

Contents

| | |
|--|-----------|
| List of Figures | 13 |
| 1 Introduction | 15 |
| 1.1 Sources of randomness | 16 |
| 1.1.1 Stochastic model | 16 |
| 1.1.2 Design approach | 17 |
| 1.2 Surveys | 17 |
| 1.2.1 Characteristics of surveys | 17 |
| 1.2.2 Sampling frame | 19 |
| 1.2.3 Probability sampling | 19 |
| 1.2.4 Sampling and inference | 19 |
| 1.3 Specific designs | 20 |
| 1.3.1 Simple random sampling | 20 |
| 1.3.2 Stratified sampling | 20 |
| 1.3.3 Cluster sampling | 21 |
| 1.4 Outline of the book | 21 |
| 1.5 Exercises | 23 |
| 2 Introduction to R | 25 |
| 2.1 Some R basics | 26 |
| 2.1.1 Object orientation | 26 |
| 2.1.2 Dataframes | 26 |
| 2.1.3 Sequences, replications, conditions and loops | 27 |
| 2.1.4 Matrices | 30 |
| 2.1.5 Storing and reading data files | 31 |
| 2.1.6 Probability distributions | 32 |
| 2.1.7 Graphics | 33 |
| 2.1.8 Linear regression | 34 |
| 2.2 Sampling from a population | 36 |
| 2.2.1 Enumeration of samples | 36 |
| 2.2.2 The sample() function | 37 |
| 2.3 Exercises | 38 |

| | | |
|----------|---|-----------|
| 3 | Inclusion probabilities | 41 |
| 3.1 | Introduction | 42 |
| 3.2 | Some notation | 42 |
| 3.3 | Inclusion indicator I | 43 |
| 3.4 | A small example | 44 |
| 3.5 | Inclusion probabilities π | 45 |
| 3.6 | Obtaining inclusion probabilities with R | 46 |
| 3.7 | Simple random sampling (SI) | 47 |
| 3.8 | Properties of the inclusion indicator | 50 |
| 3.8.1 | The expected value of the inclusion indicator | 51 |
| 3.8.2 | The variance of the inclusion indicator | 51 |
| 3.8.3 | The covariance of the inclusion indicator | 51 |
| 3.8.4 | Properties of the covariance | 52 |
| 3.8.5 | Covariance matrix and sums of sums | 53 |
| 3.9 | Exercises | 54 |
| 4 | Estimation | 57 |
| 4.1 | Introduction | 58 |
| 4.2 | Estimating functions and estimators | 58 |
| 4.3 | Properties of estimation functions | 58 |
| 4.4 | The π -estimator | 59 |
| 4.4.1 | Properties of the π -estimator | 59 |
| 4.4.2 | Expected value and variance of the π -estimator | 59 |
| 4.4.3 | An alternative expression of the variance | 62 |
| 4.4.4 | The Yates-Grundy variance of the total | 62 |
| 4.5 | Estimation using R | 64 |
| 4.5.1 | A small numerical example | 64 |
| 4.5.2 | An empirical example: PSID | 68 |
| 4.6 | Generating samples with unequal inclusion probabilities | 70 |
| 4.6.1 | Probabilities proportional to size (PPS) | 70 |
| 4.6.2 | The Sampford-algorithm | 72 |
| 4.7 | Exercises | 73 |
| 5 | Simple sampling | 75 |
| 5.1 | Introduction | 76 |
| 5.2 | Some general estimation functions | 76 |
| 5.2.1 | The π -estimator for the total | 76 |
| 5.2.2 | The π -estimator for the mean | 76 |
| 5.2.3 | The π -estimator for a proportion | 77 |

| | | |
|----------|--|------------|
| 5.3 | Simple random sampling | 77 |
| 5.3.1 | The π -estimator for the total (SI) | 78 |
| 5.3.2 | The π -estimator for the mean (SI) | 79 |
| 5.3.3 | The π -estimator for a proportion (SI) | 80 |
| 5.4 | Some examples using R | 81 |
| 5.5 | Exercises | 86 |
| 6 | Confidence intervals | 89 |
| 6.1 | Introduction | 90 |
| 6.2 | Chebyshev-inequality | 92 |
| 6.2.1 | Derivation of the Chebyshev-inequality | 92 |
| 6.2.2 | Application of the Chebyshev-inequality | 94 |
| 6.3 | Confidence intervals based on a specific sample | 94 |
| 6.4 | Some general remarks | 97 |
| 6.4.1 | No approximate normality | 97 |
| 6.4.2 | Simplified variance estimators | 97 |
| 6.4.3 | Effect of simplification in the simple random sampling case | 98 |
| 6.4.4 | Effect of simplification for the general π -estimator | 99 |
| 6.4.5 | Effect of simplification in stratified and clustered samples | 99 |
| 6.4.6 | Bootstrap | 100 |
| 6.5 | Exercises | 101 |
| 7 | Stratified sampling | 103 |
| 7.1 | Introduction | 104 |
| 7.2 | Some notation and an example | 104 |
| 7.2.1 | Notation | 104 |
| 7.2.2 | Example: Sectors of employment as strata | 105 |
| 7.3 | Estimation of the total | 108 |
| 7.3.1 | Simple random sampling within strata | 108 |
| 7.3.2 | Example: simple random sampling within sectors | 110 |
| 7.4 | Choosing the sample size for individual strata | 110 |
| 7.4.1 | The minimization problem | 111 |
| 7.4.2 | The Cauchy-Schwarz inequality | 112 |
| 7.4.3 | Solving the minimization problem | 113 |
| 7.4.4 | Example: optimal sampling size within sectors | 115 |

| | | |
|----------|--|------------|
| 7.5 | Sample allocation and efficiency | 116 |
| 7.5.1 | Variance comparisons based on the variance decomposition | 117 |
| 7.5.2 | No stratification versus proportional allocation | 118 |
| 7.5.3 | Proportional allocation versus optimal allocation | 118 |
| 7.5.4 | No stratification versus optimal allocation | 119 |
| 7.5.5 | An efficiency comparison with R | 120 |
| 7.6 | Exercises | 123 |
| 8 | Cluster sampling | 125 |
| 8.1 | Introduction | 126 |
| 8.2 | Notation | 126 |
| 8.2.1 | Clustering the population | 126 |
| 8.2.2 | Artificially clustering the PSID sample | 127 |
| 8.2.3 | Sampling clusters | 127 |
| 8.2.4 | Inclusion probabilities | 128 |
| 8.3 | Estimating the population total | 129 |
| 8.3.1 | The π -estimator of the population total | 129 |
| 8.3.2 | Variance of the π -estimator of the population total | 130 |
| 8.4 | Simple random sampling of clusters (SIC) | 131 |
| 8.4.1 | The π -estimator of the population total | 131 |
| 8.4.2 | The π -estimator in the PSID example | 131 |
| 8.4.3 | Variance of the π -estimator of the population total | 132 |
| 8.4.4 | Variance of the mean estimator in the PSID example | 133 |
| 8.5 | Exercises | 135 |
| 9 | Auxiliary variables | 137 |
| 9.1 | Introduction | 138 |
| 9.2 | The ratio estimator | 139 |
| 9.2.1 | Example of the ratio estimator using PSID data | 140 |
| 9.2.2 | Taylor series expansion | 142 |
| 9.2.3 | The approximate variance of the ratio estimator | 145 |
| 9.2.4 | Estimating the approximate variance of the ratio estimator using PSID data | 146 |

| | | |
|----------------|--|------------|
| 9.2.5 | Comparison of the ratio estimator with the simple π -estimator | 148 |
| 9.2.6 | The ratio estimator in the regression context | 149 |
| 9.2.7 | The linear regression model under specific heteroskedasticity assumption | 151 |
| 9.3 | The difference estimator | 152 |
| 9.3.1 | The difference estimator using regression notation | 152 |
| 9.3.2 | Properties of the difference estimator | 153 |
| 9.3.3 | The difference estimator of average wage using the PSID data | 154 |
| 9.4 | Exercises | 158 |
| 10 | Regression | 161 |
| 10.1 | Introduction | 162 |
| 10.1.1 | Regression without intercept | 162 |
| 10.1.2 | Regression with intercept | 165 |
| 10.1.3 | Multivariate linear regression with intercept | 167 |
| 10.2 | Variance of the parameter estimators | 169 |
| 10.2.1 | Linear approximation of the π -estimator | 169 |
| 10.2.2 | The variance of the linear approximation of the π -estimator | 171 |
| 10.2.3 | Simple regression through the origin | 175 |
| 10.2.4 | Simple regression with intercept | 176 |
| 10.2.5 | Simple regression with intercept and simple random sampling | 177 |
| 10.2.6 | Wage regression with PSID data and simple random sampling | 177 |
| 10.3 | Exercises | 180 |
| Indices | | 183 |
| | Functions Index | 183 |
| | Subject Index | 185 |