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The previous issue of *Decision Line* provided a review from Professor George Marcoulides of the LInear Structural RELations (Version 8.12)program and its PRELIS (Version 2.12) companion for analyzing structural equation models. This companion review is for EQS, another program that can analyze structural equation models, and is from George Marcoulides and Colette Lay.

A Review of EQS Structural Equations Program

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Structural equation models (SEM) are broadly defined to accomodate models that include latent variables, measurement errors in both dependent and independent variables, multiple indicators, reciprocal causation, simultaneity, and interdependence. As implemented in most computer packages, SEM includes as special cases such procedures as confirmatory factor analysis, multiple regression, path analysis, models for time-dependent data, recursive and non-recursive model for cross-sectional and longitutinal data, and covariance structure analysis. This review will focus on another leading program for analyzing structural equation models and all other models that can be conceptualized as special cases of SEM. The program is called EQS (pronounced like the letter "X") from Multivariate Software, Inc., and has been used extensively for more than a decade in many fields, ranging from social and behavioral sciences to accounting, management, and medicine (Bentler, 1995; Sadri & Marcoulides, 1994; Shen, Bentler, & Comrey, 1995).

Overview of the Product

Ease of use is certain to make EQS (Version 5) one of the leading SEM computer packages on the market. The latest version of EQS is fully compatible with earlier versions of the program and includes an **EQS for Windows Convertor** option for dealing with potentially incompatible system files from earlier versions. EQS can estimate any number of unknown parameters (depending on the platform used) according to a prespecified model and evaluate the fit of the model to some observed data. EQS features a graphical user interface (GUI) that allows for the performance of most functions through visual specification and point-and-click procedures. Although developed to perform as a specialized SEM program, EQS includes many unique data analytic and data handling functions (e.g., frequency tables, scatter plots, histograms, 3-D spinning plots, cross-tabulations, ANOVA, exploratory factor analysis, and correlation and regression analysis).

EQS is based on the Bentler-Weeks (1980) model representation. The Bentler-Weeks model can be used to estimate most SEM and related models, but is simple enough that it can be learned relatively quickly. For example, four types of variables are used in the representation, referred to by the letters V, F, E, and D. Measured variables are V, unmeasured latent variables are F, error variation in measured variables are E, and residuals in factors are D. Each variable having a V, F, E, or D designation can be followed by a one-, two-, or three-digit integer to assist with sequencing equations. Thus, the equation V1 = *F1 + E1 states that V1 is based upon a regression on F1 plus a residual term E1. The parameter for V1 on F1 is to be estimated based on empirical data.

EQS contains seven estimation procedures: Maximum Likelihood (ML), Least Squares (LS), Generalized Least Squares (GLS), Elliptical Least Squares (ELS), Elliptical Generalized Least Squares (EGLS), Elliptical Reweighted Least Squares (ERLS) and Arbitrary Distribution Generalized

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Least Squares (AGLS). All of the estimation methods are available for single group or multiple group models. Only multiple group analysis involving intercepts is restricted to ML estimation. As with other SEM programs, each of the estimation procedures is based on minimizing the discrepancy between a sample covariance (or correlation) matrix and a theoretical population matrix according to some weighting method. The estimates from each procedure are determined by varying the elements of the weight matrix under various distributional assumptions. For each estimation procedure, several goodness-of-fit indices (e.g., Akaike Information Criterion, Bentler-Bonnet Index, Comparative Fit Index) are provided to assess the adequacy of the model.

In many cases, the choice of the estimation procedure depends on the type of data included in the model. EQS can handle models with variables observed in any scale of measurement. For example, categorical variables can be included using polychoric (for correlations between two categorical variables) or polyserial correlations (for correlations between categorical and continuous variables), and parameter estimates are obtained using Generalized Least Squares estimation. To estimate the polychoric and polyserial correlations, the EQS program uses the Lee-Poon-Bentler approach (Lee, Poon, & Bentler, 1992).

EQS can also be used for conducting extensive data analysis and exploration. In fact, unlike many other specialized SEM programs, EQS includes a wide assortment of statistical and plotting options under the same program language. In addition, EQS includes extensive options for missing data imputation, constructing bootstrap estimates, and for simulation studies. Finally, EQS includes a Diagrammer feature which can be used to build complex models with just a few simple commands.

Using the Program

The EQS program begins by asking the user to open a data file. Data files can be in the form of a system file, a raw data file, a correlation matrix file or a covariance matrix file. Data can be entered directly into EQS, or imported from an existing file. EQS can also sort and merge data files, or select certain subsets for data analysis. A file must be opened before any other functions can be performed. EQS lists the files available by type, such as raw data files or system files. If a raw data file is selected, EQS prompts the user for information regarding the format of the data set, variable names, and the number of cases and variables. Once this is done, the file is saved in EQS as a system file with the raw data still intact as a data file. Program functions are henceforth performed on the system file created. Figure 1 shows the setup box for running EQS.

The Analysis option can be used to preview data before testing an SEM model. For example, there are numerous plotting functions available for exploring categorical and continuous variables, including box plots, line plots, histograms, pie charts, scatter plots and 3-D spinning plots. Figure 2 presents an example of the dialog box for using the Analysis option on a sample data set. Once the data preview is completed, one can quickly create a system file for testing a proposed model using the Build_EQS option from the main menu. Figure 3 presents a system file for an example model with 6 observed variables and 3 latent variables. The example is the well-known model of the stability of alienation study taken from the work of Wheaton, Muthen, Alwin, and Summers (1977).

This example model can also be run directly from a diagram created using the Diagrammer feature. The EQS program then translates the diagram into its command language. The Diagrammer feature can also be used to customize the basic factor structure with labels, values and parameter types. Summary statistics can also be computed and added to a proposed model. Figure 4 presents the path diagram for the example model generated using the Diagrammer feature.

Figure 5 presents some of the fit statistics generated for the example model. The fit statistics all indicate that the proposed model fairly accurately accounts for the variability observed in the data. For example, the chi-square is a measure of the difference between the sample covariance (or correlation) matrix and the fitted matrix based on the model. A small chi-square corresponds to a good fit. Other fit measures include the Bentler-Bonett Index (BBI) and the Comparative Fit Index (CFI). It is generally recognized that BBI and CFI values should be above 0.90. If the fit statistics examined suggest a poor model fit, one might benefit by examining the Lagrange Multiplier (LM) Test statistics provided as standard output. LM Test statistics (sometimes referred to as modification indices) can provide useful information for model evaluation and refinement. In summary, an LM Test statistic measures whether the model can be improved by freeing a previously

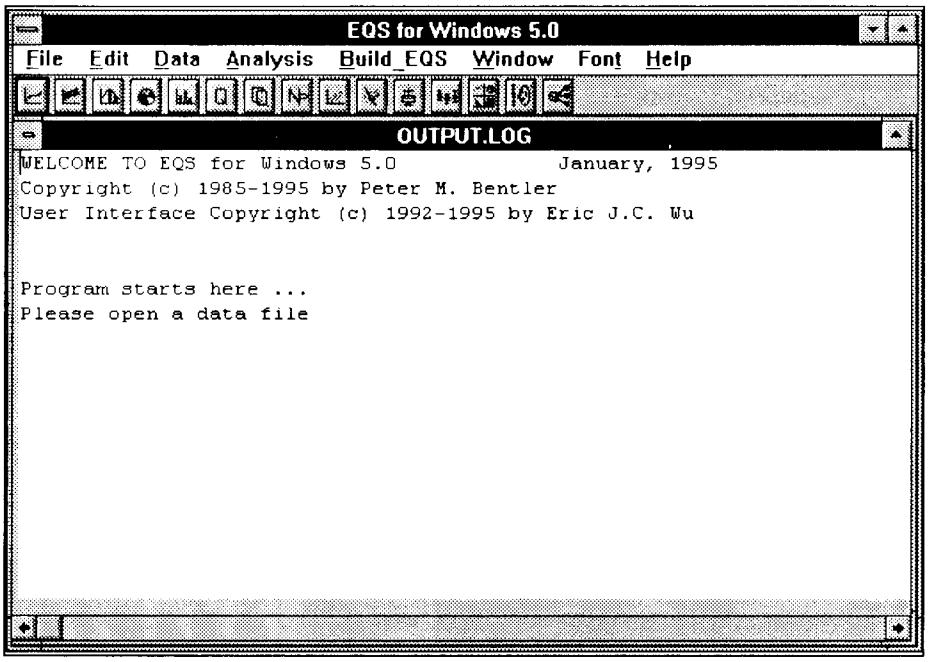

Figure 1: Initial dialog box for EQS program.

fixed parameter. For example, for each currently fixed parameter the LM Test gives an estimate of the value that parameter might take if it were freed in the model rather than constrained. The LM Test also gives how much the chi-square goodness-of-fit test is expected to change by freeing a previously fixed parameter.

Ease of Learning and of Use

EQS is extremely easy to use. The program features a graphical user interface (GUI) which makes full use of visual specification and point-and-click procedures. The dialog boxes are simple, and the output generated is excellent. Unfortunately, as with any SEM package, the difficulties lie more with understanding the theory of SEM techniques and being able to formulate an SEM model. My advice is to first work through some of the example cases provided in EQS and see how verbal theories are translated into testable models. The examples are quite easy to follow and reflect models from various areas of interest. Once the examples have been tackled, one should quickly be able to set up their own testable models.

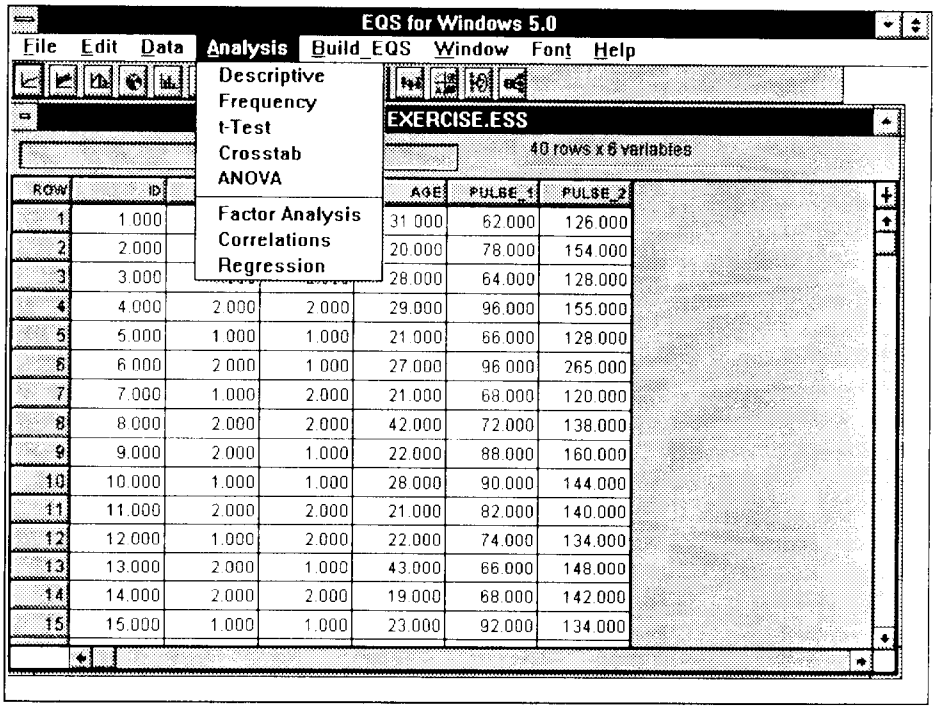

Figure 2: Dialog box for using ***Analysis*** *option on sample data.*

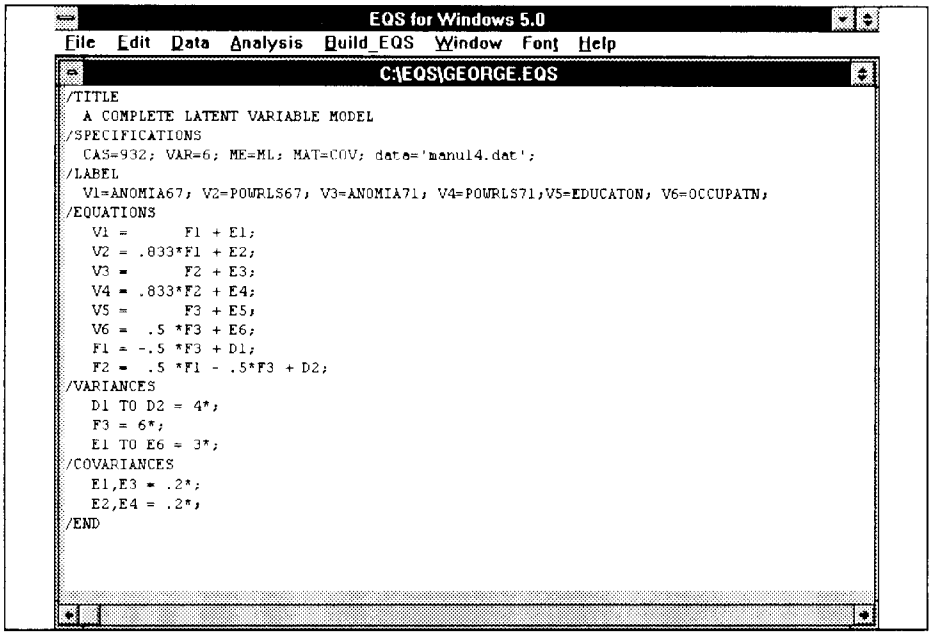

Figure 3: EQS input file for example model.

Documentation

The EQS program provides excellent documentation for both the novice and expert user in a user's guide and a program manual. The standard EQS program and installation procedures are described in the *EQS Structural Equations Program Manual*. This manual also provides a good introduction to regression, path, factor, and general structural equation models based on the Bentler-Weeks (1980) representation system implemented in EQS. The user's guide explains how to use the GUI environment and provides examples and sample data for hands-on practice. In addition, several other excellent books devoted exclusively to EQS have recently been published. These include *Structural Equation Modeling with EQS and EQS/Windows* (Byrne, 1994) and *Modelling Covariances and Latent Variables Using EQS* (Dunn, Everitt, & Pickles, 1993).

Support and Pricing

Registered EQS users can get free technical support either by telephone, fax, or e-mail, with a guaranteed 24-hour response time to questions. To speed up the response time, it is recommended that the model input file and all relevant information be provided. An online help system is also available from the main menu and includes coverage of a wide range of topics.

The EQS program is currently available for a variety of mainframe and personal computers. For personal computers the program is available on Macintosh and PC's using MS-DOS or Microsoft Windows. Both the Windows and Macintosh versions include the GUI interface for easier visual specifications and graphic display. The purchase price for either the Windows or Macintosh version is $595, and the MS-DOS version is $495. Registered users of EQS may upgrade older versions of the program. The upgrade cost is

$149 to upgrade to the latest MS-DOS version and $249 to upgrade to the latest Macintosh version. Upgrade cost for the Windows version is $149.00 if the version previously owned was 4.0, or $249.00 for version 3.0 or lower. Discounts for multi-users and network licenses can be obtained by contacting Multivariate Software, Inc.

Conclusions

The EQS program is without doubt one of the flagship SEM programs. The program can be used to test the full range of structural equation models, including regression models, confirmatory factor analysis, structured means, and multiple population comparisons. In addition, a wide assortment of statistical and plotting options are available within EQS to assist with data analysis and exploration. The Diagrammer feature is excellent and can be used to build complex models with just a few simple specifications. Finally, high quality path diagrams can be printed directly or imported into a document using any word-processing package. ■

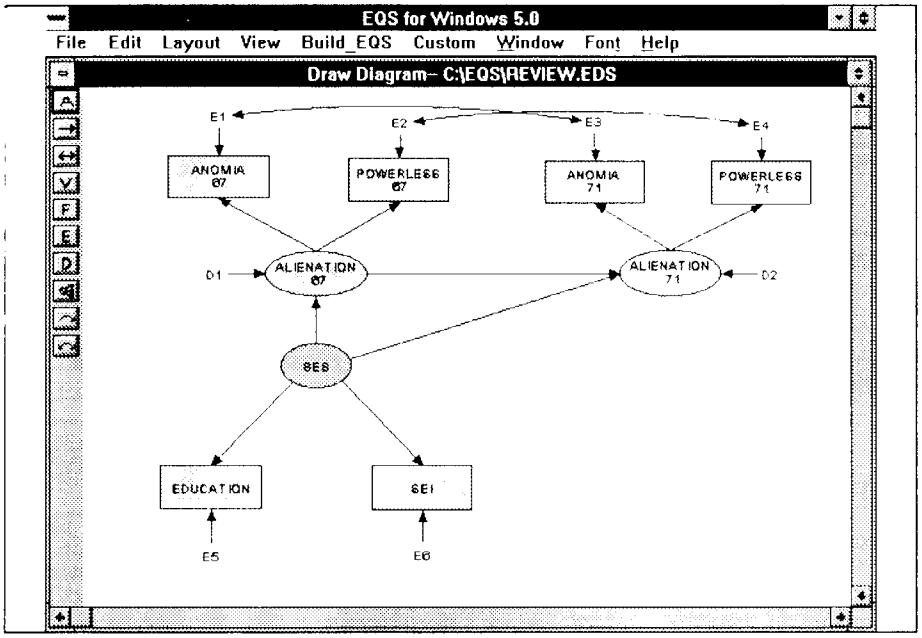

Figure 4: Path diagram for example model.

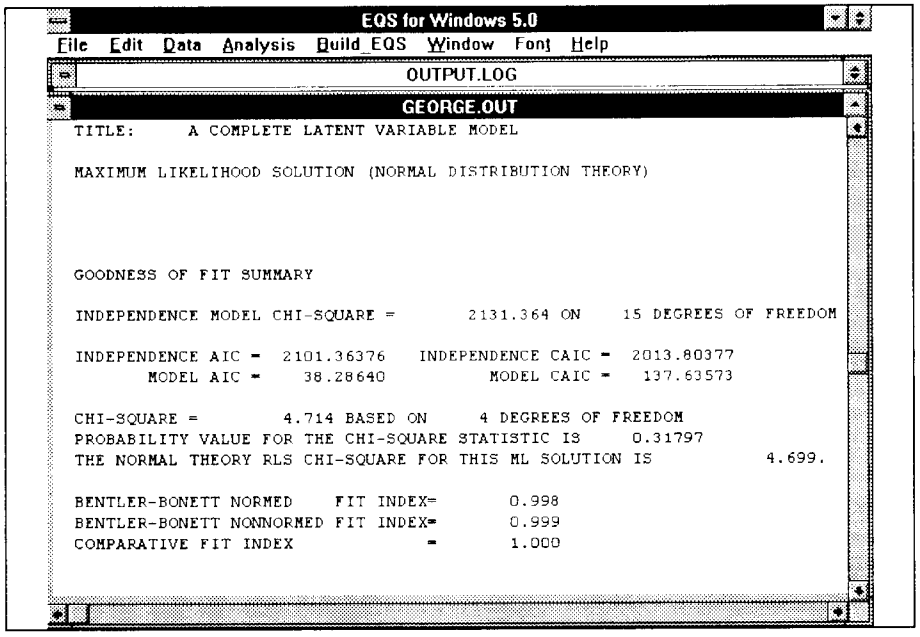

Figure 5: Fit statistics for example model.

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