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BOOK REVIEW

TIME SERIES: A DATA ANALYSIS APPROACH USING R

By Robert H. Shumway and David S. Stoffer. Published by Taylor & Francis Group, LLC, Boca Raton, London, New York, 2019. ISBN: 9780367221096 (HARDBACK)

The field of time series analysis has been studied for many decades. As such, there is a multitude of reference books dedicated to the topic, for example, ‘standard’ texts such as Brillinger (1981); Brockwell and Davis (1991); Chatfield (2013) amongsts others. With the current popularity of data science and the increasing availability of time series datasets, it is hardly surprising that there are also a number of recent sources with a more practical approach to time series analysis, particularly using the *R* programming language (R Core Team, 2019). Examples of such texts include Metcalfe and Cowpertwait (2009) or Woodward et al. (2017); in my opinion *Time Series: A Data Analysis Approach Using R* sits between the shorter online resource of Coghlan (2015) and the existing successful offerings from Shumway and Stoffer (Douc et al., 2014; Shumway and Stoffer, 2017) in both its scope and intention.

This book consists of eight chapters, and its content can be seen to divide naturally into four parts. Part one sets up time series nomenclature, mathematical notation, and introduces initial descriptions of time series, including the fundamental concept of stationarity. Much of the material here is on data exploration to demonstrate the concepts. The main part of the book provides a treatment of classical ARIMA time series models, covering topics such as estimation and forecasting for both seasonal and non-seasonal models. Example-based analyses lead the reader through the Box-Jenkins model-building procedure, including a short but perfectly adequate section on model diagnostics. I was pleased to see that some time is dedicated to (lagged) time series regression, a topic which is sometimes overlooked in introductory texts. The third section introduces filtering and spectral representations of time series, with a nicely presented overview of traditional spectral estimation techniques – quite thorough for this level of audience. The last section (and indeed chapter) contains some more advanced topics intended for further study if time in an undergraduate course permits. The authors have opted for breadth here, discussing a number of topics including GARCH processes, long memory, state space and threshold models amongst others. This means that each subject is briefly introduced in comparison to earlier chapters, serving more as starting points for study; perhaps with the exception of GARCH processes, instructors would need additional texts on these topics to do them justice. Having said that, as with earlier chapters, the questions at the end of the chapter provide interesting food for thought for the content.

The book also features some additional useful material which is deferred to a number of appendices so as not to detract from the practical focus of the book, namely (i) a somewhat densely presented crash-course on the *R* programming language for absolute beginners (ii) a ‘refresher’ chapter dedicated to introductory probability and statistics and (iii) a section containing additional details on some of the technical aspects of the book (such as causality and invertibility) which are understandably skipped earlier on in the book in favour of more complete data analyses. These extra chapters help to provide a self-contained exposition of the area.

The intended audience of the book are mathematics undergraduates taking a one semester course on time series, so the assumed knowledge of readers is introductory probability and a course on calculus. The authors frame learning time series primarily by extending concepts from linear models. Personally, I favour this approach, since it allows the book to clearly signpost similarities and differences between concepts in both topics and provides a natural learning progression from what most undergraduate students will already be familiar with. The text is peppered with snippets of *R* code to back up the theoretical content and illustrate example data analyses. This is achieved using different colours for commands, console output and comments; some may think this somewhat of a minor point to mention, but it results in an aestethically-pleasing presentation of the material. As mentioned previously, the book contains sets of problems at the end of each chapter to encourage the reader's self-learning. These aim to strike a balance between the theory and practice discussed in each chapter – there are some mathematical questions, but are mainly based around exploring datasets from the *astsa R* package (Stoffer, 2019). Many of these datasets are well-established in the pedagogical literature on time series due in part to the success of the authors' forerunner Shumway and Stoffer (2017). With the regular update of the *astsa* package, there are also some interesting new datasets from a number of different application areas. I also like that the authors include 'starred' sections, indicating more optional or standalone material, which won't affect a reader's progression through the content if skipped.

In the preface, the authors state that they aim to provide an introductory text to help students develop an appreciation for the richness and cross-disciplinary nature of studying data with temporal dependence. In my opinion, this book successfully delivers a practical tool-based approach to time series analysis at an introductory level, complementing the existing texts from the authors, which are aimed at a more advanced audience. Indeed, this book can serve as a springboard to the other more substantial texts mentioned at the start of this review, for those students wishing to delve into the topic further.

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