



From *Multiple Imputation of Missing Data Using SAS®*,
 Third Edition. Full book available for purchase [here](#).

Contents

| | |
|---|-----------|
| About This Book | vii |
| About The Authors | ix |
| Acknowledgements | xi |
| Chapter 1: Introduction to Missing Data and Methods for Analyzing Data with Missing Values | 1 |
| 1.1 Introduction | 1 |
| 1.2 Sources and Patterns of Item Missing Data | 2 |
| 1.3 Item Missing Data Mechanisms | 4 |
| 1.4 Review of Strategies to Address Item Missing Data..... | 4 |
| 1.4.1 Complete Case Analysis..... | 4 |
| 1.4.2 Complete Case Analysis with Weighting Adjustments | 5 |
| 1.4.3 Full Information Maximum Likelihood..... | 5 |
| 1.4.4 Expectation-Maximization Algorithm..... | 5 |
| 1.4.5 Single Imputation of Missing Values | 6 |
| 1.4.6 Multiple Imputation | 6 |
| 1.5 Outline of Book Chapters..... | 7 |
| 1.6 Overview of Analysis Examples..... | 7 |
| Chapter 2: Introduction to Multiple Imputation Theory and Methods..... | 11 |
| 2.1 The Origins and Properties of Multiple Imputation Methods for Missing Data..... | 11 |
| 2.1.1 A Short History of Imputation Methods | 11 |
| 2.1.2 Why the Multiple Imputation Method? | 12 |
| 2.1.3 Overview of Multiple Imputation Steps | 14 |
| 2.2 Step 1—Defining the Imputation Model..... | 16 |
| 2.2.1 Choosing the Variables to Include in the Imputation Model..... | 16 |
| 2.2.2 Distributional Assumptions for the Imputation Model | 17 |
| 2.3 Algorithms for the Multiple Imputation of Missing Values | 17 |
| 2.3.1 General Theory for Multiple Imputation Algorithms | 17 |
| 2.3.2 Methods for Monotone Missing Data Patterns | 19 |
| 2.3.3 Methods for Arbitrary Missing Data Patterns..... | 23 |
| 2.4 Step 2—Analysis of the MI Completed Data Sets | 25 |
| 2.5 Step 3—Estimation and Inference for Multiply Imputed Data Sets | 26 |
| 2.5.1 Multiple Imputation—Estimators and Variances for Descriptive Statistics and Model Parameters..... | 26 |
| 2.5.2 Multiple Imputation—Confidence Intervals | 27 |

| | |
|--|-----------|
| 2.6 MI Procedures for Multivariate Inference..... | 28 |
| 2.6.1 Multiple Parameter Hypothesis Tests | 28 |
| 2.6.2 Tests of Linear Hypotheses..... | 29 |
| 2.7 How Many Multiple Imputation Repetitions Are Needed?..... | 30 |
| 2.8 Summary | 30 |
| Chapter 3: Preparation for Multiple Imputation..... | 31 |
| 3.1 Planning the Imputation Session..... | 31 |
| 3.2 Choosing the Variables to Include in a Multiple Imputation..... | 31 |
| 3.3 Amount and Pattern of Missing Data..... | 34 |
| 3.4 Types of Variables to Be Imputed | 36 |
| 3.5 Imputation Methods..... | 39 |
| 3.6 Number of Imputations (MI Repetitions) | 39 |
| 3.7 Overview of Multiple Imputation Procedures | 40 |
| 3.8 Multiple Imputation Example | 41 |
| 3.9 Summary | 48 |
| Chapter 4: Multiple Imputation for the Analyzsis of Complex Sample Survey Data | 49 |
| 4.1 Multiple Imputation and Informative Data Collection Designs | 49 |
| 4.2 Complex Sample Surveys | 50 |
| 4.3 Incorporating the Complex Sample Design in the MI Imputation Step..... | 51 |
| 4.4 Incorporating the Complex Sample Design in the MI Analysis and Inference Steps | 53 |
| 4.5 MI Imputation and Analysis for Subpopulations of Complex Sample Design Data Sets | 57 |
| 4.6 Summary | 58 |
| Chapter 5: Multiple Imputation of Continuous Variables | 59 |
| 5.1 Introduction to Multiple Imputation of Continuous Variables | 59 |
| 5.2 Imputation of Continuous Variables with Arbitrary Missing Data..... | 60 |
| 5.3 Imputation of Continuous Variables with Mixed Covariates and a Monotone Missing Data Pattern Using the Regression and Predictive Mean Matching Methods | 68 |
| 5.3.1 Imputation of Continuous Variables with Mixed Covariates and a Monotone Missing Data Pattern Using the Regression Method | 68 |
| 5.3.2 Imputation of Continuous Variables with Mixed Covariates and a Monotone Missing Data Pattern Using the Predictive Mean Matching Method | 80 |
| 5.4 Imputation of Continuous Variables with an Arbitrary Missing Data Pattern and Mixed Covariates Using the FCS Method | 83 |
| 5.4.1 Imputation of Continuous Variables with an Arbitrary Missing Data Pattern and Mixed Covariates Using the FCS Method | 83 |
| 5.5 Summary | 89 |
| Chapter 6: Multiple Imputation of Classification Variables..... | 91 |
| 6.1 Introduction to Multiple Imputation of Classification Variables..... | 91 |
| 6.2 Imputation of a Classification Variable with a Monotone Missing Data Pattern Using the Logistic Method | 92 |
| 6.3 Imputation of Classification Variables with an Arbitrary Missing Data Pattern and Mixed Covariates Using the FCS Discriminant Function and the FCS Logistic Regression Method | 97 |
| 6.4 Imputation of Classification Variables with an Arbitrary Missing Data Pattern and Mixed Covariates: A Comparison of the FCS and MCMC/Monotone Methods..... | 103 |
| 6.4.1 Imputation of Classification Variables with Mixed Covariates and an Arbitrary Missing Data Pattern Using the FCS Method | 103 |

| | |
|--|------------|
| 6.4.2 Imputation of Classification Variables with Mixed Covariates and an Arbitrary Missing Data Pattern Using the MCMC/Monotone and Monotone Logistic Methods with a Multistep Approach | 107 |
| 6.5 Summary | 111 |
| Chapter 7: Multiple Imputation Case Studies | 113 |
| 7.1 Multiple Imputation Case Studies | 113 |
| 7.2 Comparative Analysis of HRS 2006 Data Using Complete Case Analysis and Multiple Imputation of Missing Data | 113 |
| 7.2.1 Exploration of Missing Data | 114 |
| 7.2.2 Complete Case Analysis Using PROC SURVEYLOGISTIC | 115 |
| 7.2.3 Multiple Imputation of Missing Data with an Arbitrary Missing Data Pattern Using the FCS Method with Diagnostic Trace Plots | 116 |
| 7.2.4 Logistic Regression Analysis of Imputed Data Sets Using PROC SURVEYLOGISTIC | 117 |
| 7.2.5 Use of PROC MIANALYZE with Logistic Regression Output | 118 |
| 7.2.6 Comparison of Complete Case Analysis and Multiply Imputed Analysis | 119 |
| 7.3 Imputation and Analysis of Longitudinal Seizure Data | 120 |
| 7.3.1 Introduction to the Seizure Data | 120 |
| 7.3.2 Exploratory Analysis of Seizure Data | 120 |
| 7.3.3 Conversion of Multiple-Record to Single-Record Data | 121 |
| 7.3.4 Multiple Imputation of Missing Data | 123 |
| 7.3.5 Conversion Back to Multiple Record Data for Analysis of Imputed Data Sets | 125 |
| 7.3.6 Regression Analysis of Imputed Data Sets | 126 |
| 7.4 Summary | 128 |
| Chapter 8: Preparation of Data Sets for PROC MIANALYZE | 129 |
| 8.1 Preparation of Data Sets for Use in PROC MIANALYZE | 129 |
| 8.2 Imputation of Major League Baseball Players' Salaries | 130 |
| 8.3.1 PROC GLM Output Data Set for Use in PROC MIANALYZE | 130 |
| 8.3.2 PROC MIXED Output Data Set for Use in PROC MIANALYZE | 133 |
| 8.4 Imputation of NCS-R Data | 135 |
| 8.5 PROC SURVEYPHREG Output Data Set for Use in PROC MIANALYZE | 137 |
| 8.6 Summary | 138 |
| References | 139 |
| Index | 143 |