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Forecasting, Structural Time Series Models and the Kalman Filter

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Review

Reviewed Work(s): Forecasting, Structural Time Series Models and the Kalman Filter by Andrew C. Harvey; Bayesian Forecasting and Dynamic Models by Mike West and Jeff Harrison

Review by: Robert Fildes

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Book Selection

Edited by RICHARD EGLESE and MIKE PIDD

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JOHN E. SUSSAMS: How to Write Effective Reports (2nd Edition)	1033
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Forecasting, Structural Time Series Models and the Kalman Filter

ANDREW C. HARVEY

Cambridge University Press, Cambridge, 1989. 554 + xiv pp. £55
 ISBN 0 521 32196 4

Bayesian Forecasting and Dynamic Models

MIKE WEST and JEFF HARRISON

Springer-Verlag, Berlin, 1989. 704 + xxi pp. DM 118.00
 ISBN 3 540 97025 8

For most of the past decade Andrew Harvey has been developing state-space models as an alternative to ARIMA Box-Jenkins models for describing both univariate and multivariate time series data. His new book presents a wide variety of state-space models, showing how they can be used to model the types of problems that have previously been dealt with in an ARIMA framework.

The general state-space model is of the form:

$$y_t = Z_t \alpha_t + d_t + \varepsilon_t$$

$$\alpha_t = T_t \alpha_{t-1} + c_t + R_t \eta_t$$

The parameter vector α_t is not observable but is assumed to be generated by a first order Markov process. Further assumptions must be made about the initial conditions at $t = 0$ and the distribution of the variances. By judicious choice of the various components in the equations it is possible to replicate most well-known time series models. By choosing simple parameterizations Harvey argues that much of the richness of existing time series models can be captured with the added benefit of the models being comprehensible and readily interpretable.

For example, what Harvey calls the Basic Structural Model is used in the text to describe many univariate time series. It is of the form:

$$y_t = \mu_t + \gamma_t + \varepsilon_t$$

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t$$

$$\beta_t = \beta_{t-1} + \zeta_t$$

where γ_t is a seasonal factor which may be modelled in a number of ways, μ_t represents the level and β_t the trend.

Harvey's book starts by introducing his views on the nature of time series, modelling methodology and forecasting. Chapter 2 is concerned with univariate time series where he links both *ad hoc* forecasting methods such as exponential smoothing and model based approaches such as Box-Jenkins to structural models, in particular the basic structural model above. Chapter 3 defines the state-space class of models and shows how the Kalman filter can be used to produce recursive estimates of the parameter vector α and the variance-covariance matrix of the error terms. The filter estimates are conditional on the unknown variance parameters and Harvey goes on to

consider maximum likelihood estimation. Chapter 4 considers the estimation of basic structural models in depth, including their use in prediction. Chapter 5 examines hypothesis testing within a particular class of structural model and model selection between classes of model. Chapter 6 describes many extensions to the univariate model showing how they can be dealt with through the state-space formulation. Explanatory variables are considered in Chapter 7 including modelling of count data, while Chapter 8 discusses multivariate models. The book concludes by extending the analysis to continuous time.

As an advanced text on state space models the book has no competitors although West and Harrison cover much the same ground from an explicitly Bayesian point of view. In many ways I found Chapter 2 linking state-space models to established univariate forecasting methods the most unsatisfactory in that the logic of the presentation was never clear and the attempts to offer insight cursory. As a monograph on a particular approach to modelling time series Harvey's book is a necessary addition to the time series statistician's library. The applied OR scientist interested in whether the approach has anything to offer will remain unconvinced, overwhelmed by mathematical statistics. From my own perspective I accept Harvey's argument that the basic structural model is a more sensible formulation for describing time series data. A particular attraction is that it overturns the need for assuming stationarity, so necessary in ARIMA modelling, instead focusing on the modelling of trend. One cautionary note though, if state-space models do not provide good forecasts, I suggest they cannot be taken too seriously as offering good descriptions of the data generation process. After all, univariate models are rarely of interest in themselves.

West and Harrison's book also considers a general state-space model, refining it to particularly simple cases and extending it to cover all the same problems as Harvey faces and more. The book is seen as a research monograph, also suitable for an advanced (possibly undergraduate) course. It differs from Harvey's in that the authors have long adopted an explicitly Bayesian framework to the estimation of the model's parameters. Leaving aside the philosophical considerations that lead statisticians to adopt an almost religious fervour when airing their views on Bayesian estimation, the explicitly Bayesian framework has some naturally attractive features that are not readily part of a classical framework, for example the forecast errors are essentially recursive (based on information only up to $(t - 1)$) and therefore their distribution is by definition the *ex ante* one-step-ahead forecast error distribution—an uncommonly rare feature to find.

Building on the strengths of the state-space formulation the authors make great play of the comprehensibility of each component in a good model. Chapter 1 lays down the authors' views on modelling and then goes on to give 'historical perspective and bibliographical comments' where they defend the uniqueness of the Bayesian approach to forecasting as presented in Harrison's early paper with Stevens¹. I did feel here that the reader would have to be well versed in the recent history of forecasting to appreciate the nuances of some of West and Harrison's somewhat defensive comments. Chapter 2 discusses more conventional matters with a discussion of the simplest of structural models which only includes a level equation. Chapter 3 develops a variable parameter (dynamic) version of the regression model. Chapter 4 considers the general case of the state-space model (here termed the dynamic linear model). Chapters 5–8 are concerned with time series models including seasonality while Chapter 9 discusses the inclusion of 'independent' variables. Chapters 10 and 11 describe the use of the state-space models in practice. Chapter 12 describes the multi-process models including the model first presented by Harrison and Stevens in 1971² to the OR community which attempted to include changes in the series behaviour such as an outlier, step or slope change as components in the overall model. The last three chapters discuss advanced topics including non-linear modelling.

Overall it is an impressive, coherent presentation. Certainly any researcher in the area would want a copy for his/her shelves. I found the book more intellectually satisfying than Harvey's in that with barely a nod in the direction of other approaches to forecasting, West and Harrison present their particular viewpoint. It is at its least convincing in the case studies where no comparisons are made with alternative approaches, *ex post* analysis is applied as if it were *ex ante* and little consideration is given to the question of user involvement in specifying priors or interventions, despite this being a key argument in favour of a Bayesian formulation. Nor is the limited evidence on the comparative forecasting performance of the Bayesian models discussed^{3,4}.

The Bayesian approach also has its own methodological problems, for example, that of

specifying the priors, which is addressed here as if any competent user could define appropriate distributions, but I would observe that unless the remark is regarded as a truism this is just not correct. There is also the added difficulty of dealing with the error variances. (Harvey estimates them—it is computer intensive). A resolution to this problem is attempted through the notion of the prior estimate of a discount factor which is neither intuitively obvious, nor empirically satisfactory in that performance will often depend on these estimates. That is, of course, exactly why Harvey chooses to estimate these parameters.

In summary, both books are excellent research monographs which I hope will stimulate much further research. Where both books seem to me weakest is when it comes to the question, 'Do these approaches achieve in practice, what they offer in theory?' where too little empirical evidence is presented.

ROBERT FILDES

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How to Write Effective Reports (2nd Edition)

JOHN E. SUSSAMS

Gower, Aldershot, 1991. 127 + xi pp. £17.50

ISBN 0 566 02911 1

The great strength of this volume is its comprehensiveness. Indeed its title disguises the fact that within its pages you will find guidance on all stages of a report's production: not just the writing, but also the planning, researching, presentation of data, design and reproduction.

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The quest to be comprehensive in a short volume can lead to a lack of detail: one notices this in the section on new technology, to which (on account of its increasing importance in the design and typesetting of documents) more prominence might have been given. But elsewhere Sussams displays skill in communicating a great deal of information, lucidly, in a minimum of space.

'How to Write Effective Reports' is a book to be read, not just consulted. There will be few who fail to find something helpful therein.

GARETH JOHNSTON

Mapping Strategic Thought

ANNE SIGISMUND HUFF (Editor)

John Wiley & Sons Ltd, Chichester, 1990. 426 + xvii pp. £39.95

ISBN 0 471 92632 9

Techniques of 'mapping' of all sorts have become a familiar part of the tool kit of many operational researchers in recent years, mainly for use in the problem structuring phases of our work. This excellent book offers a USA perspective on mapping and a wealth of interesting articles and ideas. For consultants who 'map a lot' and those with more than a passing interest this book is a must.