PSYCHOMETRIKA—VOL. 59, NO. 1, 135–137
MARCH 1994
COMPUTATIONAL PSYCHOMETRICS

COMPUTER ANNOUNCEMENT

AMOS: ANALYSIS OF MOMENT STRUCTURES

JAMES L. ARBUCKLE

TEMPLE UNIVERSITY

Amos implements the general approach to data analysis known as analysis of covariance structures, analysis of linear structural relations, structural equation modeling, or causal modeling. Amos will analyze data from several populations at once. It will estimate means for exogenous variables, and it will estimate intercepts in regression equations. The program will also compute full information maximum likelihood estimates in the presence of missing data. Any parameter can be fixed at a known value in advance, and any parameter can be constrained to be equal to any other parameter. Amos offers a choice of four estimation criteria discussed by Browne (1982): (a) maximum likelihood, (b) unweighted least squares, (c) generalized least squares, and (d) Browne's asymptotically distribution-free criterion.

Amos estimates the following quantities: (a) the model parameters; (b) standardized regression weights; (c) a squared multiple correlation for each endogenous variable in the model, indicating the proportion of the variance of that variable that is accounted for by the remaining variables in the model; (d) total effects; (e) regression weights for regressing the unobserved variables on the observed variables (factor score weights); (f) means, variances, covariances and correlations for all variables in the model.

Bootstrapped standard errors and confidence intervals are available for all estimates, as well as for sample means, variances, covariances and correlations. Percentile intervals and bias-corrected percentile intervals (Stine, 1989) are implemented. Bollen and Stine's (1992) bootstrap approach to model testing is also implemented.

In the case of maximum likelihood, generalized least squares and asymptotically distribution-free estimation, Amos produces the following additional output: (a) A chi-square statistic for a large sample test of the hypothesis that the specified model is correct; (b) Approximate standard errors for the parameter estimates; (c) A critical ratio for each parameter, providing a large sample test of the hypothesis that the parameter is zero in the population; (d) A large sample approximation to the variance-covariance matrix of the parameter estimates; (e) A large sample approximation to the correlation matrix of the parameter estimates; (f) An approximate standard error for the difference between each pair of parameters; (g) A critical ratio for each pair of parameters, providing a large sample test of the hypothesis that those two parameters are equal in the population.

Numerous measures of model fit are computed, including Bentler-Bonett (1980) normed and nonnormed fit indices, the Bollen (1986, 1989) indices, root mean square residual, goodness of fit and adjusted goodness of fit indices (Jöreskog & Sörbom, 1989; Tanaka & Huba, 1985) and Hoelter's (1983) critical N. Several composite measures of fit and parsimony are computed, including those due to Akaike (1987), Schwarz (1978), Bozdogan (1987), and Browne and Cudeck (1989).

Multiple models can be fitted in a single analysis. Amos examines every pair of models in which one model can be obtained by placing restriction on the parameters of the other. The program reports several statistics appropriate for comparing such models. A test of univariate normality is provided for each observed variable, as well as a test of multivariate normality. An attempt is made to detect outliers.

Amos is available in three versions.

1. The standard MSDOS version requires a hard disk and 640 K of memory. It is limited to models with no more than 50 variables and no more than 126 parameters. For asymptotically distribution-free estimation, the number of variables is limited to 15. Under some circumstances, a problem that is within these limits may still not run, for instance if the data consist of more than one sample, or if a lot of memory is occupied by memory-resident programs.
2. The extended MSDOS version of Amos requires an 80386 system with a math coprocessor, or an 80486 system. In the extended version the number of variables and the number of parameters are limited only by the amount of installed memory.
3. The Windows version requires Windows version 3.0 or later. When used with the companion program, Amos Draw, the Windows version of Amos accepts a path diagram as a model specification, and displays its parameter estimates graphically on a path diagram. The path diagrams used for model specification, as well as those that display parameter estimates, are of presentation quality. They can be printed directly, or imported into other applications, such as word processors, desktop publishing programs, and general purpose graphics programs.

A single user license for all three versions of Amos together with 340 pages of documentation can be purchased for $50 (payable to Temple University) from:

James L. Arbuckle
Department of Psychology
Temple University
Philadelphia, Pennsylvania 19122
Email:v5113e@vm.temple.edu

Users of other structural modeling programs can use Amos Draw for its drawing capabilities alone. Parameter estimates obtained from other programs can be entered by hand. Amos Draw is available through anonymous ftp from the host cronkite.temple-.edu (Internet address 129.32.1.99). Log in as user *anonymous*, and use your email address as your password. Once you are logged in, the following commands will download Amos Draw to your local system.

```
cd /pub/bin/win
get amosdpak.txt
binary
get amosdpak.exe
```

Amosdpak.exe is a self extracting archive that contains several files. *Amosdpak.txt* contains installation instructions.

References

Akaike, H. (1987). Factor analysis and AIC. *Psychometrika*, *52*, 317–332.

Bentler, P. M. & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin*, *88*, 588–606.

Bollen, K. A. (1986). Sample size and Bentler and Bonett's nonnormed fit index. *Psychometrika*, *51*, 375–377.

Bollen, K. A. (1989). A new incremental fit index for general structural equation models. *Sociological Methods and Research*, *17*, 303–316.

Bollen, K. A., & Stine, R. A. (1992). Bootstrapping goodness-of-fit measures in structural equation models. *Sociological Methods and Research*, *21*, 205–229.

Bozdogan, H. (1987). Model selection and Akaike's information criterion (AIC): The general theory and its analytical extensions. *Psychometrika*, *52*, 345–370.

Browne, M. W. (1982), Covariance structures. In D. M. Hawkins (Ed.), *Topics in applied multivariate analysis* (pp. 72-141). Cambridge: Cambridge University Press.

Browne, M. W., & Cudeck, R. (1989). Single sample cross-validation indices for covariance structures. *Multivariate Behavioral Research*, *24*, 445–455.

Hoelter, J. W. (1983). The analysis of covariance structures: goodness-of-fit indices. *Sociological Methods and Research*, *11*, 325–344.

Jöreskog, K. G., & Sörbom, D. (1989). *LISREL 7 user's guide*. Mooresville, IN: Scientific Software.

Schwarz, G. (1978). Estimating the dimension of a model. *Annals of Statistics*, *6*, 461–464.

Stine, R. (1989). An introduction to bootstrap methods: Examples and ideas. *Sociological Methods and Research*, *18*, 243–291.

Tanaka, J. S., & Huba, G. J. (1985). A fit index for covariance structure models under arbitrary GLS estimation. *British Journal of Mathematical and Statistical Psychology*, *38*, 197–201.