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Statistical Hypothesis Testing with SAS and R

Dirk Taeger and Sonja Kuhnt
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For students in statistical sciences fields, acquiring one or several statistical programming languages is one propelling skill for both industry and academia. Two common statistical programming languages are SAS and R, the former being mostly used in industry, and the latter often associated with scholarly and academic works. Nevertheless, R is finding wider application in industry as well, especially with the adoption of statistical methods which stand out as more specialized, such as machine learning and data mining. The spread of more technical methods from academia to industry has prompted a learning demand for R among practitioners in industry as well. Therefore, learning both SAS and R enhances opportunities both in industry and academia for the aspiring learner. This has prompted some authors to present these two languages in one volume. Such treatment is intended in *Statistical Hypothesis Testing with SAS and R*.

Statistical Hypothesis Testing with SAS and R is written in a modular manner where each chapter can be used independently of other chapters, hence making the book flexible enough for a customizable syllabus or adequate as a reference work. The authors have organized the seventeen chapters of the book into eleven parts, where some parts include only single chapters, implying the breadth of the coverage. The structure of each chapter is recurrent throughout the book: a brief introduction to the test, expanding on the test, providing an example with SAS and R code, and introducing relevant references for readers interested in the statistical concepts and original papers. SAS and R code along with example data are also provided on the book's companion website, together with errata notes. Each individual statistical test is succinctly described through presenting a brief description, related assumptions, test hypotheses, test statistic, test decision (when to keep or reject the hypotheses), the p value and some extra remarks about the test (which may occur in other chapters for tests of similar nature). The data sets used for each example are provided at the end of the book. SAS and R codes are used to perform the tests using an example based on the provided data sets. Both SAS and R codes are provided with outputs and comments, which is great aid in understanding and learning the coding part. The authors totally avoid the use of macros or packages and instead use original code.

Part I, *Introduction*, includes a single introductory chapter (*Statistical Hypothesis Testing*). In Chapter 1, the authors intend to build on the title of the book by elaborating on the concepts and steps of statistical hypothesis testing, with a brief historical background. Common topics in hypothesis testing, such as test statistic, null and alternative hypotheses, Type I and Type II errors, significance level and the p value are presented. In addition, the authors present an example through which they elaborate on the steps of hypothesis testing in SAS and R. Coding the statistical concepts is a very effective way to engage the audience in the learning process. The authors also outline different distributions and their corresponding generating functions in SAS and R. So, by reading Chapter One, the audience can grasp the presentation approach and the structure of all chapters in the book.

Part II, *Normal Distribution*, comprises two chapters. Chapter 2 (*Tests on the Mean*) focuses on comparing means when the distribution is normal. In Chapter 3 (*Tests on the Variance*), tests for comparison of variance between groups or models are presented. χ^2 tests on the variance for one sample (with known and unknown means), the F test on variances of two populations, and the t test on the variances of two dependent populations are presented.

Chapter 4 (*Tests on Proportions*) in Part III, *Binomial Distribution*, presents tests on proportions, such as one-sample and two-sample (equal and unequal sample sizes) proportion tests, and k-sample χ^2 distribution (contingency) tests.

Part IV, titled *Other Distributions*, includes statistical tests based on Poisson and exponential distributions. Tests on *Poisson Distribution* are introduced in Chapter 5. z and exact tests on λ, and the difference between two λ's are presented. SAS and R code with annotations, output and relevant comments are provided through an example. Chapter 6 (*Exponential Distribution*) presents statistical tests and implementation SAS and R codes for data from wait-time models.

Part V, *Correlation*, includes Chapter 7 (*Tests on Association*) which introduces statistical tests to examine relationships between models and variables. Pearson's product moment coefficient, Spearman's rank correlation coefficient, partial correlation, and z test to compare two correlation coefficients are presented in this chapter.

Part VI, *Nonparametric Tests*, includes three chapters on tests of location and rank. Chapter 8 (*Tests on Location*) presents the sign test (for median), Wilcoxon signed-rank test, Wilcoxon rank-sum test (Mann-Whitney U test), Wilcoxon matched-pairs sign rank test (for paired samples), and Kruskal-Wallis test for k-sample designs. Chapter 9 (*Tests on Scale Difference*) introduces statistical tests to determine if samples come from the same population. The Siegel-Tukey test for two samples, Ansari-Bradley test, and the Mood test are presented. SAS procedures and R functions are used to perform these tests. Chapter 10 (*Other Tests*) includes the Kolmogorov-Smirnov two-sample test to determine if two samples are drawn from the same population. This is one of the few chapters in the book that uses graphs for presenting the analysis output.

Part VII, *Goodness-of-Fit Tests*, presents two chapters for model fitting (to establish the underlying distributions of data). Chapter 11 (*Tests on Normality*) introduces tests for checking the normality of data, including the Kolmogorov-Smirnov test, Anderson-Darling test, Cramer-von Mises test, Shapiro-Wilk test, and Jarque-Bera test. Chapter 12 (*Tests on Other Distributions*) presents tests for non-Gaussian distributions.

Chapter 13 in Part VIII, *Tests on Randomness*, provides tests that verify if a sample is randomly drawn from a population. Wald-Wolfowitz run test, runs up and down test, von

Neumann test, and Bartel's test are introduced with appropriate SAS and R code, output and annotations.

Part IX includes Chapter 14 (*Tests on Contingency Tables*) which presents tests on independence of categorical data. Fisher's exact test, Pearson χ^2 test, the likelihood-ratio χ^2 test, Cohen's kappa (for agreement and symmetry), McNemar's test for change, Bowker's symmetry test, and the odds ratio test for relative hazard or risk. SAS and R codes are demonstrated for these tests using example data.

Tests on Outliers as general diagnostic procedures are presented in Chapter 15 in Part X of the book. Grubbs' test for univariate Gaussian sample, David-Hartley-Pearson test for extreme minimum and maximum values, Dixon's test for univariate Gaussian distribution, and outlier tests for exponential and uniform distributions comprise outlier tests in the chapter.

Part XI, *Tests in Regression Analysis*, the last part of the book, includes Chapter 16 (*Tests in Regression Analysis*) and Chapter 17 (*Tests in Variance Analysis*). *Tests in Regression* includes tests on regression slopes and intercept in simple and multiple regression analyses, and test for determining the significance of regression. *Tests in Variance Analysis* includes ANOVA tests and ANOVA assumption tests, such as Bartlett test and Levene test for homogeneity of variances.

Appendices, including the datasets, critical values tables, a glossary of terms (and several symbols) and an index conclude the book.

Although there are many books on SAS and R on the market, *Statistical Hypothesis Testing with SAS and R* has two distinguishing features that may count as the strengths of the book. The book does not clutter programming with teaching the reader statistics. Rather, it assumes that the audience already know the statistical methods and need just to implement them through software. This characteristic helps the audience focus on the code and the results than read or skip pages of concepts they already know. Another major feature of the book (though which may not appeal to others) is the use of original code, algorithms and built-in procedures and functions to implement the methods instead of using macros and packages. Some books (especially R books) look like a catalog of packages where the author introduces them and the reader gets to know about them and *uses* them. In contrast, this book attempts to implement statistical methods through coding, which shows how the equations and functions are reliably coded. This method is also a very efficient way to learn programming (though this may not be the primary purpose of the book).

There are other positive features in the book which are worth noting. All datasets are provided in raw form in an appendix. Statistics is the art of making sense of data and I believe the learner should see the data in the raw form and even enter them themselves as input as if they are first-hand observations. By seeing the data and knowing the story behind them, the audience can better make sense of the results from the analysis. Although the data are available online, I recommend spending some time on the data tables in the book (and even inputting them) to understand the results better. The data are short enough for this purpose. In addition, data entry and data management are parts of statistical skills one should know.

Because the book avoids teaching statistics to focus on coding, all chapters are clear and accessible for the audience who need a reference book for SAS and R code for a certain method. Expository language is kept to a minimum to the advantage of efficiency and accessibility. Nonetheless, essential statistical concepts are provided to introduce the tests.

Also, code annotations (both in SAS and R) help the reader make sense of the way methods

are implemented. The output is also explained briefly to guide the audience to what look for in the results.

Despite the foregoing strengths, the book is not clear of some drawbacks. The authors almost totally avoid the use of graphs in statistical analyses and output. Today, data visualization is one of the skills statisticians need to know to clearly communicate the results to a wider audience. In addition, using graphs can pedagogically enhance learning and understanding the results.

Minor issues with the book include some typos and linguistic inaccuracies and lack of a symbols explanation page (especially for a few European mathematical symbols). The book would make a very good text or lab supplement if it included some exercises. Also, there are too many parts compared to the number of chapters, and even some parts comprise only a single chapter. Parts could be totally eliminated or reduced by collapsing some together. In addition, choosing the names of distributions for some parts (e.g. normal or binomial) may imply that the book is theoretically oriented given its practical nature. Moreover, Part XI would more appropriately be named *linear models* to include both the regression and ANOVA chapters. In addition, because p values are computed in their exact forms, the inclusion of critical values tables in the appendix seems unwarranted.

On balance, *Statistical Hypothesis Testing with SAS and R* makes a very good choice as a reference book on SAS and R for practitioners, as well as for those who know one of these languages and intend to learn the other. The book is also good resource for courses where the goal is to teach SAS or R and the students already know the statistical methods. In addition, the book can be a great supplement to teach SAS and R for traditional statistics courses in some undergraduate programs such as psychology, education, public health and biostatistics.

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