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Title

Review of Growth Curve Modeling: Theory and Applications, by Michael J. Panik

Permalink

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Journal

Structural Equation Modeling A Multidisciplinary Journal, 23(4)

ISSN

1070-5511

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Publication Date

2016-07-03

DOI

10.1080/10705511.2016.1144479

Peer reviewed

This review is published in *Structural Equation Modeling: A Multidisciplinary Journal*

Volume 23, Issue 4, 2016

Book Review

Review of **Growth Curve Modeling: Theory and Applications**, Michael J. Panik. Hoboken, NJ: Wiley, 2014, 454 pp, \$134 Hardcover, \$107.99 E-Book.

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Michael J. Panik's *Growth Curve Modeling: Theory and Applications* presents a potpourri of methods for modeling growth with an emphasis on nonlinear growth functions and their interpretation. The stated purpose of the book is to "convey to those who attempt to monitor the change in some variable that there is no 'one-size-fits-all' approach to growth measurement." Thus, great attention is given to how growth is defined. The author presents longitudinal techniques amenable to the study of economics and includes models specifically applicable to forestry, agriculture and business, namely dynamic site equations, nonlinear regression, nonlinear mixed-effects models, yield-density curves, population dynamics, stochastic processes, and time series. The models are described with mathematical rigor and practically demonstrated with SAS syntax and annotated output. Readers are assumed to have knowledge of elementary calculus and statistics.

The book includes 10 chapters. Chapter 1 provides mathematical preliminaries necessary for subsequent discussions and proofs. These include arithmetic and geometric progression, the calculus of finite differences, logarithms, exponential functions and formulas for compound interest. Chapter 2 introduces fundamental concepts relating to growth including relative and average rates of change, discrete versus continuous growth, compound growth and growth rate variability. Chapter 3 describes parametric growth functions including linear, logarithmic, reciprocal, logistic, Gompertz, Weibull, negative exponential, among many others. The parameters of each are clarified and model derivations are included in appendices at the end of the chapter. The chapter focuses on sigmoidal (S-shaped) curves but includes examples of both exponential and linear growth curves. Chapter 4 is a comprehensive chapter on the estimation of trend. The author addresses both ordinary least squares (OLS) and maximum likelihood estimation (MLE) methods for estimating trend. The SAS system is introduced in this chapter with extensively annotated syntax that can be used for estimating linear and semi-logarithmic trends. This chapter includes a section on autocorrelated errors and polynomial models with corresponding SAS syntax and annotated output. Chapter 5 presents dynamic site equations for forest growth modeling (literally the growth of forests). Chapter 6 is a chapter on the estimation of nonlinear regression using OLS, MLE and nonlinear least squares methods. Several estimation examples are given with SAS syntax and output. This chapter describes iterative methods (optimization algorithms) used to estimate model parameters, such as the Gauss-Newton and Newton-Raphson methods, and includes several methods for generating initial values for different growth functions. Chapter 7 concerns the study of yield-density relations for

plants and plant parts and includes a number of yield-density equations. Chapter 8 is a short chapter on nonlinear mixed effects models that describes the nature of hierarchical models and includes PROC NLMIXED syntax for fitting models using PROC NLMIXED and that are based on logistic, Gompertz, Weibull, and Chapman-Richards growth curves. Chapter 9 addresses issues relating to the size and growth distribution of firms, and Chapter 10 focuses on population dynamics and includes descriptions of models used for population growth rates with related SAS syntax and output.

EVALUATION

Michael J. Panik's *Growth Curve Modeling: Theory and Applications* is not a book that deals explicitly with a latent variable modeling approach to growth curve modeling. In the social sciences the term "growth curve model" is typically used to describe either longitudinal multilevel or structural equation models that deal with latent characteristics of change and are used to study within-person change and between-person differences in the characteristics that describe change. The term "growth curve modeling" in this book is used much more broadly to mean any type of growth process that occurs over time. Although this book is rich in model variety, many of the models described might have limited use to the social science researcher. This is not to say that the techniques described in this book should not or could not be applied to the study of behavioral measures, but rather the way the techniques are presented in this book would likely require a degree of modification to be applicable to behavioral data.

Although the pages of mathematical derivations and proofs may be of less interest to the casual methodologist, the annotated SAS syntax and output that is included after almost every model in the book should be accessible to most. The SAS syntax is clearly presented and the annotated output is helpful in connecting the mathematical descriptions of the models to their applications. Many of the models and functions included in the book were developed for specific fields such as forestry, plant biology, and economics. The syntax that is included makes the applications of these models to other fields much more feasible.

There is sparse discussion of the advantages and disadvantages of the different techniques, and this book might best be read as a reference book rather than as an introduction to growth curve models in general. Chapters 3 (Parametric Growth Curve Modeling), 4 (Estimation of Trend), 6 (Nonlinear Regression), and 8 (Nonlinear Mixed-Effects Models for Repeated Measurement Data) may be the most generalizable chapters and include relevant proofs and descriptions of growth methodologies that should be useful across disciplines. Additionally Appendix 6.E Selection of Initial Values provides some useful tools for applications of the logistic, Gompertz, Weibull, and Chapman-Richards curves.