Chapter 1
Introduction

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Overview of SAS/ETS Software

SAS/ETS software, a component of the SAS System, provides SAS procedures for

- econometric analysis
- time series analysis
- time series forecasting
- systems modeling and simulation
- seasonal adjustment
- financial analysis and reporting
- access to economic and financial databases
- time series data management

In addition to SAS procedures, SAS/ETS software also includes a menu-driven system for interactive time series forecasting.

Uses of SAS/ETS Software

SAS/ETS software provides tools for a wide variety of applications in business, government, and academia. Major uses of SAS/ETS procedures are economic analysis, forecasting, economic and financial modeling, time series analysis, financial reporting, and manipulation of time series data.

The common theme relating the many applications of the software is time series data: SAS/ETS software is useful whenever it is necessary to analyze or predict processes that take place over time or to analyze models that involve simultaneous relationships.

Although SAS/ETS software is most closely associated with business and economics, time series data also arise in many other fields. SAS/ETS software is useful whenever time dependencies, simultaneous relationships, or dynamic processes complicate data analysis. For example, an environmental quality study might use SAS/ETS software's time series analysis tools to analyze pollution emissions data. A pharmacokinetic study might use SAS/ETS software's features for nonlinear systems to model the dynamics of drug metabolism in different tissues.

The diversity of problems for which econometrics and time series analysis tools are needed is reflected in the applications reported by SAS users. The following listed items are some applications of SAS/ETS software presented by SAS users at past annual conferences of the SAS Users Group International (SUGI).

- forecasting college enrollment (Calise and Earley 1997)

- testing interaction effect in reducing SIDS (Fleming, Gibson and Fleming 1996)

- forecasting operational indices to measure productivity changes (McCarty 1994)

- spectral decomposition and reconstruction of nuclear plant signals (Hoyer and Gross 1993)

- estimating parameters for the CES-Translog model (Hisnanick 1993)

- applying econometric analysis for mass appraisal of real property (Amal and Weselowski 1993)

- forecasting telephone usage data (Fishetti, Heathcote and Perry 1993)

- forecasting demand and utilization of inpatient hospital servises (Hisnanick 1992)

- using conditional demand estimation to determine electricity demand (Keshani and Taylor 1992)

- estimating tree biomass for measurement of forestry yields (Parresol and Thomas 1991)

- evaluating the theory of input separability in the production function of U.S. manufacturing (Hisnanick 1991)

- forecasting dairy milk yields and composition (Benseman 1990)

- predicting the gloss of coated aluminum products subject to weathering (Khan 1990)

- learning curve analysis for predicting manufacturing costs of aircraft (Le Bouton 1989)

- analyzing Dow Jones stock index trends (Early, Sweeney, and Zekavat 1989)

- analyzing the usefulness of the composite index of leading economic indicators for forecasting the economy (Lin and Myers 1988)

Contents of SAS/ETS Software

SAS/ETS software includes the following SAS procedures:

ARIMA	ARIMA (Box-Jenkins) and ARIMAX (Box-Tiao) modeling and forecasting
AUTOREG	regression analysis with autocorrelated or heteroscedastic errors and ARCH and GARCH modeling
CITIBASE	access to DRI/McGraw-Hill Basic Economic database files
COMPUTAB	spreadsheet calculations and financial report generation
DATASOURCE	access to financial and economic databases
EXPAND	time series interpolation and frequency conversion, and transformation of time series

FORECAST   automatic forecasting

LOAN   loan analysis and comparison

MODEL   nonlinear simultaneous equations regression and nonlinear systems
                 modeling and simulation

MORTGAGE   fixed-rate mortgage amortization

PDLREG   polynomial distributed lag regression (Almon lags)

SIMLIN   linear systems simulation

SPECTRA   spectral and cross spectral analysis

STATESPACE   state space modeling and automated forecasting of multivariate
                 time series

SYSLIN   linear simultaneous equations models

TSCSREG   time series cross-sectional regression analysis

X11   seasonal adjustment (Census X-11 and X-11 ARIMA)

SAS/ETS software also includes the following SAS macros:

%AR   generates statements to define autoregressive error models for the
                 MODEL procedure

%BOXCOXAR   investigates Box-Cox transformations useful for modeling and
                 forecasting a time series

%DFPVALUE   computes probabilities for Dickey-Fuller test statistics

%DFTEST   performs Dickey-Fuller tests for unit roots in a time series process

%LOGTEST   tests to see if a log transformation is appropriate for modeling and
                 forecasting a time series

%MA   generates statements to define moving average error models for the
                 MODEL procedure

%PDL   generates statements to define polynomial distributed lag models
                 for the MODEL procedure

These macros are part of the SAS AUTOCALL facility and are automatically available for use in your SAS program. (Refer to *SAS Macro Language: Reference, First Edition* for information about the SAS macro facility.)

The Time Series Forecasting System:

In addition to SAS procedures and macros, SAS/ETS software also includes an interactive forecasting user interface. This user interface was developed with SAS/AF software and uses PROC ARIMA to perform time series forecasting. The TSF system makes it easy to forecast time series and provides many features for graphical data exploration and graphical comparisons of forecasting models and forecasts. (SAS/GRAPH is required to use the graphical features of the system.)

Some of the features of SAS/ETS software are also available through menu driven interfaces provided by SAS/ASSIST software. (Both SAS/ASSIST software and SAS/ETS software must be licensed for you to use these features.)

The following components of SAS/ASSIST software enable you to use SAS/ETS procedures through a menu interface:

- loan analysis (uses PROC LOAN)
- regression with correction for autocorrelation (uses PROC AUTOREG)
- seasonal adjustment (uses PROC X11)
- convert frequency of time series data (uses PROC EXPAND)

About This Book

This book is a user's guide to SAS/ETS software. Since SAS/ETS software is a part of the SAS System, this book assumes that you are familiar with base SAS software and have the books *SAS Language: Reference* and the *SAS Procedures Guide* available for reference. It also assumes that you are familiar with SAS data sets, the SAS DATA step, and with basic SAS procedures such as PROC PRINT and PROC SORT. Chapter 2, "Working with Time Series Data," in this book summarizes the aspects of base SAS software most relevant to the use of SAS/ETS software.

Chapter Organization

Following a brief changes and enhancements section, this book is divided into three major parts. Part One contains general information to aid you in working with SAS/ETS Software. Part Two is the Procedure Reference that is comprised of chapters that explain the SAS procedures that make up SAS/ETS software. Finally, Part Three is the reference for the Time Series Forecasting System, an interactive forecasting menu system that uses PROC ARIMA to perform time series forecasting.

"Changes and Enhancements to SAS/ETS Software in Versions 7 and 8" summarizes the new features added to SAS/ETS software since the publication of *SAS/ETS Software: Changes and Enhancements for Release 6.12*. If you have used SAS/ETS software in the past, you may want to skim "Changes and Enhancements to SAS/ETS Software in Versions 7 and 8" to see what's new.

Part One contains the following chapters.

Chapter 1 provides an overview of SAS/ETS software and summarizes related SAS Institute publications, products, and services.

Chapter 2, "Working with Time Series Data," discusses the use of SAS data management and programming features for time series data.

Chapter 3, "Date Intervals, Formats, and Functions," summarizes the time intervals, date and datetime informats, date and datetime formats, and date and datetime functions available in the SAS system.

Chapter 4, "SAS Macros and Functions," documents SAS macros provided with SAS/ETS software. These macros use SAS/ETS procedures to perform Dickey-Fuller tests, test for the need for log transformations, or select optimal Box-Cox transformation parameters for time series data.

Chapter 5, "The SASEFAME Interface Engine," documents the SASEFAME interface engine that allows SAS users the ability to access and process time series data residing in a FAME database, and provides a seamless interface between FAME and SAS data processing.

Chapter 6, "Using the Output Delivery System," provides an introduction to the Output Delivery System (ODS).

Part Two contains the chapters that explain the SAS procedures that make up SAS/ETS software. These chapters appear in alphabetical order by procedure name.

The chapters documenting the SAS/ETS procedures are organized as follows:

1. Each chapter begins with an *Overview* section that gives a brief description of the procedure.

2. The *Getting Started* section provides a tutorial introduction on how to use the procedure.

3. The *Syntax* section is a reference to the SAS statements and options that control the procedure.

4. The *Details* section discusses various technical details.

5. The *Examples* section contains examples of the use of the procedure.

6. The *References* section contains technical references on methodology.

Part Three contains the chapters that document the features of the Time Series Forecasting System.

Typographical Conventions

This book uses several different styles of type for presenting information. The following list explains the meaning of the typographical conventions used in this book:

roman	is the standard type style used for most text.
UPPERCASE ROMAN	is used for SAS statements, options, variable names, and other SAS language elements when they appear in the text. However, you can enter these elements in your own SAS programs in lowercase, uppercase, or a mixture of the two.
UPPERCASE BOLD	is used in the "Syntax" sections for SAS keywords such as the names of statements and options.

oblique	is used for user-supplied values for options (for example, **INTERVAL**=*interval*).
bold	is used to refer to matrices and vectors
italic	is used for terms that are defined in the text, for emphasis, and for references to publications.
`monospace`	is used to show examples of SAS statements. In most cases, this book uses lowercase type for SAS statements. You can enter your own SAS statements in lowercase, uppercase, or a mixture of the two. The SAS System always changes your variable names to uppercase, but character variable values remain in lowercase if you have entered them that way. Enter any titles and footnotes exactly as you want them to appear on your output.

Output of Examples

For each example, the procedure output is numbered consecutively starting with 1, and each output is given a title. Each page of output produced by a procedure is enclosed in a box. Most of the output shown in this book was produced using the SAS System options LINESIZE=80, PAGESIZE=40, NOPAGE, and NODATE. In some cases, if you run the examples, you will get slightly different output depending on the SAS system options you use and of the precision used for floating-point calculations by your computer. This is not a problem with the software. In all situations, any differences should be very small.

Where to Turn for More Information

This section describes other sources of information about SAS/ETS software.

Online Help System

You can access online help information about SAS/ETS software in two ways, depending on whether you are using the SAS Display Manager System in the command line mode or the pull-down menu mode.

If you are using a command line, you can access the SAS/ETS help menus by typing `help` on the display manager command line. If you are using the display manager with pull-down menus instead of a command line, you can pull-down the **Help** menu and make the following selections:

- S̲AS System
- S̲AS SYSTEM HELP: Main Menu
- I̲NDEX
- S̲AS/ETS

The SAS SYSTEM HELP: SAS/ETS menu contains three parts: procedure help, SAS/ETS news, and a general review of the software.

Procedure Help

The SAS/ETS Help menu contains an entry for each SAS/ETS procedure. To access the help information for a procedure, select the entry with the procedure name. For example, to get help on the ARIMA procedure, select **ARIMA**. The help material given for each procedure is abstracted from this book.

The help menu for each procedure contains three items: Introduction, Syntax, and Additional Topics. The Introduction contains a few paragraphs describing the procedure. The Syntax item provides a quick reminder of the syntax of the statements and options that control the procedure. The Additional Topics item contains additional information and tips on using the procedure.

ETSNEWS: New Features in SAS/ETS Software

Select the ETSNEWS item for information on features that have been added to SAS/ETS software in recent releases of the product. (The ETSNEWS help can also be accessed directly from the display manager command line by typing the command `help`.)

New versions of SAS/ETS software may be released more frequently than new editions of this user's guide are published. Therefore, your version of SAS/ETS software may contain additional features not documented in this book. The ETSNEWS help menus update you on any features added since this book was published. You should also check the ETSNEWS help menus whenever you begin using a new release of the SAS System.

About SAS/ETS

The `About SAS/ETS` entry provides a general overview of SAS/ETS software. It contains information abstracted from this chapter.

Other Related SAS Institute Publications

In addition to this user's guide, SAS Institute publishes other books on using SAS/ETS software. The following books are companions to this user's guide:

- *SAS/ETS Software: Applications Guide 1, Version 6, First Edition*
- *SAS/ETS Software: Applications Guide 2, Version 6, First Edition*

The first volume, *SAS/ETS Software: Applications Guide 1*, discusses features of SAS/ETS software for time series modeling and forecasting, financial reporting, and loan analysis. The second volume, *SAS/ETS Software: Applications Guide 2*, discusses features of SAS/ETS software for econometric modeling and simulation.

Forecasting Examples for Business and Economics Using the SAS System, discusses forecasting using SAS/ETS software.

SAS Institute Short Courses

SAS Institute offers the following short courses on using SAS/ETS software:

Forecasting Techniques Using SAS/ETS Software focuses on the practical application of forecasting techniques in SAS/ETS software. The course covers

- exponential smoothing
- seasonal adjustment
- seasonal exponential smoothing
- regression models with autoregressive errors
- graphical presentation of forecasts
- forecast confidence limits
- testing for nonstationarity
- Box-Jenkins ARIMA modeling
- transfer function and intervention models
- multivariate time series analysis
- spectral analysis

Econometric Modeling Using SAS/ETS Software explains the use of the SYSLIN, SIMLIN, and MODEL procedures for analyzing systems of simultaneous equations. The course covers

- statistical problems caused by dependent regressors and simultaneous relationships
- methods of estimating simultaneous equations
- simulation and forecasting of simultaneous systems
- fitting nonlinear autoregressive models with PROC MODEL
- fitting distributed lag models with PROC MODEL
- tests on parameter estimates in simultaneous systems
- Monte Carlo simulation of equation systems

SAS Institute Technical Support Services

As with all SAS Institute products, the SAS Institute Technical Support staff is available to respond to problems and answer technical questions regarding the use of SAS/ETS software.

Major Features of SAS/ETS Software

The following sections briefly summarize major features of SAS/ETS software. See the chapters on individual procedures for more detailed information.

Regression with Autocorrelated and Heteroscedastic Errors

The AUTOREG procedure provides regression analysis and forecasting of linear models with autocorrelated or heteroscedastic errors. The AUTOREG procedure includes the following features:

- estimation and prediction of linear regression models with autoregressive errors

- any order autoregressive or subset autoregressive process

- optional stepwise selection of autoregressive parameters

- choice of the following estimation methods:

  - exact maximum likelihood

  - exact nonlinear least squares

  - Yule-Walker

  - iterated Yule-Walker

- tests for any linear hypothesis involving the structural coefficients

- restrictions for any linear combination of the structural coefficients

- forecasts with confidence limits

- estimation and forecasting of ARCH (autoregressive conditional heteroscedasticity), GARCH (generalized autoregressive conditional heteroscedasticity), I-GARCH (integrated GARCH), E-GARCH (exponential GARCH), and GARCH-M (GARCH in mean) models

- ARCH and GARCH models can be combined with autoregressive models, with or without regressors

- estimation and testing of general heteroscedasticity models

- variety of model diagnostic information including

  - autocorrelation plots

  - partial autocorrelation plots

  - Durbin-Watson test statistic and generalized Durbin-Watson tests to any order

  - Durbin h and Durbin t statistics

  - Akaike information criterion

  - Schwarz information criterion

  - tests for ARCH errors

  - Ramsey's RESET test

  - Chow and PChow tests

  - Phillips-Perron stationarity test

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> – CUSUM and CUMSUMSQ statistics

- exact significance levels (*p*-values) for the Durbin-Watson statistic

- embedded missing values

Simultaneous Systems Linear Regression

The SYSLIN procedure provides regression analysis of a simultaneous system of linear equations. The SYSLIN procedure includes the following features:

- estimation of parameters in simultaneous systems of linear equations

- full range of estimation methods including

    - ordinary least squares (OLS)
    - two-stage least squares (2SLS)
    - three-stage least squares (3SLS)
    - iterated 3SLS
    - seemingly unrelated regression (SUR)
    - iterated SUR
    - limited-information maximum-likelihood (LIML)
    - full-information maximum-likelihood (FIML)
    - minimum-expected-loss (MELO)
    - general K-class estimators

- weighted regression

- any number of restrictions for any linear combination of coefficients, within a single model or across equations

- tests for any linear hypothesis, for the parameters of a single model or across equations

- wide range of model diagnostics and statistics including

    - usual ANOVA tables and R^2 statistics
    - Durbin-Watson statistics
    - standardized coefficients
    - test for over-identifying restrictions
    - residual plots
    - standard errors and T tests
    - covariance and correlation matrices of parameter estimates and equation errors

- predicted values, residuals, parameter estimates, and variance-covariance matrices saved in output SAS data sets

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Linear Systems Simulation

The SIMLIN procedure performs simulation and multiplier analysis for simultaneous systems of linear regression models. The SIMLIN procedure includes the following features:

- reduced form coefficients
- interim multipliers
- total multipliers
- dynamic forecasts and simulations
- goodness-of-fit statistics
- processes equation system coefficients estimated by the SYSLIN procedure

Polynomial Distributed Lag Regression

The PDLREG procedure provides regression analysis for linear models with polynomial distributed (Almon) lags. The PDLREG procedure includes the following features:

- any number of regressors may enter as a polynomial lag distribution, and any number of covariates may be used
- any order lag length and degree polynomial for lag distribution may be used
- optional upper and lower endpoint restrictions
- any number of linear restrictions may be placed on covariates
- option to repeat analysis over a range of degrees for the lag distribution polynomials
- support for autoregressive errors to any lag
- forecasts with confidence limits

Nonlinear Systems Regression and Simulation

The MODEL procedure provides parameter estimation, simulation, and forecasting of dynamic nonlinear simultaneous equation models. The MODEL procedure includes the following features:

- nonlinear regression analysis for systems of simultaneous equations, including weighted nonlinear regression
- full range of parameter estimation methods including
  - nonlinear ordinary least squares (OLS)
  - nonlinear seemingly unrelated regression (SUR)
  - nonlinear two-stage least squares (2SLS)

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- – nonlinear three-stage least squares (3SLS)
- – iterated SUR
- – iterated 3SLS
- – generalized method of moments (GMM)
- – nonlinear full information maximum likelihood (FIML)

- supports dynamic multi-equation nonlinear models of any size or complexity
- uses the full power of the SAS programming language for model definition, including left-hand side expressions
- hypothesis tests of nonlinear functions of the parameter estimates
- linear and nonlinear restrictions of the parameter estimates
- bounds imposed on the parameter estimates
- computation of estimates and standard errors of nonlinear functions of the parameter estimates
- estimation and simulation of Ordinary Differential Equations (ODE's)
- vector autoregressive error processes and polynomial lag distributions easily specified for the nonlinear equations
- variance modeling (ARCH, GARCH, and others)
- computes goal-seeking solutions of nonlinear systems to find input values needed to produce target outputs
- dynamic, static, or *n*-period-ahead-forecast simulation modes
- simultaneous solution or single equation solution modes
- Monte Carlo simulation using parameter estimate covariance and across-equation residuals covariance matrices or user specified random functions
- a variety of diagnostic statistics including

  - – model R^2 statistics
  - – general Durbin-Watson statistics and exact p-values
  - – asymptotic standard errors and T tests
  - – first stage R^2 statistics
  - – covariance estimates
  - – collinearity diagnostics
  - – simulation goodness-of-fit statistics
  - – Theil inequality coefficient decompositions
  - – Theil relative change forecast error measures
  - – heteroscedasticity tests
  - – Godfrey test for serial correlation
  - – Chow tests

- block structure and dependency structure analysis for the nonlinear system
- listing and cross reference of fitted model
- automatic calculation of needed derivatives using exact analytic formula

- efficient sparse matrix methods used for model solution; choice of other solution methods

- model definition, parameter estimation, simulation, and forecasting may be performed interactively in a single SAS session or models can also be stored in files and reused and combined in later runs

ARIMA (Box-Jenkins) and ARIMAX (Box-Tiao) Modeling and Forecasting

The ARIMA procedure provides the identification, parameter estimation, and forecasting of autoregressive integrated moving average (Box-Jenkins) models, seasonal ARIMA models, transfer function models, and intervention models. The ARIMA procedure includes the following features:

- complete ARIMA (Box-Jenkins) modeling with no limits on the order of autoregressive or moving average processes
- model identification diagnostics, include the following:

    - autocorrelation function
    - partial autocorrelation function
    - inverse autocorrelation function
    - cross-correlation function
    - extended sample autocorrelation function
    - minimum information criterion for model identification
    - squared canonical correlations

- stationarity tests
- intervention analysis
- regression with ARMA errors
- transfer function modeling with fully general rational transfer functions
- seasonal ARIMA models
- ARIMA model-based interpolation of missing values
- several parameter estimation methods including

    - exact maximum likelihood
    - conditional least squares
    - exact nonlinear unconditional least squares

- forecasts and confidence limits for all models
- forecasting tied to parameter estimation methods: finite memory forecasts for models estimated by maximum likelihood or exact nonlinear least squares methods and infinite memory forecasts for models estimated by conditional least squares
- a variety of model diagnostic statistics including

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   – Akaike's information criterion (AIC)

   – Schwarz's Bayesian criterion (SBC or BIC)

   – Box-Ljung chi-square test statistics for white noise residuals

   – autocorrelation function of residuals

   – partial autocorrelation function of residuals

   – inverse autocorrelation function of residuals

State Space Modeling and Forecasting

The STATESPACE procedure provides automatic model selection, parameter estimation, and forecasting of state space models. (*State space models* encompass an alternative general formulation of multivariate ARIMA models.) The STATESPACE procedure includes the following features:

- multivariate ARIMA modeling using the general state space representation of the stochastic process

- automatic model selection using Akaike's information criterion (AIC)

- user-specified state space models including restrictions

- transfer function models with random inputs

- any combination of simple and seasonal differencing; input series can be differenced to any order for any lag lengths

- forecasts with confidence limits

- can save selected and fitted model in a data set and reuse for forecasting

- wide range of output options; print any statistics concerning the data and their covariance structure, the model selection process, and the final model fit

Spectral Analysis

The SPECTRA procedure provides spectral analysis and cross-spectral analysis of time series. The SPECTRA procedure includes the following features:

- efficient calculation of periodogram and smoothed periodogram using fast finite Fourier transform and Chirp algorithms

- multiple spectral analysis, including raw and smoothed spectral and cross-spectral function estimates, with user-specified window weights

- choice of kernel for smoothing

- outputs the following spectral estimates to a SAS data set:

   – Fourier sine and cosine coefficients

   – periodogram

   – smoothed periodogram

   – cospectrum

- quadrature spectrum
- amplitude
- phase spectrum
- squared coherency

- Fisher's Kappa and Bartlett's Kolmogorov-Smirnov test statistic for testing a null hypothesis of white noise

Seasonal Adjustment Using X-11 and X-11 ARIMA Methods

The X11 procedure provides seasonal adjustment of time series using the Census X-11 or X-11 ARIMA method. The X11 procedure is based on the U.S. Bureau of the Census X-11 seasonal adjustment program and also supports the X-11 ARIMA method developed by Statistics Canada. The X11 procedure includes the following features:

- decomposition of monthly or quarterly series into seasonal, trend, trading day, and irregular components
- both multiplicative and additive form of the decomposition
- includes all the features of the Census Bureau program
- supports the X-11 ARIMA method
- supports sliding spans analysis
- processes any number of variables at once with no maximum length for a series
- performs tests for stable, moving and combined seasonality
- can optionally print or store in SAS data sets the individual X11 tables showing the various components at different stages of the computation. Full control over what is printed or output
- can project seasonal component one year ahead enabling reintroduction of seasonal factors for an extrapolated series

Time Series Cross-Sectional Regression Analysis

The TSCSREG procedure provides combined time series cross-sectional regression analysis. The TSCSREG procedure includes the following features:

- estimation of the regression parameters under several common error structures:
  - Fuller and Battese method (variance component model)
  - Parks method (autoregressive model)
  - Da Silva method (mixed variance component moving-average model)
  - one-way fixed effects
  - two-way fixed effects
  - one-way random effects

- two-way random effects
- any number of model specifications
- unbalanced panel data for the fixed or random effects models
- variety of estimates and statistics including

  - underlying error components estimates
  - regression parameter estimates
  - standard errors of estimates
  - *t*-tests
  - R-squared statistic
  - correlation matrix of estimates
  - covariance matrix of estimates
  - autoregressive parameter estimate
  - cross-sectional components estimates
  - autocovariance estimates
  - F-tests of linear hypotheses about the regression parameters
  - specification tests

Automatic Time Series Forecasting

The FORECAST procedure provides forecasting of univariate time series using automatic trend extrapolation. PROC FORECAST is an easy-to-use procedure for automatic forecasting that uses simple popular methods that do not require statistical modeling of the time series, such as exponential smoothing, time trend with autoregressive errors, and the Holt-Winters method.

The FORECAST procedure supplements the powerful forecasting capabilities of the econometric and time series analysis procedures described above. You can use PROC FORECAST when you have many series to forecast and want to extrapolate trends without developing a model for each series.

The FORECAST procedure includes the following features:

- choice of the following four forecasting methods:

  - exponential smoothing: single, double, triple, or Holt two-parameter smoothing
  - stepwise autoregressive models with constant, linear, or quadratic trend and autoregressive errors to any order
  - Holt-Winters forecasting method with constant, linear, or quadratic trend
  - additive variant of the Holt-Winters method

- support for up to three levels of seasonality for Holt-Winters method: time-of-year, day-of-week, or time-of-day
- ability to forecast any number of variables at once
- forecast confidence limits for all methods

Time Series Interpolation and Frequency Conversion

The EXPAND procedure provides time interval conversion and missing value interpolation for time series. The EXPAND procedure includes the following features:

- conversion of time series frequency; for example, constructing quarterly estimates from annual series or aggregating quarterly values to annual values
- conversion of irregular observations to periodic observations
- interpolation of missing values in time series
- conversion of observation types; for example, estimate stocks from flows and vice versa. All possible conversions supported between
  - beginning of period
  - end of period
  - period midpoint
  - period total
  - period average
- conversion of time series phase shift; for example, conversion between fiscal years and calendar years
- choice of four interpolation methods:
  - cubic splines
  - linear splines
  - step functions
  - simple aggregation
- ability to transform series before and after interpolation (or without interpolation) using:
  - constant shift or scale
  - sign change or absolute value
  - logarithm, exponential, square root, square, logistic, inverse logistic
  - lags, leads, differences
  - classical decomposition
  - bounds, trims, reverse series
  - centered moving, cumulative, or backward moving average
  - centered moving, cumulative, or backward moving corrected sum of squares
  - centered moving, cumulative, or backward moving sum
  - centered moving, cumulative, or backward moving median
  - centered moving, cumulative, or backward moving variance
- support for a wide range of time series frequencies:
  - YEAR
  - SEMIYEAR

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- QUARTER
- MONTH
- SEMIMONTH
- TENDAY
- WEEK
- WEEKDAY
- DAY
- HOUR
- MINUTE
- SECOND

- The basic interval types can be repeated or shifted to define a great variety of different frequencies, such as fiscal years, biennial periods, work shifts, and so forth.

Access to Financial and Economic Databases

The DATASOURCE procedure provides a convenient way to read time series data from data files supplied by a variety of different commercial and governmental data vendors. The DATASOURCE procedure includes the following features:

- support for data files distributed by the following data vendors:

  - DRI/McGraw-Hill
  - FAME Information Services
  - Haver Analytics
  - Standard & Poors Compustat Service
  - Center for Research in Security Prices (CRSP)
  - International Monetary Fund
  - U.S. Bureau of Labor Statistics
  - U.S. Bureau of Economic Analysis
  - Organization for Economic Cooperation and Development (OECD)

- ability to select the series, time range, and cross sections of data extracted

- can create an output data set containing descriptive information on the series available in the data file

- can read EBCDIC tapes on ASCII systems and vice versa

The CITIBASE procedure provides a convenient way to read time series from DRI Basic Economic (formerly CITIBASE) data files and Haver Analytics data files. The CITIBASE procedure has been superseded by the DATASOURCE procedure but is supported for compatibility with previous releases of SAS/ETS software. The CITIBASE procedure includes the following features:

- reads DRI Basic Economic or Haver Analytics database files and creates SAS data sets containing annual, quarterly, monthly, or weekly data series

- reads both tape and diskette format DRI Basic Economic files
- reads EBCDIC tapes on ASCII systems and vice versa
- ability to select the series and the time range read
- optionally creates an output data set containing descriptive information on the series in the DRI Basic Economic file

Spreadsheet Calculations and Financial Report Generation

The COMPUTAB procedure generates tabular reports using a programmable data table.

The COMPUTAB procedure is especially useful when you need both the power of a programmable spreadsheet and a report generation system, and you want to set up a program to run in batch mode and generate routine reports. The COMPUTAB procedure includes the following features:

- report generation facility for creating tabular reports such as income statements, balance sheets, and other row and column reports for analyzing business or time series data
- can tailor report format to almost any desired specification
- uses the SAS programming language to provide complete control of the calculation and format of each item of the report
- reports definition in terms of a data table on which programming statements operate
- a single reference to a row or column brings the entire row or column into a calculation
- can create new rows and columns (such as totals, subtotals, and ratios) with a single programming statement
- access to individual table values is available when needed
- built-in features to provide consolidation reports over summarization variables

Loan Analysis, Comparison, and Amortization

The LOAN procedure provides analysis and comparison of mortgages and other installment loans. The LOAN procedure includes the following features:

- contract terms for any number of different loans may be input and various financing alternatives may be analyzed and compared
- analysis of four different types of loan contracts including
  - fixed rate
  - adjustable rate
  - buydown rate
  - balloon payment

- full control over adjustment terms for adjustable rate loans: life caps, adjustment frequency, and maximum and minimum rates

- support for a wide variety of payment and compounding intervals

- loan calculations can incorporate initialization costs, discount points, down payments, and prepayments (uniform or lump-sum)

- analysis of different rate adjustment scenarios for variable rate loans including

  - worst case
  - best case
  - fixed rate case
  - estimated case

- can make loan comparisons at different points in time

- can make loan comparisons at each analysis date on the basis of five different economic criteria

  - present worth of cost (net present value of all payments to date)
  - true interest rate (internal rate of return to date)
  - current periodic payment
  - total interest paid to date
  - outstanding balance

- can base loan comparisons on either after-tax or before-tax analysis

- reports best alternative when loans of equal amount are compared

- amortization schedules for each loan contract

- when starting date is specified, output shows payment dates rather than just payment sequence numbers

- can optionally print or output to SAS data sets the amortization schedules, loan summaries, and loan comparison information

- can specify rounding of payments to any number of decimal places

The MORTGAGE procedure provides amortization schedules for fixed rate mortgages. The MORTGAGE procedure has been superseded by the LOAN procedure but is supported for compatibility with previous releases of SAS/ETS software. The MORTGAGE procedure includes the following features:

- fixed rate mortgage calculations and amortization schedules

- loan amount, payment, interest rate, or length of loan computed given the other three items

- supports a wide variety of payment and compounding intervals

- payment schedule with principal and interest division and ending balance printed or output to a data set

Time Series Forecasting System

SAS/ETS software includes the *Time Series Forecasting System*, a point-and-click application for exploring and analyzing univariate time series data. You can use the automatic model selection facility to select the best-fitting model for each time series, or you can use the system's diagnostic features and time series modeling tools interactively to develop forecasting models customized to best predict your time series. The system provides both graphical and statistical features to help you choose the best forecasting method for each series.

The system can be invoked from the Solutions menu under Analysis, by the Forecast command, and by the Forecasting icon in the Data Analysis folder of the SAS Desktop.

The following is a brief summary of the features of the Time Series Forecasting system. With the system you can

- use a wide variety of forecasting methods, including several kinds of exponential smoothing models, Winters method, and ARIMA (Box-Jenkins) models. You can also produce forecasts by combining the forecasts from several models.

- use predictor variables in forecasting models. Forecasting models can include time trend curves, regressors, intervention effects (dummy variables), adjustments you specify, and dynamic regression (transfer function) models.

- view plots of the data, predicted versus actual values, prediction errors, and forecasts with confidence limits. You can plot changes or transformations of series, zoom in on parts of the graphs, or plot autocorrelations.

- use hold-out samples to select the best forecasting method.

- compare goodness-of-fit measures for any two forecasting models side by side or list all models sorted by a particular fit statistic.

- view the predictions and errors for each model in a spreadsheet or view and compare the forecasts from any two models in a spreadsheet.

- examine the fitted parameters of each forecasting model and their statistical significance.

- control the automatic model selection process: the set of forecasting models considered, the goodness-of-fit measure used to select the best model, and the time period used to fit and evaluate models.

- customize the system by adding forecasting models for the automatic model selection process and for point-and-click manual selection.

- save your work in a project catalog.

- print an audit trail of the forecasting process.

- save and print system output including spreadsheets and graphs.

Related SAS Software

Many features not found in SAS/ETS software are available in other parts of the SAS System. If you don't find something you need in SAS/ETS software, you may find it in one of the following SAS software products.

Base SAS Software

The features provided by SAS/ETS software are extensions to the features provided by base SAS software. Many data management and reporting capabilities you will need are part of base SAS software. Refer to *SAS Language: Reference* and the *SAS Procedures Guide* for documentation of base SAS software.

The following sections summarize base SAS software features of interest to users of SAS/ETS software. See Chapter 2 for further discussion of some of these topics as they relate to time series data and SAS/ETS software.

SAS DATA Step

The DATA step is your primary tool for reading and processing data in the SAS System. The DATA step provides a powerful general purpose programming language that enables you to perform all kinds of data processing tasks. The DATA step is documented in *SAS Language: Reference*.

Base SAS Procedures

Base SAS software includes many useful SAS procedures. Base SAS procedures are documented in the *SAS Procedures Guide*. The following is a list of base SAS procedures you may find useful:

CATALOG	for managing SAS catalogs
CHART	for printing charts and histograms
COMPARE	for comparing SAS data sets
CONTENTS	for displaying the contents of SAS data sets
COPY	for copying SAS data sets
CORR	for computing correlations
CPORT	for moving SAS data libraries between computer systems
DATASETS	for deleting or renaming SAS data sets
FREQ	for computing frequency crosstabulations
PLOT	for printing scatter plots
PRINT	for printing SAS data sets
RANK	for computing rankings or order statistics
SORT	for sorting SAS data sets
SQL	for processing SAS data sets with Structured Query Language
STANDARD	for standardizing variables to a fixed mean and variance
MEANS	for computing descriptive statistics and summarizing or collapsing data over cross sections

TABULATE	for printing descriptive statistics in tabular format
TIMEPLOT	for plotting variables over time
TRANSPOSE	for transposing SAS data sets
UNIVARIATE	for computing descriptive statistics

Global Statements

Global statements can be specified anywhere in your SAS program, and they remain in effect until changed. Global statements are documented in *SAS Language: Reference*. You may find the following SAS global statements useful:

FILENAME	for accessing data files
FOOTNOTE	for printing footnote lines at the bottom of each page
%INCLUDE	for including files of SAS statements
LIBNAME	for accessing SAS data libraries
OPTIONS	for setting various SAS system options
RUN	for executing the preceding SAS statements
TITLE	for printing title lines at the top of each page
X	for issuing host operating system commands from within your SAS session

Some base SAS statements can be used with any SAS procedure, including SAS/ETS procedures. These statements are not global, and they only affect the SAS procedure they are used with. These statements are documented in *SAS Language: Reference*.

The following base SAS statements are useful with SAS/ETS procedures:

BY	for computing separate analyses for groups of observations
FORMAT	for assigning formats to variables
LABEL	for assigning descriptive labels to variables
WHERE	for subsetting data to restrict the range of data processed or to select or exclude observations from the analysis

SAS Functions

SAS functions can be used in DATA step programs and in the COMPUTAB and MODEL procedures. The following kinds of functions are available:

- character functions for manipulating character strings
- date and time functions, for performing date and calendar calculations
- financial functions, for performing financial calculations such as depreciation, net present value, periodic savings, and internal rate of return
- lagging and differencing functions, for computing lags and differences
- mathematical functions, for computing data transformations and other mathematical calculations

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- probability functions, for computing quantiles of statistical distributions and the significance of test statistics

- random number functions, for simulation experiments

- sample statistics functions, for computing means, standard deviations, kurtosis, and so forth

SAS functions are documented in *SAS Language: Reference*. Chapter 2 discusses the use of date and time and lagging and differencing functions. Chapter 3, "Date Intervals, Formats, and Functions," contains a reference list of date and time functions.

Formats, Informats, and Time Intervals

Base SAS software provides formats to control the printing of data values, informats to read data values, and time intervals to define the frequency of time series. See Chapter 3 for more information.

SAS/GRAPH Software

SAS/GRAPH software includes procedures that create two- and three-dimensional high resolution color graphics plots and charts. You can generate output that graphs the relationship of data values to one another, enhance existing graphs, or simply create graphics output that is not tied to data. SAS/GRAPH software can produce

- charts

- plots

- maps

- text

- three-dimensional graphs

With SAS/GRAPH software you can produce high-resolution color graphics plots of time series data.

SAS/STAT Software

SAS/STAT software includes procedures for a wide range of statistical methodologies including

- logistic regression
- censored regression
- principal component analysis
- structural equation models using covariance structure analysis
- factor analysis
- survival analysis
- discriminant analysis
- cluster analysis

- categorical data analysis; log-linear and conditional logistic models
- general linear models
- mixed linear models
- generalized linear models
- response surface analysis

SAS/STAT software is of interest to users of SAS/ETS software because many econometric and other statistical methods not included in SAS/ETS software are provided in SAS/STAT software. The section "Econometric Methods in Other SAS Software" later in this chapter discusses these method in greater detail.

SAS/IML Software

SAS/IML software gives you access to a powerful and flexible programming language (Interactive Matrix Language) in a dynamic, interactive environment. The fundamental object of the language is a data matrix. You can use SAS/IML software interactively (at the statement level) to see results immediately, or you can store statements in a module and execute them later. The programming is dynamic because necessary activities such as memory allocation and dimensioning of matrices are done automatically.

You can access built-in operators and call routines to perform complex tasks such as matrix inversion or eigenvector generation. You can define your own functions and subroutines using SAS/IML modules. You can perform operations on an entire data matrix. You have access to a wide choice of data management commands. You can read, create, and update SAS data sets from inside SAS/IML software without ever using the DATA step.

SAS/IML software is of interest to users of SAS/ETS software because it enables you to program your own econometric and time series methods in the SAS System. It contains subroutines for time series operators and for general function optimization. If you need to perform a statistical calculation not provided as an automated feature by SAS/ETS or other SAS software, you can use SAS/IML software to program the matrix equations for the calculation.

SAS/INSIGHT Software

SAS/INSIGHT software is a highly interactive tool for data analysis. You can explore data through a variety of interactive graphs including bar charts, scatter plots, box plots, and three-dimensional rotating plots. You can examine distributions and perform parametric and nonparametric regression, analyze general linear models and generalized linear models, examine correlation matrixes, and perform principal component analyses. Any changes you make to your data show immediately in all graphs and analyses. You can also configure SAS/INSIGHT software to produce graphs and analyses tailored to the way you work.

SAS/INSIGHT software is an integral part of the SAS System. You can use it to examine output from a SAS procedure, and you can use any SAS procedure to analyze results from SAS/INSIGHT software.

SAS/INSIGHT software includes features for both displaying and analyzing data interactively. A data window displays a SAS data set as a table with columns of the table displaying variables and rows displaying observations. Data windows provide data management features for editing, transforming, subsetting, and sorting data. A graph window displays different types of graphs: bar charts, scatter plots, box plots, and rotating plots. Graph windows provide interactive exploratory techniques such as data brushing and highlighting. Analysis windows display statistical analyses in the form of graphs and tables. Analysis window features include

- univariate statistics
- robust estimates
- density estimates
- cumulative distribution functions
- theoretical quantile-quantile plots
- multiple regression analysis with numerous diagnostic capabilities
- general linear models
- generalized linear models
- smoothing spline estimates
- kernel density estimates
- correlations
- principal components

SAS/INSIGHT software may be of interest to users of SAS/ETS software for interactive graphical viewing of data, editing data, exploratory data analysis, and checking distributional assumptions.

SAS/CALC Software

SAS/CALC software provides all-purpose spreadsheet capabilities for information management. In addition to standard spreadsheet features, SAS/CALC software has an important advantage: its direct link to the SAS System. To define relationships among the rows and columns of the spreadsheet, you can use cell formulas or SAS/CALC software's own programming language (similar to the DATA step language). SAS/CALC software can transform SAS data sets into spreadsheets and create SAS data sets from spreadsheets for further processing by other SAS procedures or a DATA step.

You can build two- and three-dimensional spreadsheet applications using features such as formulas, linked spreadsheets, what-if and goal-seeking analysis, and the powerful programming language. You can also review your links with the drilldown function. Function keys, the point and click and pull-down windowing enviroment,

interface to SAS/AF software, and help windows make SAS/CALC software easy to use and easy to provide users with turnkey applications.

SAS/OR Software

SAS/OR software provides SAS procedures for operations research and project planning and includes a menu driven system for project management. SAS/OR software has features for

- solving transportation problems
- linear, integer, and mixed-integer programming
- nonlinear programming and optimization
- scheduling projects
- plotting Gantt charts
- drawing network diagrams
- solving optimal assignment problems
- network flow programming

SAS/OR software may be of interest to users of SAS/ETS software for its mathematical programming features. In particular, the NLP procedure in SAS/OR software solves nonlinear programming problems and can be used for constrained and unconstrained maximization of user-defined likelihood functions.

SAS/QC Software

SAS/QC software provides a variety of procedures for statistical quality control and quality improvement. SAS/QC software includes procedures for

- Shewhart control charts
- cumulative sum control charts
- moving average control charts
- process capability analysis
- Ishikawa diagrams
- Pareto charts
- experimental design

SAS/QC software also includes the SQC menu system for interactive application of statistical quality control methods and the ADX Interface for experimental design.

Econometric Methods in Other SAS Software

Many econometric methods overlap statistical methodology used in other fields. In the SAS System, these methods are included in SAS/STAT software. General function optimization tools are included in SAS/OR software and in SAS/IML software.

The following features of SAS/STAT software complement SAS/ETS software for econometric analysis.

Qualitative Dependent Variables and Logistic Regression

The LOGISTIC procedure in SAS/STAT software fits linear logistic regression models for binary or ordinal response data by the method of maximum likelihood. Subsets of explanatory variables can be chosen by various model-selection methods. Regression diagnostics can be displayed for the binary response model. The logit link function in the logistic regression models can be replaced by the normit (probit) function or the complementary log-log function.

Limited Dependent Variables, Censored Regression, and Tobit Models

The LIFEREG procedure in SAS/STAT software fits parametric models to failure time or other kinds of duration data that may be right-, left-, or interval-censored. The models for the response variable consist of a linear effect composed of the exogenous covariables together with a random disturbance term. The distribution of the random disturbance can be taken from a class of distributions that includes the extreme value, normal and logistic distributions and (by using a log transformation) exponential, Weibull, lognormal, loglogistic, and gamma distributions.

While PROC LIFEREG is tailored for survival analysis, the same kinds of censoring arises in econometric data. PROC LIFEREG is a powerful tool for censored regression, including Tobit analysis.

Cox Proportional Hazards Model

The PHREG procedure in SAS/STAT software performs regression analysis of survival or duration data based on the Cox proportional hazards model. Cox's semiparametric model is widely used in the analysis of survival time, failure time, or other duration data to explain the effect of exogenous explanatory variables.

The population under study may consist of a number of subpopulations, each of which has its own baseline hazard function. PROC PHREG performs a stratified analysis to adjust for such subpopulation differences. The Cox model also allows time-dependent explanatory variables. A time-dependent variable is one whose value for any given individual can change over time. Time-dependent variables have many useful applications in survival analysis.

PROC PHREG includes the following features:

- tests of linear hypotheses about the regression parameters
- conditional logistic regression analysis for matched case-control studies
- creates an output SAS data set containing survivor function estimates and residuals
- creates a SAS data set containing estimates of the survivor function at all event times for a given realization of the explanatory variables
- four model selection methods: forward selection, backward selection, stepwise selection, and best subset selection
- several methods for handling ties

PROC PHREG is also useful for the econometric analysis of discrete choice models.

Random Effects Models and the Analysis of Panel Data

SAS/STAT software contains two procedures for fitting general linear models to panel data. The GLM procedure fits general linear models involving fixed effects. The more general MIXED procedure fits mixed linear models containing both fixed and random effects.

The MIXED procedure provides easy accessibility to a variety of mixed models useful in many common statistical analyses, including split-plot designs, repeated measures, random coefficients, best linear unbiased predictions, shrinkage estimators, and heterogeneous variances. In the style of the GLM procedure, PROC MIXED fits the specified mixed linear model and produces appropriate statistics.

Some features of PROC MIXED are

- covariance structures, including simple random effects, compound symmetry, unstructured, AR(1), Toeplitz, and spatial
- syntax similar to that of PROC GLM, using the MODEL, RANDOM, and REPEATED statements for model specification, and the CONTRAST, ESTIMATE, and LSMEANS statements for inferences
- appropriate standard errors for all specified estimable linear combinations of fixed and random effects, and corresponding t- and F-tests
- subject and group effects that enable blocking and heterogeneity
- REML and ML estimation methods
- capacity to handle unbalanced data
- ability to create a SAS data set corresponding to any printed table

Covariance Structure Analysis of Linear Structural Models

The CALIS procedure (Covariance Analysis and Linear Structural Equations) in SAS/STAT software estimates parameters and tests the appropriateness of linear structural equation models using covariance structure analysis.

The CALIS procedure can be used to estimate parameters and test hypotheses for constrained and unconstrained problems such as

- multiple and multivariate linear regression
- path analysis and causal modeling
- simultaneous equations models with reciprocal causation
- exploratory and confirmatory factor analysis of any order
- three-mode factor analysis
- canonical correlation
- a wide variety of other linear and nonlinear latent variables models

Principal Components

The PRINCOMP procedure in SAS/STAT software performs principal components analysis. Output data sets containing eigenvalues, eigenvectors, and standardized or unstandardized principal components scores can be created.

MLE for User-Defined Likelihood Functions

There are three SAS procedures that enable you to do maximum likelihood estimation of parameters in an arbitrary model with a likelihood function that you define: PROC MODEL, PROC NLP, and PROC IML.

Maximum likelihood can often be cast as an equivalent least squares problem through the use of appropriate transformations. The MODEL procedure in SAS/ETS software enables you to minimize a sum of squares function. If you can write a sum of squares function that is minimized when the likelihood function is maximized, then you can use the MODEL procedure in SAS/ETS software.

The NLP procedure in SAS/OR software is a general nonlinear programming procedure that can maximize a general function subject to linear equality or inequality constraints. You can use PROC NLP to maximize a user-defined nonlinear likelihood function.

You can use the IML procedure in SAS/IML software for maximum likelihood problems. The optimization routines used by PROC NLP are available through IML subroutines. You can write the likelihood function in the SAS/IML matrix language and call the constrained and unconstrained nonlinear programming subroutines to maximize the likelihood function with respect to the parameter vector.

Kalman Filtering and Time Series Analysis in SAS/IML

SAS/IML software includes a library of functions for Kalman filtering and time series analysis.

The Kalman Filter functions perform:

- covariance filtering and prediction
- fixed-interval smoothing
- diffuse covariance filtering and prediction
- diffuse fixed-interval smoothing

The time series analysis subroutines are an adaptation of parts of the TIMSAC (TIMe Series Analysis and Control) package developed by the Institute of Statistical Mathematics (ISM) in Japan.

The TIMSAC library contains subroutines to do the following:

- Bayesian seasonal adjustment modeling
- time series decomposition analysis
- locally stationary univariate AR model fitting
- locally stationary multivariate AR model fitting
- multivariate AR model fittintg
- periodic AR model fitting
- multivariate ARMA model forecasting and forecast error variance
- polynomial roots or ARMA coefficients computation
- time varying coefficient AR model estimation
- univariate AR model fitting

Refer to *SAS/IML Software: Usage and Reference* for details.

Other Statistical Tools

Many other statistical tools are available in base SAS, SAS/STAT, SAS/OR, SAS/QC, SAS/INSIGHT, and SAS/IML software. If you don't find something you need in SAS/ETS software, you may find it in SAS/STAT software and in base SAS software. If you still don't find it, look in other SAS software products or contact the SAS Institute Technical Support staff.

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