice</i>	61
<i>The Ordered Logistic Model</i>	62
<i>The Ordered Probit Model</i>	66
<i>Unordered Multiple Choice</i>	68
<i>Multinomial Logit Model</i>	70
<i>Probabilistic Choice</i>	73
<i>Multinomial Logit—Parameter Estimation</i>	76
<i>Multinomial Probit Model</i>	80
<i>Sequential Models</i>	82
Multiple Discriminant Analysis	84
<i>Introduction</i>	84
<i>Classification Probabilities</i>	85
<i>Classification—Group Assignments</i>	88
<i>Significance Tests</i>	91
<i>Discriminant Functions</i>	96
Special Topics	101
<i>Nonrandom Sampling</i>	101
<i>Model Selection—Goodness of Fit</i>	104
<i>Model Selection—Theoretical Considerations</i>	109
<i>Example—Director Interlocks IV</i>	112
III. Discriminant Analysis Application Problems	119
Introduction	119
Violation of the Assumptions of the Discriminant	
Analysis Model	120
<i>Multivariate Normality</i>	120
<i>Unequal Group Covariance Matrices</i>	126
<i>The Definitions of the Groups</i>	129
The Relative Significances of Individual Variables	135
Reduction of Dimensionality and Elimination of	
Insignificant Variables	144
<i>Variable Selection Methods</i>	145
<i>Elimination of Discriminant Functions</i>	148
Specification of Classification Schemes	150
<i>The Selection of the Appropriate A Priori Probabilities</i>	
<i>and Costs</i>	150
<i>Assessment of Classification Error Rates</i>	153

Time-Series Applications	158
Summary and Conclusions	160
 IV. Credit Scoring Applications	 167
Introduction	167
The Methodology of Credit Scoring Models	168
Review of Credit Scoring Models	172
Methodological and Statistical Problems in Credit Scoring Models	189
<i>Distribution of the Variables</i>	190
<i>Equal versus Unequal Covariances</i>	191
<i>The Role of Individual Variables</i>	191
<i>Problems in the Definitions of the Groups</i>	192
<i>Use of Inappropriate A Priori Probabilities and Costs of Misclassification</i>	193
<i>Estimation of Classification Error Rates</i>	194
<i>Selection of Analysis Samples</i>	194
<i>Time-Series Problems</i>	196
Summary and Conclusions	196
 V. The Application of Statistical Classification	 199
Methods to Bond Quality Ratings	199
Introduction	199
Statistical Bond Rating Analysis	201
Evolution of Statistical Techniques	202
<i>Multiple Regression Analysis Studies</i>	203
<i>Discriminant Analysis Studies</i>	205
<i>Logit Analysis</i>	210
How Accurate Have Statistical Bond Rating Studies Been?	211
Rating Replication Results—Can They Be Improved?	214
<i>Statistical Methodology</i>	215
<i>Industry Effects</i>	215
<i>Bond Rating—A Subjective Process</i>	216
<i>Mixed Bond Ratings—An Observed Phenomenon</i>	217
Conclusion	218
Appendix A	220
Appendix B	224

VI. Statistical Classification Models Applied to Common Stock Analysis	227
Introduction	227
Common Stock Investment Category Classification	228
Common Stock Price and Earnings Performance Classification	232
<i>Price-Earnings (P-E) Ratios</i>	232
<i>Price Volatility Classification</i>	235
<i>Earnings Classification</i>	236
Discrimination Based on Accounting Information and Common Stock Returns Performance	237
<i>Collinearity and Multivariate Normality</i>	240
<i>Sample Properties and Estimation Results</i>	241
Capital Structure Decisions and Classification Techniques	242
<i>Debt versus Equity</i>	242
<i>Convertible Debt Characteristics: Debt or Equity</i>	243
<i>Share Repurchase</i>	244
Summary and Conclusion	246
Appendix	248
 VII. Failure–Prediction Models for Nonfinancial Firms	 255
Introduction	255
Models for Predicting Business Failures: Why, What, How, and for Whom	255
<i>Why Predict Business Failures?</i>	255
<i>What Business Failure to Predict?</i>	256
<i>How to Predict Business Failures</i>	257
<i>For Whom the Prediction Tolls</i>	257
A Decade of Failure Prediction: Beaver (1967) to Altman (1977)	257
<i>Beaver (1967)</i>	258
<i>Altman (1968) to (1977)</i>	262
<i>Altman's Critics</i>	270
Zeta Analysis	272
<i>Altman, Haldeman and Narayana (1977)</i>	272
Seven Other Models	277
<i>Blum's Failing Company Model (1974)</i>	277
<i>Deakin (1972)</i>	280
<i>Libby (1975)</i>	283

<i>Deakin (1977)</i>	286
<i>Edmister (1972)</i>	289
<i>Elam (1975)</i>	292
<i>Wilcox (1971a), (1971b), (1973), and (1976)</i>	295
Epilogue	300
Appendix	303

VIII. Early-Warning Systems for Financial Institutions	307
Introduction	307
The Financial Environment in the 1980s	308
The Concept of an Early-Warning System	308
Information Available for Identifying Banks with Financial Difficulties	309
Early Warning and Bank Supervisory Issues	310
FDIC Studies	312
<i>Meyer and Pifer (1970)</i>	312
<i>Sinkey (1974–1979)</i>	315
<i>Population Predictions: National Banks</i>	325
<i>The Outlier Approach</i>	326
<i>The Failed-Bank Approach</i>	328
<i>Critique of FDIC Research</i>	332
Federal Reserve Bank of New York Studies	333
<i>Introduction: Martin (1977)</i>	333
The National Bank Surveillance System	339
<i>Introduction</i>	339
<i>The Components of NBSS</i>	339
<i>The NBSS Outlier or Peer-Group Approach</i>	340
<i>Summary and Conclusions</i>	344
<i>Critique</i>	344
Federal Reserve Studies	345
<i>Hanweck (1977a, b)</i>	345
<i>The Simulation Model</i>	345
<i>The Failure-Prediction Model</i>	346
Other Studies	348
<i>Introduction</i>	348
<i>Santomero and Vinso (1977)</i>	349
<i>Pettway (1980)</i>	354
<i>Shick and Sherman (1980)</i>	356
<i>Pettway and Sinkey (1980)</i>	356
<i>Altman (1977)</i>	357

<i>Collins (1980)</i>	361
<i>Altman and Loris (1976)</i>	361
Epilogue on Early-Warning Systems	364
Appendix	367
References	373
Author Index	405
Subject Index	413