**Benchmarking, Temporal Distribution, and Reconciliation Methods for Time Series.**

Estela Bee Dagum and Pierre A. Cholette. New York: Springer Science+Business Media, LLC, 2006. ISBN-10: 0-387-31102-5. xiii + 409 pp. $69.95

This monograph, the first devoted to the interrelated topics of its title, is a distillation of its authors' unrivaled two decades and more of research and practical experience at Statistics Canada in the topic areas.

To provide motivation and context, we quote from the Forward. After stressing the importance of official economic statistics to governments at all geographic levels, school boards, central banks, businesses, industries and economic analysts, the authors write, “A common misconception is that time series data originate from the direct and straightforward compilations of survey data, censuses and administrative records. On the contrary, before publication time series are subject to statistical adjustments intended to facilitate analysis, increase efficiency, reduce bias, replace missing values, correct errors, and satisfy cross sectional additivity constraints”.

To illustrate these adjustments and the terminology used, we give an example for each of the main topic areas using the authors' preferred terminology. An instance of *benchmarking* is the modification of data from a monthly survey to sum to the statistically more accurate annual totals from larger annual surveys (using a procedure expected to approximately preserve some important features of the original data). Similarly, because of the sampling weights used, state or province level industry data for a suite of industries often do not sum to the national values by industry or to total industry values by state or province. *Reconciliation* (or *balancing*) methods produce conforming sums. Calendar month data must often be produced from enterprise data reported for four- or five-week intervals (whose dates can vary among reporters), an instance of the task known as *calendarization*. Finally, for national accounts and other purposes, often a seasonal quarterly version is produced of a time series for which only annual data are available, by using the annual values and a related seasonal quarterly series. This is an instance of *interpolation* for a stock series or, for a flow series, of *temporal distribution* (or *temporal disaggregation*), so named because the quarterly values produced for each year must sum to the year's observed annual value.

The monograph surveys a broad literature (134 references, including references for relevant time series background), and it provides a largely unifying perspective based on the very general and versatile Cholette-Dagum regression model (hereafter C-D model) whose initial version was published in Cholette and Dagum (1994) and then developed further in later references cited.

Take benchmarking as an example. The prorating method and especially the Denton (1971) method (1,850,000 “hits” from a

Google search) are widely used and computationally simple benchmarking methods for constraining annual totals of monthly values. However, the former usually produces a spurious discontinuity in the benchmarked values between the end of each year and the first month of the next year, and the latter tends to generate large revisions to earlier benchmarked data when a new annual value is added to the set of constraining values. The C-D additive and multiplicative benchmarking models avoid these defects by incorporating an error model whose autocorrelations at monthly lags are those of a (usually prespecified) autoregressive model of order one or two. This and other features of its flexible structure allow the additive model to be used for additive, proportional, or a mixture of additive and proportional benchmarking. For positive series with large seasonal amplitudes, the C-D multiplicative benchmarking model produces positive benchmark values and appropriately allocates more of the annual discrepancies being removed to the seasonally larger values.

Analogous remarks apply to the popular Chow-Lin regression method (1971, 1976) (280,000 “hits” from a Google search) applied for interpolation and temporal distribution, some of whose limitations are made clear, along with possible remedies, through the framework of C-D regression-based methods.

The C-D regression framework has a number of desirable properties. For example, it is flexible enough to reconcile systems of series that have one or multiple sets of cross sectional constraints while maintaining most of the temporal aggregation constraints; it permits hierarchical reconciliation, which greatly reduces calculations with no loss of optimality; and, depending on the covariance matrices available for the series to be reconciled, different criteria can be optimized. Also, explicit matrix algebra formulas (sometimes requiring calculation of inverses, or generalized inverses, of large matrices) are available for its results. For its implementation in various contexts, pseudo-algorithms are provided.

The authors have made substantial pedagogical efforts throughout to enable the reader to understand the methods and their associated compromises. Many examples using both simulated and official published data are provided to illustrate the statistical models as they are developed. To facilitate understanding and comparison of alternative methods, the example of Canadian Total Retail Sales is followed through the successive methods chapters. There is also a valuable extensive and detailed discussion (Section 11.4) on detecting data problems that commonly afflict large time series data sets, especially those to which reconciliation methods are applied.

Chapter 1 introduces and motivates all the topics in the book’s title and others that will be addressed. Chapter 2 can be warmly recommended to anyone seeking motivation and understanding regarding the components of a seasonal time series that play a role in seasonal adjustment and regarding the associated models for holiday and trading (or working) day effects and outliers. The remaining chapters can be divided into two parts: part 1 consists of Chapters 3 to 10, which focus on adjustments for a single time series; part 2 consists of Chapters 11 to 14, which are devoted to adjustments of systems of time series.

Chapters 3, 4, 5, 6 and 8 focus exclusively on benchmarking methods. Chapter 3 and 5 develop, respectively, the Cholette-Dagum additive and multiplicative regression-based benchmarking models. Chapter 4 discusses construction of the covariance matrices used in benchmarking and their role in the very important decision of weak versus strong movement preservation. Chapter 6 reviews in depth the classical Denton method and its first and second difference variants. It demonstrates the advantages of the C-D additive regression-based model over the Denton additive and proportional methods. (Statistics Canada has developed a SAS *Proc Benchmarking* implementing the C-D approach. It is available from forillon@statcan.ca for evaluation.) Chapter 8 presents two benchmarking models based on signal extraction via state-space models.

Chapter 7 deals with temporal distribution, interpolation and extrapolation. The discussion starts with simple ad hoc procedures and moves next to widely used more formal methods such as the Chow-Lin regression method and its dynamic variants. (An assortment of these methods is implemented in Eurostat's *Ecotrim* software for temporal distribution available at http://circa.europa.eu/Public/irc/dsis/ecotrim/library .) The chapter concludes with C-D regression-based methods. Chapter 9 concerns the problem of calendarization, focusing mostly on transforming data from fiscal periods to calendar periods. It notes the important limitations of simple assignment and fractional calendarization procedures and contrasts them with the Denton- and the C-D regression-based calendarization methods.

Chapter 10 presents the generalized dynamic stochastic regression model (Dagum, Cholette and Chen, 1998). This provides a unified regression-based framework for all the adjustments of a single time series treated as separate problems in the previous chapters. The ARIMA model-based method with signal extraction, the modified Denton method and its variants, the smoothing method for interpolation and temporal distribution by Boot, Feibes and Lisman (1967), and the Chow-Lin method and its variants are shown to be the special cases of the general regression model.

Chapters 11 to 14 address the problem of reconciliation of systems of time series focusing on one-way and two-way classified systems of series. Chapter 11 reviews Iterative Proportional Fitting (*raking*) and influential early least squares procedures and introduces the general regression-based reconciliation method. Chapter 12 formulates the one-way reconciliation model for systems with one set of cross sectional constraints. Chapter 13 introduces the marginal two-way reconciliation model for the situation in which cross sectional constraints pertain only to the row and column totals of a two-way system of series and the grand total of the system. Chapter 14 presents the general two-way reconciliation model and a variant that is applicable to very large systems such as those of economic Input-Output models.

We regard *Benchmarking, Temporal Distribution, and Reconciliation Methods for Time Series* as an essential reference for statistical institutes and central banks and for statisticians and economists who have to address similar time series data issues. Some background in linear models is needed to understand certain (carefully discussed) aspects of the C-D model. Familiarity with autoregressive models is enough time series background for the material that does not involve ARIMA forecasting (in Chapter 7) or signal extraction methods. For the latter, some knowledge is needed of ARIMA models, structural models, and state space methods. The book could serve as a textbook for a graduate level special topics course.

The views expressed by the reviewers are their own and not necessarily those of their respective agencies.

Baoline CHEN and David FINDLEY
*U.S. Bureau of Economic Analysis and U.S. Census Bureau*

REFERENCES

Boot, J.C.G., Feibes, W. and Lisman, J.H.C. (1967), “Further methods of derivation of quarterly figures from annual data,” *Applied Statistics*, 16, 65-75.

Chow, G.C. and Lin, A.L. (1971), “Best linear unbiased interpolation, distribution and extrapolation of time series by related series,” *The Review of Economics and Statistics*, 53, 372-375.

Chow, G.C., Lin, A.L. (1976), “Best linear unbiased estimation of missing observations in an economic time series,” *Journal of the American Statistical Association*, 71, 719-721.

Denton, F.T. (1971), “Adjustment of monthly or quarterly series to annual totals: An approach based on quadratic minimization,” *Journal of the American Statistical Association*, 66, 99-102.

Cholette, P.A. and E.B. Dagum (1994), "Benchmarking time series with autocorrelated sampling errors," *International Statistics Review* 62, 365-377.

Dagum, E.B., Cholette, P.A. and Chen, A.G. (1998), “A unified view of signal extraction, benchmarking, interpolation and extrapolation of time series,” *International Statistical Review*, 66, 245–269.